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Revised RCRA Facility Investigation Phase II Report North Colony Landfarm Navajo Refinery, Artesia, New Mexico

Volume I

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Environmental Bureau
Oil Conservation Division

prepared for:

Navajo Refining Company
501 East Main Street
P. O. Drawer 159
Artesia, New Mexico 88210

November 1997

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12258 Mountain Haze NE, Albuquerque, NM 87122 (505) 856-1755

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1.0 EXECUTIVE SUMMARY

From 1980 to 1990 the RCRA-permitted hazardous waste treatment unit known as the North Colony Landfarm (NCL), located at Navajo Refining Company's Artesia refinery, received and managed several RCRA-listed refinery wastes. The NCL has not received such wastes since 1990, but continues to be managed for biodegradation of residual hydrocarbons. Beginning prior to 1982 and continuing to the present, numerous soils and hydrogeologic studies have been conducted at the NCL.

The earliest studies reviewed for the revised Phase II report included installation of soil lysimeters and groundwater monitor wells interior to and on the periphery of the landfarm in 1982 followed by soil coring and analyses in 1989 and 1990. Also in 1990, a hydrogeologic study was conducted that was the basis of the Alternative Source Demonstration submitted to the New Mexico Environment Department (NMED).

In 1994 and 1995 Phase I and Phase II RCRA Facility Investigations (RFI) were required to be conducted at the site. The RFI process was initiated in response to environmental sample data which indicated the presence of hazardous waste constituents in soils and groundwater beneath the unit that were similar to those applied to the unit. The Phase I RFI included trench excavations, and shallow and deep soil coring. Phase II activities included the installation of additional groundwater monitor wells followed by groundwater sampling, expanded soil coring away from the landfarm, and collection of aquifer data including continuous water levels and hydraulic conductivity measurements.

In response to a Notice of Deficiency from the NMED Hazardous and Radioactive Materials Bureau (HRMB) in April 1997, RFI supplemental investigation activities were performed in the Summer of 1997. These included compilation and review of past soils and groundwater analytical data, collection of additional groundwater water level data, further soil and groundwater sampling, statistical analysis of data, and, finally, modeling of contaminant transport in the vadose and saturated groundwater zones.

A summary of the activities, results and conclusions from each of the RFI investigative studies is provided below. The conclusions arising from the various investigative phases may have been modified due to more recent information from subsequent study. The earlier conclusions are listed as modified if they are no longer valid.

1.1 RFI Phase I

RFI Phase I investigation activities at the unit in Spring 1994 included the completion of four observation and sampling trenches, 24 soil borings, a deep (100-feet) geotechnical boring, groundwater elevation contour mapping based on measurements obtained from existing monitoring wells, and the survey and mapping of current surface elevations.

The soil sample analytical results for chromium and lead indicate that landfarm soils have adequately immobilized chromium and lead within the unit treatment zone. No evidence was found to indicate that either of these metal constituents has migrated below the base of the unit.

The unit is underlain by a near-surface saturated zone (NSSZ) consisting of interbedded zones of clayey sand and caliche gravel bounded above and below by much less permeable clayey silts and clays. A large portion of the NSSZ underlying the unit has been impacted by one or more petroleum product releases originating from a source located upgradient to the unit. The NSSZ appears to respond rapidly to local precipitation events, suggesting that this water-bearing zone is directly associated with a local recharge area located upgradient of the NCL. Results of the deep geotechnical boring completed to the north of the unit indicate that the NSSZ is underlain by at least 60-70 ft. of impermeable clay. In addition, other geotechnical borings completed in conjunction with refinery construction activities located upgradient of the unit yield a similar geological profile.

Prior to the performance of the NCL RFI, a significant hydrocarbon release to the NSSZ, which consisted of a refined petroleum product originating from an unrelated source located partially upgradient (south) of the NCL, was had been partly characterized. This refined-product release resulted in the presence of free-phase product in groundwater monitoring wells located immediately downgradient of the NCL.

A comparison of historic groundwater elevation measurements with more recent (1994) measurements from the same monitoring wells demonstrates that the upper surface of the NSSZ is capable of significant fluctuations in elevation. On at least one occasion (in 1982), fluids in the NSSZ were documented to rise to an elevation which would place it within a few feet of the base of the NCL treatment zone. Furthermore, inspection of the excavation sidewall at one of the observation trenches completed during the RFI field investigation provided strong visual evidence to indicate that hydrocarbon contamination present in the NSSZ had apparently migrated upwards through the soil profile to at least within approximately 2 ft. of the base of the treatment zone.

Evidence of subsurface hydrocarbon contamination was found in six of eight deep soil borings completed at the unit. However, in four of the six borings, organic constituents were reported only at the lowest sample interval, between 13 and 15 ft., suggesting that the source for these contaminants was not from wastes applied to the NCL, but originated instead in the upgradient hydrocarbon plume present in the NSSZ. Evidence of hydrocarbon contamination immediately below the base of the unit in a manner consistent with a potential release from the unit was observed in only one of eight deep soil borings.

Subsequent to the completion of RFI field investigation activities, the site was revisited in June 1994 and a series of observation trenches were completed south of the NCL between the unit and the source area for the upgradient hydrocarbon plume which partially underlies the unit. Subsurface soils sampled at these upgradient trench locations exhibited hydrocarbon contamination that was highly similar to that observed beneath the NCL in terms of existing constituents, the magnitude of contamination, and the subsurface elevations at which contamination occurred. Furthermore, analysis of free-phase hydrocarbons sampled from a recovery trench constructed to intercept the upgradient plume also demonstrated that constituents present in the plume were identical to those identified in subsurface soil samples collected at the NCL.

Based on the available information, the Phase I study concluded that existing subsurface contamination underlying the NCL is primarily, if not entirely, the result of subsurface migration of an unrelated hydrocarbon product plume (most likely consisting of a mid-range, diesel-like fuel product) transported to the NCL in the NSSZ underlying the unit. Hydrocarbon contaminants contained in the upgradient plume are highly similar to contaminants that could potentially have been released from the base of the NCL treatment zone. Periodic fluctuations in the level of the NSSZ have previously caused its upper boundary to approach at least within a few feet of the base of the unit in areas where subsurface clay is not present to act as a low permeability layer, or where clay contains sufficient coarse material and root channels to allow upward fluid penetration under hydraulic pressure. As a result, unambiguous evidence of a release from the unit is unlikely to be obtained. However, given the nature of the waste constituents that could potentially have been from the NCL (i.e. refinery waste residuals consisting of heavier-end hydrocarbons), it is likely that the impact of any potential releases from the unit on the unrelated subsurface plume would be minimal. In effect, the converse is true: The off-site hydrocarbon plume has severely impacted soils beneath the landfarm treatment zone.

In consideration of the findings detailed above, the Phase I report concluded that most if not all the existing contamination present in groundwater underlying the NCL is the result of an unrelated hydrocarbon release that has migrated on-site. From the viewpoint of overall environmental risk to human health and the environment, it is highly unlikely that the quality of the existing groundwater beneath the unit has been, or is likely to be, affected by any potential releases from the unit in any meaningful way. Therefore, the Phase I report recommended that future remedial investigations and actions should be directed to delineation, interception, and treatment or recovery of the hydrocarbon product contained in the NSSZ present in the vicinity of the unit.

1.2 RFI Phase II

The initial NCL RFI study included the completion of a series of soil borings and trench excavations at the NCL. NMED concluded that the possibility could not be ruled out that a release of unit-applied waste constituents had contaminated the near-surface saturated zone (NSSZ) underlying the unit to some extent. NRC was not able to state with absolute assurance that no release had occurred, although the preponderance of evidence showed that this was not the case. Consequently, NMED required the execution of a second RFI phase for the NCL in order to further characterize and delineate the released hydrocarbon product contaminants in the vicinity of the NCL.

The RFI Phase II required to be performed in 1995 was a follow-up to the initial RFI effort conducted at the unit in 1994, and was intended to further characterize and delineate the extent of hydrocarbon contamination in groundwater underlying and downgradient of the NCL. To achieve those objectives, the RFI Phase II involved the completion of a series of 24 soil borings downgradient of the NCL, installation of one upgradient and four downgradient groundwater monitoring wells, environmental analysis of groundwater samples obtained from those wells, and groundwater elevation measurements and aquifer tests conducted to describe key aquifer characteristics.

The findings of the RFI Phase II study further verified the initial findings and conclusions of the RFI Phase I investigation. As reported in the Phase II summary, the combined observations and data generated from the Phase I and II RFI efforts at the NCL yielded the following major findings:

1. Observations from soil borings and observation trenches completed at the NCL indicate that hydrocarbon contamination found in or immediately above the water table underlying the unit originates from a contaminant source which is unrelated to former waste management activities at the NCL. Rather, the evidence suggests that contamination beneath the unit primarily results from migration of hydrocarbon contaminants originating from a previously identified product release located upgradient and cross-gradient to the NCL.

2. The NSSZ in the vicinity of the NCL consists of a highly variable network of caliche gravel and fine-grained clayey sand and silt seams located at depths ranging between approximately 15 to 35 feet below surface grade. These water-bearing seams are typically limited in vertical and horizontal extent, and are interbedded with extensive zones of relatively tight clays and silts.

3. The bulk of the hydrocarbon release (in the form of free-phase product) is found in a subsurface plume that conforms to the prevailing direction of groundwater movement. The boundaries of the product plume have been delineated by a series of soil observation borings and groundwater monitoring wells completed during the RFI Phase II activities.

4. The NSSZ exists under distinctly semi-confined conditions, and is subject to potentially rapid and highly variable potentiometric fluctuations in response to local precipitation events. Portions of a municipal stormwater ditch located south and west of the NCL are a possible source for transient fluctuations in both the direction of local groundwater movement and the hydraulic potential; which, in turn, has driven hydrocarbon contamination horizontally to points under and beyond the NCL, as well as upward towards the base of the unit.

1.3 RFI Supplemental Investigation

RFI supplemental activities were performed during June through October 1997 in response to the April 21, 1997 HRMB letter of deficiency and a follow-up letter of violation dated May 21, 1997. Following receipt of those letters, NRC provided the HRMB with a proposed Plan of Corrective Action dated June 13, 1997, which required additional investigation at the NCL. The work involved data collection, compilation and analysis of existing technical material, and further on-site investigations.

Technical data and information generated during previous work efforts were utilized to assess contaminant occurrence, concentrations and frequency. All readily available hydrogeologic and soils reports directly pertinent to the NCL site beginning in 1982 were compiled and copies are provided with this investigation report. NCL groundwater monitoring reports beginning in 1990 were collected, reviewed, and are tabulated for this report. Statistical analyses were performed on current and past soil and groundwater data to evaluate the probability of a release from the unit to soils and groundwater. Modeling of vadose and saturated zone flow processes was performed to determine fate and transport of contaminates in the event of releases from the landfarm.

Further on-site investigation was conducted to provide data to correct deficiencies identified by the HRMB. This included soil sampling to collect additional background data for metal constituents, placement of temporary well points beneath the landfarm to determine hazardous constituent concentrations in groundwater, and installation of water level data recorders in several monitor wells to determine response of the NSSZ to precipitation.

The results of the RFI Supplemental Investigation support and validate information generated by the previous studies and investigations at the site. Specifically, the information reviewed and data generated as a result of the 1997 activities produce the following major findings:

1. Review of historical groundwater monitoring data from background well NCL-31 reveals elevated levels of organic constituents (including benzene at 26 ug/L) from 1990 through 1994. The well was replaced as a background monitor well by MW-53 in 1995. Similarly, downgradient wells NCL 33 and 44, located immediately outside of the perimeter fence in the northeast and north-central areas of the landfarm, recorded significant detections of organic constituents during the same time period. MW-34, located south of the landfarm entrance gate along the east perimeter fence, contains measurable levels of free-phase hydrocarbons

2. Benzene and total BTEX concentration maps of groundwater quality beneath the NCL show elevated concentrations of these constituents under the central and southern portion of the landfarm with the highest concentrations occurring along the southern (upgradient) boundary of the site. The landfarm location is partially downgradient from an area of above ground storage tanks containing various refined petroleum products some of which have experienced product releases in the past.

3. Analysis of the free-phase hydrocarbon product found in monitor well NCL-34 has determined that the product is a biologically degraded crude oil with approximately 48 percent of the sample occurring in the diesel range organics. The approximate range of product mix is 70 to 80 percent crude oil and 20 to 30 percent diesel fuel with the diesel fuel of more recent origin.

4. Based on review of information from the available studies, sections of the NSSZ beneath the unit have been affected by at least two unrelated hydrocarbon excursions that have migrated under the site from other areas of the refinery. These include a diesel fuel release prior to 1990 from an underground line in the area of Tanks 834 and 838 which apparently impacted the south central and southeastern portion of the NCL, and a crude oil release (date and source unknown) currently affecting NCL-34. There is a possibility of other undocumented older release(s) from a source likely further south than the area of Tank 838. As a result of these leaks, in 1990 NRC installed two product recovery trench systems in the area directly south of the NCL.

5. Comparison of groundwater elevation data from several up- and down- gradient monitor wells immediately adjacent to the NCL shows an immediate significant response to precipitation in MW-19 (upgradient) and lessor but measurable responses in two other wells (NCL-32 and NCL-44) located on the opposite side of the landfarm. The elevated hydrograph peaks noted on the hydrographs for these wells show that a rainfall-induced pulse mechanism provides a steep but temporary hydraulic gradient moving contaminants northeasterly from the southern edge of the landfarm.

6. Review of the lithologic boring logs and chemical data reveals that while soil material immediately above the base of the treatment zone and deeper in the vicinity of the NSSZ is contaminated, the intermediate material generally does not exhibit discoloration or odors and is mostly free of detectable concentrations of hydrocarbons.

7. Statistical analysis of soil data from landfarm and background core samples was performed that shows no statistically significant increase in chromium and lead concentrations in samples from beneath the landfarm treatment zone as compared to background soil concentrations.

8. Statistical analysis of groundwater sample data shows no statistically significant increase in chromium and lead concentrations in upgradient and downgradient monitor wells. Monitor well NCL-34, containing a mixture of crude and diesel oil free-phase hydrocarbons, exhibits highly variable and elevated metals concentrations, and was not included in the statistical analysis.

9. Even for those borings where the intermediate zone exhibited some evidence of hydrocarbons, the similarity of the chemical constituents in the contaminants is such that it is not possible to differentiate between possible sources based solely on chemical analysis of the material.

10. Vadose zone modeling performed with an EPA-approved model (VLEACH) using conservative assumptions shows that concentrations of organic constituents detected in soils immediately beneath the landfarm treatment zone would result in concentrations in groundwater less than Safe Drinking Water Act maximum contaminant levels (MCLs). For benzene (the most sensitive drinking water constituent), the model predicted the maximum concentration in groundwater would be 2.6 micrograms per liter (ug/L) which is less than the MCL of 5 ug/L. The worst-case scenario modeled assumes constituents

are immediately transported from beneath the treatment zone to groundwater by a hypothetical preferential pathway (such as a root hole). Although structures believed to be root holes were detected in some Phase I observation trenches, there is no evidence that such channels are continuous from surface to the groundwater surface. Therefore, even assuming that releases from the treatment zone were responsible for the contamination immediately beneath the zone (and there is strong evidence that the contamination originated from the unrelated plume below), such releases would have had no significant impact on groundwater.

11. Saturated zone groundwater modeling was performed using an U.S. Geological Survey flow model (MODFLOW) as modified for contaminant fate and transport (MT3D). Using a benzene concentration derived from the vadose zone model as a starting value (2.6 ug/L), 30-year simulated contaminant fate and transport will result in decreasing concentrations downgradient. Contaminant movement will be less than 200 feet before they are dissipated to less than 0.05 ug/L (50 parts per trillion) due to natural advective and dispersive processes.

1.4 Investigation Conclusions

The scientific data and technical information collected and generated during previous RFI and other investigations conducted at this facility demonstrated the impact that migration of offsite hydrocarbons under the NCL have had on soils and groundwater beneath the unit. Because landfarm constituents contain similar hydrocarbon contaminants, the effect of minimal releases from the base of the unit, if any, on underlying soils and groundwater has not been quantifiable. The most that could be concluded was that, in relative terms, the environmental significance of any release from the unit to the subsurface was negligible compared to the effect of the offsite hydrocarbons.

Using the maximum contaminant values from existing soils data, and EPA-approved statistical and computer modeling techniques employing conservative assumptions, the RFI supplemental investigation quantified the impacts of the postulated releases and concludes that the maximum possible effect on near-surface groundwater beneath the site would not cause an excedance of EPA drinking water standards. Additionally, the computer modeling predicted that such contamination would be dissipated within 200 feet of the unit boundaries and on property currently owned by Navajo.

Because of the similarities of the types of hydrocarbons, it still not possible to demonstrate absolutely that a release of hydrocarbons from the NCL has not occurred. However, the information generated for this report now provides a scientific estimate as to the maximum possible magnitude of such a release and the impacts on soil and groundwater media surrounding the site. This will allow decision-making regarding the future of the NCL to proceed, and the RCRA issues of unit Closure and Post-closure care to be resolved.

1.5 Recommendations

Even to the extent that releases may have occurred, the available environmental observations and environmental data indicate that the product plume is contained entirely within the confines of the NSSZ, and poses no threat of contamination to deeper groundwater resources. The NSSZ primarily consists of a highly variable network of relatively low-volume, semi-confined channels contained within a surrounding matrix of low-permeability silts and clays, such that petroleum product is distributed in a discontinuous manner within the delineated plume. Therefore, the construction of interception trenches across the product flow path has been recommended as the only feasible option for capture and recovery of released hydrocarbon product.

Based on the location of free-phase product within the NSSZ, and physical constraints imposed by Eagle Draw and various surface and subsurface refinery installations, two separate trench installations have been recommended for the interception and recovery of the hydrocarbon product. A primary trench located 400 feet east of the NCL and immediately west of Eagle Draw would recover product and contaminated groundwater. In addition, a secondary trench located east of Eagle Draw and 850 feet northeast of the NCL would serve as a recovery system to collect contamination which migrated beyond the primary trench prior to its installation. NRC is currently evaluating several hydrocarbon recovery proposals and expects to complete installation of recovery systems during the first quarter of 1998.

In addition to the trenches, it is suggested that hydrocarbon recovery be initiated at NCL-34 using a skimmer system. The diameter of the well (2 inches) will limit available recovery options, but the product in that well continues to be pervasive. Due to the well's proximity to the landfarm, some portion of the hydrocarbon product no doubt extends under the site and should be removed so as to facilitate any further investigation which might be necessary as well as to prevent future downgradient hydrocarbon movement.

2.0 INTRODUCTION

The following sections provide a brief introduction to the background and the scope and goals of the RFI investigation reported herein and to the organization of the report.

2.1 Background to the RCRA Facility Investigation

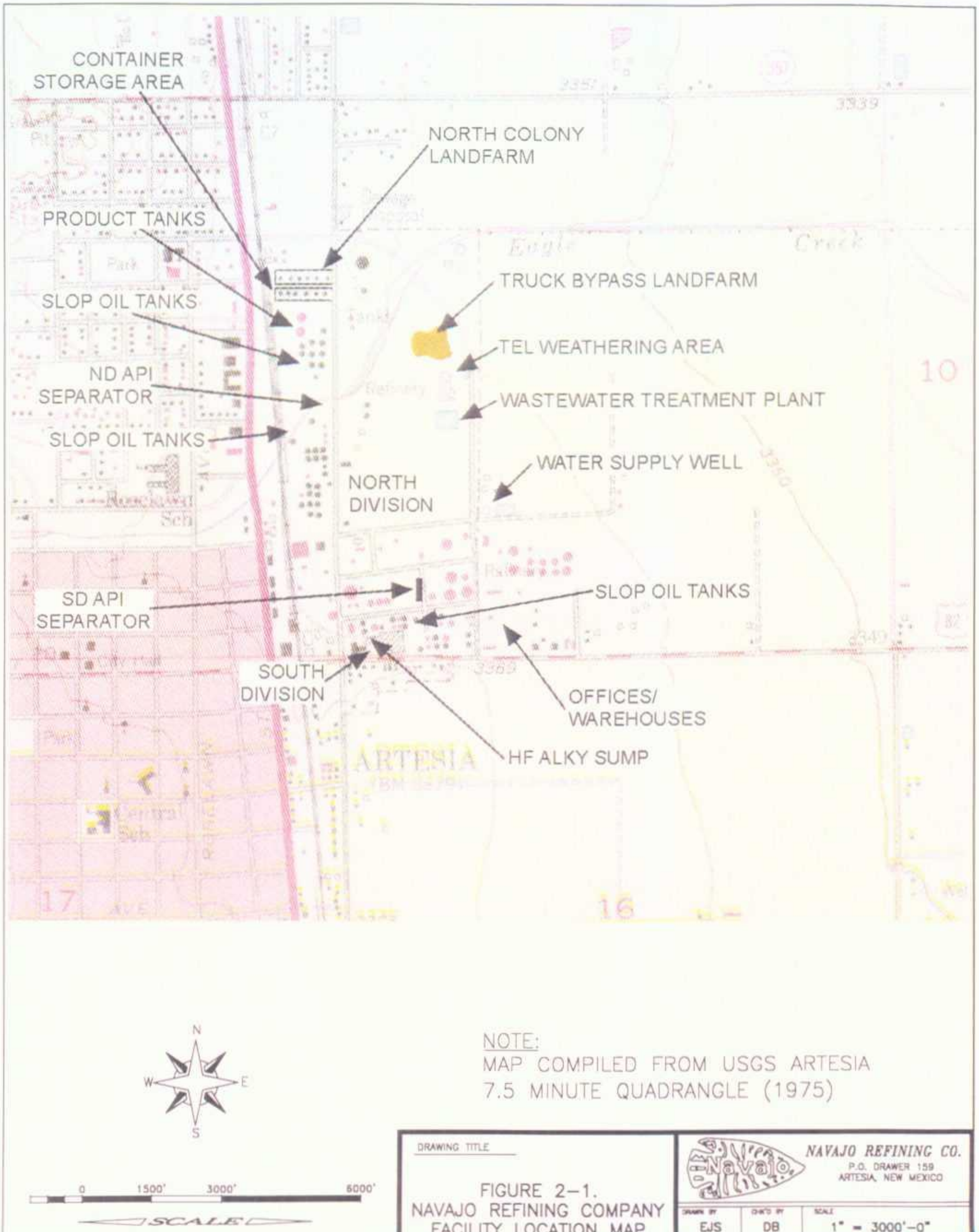
Navajo Refining Company (NRC) operates a petroleum refinery (EPA ID No. NMD 048918817) located at 501 East Main Street, Artesia, New Mexico (Figure 2-1). The refinery is regulated under the Resource Conservation and Recovery Act (RCRA), as amended by the Hazardous and Solid Waste Amendments of 1984 (HWSA).

This document addresses the North Colony Landfarm (NCL) which is a land treatment unit located in the northwest portion of the refinery that was operated by Navajo between 1980 and 1990 under the auspices of New Mexico Hazardous Waste Permit No. NMD048918817-1.

Subsequent to the generation of environmental monitoring data which suggested a potential release to subsurface soils underlying the base of the unit, a RCRA Facility Investigation (RFI) was required to be conducted for the NCL. The purpose of the RFI was to determine whether releases of hazardous waste or hazardous waste constituents have occurred from the unit and to determine the nature and extent of any release found to have occurred. The RFI was based on the approved workplan submitted to the Hazardous and Radioactive Materials Bureau (HRMB) of the New Mexico Environment Department (NMED) in March 1994. The RFI was performed in 1994 in accordance with the workplan and the RFI findings were subsequently presented in the report entitled "RCRA Facility Investigation, North Colony Landfarm, July 1994."

After submittal of the NCL RFI report and review by the HRMB, the agency in a letter dated December 30, 1994, required that a second phase of the RFI be undertaken to collect additional information regarding the extent of hydrocarbon contamination in shallow groundwater beneath the unit. A technical workplan designed to obtain the required environmental information was developed, was incorporated into the original RFI workplan (re-titled as the RFI Phase I and Phase II workplan), and was subsequently approved by NMED in April 1995. RFI field work was performed in the Summer and Fall of 1995, and the "RCRA Facility Investigation, Phase II Report, North Colony Landfarm, February, 1996" was submitted to the agency on February 28, 1996.

By letter dated April 21, 1997, the NMED disapproved the February 1996 report and required that a revised report addressing the deficiencies listed in the disapproval letter be submitted to the HRMB for further review. Subsequently, on May 21, 1997, the agency issued a Letter of Violation reiterating the deficiencies in the April 21 letter but waiving enforcement action if corrective actions are completed voluntarily. NRC responded by letter dated June 13, 1997, that included a Proposed Plan of Corrective Action. The additional investigative work completed and the results presented in this report were undertaken pursuant to the Plan of Corrective Action proposed in the June 13 letter.



NOTE:
MAP COMPILED FROM USGS ARTESIA
7.5 MINUTE QUADRANGLE (1975)

DRAWING TITLE

FIGURE 2-1.
NAVAJO REFINING COMPANY
FACILITY LOCATION MAP

NAVAJO REFINING CO.
P.O. DRAWER 159
ARTESIA, NEW MEXICO

DRAWN BY	CHK'D BY	SCALE	
EJS	DB	1" = 3000'-0"	
DATE	APPR BY	DRAWING NUMBER	REV.
11-3-97	–	FIG21.DWG	0

2.2 Scope and Goals of the Supplemental RFI

The scope of the supplemental RFI was based on the commitments made by Navajo in the Proposed Plan of Corrective Action referenced above. Briefly, NRC was to characterize the properties of the soil chemicals and contaminants, perform statistical analyses on soil and groundwater data, determine the extent of contamination in the near-surface saturated zone beneath the NCL, and perform vadose (unsaturated) and saturated zone modeling to evaluate the magnitude, and fate and transport of contaminants which may have been released from the landfarm.

A secondary goal was to update information presented in the previous RFI reports and provide the agency with copies of studies conducted prior to the Phase I RFI. Also to be provided was a compilation of recent groundwater monitoring data so that water quality information could be quickly located, temporal changes evaluated, and constituent comparisons performed on the NCL wells.

2.3 Organization of the RFI Report

The RFI report is organized into eight sections and supporting appendices. Section 3.0 describes the environmental setting at the facility. Section 4.0 provides a synopsis of the history of the Navajo Refinery, the current status of the NCL, characteristics of the wastes applied to the NCL, and a summary of pre-RFI investigations. Section 5.0 summarizes the RFI investigation activities, and Section 6.0 describes the results of those activities. Section 7.0 provides interpretive discussion of the investigation results, and Section 8.0 details the conclusions and recommendations of the investigation.

3.0 ENVIRONMENTAL SETTING

3.1 Climatology

The Artesia, New Mexico area has a semiarid continental climate, characterized by hot summers and mild winters. Measurable rainfall occurs approximately 42 days per year and annual snowfall averages 3-8 in. to yield an average annual precipitation of 10-14 in., with nearly 80% falling from May through October. Lake evaporation in the Eddy County area is 66-72 in. per year, of which two-thirds also takes place from May through October. Thus, the net loss between precipitation and evaporation ranges from 52-62 in. per year. Minimum temperatures are typically 44.0°-49.0°F, but can fall below 0°F in winter; maximum temperatures can exceed 100°F on summer days. The frost-free season is April to October (NOAA, 1982).

3.2 Topography and Surface Water

The Navajo Refinery facility is located on the east side of Artesia in the broad Pecos River Valley of eastern New Mexico. The average elevation of the city of Artesia is 3,380 feet above mean sea level (MSL). The plain on which Artesia lies slopes eastward at about 30 feet per mile. Surface drainage is dominated by small ephemeral creeks and arroyos that flow eastward to the Pecos River, located approximately 3 miles east of the facility.

Natural surface drainage at the facility is to the north and east. The major drainage in the immediate area of the site is Eagle Draw[a], an ephemeral watercourse that runs southwest to northeast through the process area of the refinery, and thence runs eastward into the Pecos River (Figure 3-1). As it passes through the city of Artesia upstream of the facility, Eagle Draw functions as a major stormwater conveyance for the community. It also drains outlying areas westward towards the Sacramento Mountains, and previously was periodically scoured by intense stormwater events.

The elevation of Eagle Draw is 3,360 feet at its entrance to the refinery and decreases to approximately 3,305 feet at its junction with the Pecos River. A large portion of the facility is within the 100-year floodplain of either Eagle Draw or the Pecos River. However, Eagle Draw has been channeled from west of Artesia to the Pecos. A large flood control dam and temporary storage reservoir has been completed along Eagle Draw west of Artesia which protects the city by reducing the severity of any large runoff events from the upland and mountain areas to the west. In the vicinity of the refinery, Eagle Draw channel has been cemented from Highway 285 past the refinery process and storage areas to protect structures during flood events. According to the RCRA Preliminary Review (PR) (A.T. Kearney and Harding Lawson, 1986) prepared for this facility, the completed flood control measures should effectively remove Artesia and the refinery from Eagle Draw's 100-year floodplain.

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[a] Eagle Draw is shown on regional maps as Eagle Creek. The local terminology "Eagle Draw" is maintained and utilized in this report.

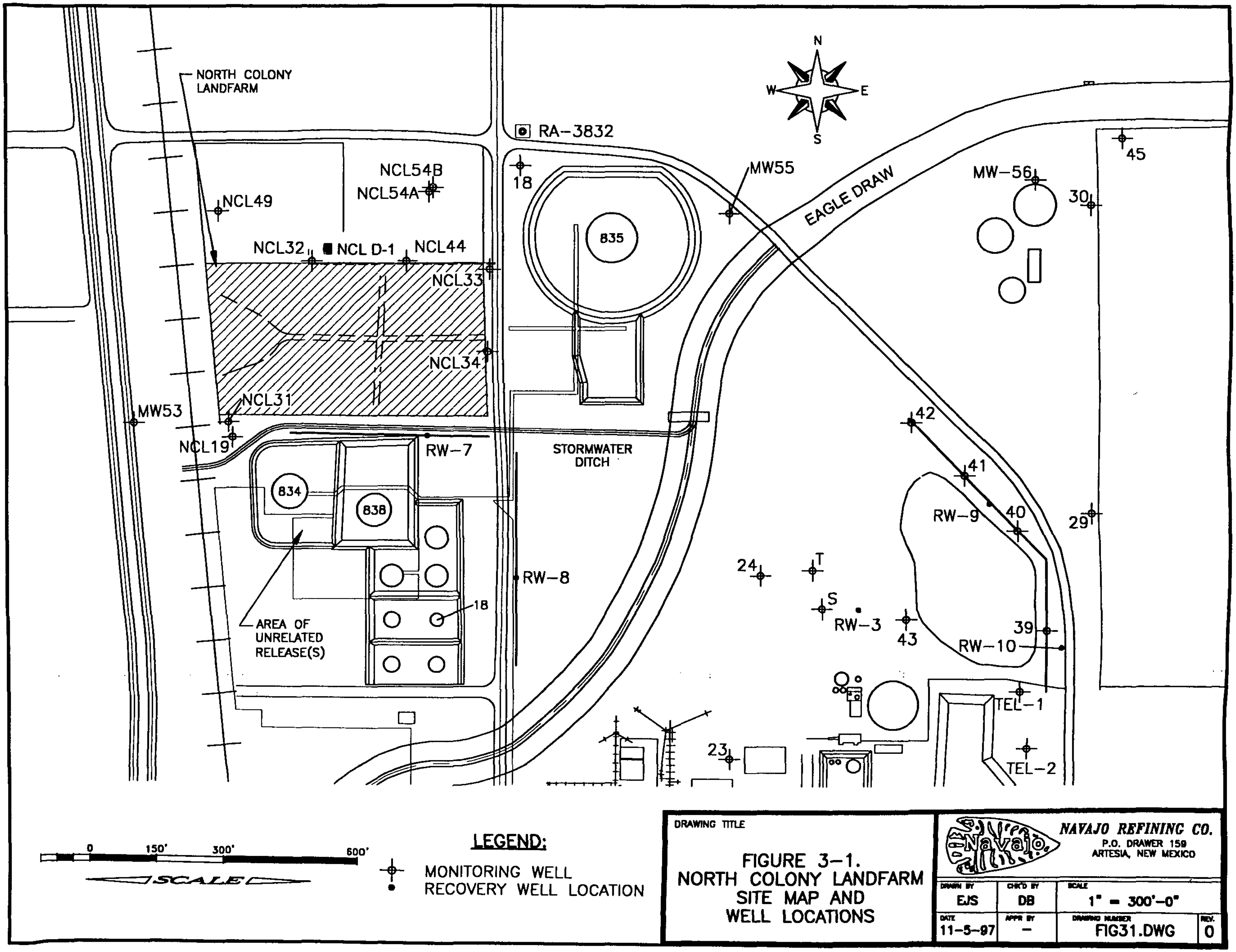

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FIGURE 3-1.
NORTH COLONY LANDFARM
SITE MAP AND
WELL LOCATIONS

A minor stormwater conveyance which receives runoff from city streets west of the refinery passes immediately to the south of the NCL before it empties into Eagle Draw (Figure 3-1). Groundwater observations obtained during the performance of the RFI Phase I suggested that fluctuations in hydraulic potential and direction of flow in the NSSZ in the vicinity of the NCL may be significantly influenced by this surface drainage feature.

3.3 Soils

Soils at the refinery are primarily of the Pima and Karro series. The North Colony landfarm is about 60% Pima soils and 40% Karro soils. The frost-free season for Pima and Karro soils is 195 to 210 days. Extended periods of cold weather are rare and frost action potential is slight. In general, soils in the area do not freeze at depths greater than a few inches for more than a few days at a time (USDA - SCS, 1971).

The Pima and Karro soils have similar properties. Pima soils are deep, well-drained, dark colored, calcareous soils, which occur on floodplains of narrow drainageways (e.g., Eagle Draw). These soils have moderate shrink-swell potential, and were subject to periodic flooding. Runoff from Pima soils is slow, permeability is moderately slow, and the water-holding capacity is high. The effective rooting depth is greater than 5 feet, and the water table is deeper than 5 feet.

The Karro soils are highly calcareous. Calcium carbonate typically accumulates at a depth of about 45 inches. These soils are found on level to gently sloping terrain and are susceptible to wind erosion. Runoff is slow and water-holding capacity is high. Permeability is moderate, and the effective rooting depth and the water table are both over 5 feet deep.

3.4 Geology

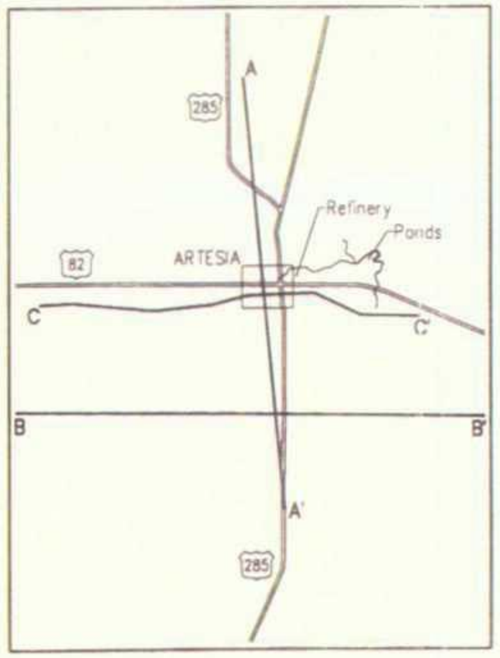
Navajo Refinery is located on the Northwest Shelf of the Permian Basin. In this region, the deposits are comprised of approximately 250 to 300 feet of Quaternary alluvium unconformably overlying approximately 2,000 feet of Permian clastic and carbonate rocks. These Permian deposits unconformably overlie Precambrian syenite, gneiss, and diabase crystalline rocks (Kelley, 1971; Welder, 1983). The relationships between the sedimentary deposits are shown in Figures 3-2 and 3-3 and discussed below.

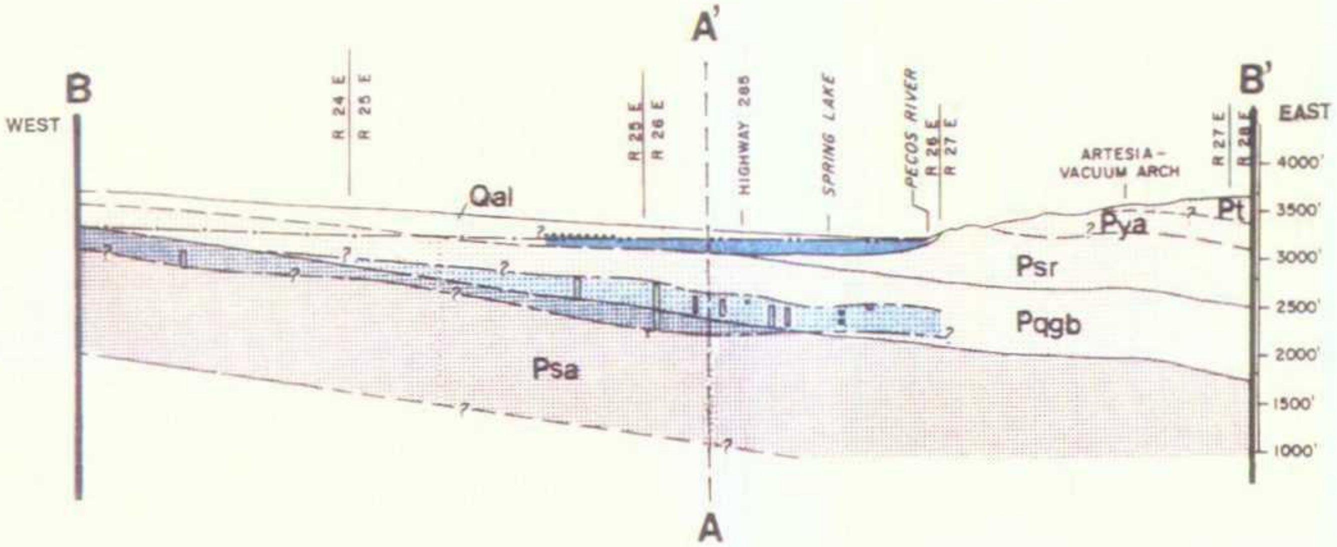
3.4.1 San Andres Formation

The San Andres Formation, oldest of the Permian units discussed in this report, lies immediately above the Precambrian crystalline basement rocks and beneath the Grayburg and Queen Formations. The San Andres Formation is composed mainly of limestone and dolomite containing irregular and erratic solution cavities, which range up to several feet in diameter. Its thickness is greater than 700 feet The upper portion of the formation is composed of oolitic dolomite with some anhydrite cement. The deep well lithologic logs from the refinery area indicate that the San Andres Formation is primarily carbonate (logged by drillers as lime or limerock) and probably includes limestone and dolomite.

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



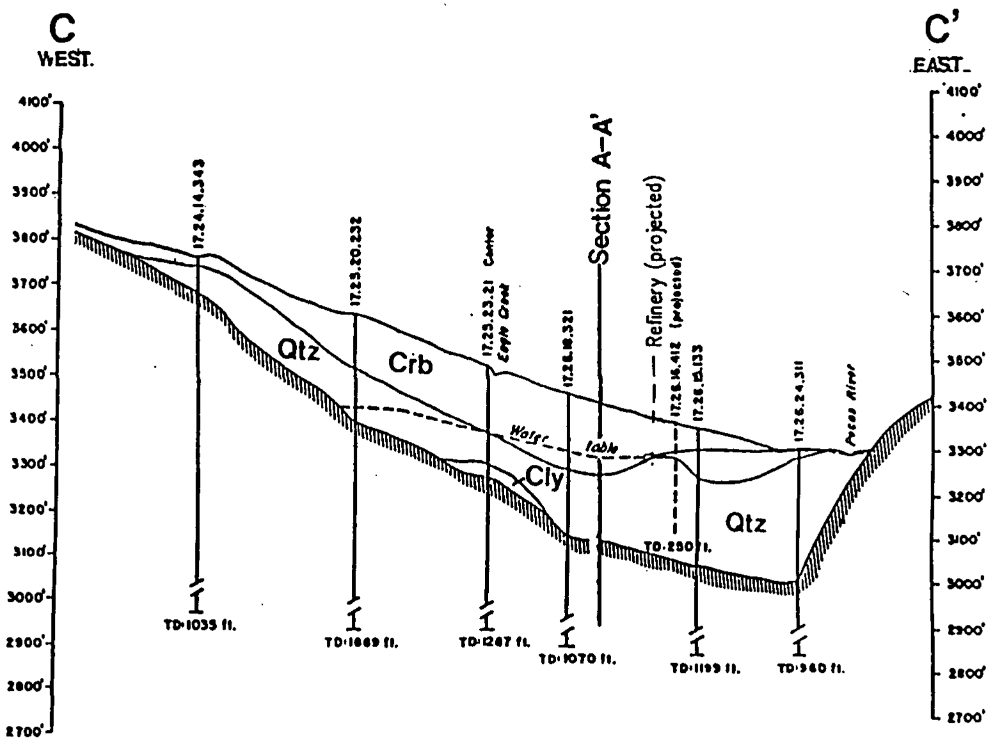


0 1 2 3 4 5 6 7 8 9 10 MILES

VERTICAL EXAGGERATION X 10
NATIONAL GEODETIC VERTICAL DATUM OF 1929

NOTE: MODIFIED FROM WELDER (1983)

DRAWING TITLE FIGURE 3–2. REGIONAL GEOLOGIC CROSS SECTIONS A–A', B–B' AND LOCATION MAP	NAVAJO REFINING CO. P.O. DRAWER 159 ARTESIA, NEW MEXICO			
	DRAWN BY EJS	CHK'D BY DB	SCALE AS SHOWN	
	DATE 11–5–97	APPR BY –	DRAWING NUMBER FIG32.DWG	REV. 0



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.

0 1 2 MILES

Vertical exaggeration x 53
Datum is mean sea level

NOTE: MODIFIED FROM LYFORD (1973)

DRAWING TITLE	NAVAJO REFINING CO. P.O. DRAWER 159 ARTESIA, NEW MEXICO			
FIGURE 3–3. REGIONAL GEOLOGIC CROSS SECTION C–C'	DRAWN BY EJS	CHK'D BY DB	SCALE AS SHOWN	
	DATE 11–5–97	APPR BY –	DRAWING NUMBER FIG33.DWG	REV. 0

3.4.2 Permian Artesian Group

The Permian Artesian Group is comprised of five formations (in ascending order): the Grayburg, Queen, Seven Rivers, Yates, and Tansill Formations. The Yates and Tansill Formations outcrop at the surface east of the Pecos River and are not present in the vicinity of the refinery. The Permian formations dip 1° to 3° toward the southeast, without any reported major structural features (Lyford, 1973; Welder, 1983).

3.4.2.1 Grayburg and Queen Formations

In the area of the refinery the Grayburg and Queen Formations have been mapped as a single unit by geologists as collectively consisting of about 700 feet of interbedded dolomite and calcareous dolomite, gypsum, fine-grained sandstone, carbonates, siltstone, and mudstone. Lithologies of the Queen Formation are similar to those of the Grayburg Formation with the principal difference being a higher proportion of clastics in the Queen, which conformably overlies and grades into the Grayburg Formation. The Grayburg is thought to disconformably overlie the San Andres Formation. In locations where the Seven Rivers Formation is absent, the upper portion of the Queen acts as a confining bed between the deep artesian aquifer and the valley fill aquifer (Section 3.5).

3.4.2.2 Seven Rivers Formation

The uppermost Permian formation in the Artesia area is the Seven Rivers Formation, which outcrops east of the Pecos River. This eastward-dipping formation is eroded and buried by the valley fill alluvium at a depth of 300 feet in the area between the river and the refinery. In the vicinity of the refinery, the formation thins, and it disappears farther west. Where the formation is present at depth, it consists of a sequence of evaporites, carbonates, gypsum, and shale, with isolated sand and fractured anhydrite/gypsum lenses. A thorough evaluation of all available borehole logs, supported by an International Technology Corporation Report (1990), provided no evidence that the Seven Rivers Formation is present (at any depth) beneath the refinery. All lithologic logs of wells completed in the refinery area describe unconsolidated alluvial materials to depths from 20 to 250 feet.

3.4.3 Quaternary Alluvium

The Quaternary alluvium in the refinery area is dominantly comprised of clays, silts, sands, and gravels deposited in the Pecos River valley. These "valley fill" deposits extend in a north-south belt approximately 20 miles wide, generally west of the Pecos River. The thickness of the valley fill varies from a thin veneer on the western margins of the Pecos River valley to a maximum of 300 feet in several depressions, one located beneath the refinery. These depressions have resulted from dissolution of the underlying Permian carbonates and evaporates. The sedimentology and mineralogy of the valley fill deposits can be divided into three units: the underlying quartzose unit, the interbedded clay unit, and the uppermost carbonate gravel unit.

3.4.3.1 Quartzose Unit

The quartzose unit consists primarily of fragments of quartz and igneous rocks cemented by calcium carbonate. This unit is laterally continuous throughout the Pecos River valley and is generally less than 250 feet in thickness. The quartzose unit unconformably overlies Permian rocks and is correlative with the quartzose conglomerate described by Fiedler and Nye (1933), and Morgan (1938). The lower quartzose gravels are commonly used for groundwater production.

3.4.3.2 Clay Unit

The clay unit is not laterally continuous throughout the valley fill deposits, but occurs in isolated lenses generally overlying the quartzose unit. The clay unit is comprised of light- to medium-gray clays and silts deposited in localized ponds and lakes. These ponds and lakes may have formed in conjunction with dissolution and collapse of the underlying Permian rocks.

3.4.3.3 Carbonate Gravel Unit

The carbonate gravel unit blankets the other valley fill units and forms a fairly uniform slope from the Permian rock outcrop areas on the west side of the valley east to the Pecos River floodplain. The unit consists of coarse-grained carbonate gravel deposits along major drainageways to the Pecos River which grade into brown calcareous silts and thin masses of caliche in the interstream regions. The carbonate gravel unit includes the Lakewood, Orchard Park, and Blackdom terrace deposits referenced by Fiedler and Nye as well as Holocene and Pleistocene Pecos River alluvial deposits. The Lakewood deposits, the lowest of the three terrace units, essentially are the current alluvial sediments in the floodplain along the river. They consist of brown sandy brown silt interbedded with lenses of gravel and sand, and some localized caliche in higher parts. The Lakewood terrace is confined to the area immediately adjacent to the river and is underlain by Pleistocene alluvium deposited by the Pecos and its tributaries.

The Orchard Park terrace surface gently rises in elevation to between 5 and 25 feet above the Lakewood terrace. The Orchard Park is generally less than 20 feet in thickness in the refinery area and is comprised of silt interbedded with poorly sorted lenses of pebbles in a silt and sand matrix. Caliche commonly occurs in the upper layers. The Blackdom terrace is about 40 to 50 feet in elevation above the Orchard Park terrace west of Artesia. However, the deposits associated with the Blackdom terrace are generally less than 20 feet in thickness. The Blackdom terrace deposits are coarser-grained than the deposits associated with the Orchard Park and Lakewood terraces. In addition, the caliche soils have a higher density than those developed on the Orchard Park terrace.

3.5 Groundwater

The principal aquifers in the Artesia area are within the San Andres Formation and the valley fill alluvium (Welder, 1983). Within the valley fill in the vicinity of the refinery process area is a near-surface water-bearing zone, 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 is herein called the *deep artesian aquifer*, whereas the water-bearing zones of the shallower, alluvial valley fill aquifer, including those near the refinery evaporation ponds, are referred to collectively as the *valley fill aquifer*. Adjacent to the refinery, the first water-bearing zone in the valley fill aquifer is referred to as the *near-surface saturated zone* (abbreviated as "NSSZ").

3.5.1 Deep Artesian Aquifer

The deep artesian aquifer is closely related to the Permian 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 feet and the aquifer thickness is about 440 feet (Welder, 1983). The Seven Rivers Formation and the other members of the Artesia group are generally considered confining beds, although some pumpage occurs locally from fractures and secondary porosity in the lower Grayburg and Queen members.

The deep artesian aquifer has been extensively developed for industrial, municipal, and agricultural use. The quality of water from this aquifer ranges from 500 to more than 5,000 ppm total dissolved solids (TDS) depending on location. In the area of Artesia, water is generally derived from depths ranging from 850 to 1,250 feet below ground surface. The aquifer is recharged in the Sacramento Mountains to the west of Artesia. Extensive use of this aquifer in recent decades has lowered the potentiometric head in the aquifer in some locations to 50 to 80 feet below ground level, although extensive rainfall in 1991 brought the water levels in some wells close to, or above, the surface.

3.5.2 Valley Fill Aquifer

Quaternary alluvial deposits of sand, silt, clay, and gravel are the main components of the valley fill aquifer. These sediments are about 300 feet thick in the area between the refinery and the Pecos River. Lyford (1973) researched these deposits and described 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 was not identified by Lyford (1973) 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[sum]," "gumbo"). However, these clays may be more closely related to the fine-grained materials of the carbonate gravel unit found in the interstream areas between the major drainageways.

The thickness of these clay/gypsum mixtures ranges from 20 to 160 feet. The intervals of occurrence differ from well to well, and thin zones of sand or gravels are interspersed in the upper 100 feet. Drillers seeking deep artesian water drill through the valley fill zone and usually log large sections of the intervening zones as "clay and gyp." This lack of detail makes it difficult to correlate specific zones of coarse-grained sediments within the silt and clay deposits. However, drillers wanting to complete wells in the valley fill tend to be more careful in their descriptions and are more likely to record small-scale changes in lithology.

The carbonate gravel unit, described earlier, is the uppermost alluvial unit in the valley fill. Coarse-grained gravels deposited in the major tributaries to the Pecos River grade to calcareous silts and thin zones of caliche in the interstream areas. Near the surface, groundwater is localized in thin discontinuous gravel beds typical of braided channel material deposited during flood events originating in the foothills and Sacramento Mountains to the west.

After examination of drillers' reports, Welder (1983) reported that the valley fill wells tap from one to five water-producing zones. Thicknesses of up to 170 feet have been reported for water-production zones, but most are less than 20 feet. Producing zones are principally sand and gravel separated by less permeable lenses of silt and clay. Wells in the valley fill are completed at depths from 125 feet to deeper than 300 feet, but most in the Artesia area are between 200 and 300 feet deep. Water levels in the valley fill range from 40 to 60 feet below ground level, and the formation yields water containing 500 to 1,500 ppm TDS. The average transmissibility of the alluvium has been estimated at 100,000 to 150,000 gallons per day per square foot, and the average coefficient of storage at about 10% (Hendrickson and Jones, 1952).

Recharge of the shallow valley fill aquifer is generally attributed to irrigation return flow from pumpage of the aquifers and from infiltration from the Pecos River. In areas of the valley where the San Andres and the valley fill aquifers are hydraulically connected in the subsurface, water tends to flow up from the deep to the shallow aquifer except in areas of heavy San Andres pumpage. The general direction of groundwater flow in the valley fill aquifer follows the regional stratigraphic dip eastward 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). The potentiometric surface of the shallow aquifer slopes gently east and southeast, following regional stratigraphic dips. However, south of Artesia in the vicinity and immediately east of Highway 285, heavy pumping between 1938 and 1975 reversed the hydraulic gradient. In this area, the potentiometric surface forms a shallow trough owing to extensive water use for irrigation.

Adjacent to the Pecos River, the valley fill alluvium contains groundwater beginning at a depth of 6 to 12 feet. The alluvium is predominantly silty sand, which possibly contains lenses of higher permeability material. Groundwater flow is subparallel to the Pecos River Valley, and is generally toward the river, although during periods of high river flow, the hydraulic gradient may be away from the river into the alluvium. However, this reversal has not been adequately documented.

3.5.3 Near-Surface Saturated Zone

The agricultural land at Artesia is part of the Orchard Park terrace deposit, which forms a thin veneer overlying older valley fill alluvium. Orchard Park deposits are characterized by silt and sand, with some thin clay lenses and pebbly beds, and chalky caliche common in upper areas of the deposit. Both the caliche and thin pebble beds were found during the drilling of monitor wells and borings during previous site investigations. However, thick, extensive clay zones were also found in these deposits.

At the time of the NCL RFI Phase I study, a deep geotechnical boring was completed to a total depth of 100 feet at a location immediately north of the NCL (Figure 3-1). The deep boring profile reveals caliche gravel seams distributed from about 14 to 38 feet, with the first saturated gravel seam being encountered at 21 feet. The uppermost water-bearing zone in this area, the near-surface saturated zone (NSSZ), is primarily underlain by at least 60 feet of dry, hard clays (Appendix B). The RFI Phase I deep boring profile is consistent with borehole logs for two geotechnical borings which were completed south of the NCL in preparation for unrelated facility construction activities (Figure 7-6).

A review of the lithologic logs from monitor wells installed near the refinery process area shows the NSSZ overlaying the main valley fill alluvium in that vicinity and containing water of variable quality in fractured caliche, and sand and gravel lenses at depths of 15 to 30 feet. This water is under artesian pressure for at least some or most of the year with static water levels 3 to 5 feet above the top of the saturated zones. Groundwater elevations in the vicinity of the landfarm can vary significantly over a short period of time (Section 6.2.1), and transient infiltration of hydrocarbon-containing groundwater into overlying low-permeability strata via existing preferential pathways (old root channels and the discontinuous network of caliche gravel seams underlying the base of the NCL unit) has also been documented (Section 6.1.1).

Locally, the NSSZ is likely connected to Eagle Draw west of the refinery and appears to discharge to marshes and shallow alluvium along the west side of the Pecos River. The most probable sources of the water are thought to be recharge from Eagle Draw, and lawn watering runoff from the grass-covered urban park that occupies the Eagle Draw channel immediately upstream of the refinery. In the vicinity of the NCL, a further source of water is believed to be infiltration from the adjacent city stormwater runoff ditch located on the south side of the NCL. The water in the NSSZ is highly variable in quality, volume, areal extent, and saturated thickness. Concentrations of total dissolved solids exceeding 2,000 mg/l and sulfate exceeding 500 mg/l have been recorded in the vicinity of the landfarm (Geraghty & Miller, 1982).

Although groundwater movement beneath the refinery facility is generally to the east, groundwater level measurements conducted show shallow groundwater movement to the northeast in the vicinity of the NCL. The presence of Eagle Draw, irrigation of an urban park immediately west of the refinery, and the stormwater drainage ditch located immediately south of the NCL are believed to act as recharge sources that cause a slightly semicircular groundwater mound to exist in the vicinity of the NCL. The configuration of the apparent mound may vary depending on the amount and frequency of local recharge. The groundwater mound dissipates east of the refinery, and eastward movement towards the river resumes (NRC RFI Three-Mile Ditch and Evaporation Pond, Phase II report, 1993).

3.6 Identification of Potential Receptors

The community of Artesia is located directly adjacent to the facility. The Preliminary Review (PR) conducted at the facility in 1986 concluded that it does not appear likely that releases from SWMUs at the refinery would affect groundwater quality in the deep artesian aquifers (San Andres and Grayburg/Queen Formations). A review of the published literature and recent investigations supports that conclusion.

The U.S. Geological Survey studies cited earlier (Lyford, 1973, and Welder, 1983) document non-pumping artesian water levels close to the surface and as much as 40 feet higher than valley fill aquifer levels. Wells completed in the deep valley fill near the refinery also appear artesian, with major water producing zones located 200 to 300 feet deep and water levels rising to within 50 feet of the surface. Artesian pressure, depth from the surface to the major water supply aquifers, and the presence of fine-grained materials acting as confining beds appear to be adequate to prevent downward migration of waste constituents at the refinery process areas. Additionally, public water supply wells are located to the west and upgradient of the refinery process areas.

Recent work (documented in the revised NRC RFI Phase II report for the out-of-service Three-Mile wastewater ditch and evaporation ponds submitted to the USEPA in November, 1993) included a detailed analytical comparison of the groundwater in the near-surface saturated zone with water from several valley fill aquifer wells nearby. The comparison, using Piper trilinear mixing diagrams, did not show any compositional relationship between the two zones.

As described in the PR, the nature of the North Colony Landfarm wastes would indicate that some volatilization could occur. Because the surrounding area is populated, the PR stated that the general population could be affected by long-term volatilization of wastes if wind dispersal is not effective in limiting concentrations. However, the above statement was based on the assumption that wastes containing volatile organic compounds would continue to be applied on the landfarm over long periods of time, operational conditions that no longer exist. Waste applications to the NCL ceased in 1990, and treatment of unit soils by tilling, fertilization and irrigation has routinely occurred in order to maximize the degradation of organic constituents. Based on the characteristics of the applied waste, the elapsed time since the last application, the continuous treatment of unit soils since that time, and the rapidity with which volatile compounds degrade, the potential exposure of the surrounding population of Artesia to any volatile organic constituents now originating from the landfarm is likely negligible.

4.0 SOURCE CHARACTERIZATION

4.1 Facility Background

Oil wells were first drilled in southeastern New Mexico in the early 1920s. In April, 1924, the Artesia field opened with the production of 90 barrels of oil. Red Lake Field and Maljamar Field followed within two years. Three years later (1929), another large field, Grayburg-Jackson, began production. Subsequently, other significant fields have been brought into production in the region.

With the 1924 development of commercial quantities of oil in the Artesia field, the need arose for local refining capacity. A partnership was formed to construct a 1,000-barrels per day (BPD) crude oil refinery at Artesia in 1925. The refinery process area was constructed along the south bank of Eagle Creek and tank storage areas were located just south of the North Colony Landfarm. Partners were Tomas Flynn, Van Welch, and Martin Yates II. As oil production continued to grow, a second refinery was built in 1931, directly south of the first, by Maljamar Oil and Gas Company. This second plant, known as the Malco Refinery, initially had a capacity of 1,800 BPD. About this same time, Continental Oil Company (Conoco) purchased the interests of Flynn, Welch, and Yates in the first refinery.

On January 1, 1942, Robert O. Anderson of Roswell, NM, in partnership with Louis Bell, purchased the second (Malco) refinery from Maljamar Oil and Gas Company. Bell shortly sold his interests to Anderson. Under Anderson's direction, the refinery capacity was increased to 5,000 BPD.

Although Conoco continued expansion of the original refinery, the plant facilities became obsolete. To overcome deficiencies, Conoco purchased the Malco Refinery from Anderson in May 1959. The older refinery north of the Malco Refinery was merged through interconnecting pipelines. Petroleum products produced from the North and South Division refinery units covered a wide range and had a combined capacity of 16,000 BPD.

In 1961, the Antitrust Division of the U.S. Justice Department filed suit claiming Conoco to be in violation of antitrust laws. After many court battles, in 1968 the U.S. Supreme Court ordered Conoco to divest within a year. Conoco sold its interests in the refinery, crude oil gathering lines, product pipelines, and El Paso terminals to a newly formed partnership, Navajo Refining Company. Partners were C.L. Norsworthy, Jr., of Dallas, Texas and the Holly Corporation, then of Azusa, California. Subsequent to that purchase, Navajo began to integrate operations into a single refinery capable of processing New Mexico sour (i.e., asphalt-based) crude in the South Division and New Mexico intermediate (i.e., paraffin-based) crude in the smaller North Division. Recent construction, mostly in the North Division, has expanded refining capacity to about 60,000 BPD per day.

The major refining processes at the facility are:

- Crude oil fractionation,
- Fluidized catalytic cracking,
- Alkylation,
- Reforming; and
- desulfurization.

Auxiliary activities associated with these processes separate impurities from the feedstocks and products, or are required for the operation and maintenance of the refinery. The units associated with these auxiliary activities include boilers, cooling towers, storage tanks, water purification facilities, desalting units, and drying and sweetening units.

The production activities at the Navajo Refinery generate a variety of solid wastes and wastewater streams. Prior to the November 8, 1990 effective date of the land disposal restrictions for third-third hazardous wastes, these RCRA wastes (oil/water separator sludges, heat exchanger bundle cleaning sludges, slop oil emulsion solids, and, when produced, leaded tank bottoms) were disposed at the facility's RCRA-permitted North Colony Landfarm. Subsequent to that date, Navajo recycles much of its hazardous waste and consolidates the remainder for shipment to RCRA-permitted disposal facilities outside New Mexico.

4.2 Unit Description

Navajo operated the hazardous waste treatment and disposal site known as the North Colony Landfarm from 1980 to 1990. The location of the NCL was shown previously in Figure 3-1. Prior to the landfarm, the site had been a Conoco company housing colony. The NCL consists of an approximately 4-acre unit located in an area which slopes gently towards the northeast. A 3.5 feet compacted earthen dike around the site is designed to contain the rainfall from a 24-hour, 100-year storm and to withstand the effects of a 100-year flood event.

Hazardous waste applications occurred on the landfarm between May 1980 and September 1990. Approximately 55,000 gallons of listed RCRA wastes were applied to the unit over that time period. Applied wastes were primarily K048, K049, and K051-K052. Applied wastes were tillage-incorporated into the surface soils after application.

The properties of the soils in the area of the NCL were previously characterized in the facility Part B permit. Pima series soils reportedly cover 60 percent of the unit, with the remaining 40 percent belonging to the Karro series.

4.3 Previous Investigations

Prior to the commencement of the RFI investigations in 1994, a number of soils and groundwater studies were performed to assess the likelihood of a release from the base of the unit, to install additional groundwater monitoring wells, and to investigate the source of hydrocarbons detected in the vicinity of and beneath the unit. This section will list and briefly summarize the studies. Copies of the cited studies are included as an appendix to this document (Appendix H).

a) "Installation of Groundwater Monitoring System at the Navajo Refining Company," prepared by Geraghty & Miller, Inc., December 1982. The report provides a discussion of subsurface geology and hydrogeology, presents test results for soil physical parameters (e.g. grain size and laboratory hydraulic conductivity), and lists chemical sampling results for metals in soils, and metals and indicator parameters in groundwater. The report notes an organic odor penetrating the silty clay at the facility.

b) January 19, 1990 NRC letter to HRMB transmitting the analytical results of soil cores taken at the NCL during November 1989. Four sets of soil cores were taken, one from each NCL cell. Each set had a sample recovered from within the top 12 inches of the zone of incorporation (ZOI), and a sample from below the treatment zone (BTZ) at a distance ranging between 4.6 and 6.45 feet below the top of the original treatment zone.

c) "North Colony Landfarm—Alternative Source Demonstration," prepared by John W. Shomaker, Inc., April 9, 1990. The report provides lithologies and cross-section diagrams for 35 borings drilled in the vicinity of the NCL in January and February 1990 to delineate and provide information regarding the source of the plume impacting soil and groundwater beneath the NCL.

d) Draft "Report of Investigation and Monitoring Work Completed at the TEL and North Colony Landfarm Sites from June 14 to 19, 1990," by John W. Shomaker, Inc., July 24, 1990. The draft report provides lithologies, cross-sections, and well completion diagrams for the investigation whose purpose was to further delineate the extent of the hydrocarbon contamination and install additional monitor wells.

e) July 6, 1990 letter to NRC from the NM Bureau of Mines and Mineral Resources transmitting the results of chemical and mechanical analyses of core samples obtained during the June 14 to 19, 1990 drilling and sampling at the TEL and NCL locations.

f) July 13, 1990 NRC letter to HRMB providing a statistical comparison of background inorganics versus inorganics detected in 10 samples from each of the four landfarm cell areas. The landfarm was sampled during the period June 12-15, 1990. The letter also includes a table summarizing the detection of organic constituents in the same sample set. The only constituent showing a statistically significant increase above background was Vanadium in landfarm cell B.

4.4 Constituent Characterization

The following sections provide a discussion on the properties of the chemical contaminants which have been detected in sampling of soils at the base of the NCL treatment zone. This is followed by a section on fate and transport processes including physical, chemical and biological that act on the constituents.

4.4.1 Properties of Heavy Metals in NCL Soils

The solubility and mobility of metals (i.e. chromium and lead) vary dramatically as a function of water chemistry (for example, pH, Eh, and ionic strength), aquifer matrix composition, and the chemical characteristics of the metal. The extent of movement of a metal in the soil system is intimately related to the solution and surface chemistry of the soil and to the specific properties of the metal and any associated waste matrix.

The retention mechanisms for metals added to soil include adsorption of the metal by the soil solid surfaces and precipitation. The retention of cationic metals by soil has been correlated with such soil properties as pH, redox potential, surface area, cation exchange capacity, organic matter content, clay content, iron and manganese oxide content, and carbonate content. Anion retention has been correlated with pH, iron and manganese oxide content, and redox potential (Mclean and Bledsoel, 1992). In addition to soil properties, consideration must be given to the type of metal and its concentration and to the presence of competing ions, complexing ligands, as well as pH and redox potential of the soil-waste matrix.

Because of the wide range of soil characteristics and various forms by which metals can be added to soil, evaluating the extent of metal retention by a soil is site/soil/waste specific. Changes in the soil environment over time, such as the degradation of the organic waste matrix, changes in pH, redox potential, or soil solution composition, due to various remediation schemes or to natural weathering processes also may enhance metal mobility. The extent of vertical contamination is intimately related to the soil solution and surface chemistry of the soil matrix with reference to the metal and waste matrix.

In general, oxidizing conditions favor retention of metals in soils. The pH of the soil system is a very important parameter, directly influencing sorption/desorption, precipitation/dissolution, complex formation, and oxidation-reduction reactions. In general, maximum retention of cationic metals occurs at pH >7 and maximum retention of anionic metals occurs at pH <7.

4.4.1.1 Chromium

Chromium exists in two possible oxidation states in soils: the trivalent chromium, Cr(III) and the hexavalent chromium. Cr(VI) is limited to positively charged exchange sites, the number of which decreases with increasing soil pH (Mclean and Bledsoe, 1992).

In a study of the relative mobility of 11 different trace metals for a wide range of soils, Korte et al. (1976) found that clay soil, containing free iron and manganese oxides, significantly retarded Cr (VI) migration. Hexavalent chromium was found to be the only metal studied that was highly mobile in alkaline soils. According to this study, parameters that contribute to immobilization of Cr (VI) in the soils were free iron oxides, total manganese, and soil pH. The same study indicated that soil properties including cation exchange capacity, surface area and percent clay have no significant influence on Cr (VI) mobility (Mclean and Bledsoe, 1992).

Trivalent chromium is readily adsorbed by soils. In a study of the relative mobility of metals in soils at pH 5, Cr (III) was found to be the least mobile. Among the various oxidation states of chromium, Cr, Cr (III) and Cr (VI) are stable in water. The solubility of chromium is relatively low at pH 8-9.5 (Matthess, 1982).

Complexing and solubility complexation by both organic and inorganic ligands plays a vital role in the movement, mobility, and bioavailability of transition and other heavy metals to biota in soils and sediments through influencing their solubility and sorption to both immobile mineral and organic surfaces in soil (Allen et al, 1995). For example, reduction of Cr(VI) to CR(III) causes a change in species (i.e. from an anion to a cation (Cr^{3+})), and thus its sorptive characteristics.

The redox activity of mineral surfaces also will affect the oxidation state, and consequently the speciation and chemical behavior, of redox sensitive metal ions in the surrounding solution. One example of such a possible redox couple with a metal ion is Cr, which may exist as a Cr (VI) anion in solution. A reduced Fe clay will react with the Cr (VI) species, reducing it to Cr^{3+}, which will either be cationic or precipitated as the oxide. By this process, Cr will be less mobile and less hazardous in the soil environment. Predictions of the fate and behavior of metals in the vadose zone, therefore, must account for redox transformations of the metal ion at mineral surfaces (Allen et al., 1995).

4.4.1.2 Lead

Soluble lead added to the soil reacts with clays, phosphates, sulfates, carbonates, hydroxides, and organic matter such that Pb solubility is greatly reduced. At pH values above 6, lead is either adsorbed on clay surfaces or forms lead carbonate. Lead is adsorbed more readily than most other metals. However, lead can have a strong affinity for organic ligands and the formation of such complexes may greatly increase the mobility of Pb in soils (Mclean and Bledsoe, 1992).

Korte et al. (1976) qualitatively ranked the relative mobility of 11 metals added to 10 soils to simulate movement of metals under an anaerobic landfill situation. Of the cationic metals studied, lead and copper were the least mobile. Clay soils, such as those found at the North Colony Landfarm, were effective in attenuating the metals, while sandy soils and/or soils with low pHs did not retain the metals effectively. For the anionic metals, clay soils containing oxides with low pH were relatively effective in retaining the anions. As with cationic metals, the light textured soils were least effective in retaining the anions (Mclean and Bledsoe, 1992).

Hydroxides and oxyhydroxides of iron, manganese, and aluminum are widely distributed as weathering and precipitation products. Many heavy metals such as lead are adsorbed on the colloidal particles or co-precipitated and occur in sedimentary iron and manganese ores (Allen et. al., 1995).

4.4.2 Properties of Volatiles and Semivolatiles in NCL Soils

Volatile and semivolatile compounds of concern at the site which are listed in Table 4-1 below have different physical and chemical properties such as solubility, vapor pressure, molecular weight, and number of aromatic rings. These and other characteristics influence where volatile and semivolatile compounds will be found in the environment and the potential for environmental effects.

Reasonable indicators of the fate, volatility, and mobility of volatiles and semivolatiles include their solubility, molecular weight, organic carbon distribution coefficient (K_{OC}), henry's constant, vapor pressure, octonal/water partitioning coefficient, bioconcentration factor, and number of aromatic rings. Using these and other criteria it is possible to estimate the relative fate and transport characteristics of organic compounds. In general, the higher the molecular weight, number of rings, octanol/water partitioning coefficient, the less mobile and less biodegradable the organic compound becomes. As aqueous solubility and vapor pressure increase, there is greater mobility and potential for biodegradation. Therefore volatiles such as benzene, toluene, ethylbenzene, and xylene are more mobile and have potential to biodegrade faster than semivolatiles.

The Table below lists relevant characteristics of the volatiles and semivolatile compounds which are of potential concern beneath the North Colony Landfarm.

Table 4-1. Properties of Volatiles and Semi-Volatile Constituents Detected at the NCL

Parameter	Organic Carbon Distribution Coefficient (cc/g)	Henry's Constant (dimensionless)	Water Solubility (mg/l)	Free Air Diffusion Coeff. (cm^2/sec)	EPA MCL (mg/l)
Volatiles					
Benzene	1.81	0.22	1780	0.09234	0.005
Ethylbenzene	2.83	0.321	152	0.0707	0.7
Toluene	2.41	0.269	515	0.8301	1.0
meta-Xylene	2.84	0.281	200	0.0759	10
ortho-Xylene	2.84	0.201	170	0.0759	10
para-Xylene	2.84	0.285	198	0.0759	10
Semi-volatiles					
Acenaphthene	3.70	0.0488	3.88	ND	NA
Anthracene	4.10	0.00137	0.075	ND	NA
Dibenzofuran	ND	ND	ND	ND	NA
Fluorene	3.90	1.90	1.90	ND	NA
1-methyl naphthene	ND	ND	ND	ND	NA
2-methyl naphthene	3.93	25.4	25.4	ND	NA
naphthalene	3.11	31.0	31.0	ND	NA
Phenanthrene	4.10	1.18	1.18	ND	NA
Pyrene	4.58	0.15	0.15	ND	NA

Notes:

ND -- no data, NA -- not applicable

Reference (Ravi, 1990)

4.4.3 Fate and transport processes

Chemical, physical, and biological processes influence the chemical fate of volatiles and semivolatiles. Chemical processes include dissolution, hydrolysis, photolysis, and oxidation-reduction reactions. Physical processes include advection, volatilization, dispersion, diffusion, and sorption to soil and sediments. Biological processes include biodegradation by naturally occurring micro-organisms, and bioconcentration in organisms. These processes are all dependent on site specific conditions, such as physical characteristics of the environmental media, the properties of the chemicals in the mixture, and other factors such as temperature, pH, and humidity.

The sections below discuss the chemical, physical and biological processes that affect the behavior of semivolatile and volatile parameters of concern in soils beneath the North Colony Landfarm.

4.4.3.1 Chemical and Physical Processes

Chemical transport properties such as solubility, volatility, and sorption potential are often used to evaluate and predict how a chemical will behave in the environment. In general, lighter hydrocarbon mixtures like the volatile hydrocarbon benzene, contain constituents with a higher water solubility and volatility and lower sorption potential than heavier mixtures. BTEX compounds are generally more soluble in water, and do not readily sorb to soils. Once the soluble fraction has leached downward, the constituents remaining in the unsaturated soil generally include heavier hydrocarbons. These chemicals are subject to additional fate processes, governed by diffusion, dissolution, and abiotic or biotic transformations, which further reduce the concentrations of these chemicals over time (Lesage, 1992).

4.4.3.2 Biological processes

Biological processes include degradation of chemicals in environmental media (e.g., biodegradation), and uptake of chemical from biota and the potential transfer in the food chain. Many hydrocarbon compounds have been shown to be ultimately metabolized by both animals and microorganisms to carbon dioxide and water (Lesage, 1992). Aromatics are readily used by microbes. As the molecular weight of the chemicals increase, the potential for bioconcentration tends to increase. Therefore, the potential for bioconcentration would be greater for the semivolatiles.

4.4.3.3 Weathering Processes

Weathering includes the sum total of all chemical, physical, and biological processes working to degrade the concentration of a chemical over time. The weathering process at the North Colony Landfarm can be demonstrated by considering the following example. If hydrocarbon compounds were released from the landfarm to shallow unsaturated soils, the lighter, volatile compounds would tend to be released to the air through volatilization before they would have infiltrated substantially into the surface soils. Once leached down into the soil, the remaining lighter fraction could readily be degraded by resident microorganisms through the process of microbial biodegradation. The heavier, longer chain compounds such as pyrene would tend to comprise an increasing percentage of the mixture over time, due to its lower mobility, solubility, volatility, and lower potential for biodegradation.

Other site specific environmental conditions which have potential to influence the rate of weathering of organic compounds includes the clayey nature of the soils. Clayey soils tend to retard chemical transport. The low hydraulic conductivity of the shallow soils (approximately 1×10^{-6} cm/s or greater) retards vertical migration of volatile and semivolatile compounds. In addition, the annual rainfall (approximately 13 inches) and resulting low recharge due to the desert climate, impedes migration of the organics.

These fate processes affect the chemical concentration, migration potential, persistence, and composition of volatile and semivolatile mixtures in the shallow unsaturated soils underlying the North Colony landfarm. Thus, chemical fate and weathering processes are key to the evaluation of site specific conditions.

5.0 UNIT INVESTIGATION ACTIVITIES

This section will describe the work undertaken in the separate phases of the RFI investigation. It is organized by soil and groundwater components so that the reader can follow the progression of the investigation with respect to these key activities. Following the report of the on-site investigation activities, statistical methods to evaluate possible excursions of metals in soils and groundwater are described, followed by a description of the vadose and saturated zone computer modeling efforts.

5.1 Soils

5.1.1 Pre-1994 Soils Investigations

A series of soils investigations were performed in 1989 and 1990 that collected information on subsurface conditions beneath and in the vicinity of the NCL. This work is referenced in report Section 4.3, Previous Investigations, and includes the soil coring conducted in November 1989 and June 1990. The earlier data sets provide valuable information on soil background concentrations of heavy metals and are used in the statistical analyses to evaluate metals migration in soils.

The November 1989 study collected four cores each from the zone of incorporation (ZOI) and from below the treatment zone (BTZ) between 4.6 and 6.0 feet below the estimated top of the original treatment zone (89-001 to 89-004). The June 1990 study collected ten BTZ samples (plus duplicates) from each of the four landfarm cells (A-D) at a depth from 5 to 6 feet below the original soil surface (e.g. A1, B2, C3, etc.). Eight background samples were collected at a depth from 5 to 5.5 feet below ground surface (BG1 to BG8). The location of these sample sets is shown in Figure 5-1, and copies of the correspondence are provided in Appendix H. Analytical data sheets for the 1989 samples are included with the correspondence in the appendix. Both the data summary sheets and the data are provided for the 1990 sampling event.

5.1.2 RFI Phase I Soils Investigation, 1994

The NCL RFI soils investigation included two basic components: (1) the excavation of four observation trenches and (2) the completion of 24 soil borings. Locations for the 1994 observation trenches and soil borings are shown in Figure 5-2. The following report sections provide a general description of the procedures followed during the NCL soils investigation. A comprehensive description of the methods and procedures followed for trench excavation and backfilling, boring completions, sample collection, handling and documentation are presented in the approved NCL RFI work plan (March 1994).

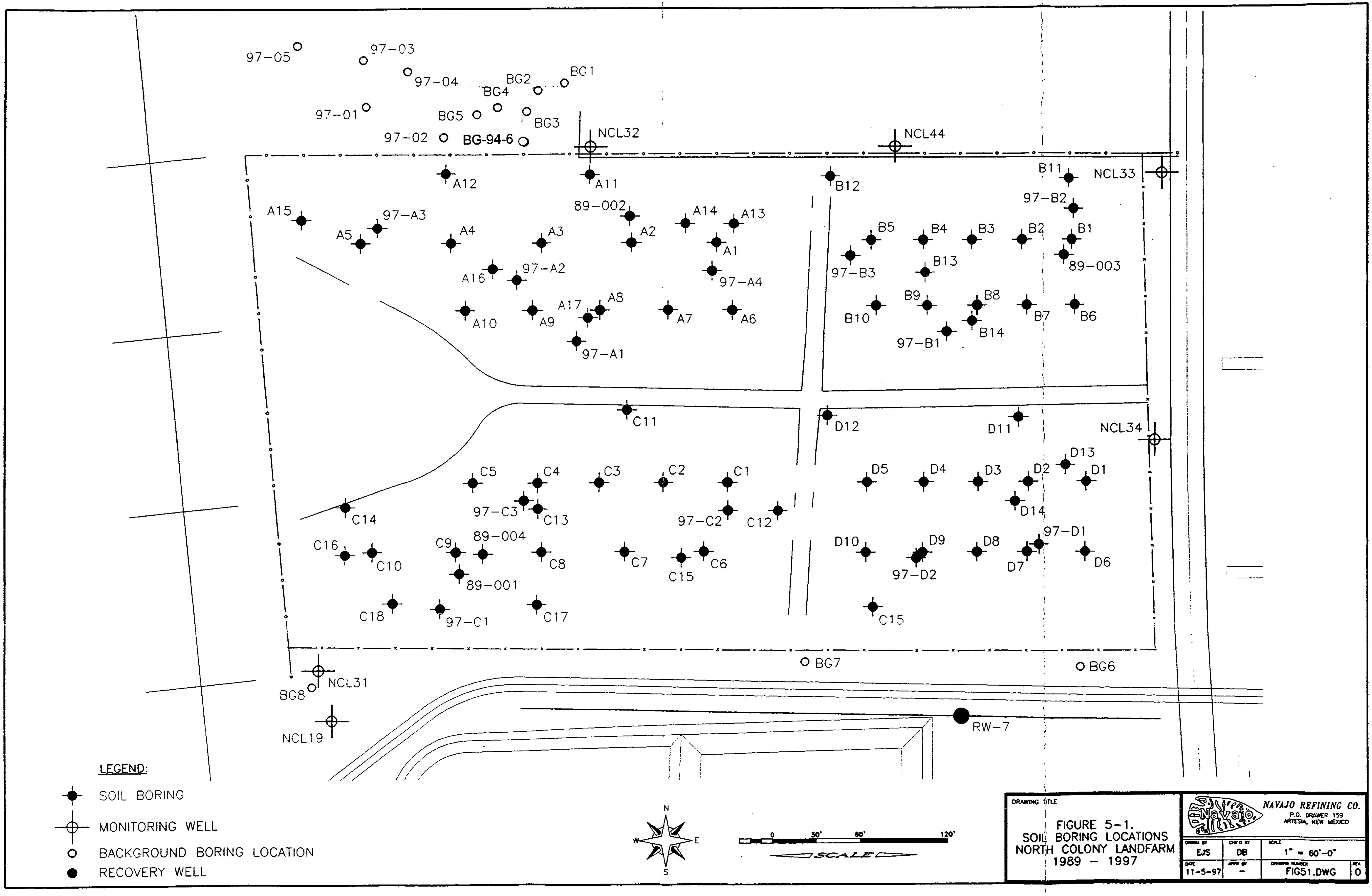


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FIGURE 5-1.
SOIL BORING LOCATIONS
NORTH COLONY LANDFARM
1989 - 1997

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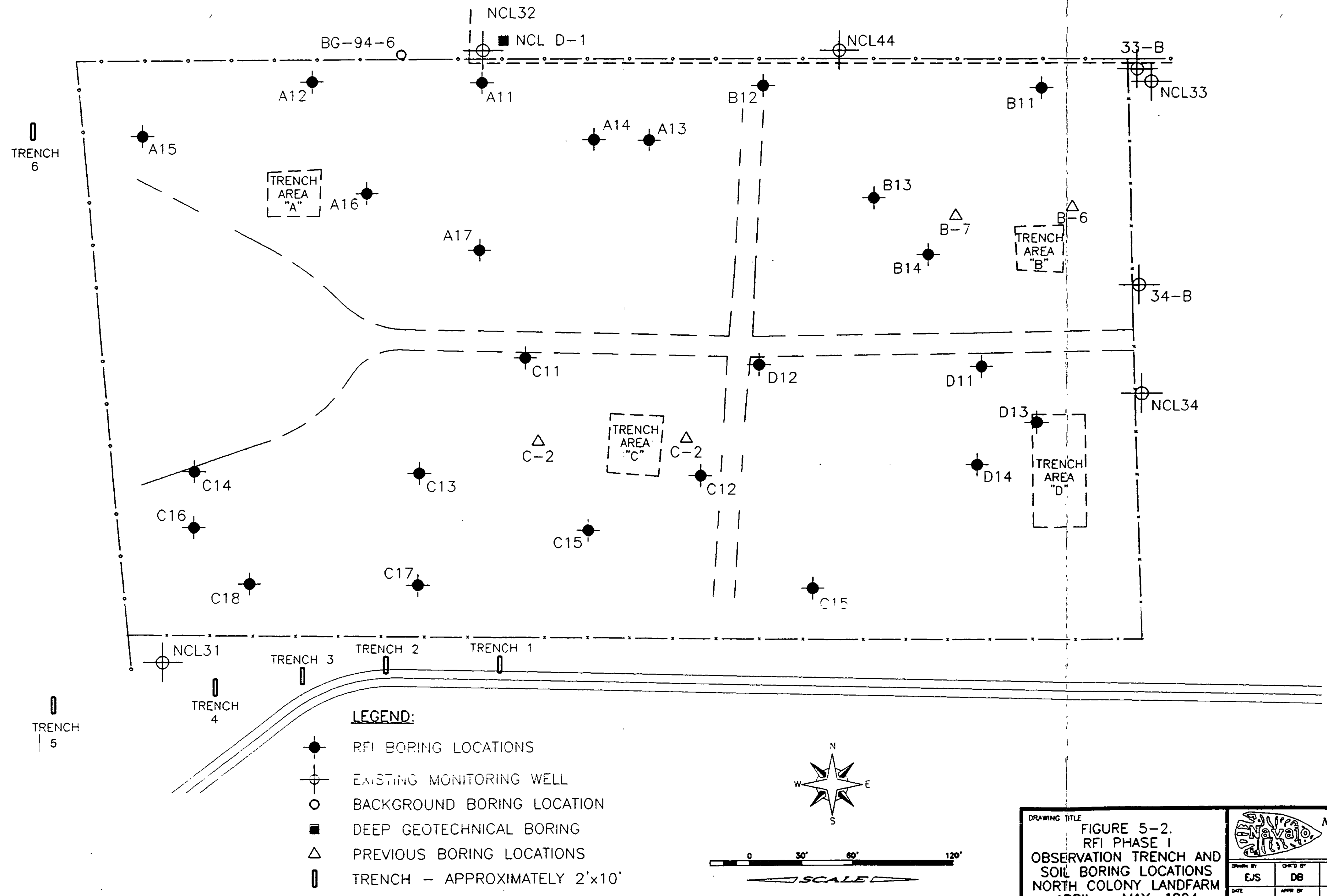

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FIGURE 5-2.
RFI PHASE I
OBSERVATION TRENCH AND
SOIL BORING LOCATIONS
NORTH COLONY LANDFARM
APRIL – MAY, 1994

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5.1.2.1 Observation Trenches

In order to visually inspect the subsurface soil profile and obtain corresponding environmental samples from observed soil zone intervals, four observation trenches were excavated, one at each of the four unit cells designated as A-D (Figure 5-2). Each trench was excavated to a final depth of approximately 10 feet below the original land surface. For safety considerations, trenches were "stair-stepped" into the subsurface using a bulldozer and backhoe so that the maximum height of any exposed vertical sidewall did not exceed 4 feet.

At each of the excavated trench locations, samples were obtained from trench sidewalls at designated intervals of 5, 7, and 9 feet below the elevation of the original land surface. The depth below surface grade at which the top of the original land surface was located was determined by visual inspection of the excavation sidewall. A benchmark grade stake was placed adjacent to each trench, and a laser transit and rod were employed to measure vertical distances to the three specified sample intervals from surface grade at the point of the benchmark stake. The total depth to each designated sample interval was comprised of the depth from surface grade to each sample interval minus the distance from surface grade to the original land surface.

Subsequent to the completion of trench excavation and sampling activities, the elevations of the grade stakes were determined by a professional survey crew. Based on the elevation of the grade stakes and the estimated depth of the original land surface, the elevations of the trench sample intervals were calculated.

For sample collection, decontaminated 2-inch diameter by 6-inch long brass inner sleeves were inserted into a stainless steel core sampler. The core sampler was then impact-driven into the trench sidewall at each sample location. The inner sample sleeves were removed from the core sampler and the open ends were quickly sealed with Teflon tape and plastic caps.

At each trench sidewall sample interval depth, two samples were collected at a horizontal interval of approximately 3 feet. Thus, a minimum of six samples were collected from each trench. However, in one of the four trenches (Trench Area D) anomalous soil conditions were encountered where part or all of an old steel-reinforced concrete structure was unearthed. The former purpose and function of the structure is unknown, although refinery staff believe it may have served as a water cistern for the old housing area. Soils in the vicinity of the buried structure exhibited hydrocarbon contamination that apparently preceded the initiation of landfarm operations. After consulting with the on-site NMED representative, the trench was extended further south to permit the collection of soil samples unimpacted by the structure. However, supplementary samples were also obtained from the trench area observed to be impacted by the buried structure. At each designated sample interval, a biased sample was obtained from the visually impacted area, so that three additional samples were collected from Trench Area D.

Soil samples collected from the observation trenches were analyzed for total chromium, lead, BTEX and semi-volatile organic constituents (SVOAs).

5.1.2.2 Soil Borings

Soil borings were completed at the NCL by use of a 4.25-inch I.D. hollow stem auger external to a 5-foot long CME split-barrel continuous sample tube recovery tool (ASTM-D 4700-91). Soil borings were obtained at 23 locations, as well as at a background soil boring location (BG-94-06) north of the unit (Figure 5-2). Of the completed soil borings, sixteen, including one background boring, were shallow (sample interval depth of 5.5 to 6.5 feet from the original land surface), while the remaining eight locations consisted of slightly deeper borings (sample depth intervals of 5-7, 7-9, 9-11, 11-13, and 13-15 feet below the original land surface).

One of the initially proposed shallow boring locations (D-13) was not attempted. Proposed boring location D-13 was situated in an area in which the unidentified concrete structure was unearthed (see preceding section). Subsequent to its discovery, and prior to the execution of the soil boring investigation, the structure was excavated, and the excavation filled with clean backfill. Also, due to the presence of the very wet soil conditions prevalent at the NCL at the time of soil boring investigation activities, soils in the recently excavated area were judged to be insufficiently stable to support drilling rig access to this area of the NCL.

The 16 shallow soil boring samples were analyzed for chromium and lead, while samples obtained from the eight deep borings were analyzed for chromium, lead, BTEX, and SVOAs. After collection of samples at each boring, the holes were backfilled with bentonite, which was subsequently hydrated to enhance sealing.

5.1.2.3 Geotechnical Boring

A deep boring was completed to a depth of 100 feet at an area immediately north of the NCL and adjacent to Monitor Well 32 (Figure 5-2). This location was selected to avoid areas of known groundwater contamination existing in the vicinity the landfarm. The deep boring was intended to provide a characterization of the uppermost aquifer underlying the shallow near-surface saturated zone, and to provide a general description of the local geologic conditions. Previous borings at the landfarm were limited to depths of approximately 25-30 feet.

Core samples for examination and logging were obtained at intervals of five feet using the split-barrel continuous sample tube recovery method. After logging, cores were discarded except for several clay sections which were preserved for future viewing. Except for shallow thin clayey sand and gravely zones near the surface, no saturated zones containing free water were encountered. Therefore, the hole was not completed as a piezometer and was abandoned. Plugging was performed using a cement grout mixture pumped down hole through a tremie pipe. Although the location is shown on the site map, no surface marker was set.

5.1.3 Additional Site Investigation, 1994

Subsequent to completion of the RFI work outlined in the Phase I workplan, Navajo undertook to better define the subsurface extent of non-NCL hydrocarbon contamination upgradient of the landfarm. The analytical results of the soil sampling conducted during the North Colony Landfarm (NCL) RCRA Facility Investigation (RFI) suggested that the documented upgradient offsite hydrocarbon release extended further to the west than was originally assumed. Because groundwater movement in the vicinity of the suspected release point (underground piping at a diesel storage tank) is generally northeasterly, previous effects in investigation and product recovery were concentrated in the area northeast of the leak site. As a result of previous investigation (Shoemaker, 1990) the approximate area of known impact along the south NCL fence line occurred from the southeast fence corner westward about 400 feet. To determine whether there were hydrocarbon impacts further west, a series of trenches were dug exterior to the NCL south fence line westward of the known contamination area.

5.1.3.1 Trench Installation

Six trenches were dug with a backhoe on June 21, 1994 to determine the subsurface extent of hydrocarbon impacts upgradient of the landfarm. The trenches were installed on the south side of the access easement to monitor well MW-32 with the north end of Trenches 1 through 4 located at distances from 17 to 28 feet south of the landfarm fence (Figure 5-2). The south end of Trenches 1, 2 and 3 were adjacent to a storm runoff ditch which enters the Navajo property from the west and drains Artesia city streets and urban areas. The drainage ditch separates the tank storage area to the south from the NCL. Trench 4 was located in a triangle of land formed by a change in direction of the ditch upon entering the Navajo property. Trenches 5 and 6 were dug west of the NCL near the southwest and northwest landfarm corners, respectively. All trenches were oriented north-south and were approximately ten feet long and about 10 feet deep. A record of the trench lithology was made at each excavation although readings are approximated using a tape measure from the surface. Direct entry and measurement of the trench sections was not possible for safety considerations. The trench logs are included with Appendix B. As described in Section 5.1.3.2 below, samples for hydrocarbon analysis were collected where visual and olfactory observation indicated hydrocarbon presence. The locations of the trenches were measured from surveyed NCL landmarks, and vertical elevations of the trench surface, base of trench and approximate sample locations were surveyed using the elevation of MW-31 as the benchmark. At the conclusion of observations, the trenches were backfilled with the excavated material.

5.1.3.2 Sample Collection

Soil samples were collected for laboratory analysis from four of the six trenches where visual evidence and odor indicated the presence of hydrocarbon contamination. Because of trench entry constraints, samples were collected from the backhoe bucket which contained dirt obtained from the zone of contamination. Soil samples were collected in glass jars provided by the laboratory, preserved with ice, and shipped with chain-of-custody forms. A fluid sample also was collected from the east-west product recovery trench (RT-7) located approximately 25 feet south of the drainage ditch. This sample was collected from a trench observation well located approximately 150 feet west of the recovery pump installation.

5.1.4 RFI Phase II Soils Investigation, 1995

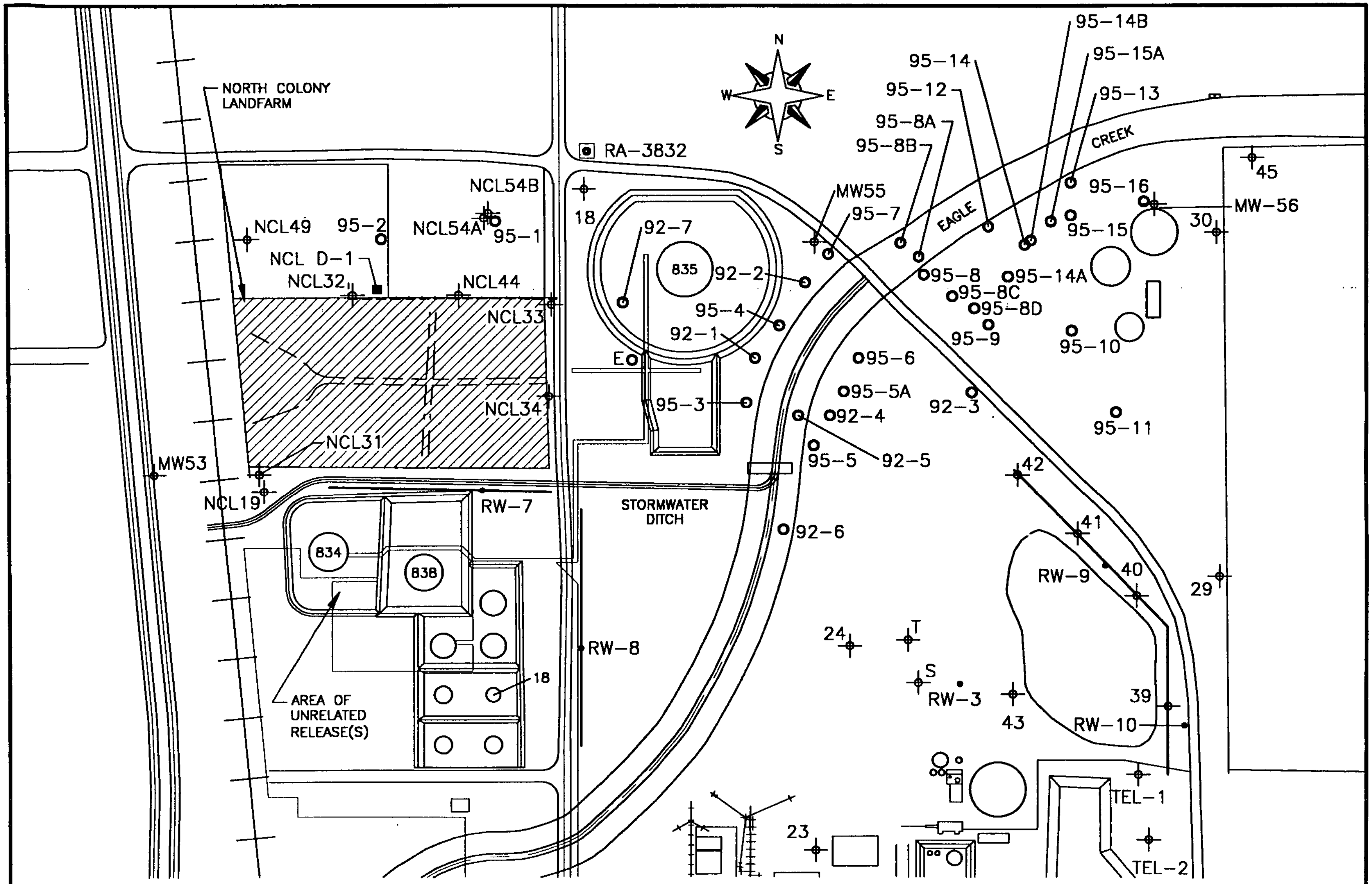
During the performance of the NCL RFI Phase II field activities, a total of 24 soil borings were completed in the vicinity of the NCL in the summer and fall of 1995. Three of the borings (NCL 95-01, -07, and -16) were subsequently installed as groundwater monitoring wells (Section 5.2). Pursuant to Section 4.1.2.3.1 of the RFI workplan, soil borings were initially completed on

200-foot centers, modified as necessary for locations of refinery equipment or utilities. When hydrocarbons were encountered, borings intermediate to the primary locations also were completed. These were labeled with a letter modifier (e.g., NCL 95-08A). The locations for the RFI Phase II soil borings are presented in Figure 5-3, which also shows the locations of 7 additional soil borings (92-XX) which were completed in conjunction with compliance activities pre-dating the RFI Phase II.

The soil borings were accomplished using a direct push method as described in the February 1995 RFI Phase II workplan (Section 4.1.2.3.1), or the more conventional coring method using a 5-foot, 3-1/2-inch-ID core barrel advanced ahead of an 8-1/4-inch hollow-stem auger flight. In the direct push method, the CME-75 drill rig used its hydraulic system to advance a 2-inch-diameter, 2-foot-long split-spoon barrel. No drill cuttings were produced using this method. Depending on specific borings, boring cores were obtained at 2-foot intervals, beginning at 3 to 5 feet, and then continuing again at 8 to 10 feet and consecutive 2-foot intervals thereafter to the final boring depth. If the larger core barrel recovery method was used, samples were collected at 5-foot intervals beginning at a boring depth of 4 feet. Sample cores were recovered for observation, logging, and field measurements of vapor-phase volatiles using a calibrated photoionization detector (PID). Exploratory holes drilled adjacent to primary holes were cored with a 3-1/2-inch-OD solid-stem auger. Logging of these extra holes was performed from drill cuttings and generally only visual observations were recorded, although some samples for PID readings were collected only at depths where hydrocarbons were detected. Final boring depths ranged from approximately 15 to 28 feet. All boreholes were backfilled with bentonite which was hydrated with 5 gallons of fresh water.

Descriptive logs for the RFI Phase II borings are presented in Appendix B. Also presented in the appendix are logs for the additional boring locations shown in Figure 5-3 which were completed prior to the execution of the RFI Phase II study. These include seven borings completed by NRC in the study area in August 1992 and the log of the deep boring located adjacent to NCL-32 that was completed in 1994 as part of the NCL Phase I investigation. Logs of two deep geotechnical borings cored prior to construction of new refinery processing unit are included also.

In addition to the physical observations and field PID testing, three groundwater samples were collected at borings NCL 95-01, -02, and -07 within 24 hours of completion of the borings. Collection of those groundwater samples and subsequent analytical data was intended to provide supplementary information regarding the presence/absence of dissolved-phase hydrocarbon contaminants. The analytical data generated from the boring groundwater samples, together with the soil boring visual and PID observations, was subsequently considered during the selection process for RFI Phase II downgradient groundwater monitoring well locations. Further discussion of the groundwater samples collected from RFI Phase II soil borings is provided in Section 5.2.2.



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LEGEND:

- MONITOR WELL
- ○ BORING LOCATION
- ■ DEEP GEOTECHNICAL BORING (1994)
- ● RECOVERY WELL LOCATION

NOTE: BORING LOCATIONS APPROXIMATE (TAPED, NOT SURVEYED)

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FIGURE 5-3.
RFI PHASE II
SOIL BORING LOCATIONS
NORTH COLONY LANDFARM
JUNE – AUGUST, 1995

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5.1.5 RFI Supplemental Soils Investigation, 1997

The RFI supplemental soils investigation activities were proposed in the "Response and Proposed Plan of Corrective Action" included as an attachment to NRC's June 13, 1997, response to NMED's May 21, 1997 letter of violation. Soil activities included collection of additional background soil samples for metals, and collection of soil samples for analysis at locations adjacent to where monitor wells MW-54A, -54B, -55 and -56 were installed in 1995.

5.1.5.1 Collection of Background Soil Samples

To provide a larger population for statistical analysis, additional soil samples were collected for analysis of chromium and lead to supplement the background samples collected in 1990 and the single sample collected in 1994. The area selected for additional sampling was located immediately northwest of the north boundary of the landfarm and between monitor wells NCL-32 and NCL-49 (Figure 5-4). Because the area where the landfarm is located has been heavily industrialized for over 70 years, this is the closest undisturbed location suitable for collection of background samples. Physically, this is an undeveloped area owned by NRC that is adjacent to a gravelled driveway used for truck access to a crude oil unloading area.

Locations chosen for sampling were selected using a random number table and a grid system. The starting point for the grid system was the NCL northwest corner post and the grid was a rectangle bounded by NCL-32 on the east, and NCL-49 on the north. Consecutive three-digit numbers representing easterly and northerly coordinates (in feet) were selected from the table until five sites were located within the grid.

Soil borings were advanced using a B-61 hollow-stem auger operated by Layne Environmental Services of El Paso. Splitspoon samples were collected at depths of 5-7, 7-9, and 9-11 feet for analysis of chromium and lead metals. Samples were collected in a clean 2-inch by 2-foot long metal splitspoon advanced ahead of the auger by a downhole hammer using standard ASTM geotechnical sampling procedures. After collection of samples at each boring, the holes were backfilled with clean cuttings.

5.1.5.2 Collection of Soil Samples at Monitor Wells

At the time of installation of new monitor wells MW-53, 54(A and B), 55 and 56, PID analyses were performed on soil samples collected every 2 feet during drilling of the well. However, soil samples were not collected for laboratory analysis and evaluation. Accordingly, the locations of wells MW-54, -55 and -56 were revisited and soil borings were drilled between 14 and 18 feet downgradient of the current location. Soil samples were collected by cleaned splitspoon at depths of 5 to 7, 9 to 11, 13 to 15, 18 to 20 and 23 to 25 feet below the surface and analyzed for volatiles and semi-volatiles (EPA SW-846 methods 8240 and 8270, respectively) and chromium and lead metals (EPA SW-846 method 6010). Upon completion, the bottom of each hole from approximately 10 feet to total depth were backfilled with bentonite and hydrated. The remainder of each hole was backfilled with clean cuttings.

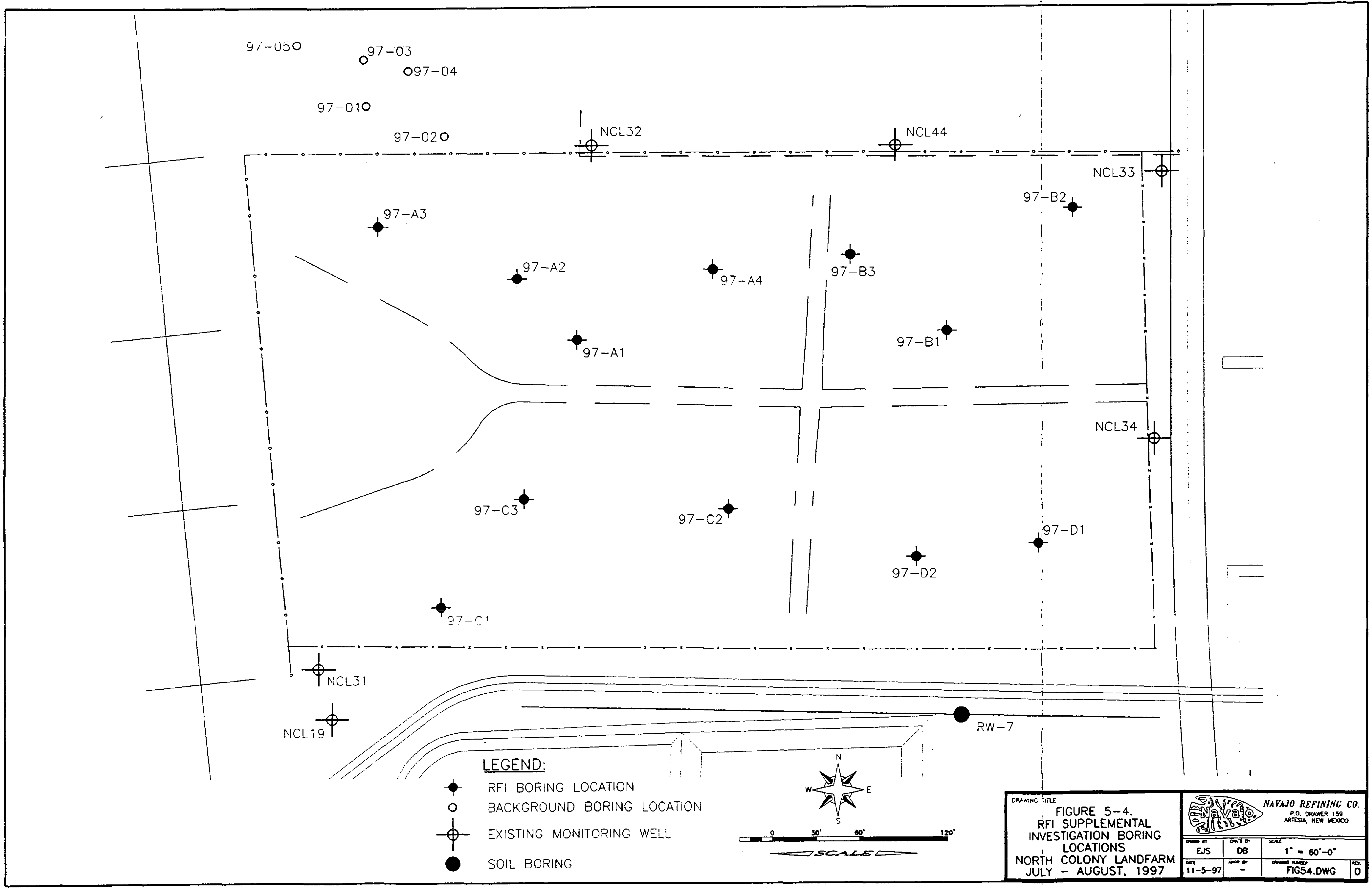

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FIGURE 5-4.
RFI SUPPLEMENTAL
INVESTIGATION BORING
LOCATIONS
NORTH COLONY LANDFARM
JULY - AUGUST, 1997

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5.1.6 Landfarm Elevation Survey

Because accurate surface locations and elevations are necessary to establish the position of the trenches and soil borings, the elevation of subsurface profiles, and groundwater flow direction, the immediate area of the NCL was surveyed in 1994 by John D. Jacquess & Associates of Roswell, a professional land surveyor registered in the State of New Mexico. In addition to establishing surface elevations, all groundwater monitoring wells were re-surveyed, including the elevation of the casing, top of the protective cover, and the land surface elevation of each well.

5.2 Groundwater

5.2.1 RFI Phase I Groundwater Investigation, 1994

The groundwater portion of the RFI Phase I workplan was predicated on locating the next water bearing zone beneath the near-surface saturated zone so that the extent and hydrologic characteristics of this zone could be defined. Such a zone was not located within 100 feet below the land surface at the NCL site (Section 6.1.3). Therefore, groundwater work in the 1994 investigation was limited to confirming the direction of groundwater flow at the landfarm to aid in interpretation of the chemical data obtained during the soil sampling phase of the investigation.

5.2.2 RFI Phase II Groundwater Investigation, 1995

Groundwater activities conducted during the RFI Phase II investigation included installation, development and sampling of new groundwater monitoring wells; hydraulic conductivity testing of two wells; and periodic and continuous measurement of groundwater elevations in new and existing monitor wells at the site.

5.2.2.1 Monitor Well Installation

Five new groundwater monitoring wells (MW-53, 54A, 54B, 55, and 56) were installed during the RFI Phase II. MW-53 was installed as an upgradient well, and the remaining wells were located so as to be immediately downgradient of the hydrocarbon product plume. The new well locations are included on Figure 3-1, together with locations of several pre-existing groundwater monitoring wells associated with the refinery's groundwater monitoring network. The new monitoring wells were installed according to the methods and procedures delineated in the February 1995 RFI Phase II workplan. Details of monitoring well installation and construction are shown in Appendix B.

Well MW-53 was installed in June 1995 at the request of the NMED to serve as a replacement upgradient well for NCL-31 which is located adjacent to, but off-gradient from, the petroleum product tankfarm from which the hydrocarbon plume originated. Wells MW-54A, 55, and 56 were installed in conjunction with the associated soil borings (NCL 95-01, 95-07, and 95-16, respectively) which were initially cored at the respective monitoring well locations.

Wells MW-55 and 56 were installed in August 1996 immediately after delineation of the hydrocarbon plume was completed. Screen placement in these wells was several feet above the depth where saturation was first encountered. However, the water level inside the boreholes was suppressed by the thinness of the water bearing zones and thick smearing of the plastic clays along the outside hollow stem auger flights. Because of these factors and because the groundwater exhibits semi-confined conditions, the final water level was slightly above the level of the screen. This will not affect use of these two wells for their designed purpose which is the early detection of dissolved-phase hydrocarbons. To prevent this problem from affecting the final well, MW-54 was scheduled for completion with a 15-foot screen.

Well MW-54 installation was delayed due to a lack of access to the property site by the existing landowner. The well was installed in December 1995 after the property was acquired by NRC. During the drilling of this well, a deeper zone of saturation was encountered at 30 feet and the well was completed as a shallow monitor well (MW-54A). A second well (MW-54B) was completed into the slightly deeper zone to sample water and test the hydraulic properties of the lower zone.

The locations and elevations of the monitor wells installed during the NCL investigation were professionally surveyed by John W. West Engineering Company of Hobbs, New Mexico. The location and elevation coordinates of the most recently installed wells were merged with surveyed data previously provided by John D. Jacquess & Associates of Roswell for the Phase I investigation. The resultant data, together with additional information provided by the refinery, were used to produce the base map upon which information generated during this study were plotted.

5.2.2.2 Monitoring Well Development and Groundwater Sampling

Following their installation, groundwater monitoring wells were developed according to the methods described in the February 1995 RFI Phase I and II workplan (Section 4.2.2.7), and groundwater samples were then collected from the wells according to the procedures and methods also described in the workplan (Section 4.2.3). Details of well development for each installation are included with the lithologic logs presented in Appendix B.

During the course of the RFI Phase II field work, groundwater samples were collected from all five newly installed monitoring wells, as well as from MW-18, a previously installed monitoring well (Figure 3-1). Groundwater samples were subject to analysis for the following environmental parameters:

- volatiles (SW-846 Method 8240);
- semivolatiles (SW-846 Method 8270);
- total metals (SW-846, various methods); and
- general water chemistry parameters.

In addition to the groundwater samples collected from the completed monitoring wells, three additional groundwater samples were also obtained from completed soil borings, as described previously in Section 5.1.4. These latter samples were analyzed for BTEX constituents according to SW-846 Method 8240. Analytical data for all groundwater samples are presented in Section 6.2.7 with the data sheets reproduced in Appendix G.

5.2.2.3 Hydraulic Conductivity Tests

Following monitoring well installation, a series of tests were conducted in order to characterize the NSSZ in terms of key hydrogeological parameters. In order to characterize the *in situ* hydraulic conductivity of the NSSZ in the area of investigation, a standard "slug test" was performed at groundwater monitoring wells MW-54A and MW-54B. Slug tests utilize an object of known volume (a "slug") that is inserted into and removed from the well while measurements are made of time response for water to return to the original static water level. Since dimensions of the slug and wellbore are known, the time required for the water level to stabilize is proportional to the hydraulic conductivity of the formation. Because the slug used to test monitoring wells MW-54A and 54B displaced a relatively small volume of water, the time for the wells to recover was on the order of minutes, and a datalogger was required to provide accurate measurements for the conductivity calculations.

The slug used in this procedure was a section of one-inch PVC pipe with an outside diameter of 1-5/16 inch (0.11 foot) and a length of 6.25 feet. The casing section was filled with clean pea gravel for ballast, sealed at the top and bottom with 1-5/8-inch OD caps, and secured with small stainless steel screws. An eye hook was attached to the top cap and clean rope attached for lowering into the wells. The total volume displaced by the slug was 0.45 gallons.

Data collection equipment included a battery-powered In Situ™ 1000C data logger and an In Situ™ 10-psi pressure transducer. The transducer was placed downhole at a depth below the base of the inserted slug. The test was initiated by activating the data logger and quickly lowering the slug into the well. After the water level stabilized at its static level, the second phase of the test was initiated by withdrawing the slug from the well and recording the rising water level until it returned to the static level.

Depending on aquifer properties, slug test results are evaluated using two procedures. Based on aquifer discharge and recharge response rates that were recorded at the time of the tests, the slug test data was analyzed according to the method of Bouwer and Rice (1976) and Bouwer (1989), and the method of Cooper, et al. (1967).

Equations, slug test parameters, and data graphs associated with the calculation of aquifer hydraulic conductivities are included in Appendix F, and a summary of hydraulic conductivity calculations is presented in Section 6.2.4, Table 6-20.

5.2.2.4 Groundwater Elevation Measurements, 1995

Two types of groundwater elevation measurements were obtained during the course of the RFI Phase II. Routine measurements of water level elevations were made at wells previously installed at the NCL and in the newly drilled NCL wells. These measurements were made by NRC staff or by their consultant. A second type of measurement was obtained by the installation of a continuous water level data recorder in an unused monitor well adjacent to the landfarm. Both types of measurements are discussed further below.

5.2.2.4.1 Periodic Elevation Measurements

A series of routine measurements were obtained immediately following installation at the five monitoring wells which were drilled during the course of the RFI Phase II. These initial measurements were recorded with the other lithologic and hydrologic information on the boring logs reproduced in Appendix B. In addition, NRC refinery staff obtained groundwater elevation data in conjunction with routine sampling of existing NCL monitor wells pursuant to provisions of the NCL RCRA permit. Also, supplementary data for use in the current study was obtained by NRC and consultant staff during this and other refinery hydrologic investigative activities.

5.2.2.4.2 Continuous Elevation Measurements

At groundwater monitoring well NCL-19, a down-hole pressure transducer linked to an electronic continuous data recorder was installed in order to obtain an instantaneous profile of groundwater elevation trends over an extended period of time. The selected monitor well was initially installed as the NCL upgradient monitor well, but was replaced in 1982 by a well drilled a short distance away constructed to RCRA standards (NCL-31). Although unused, the large-diameter well is completed in the NSSZ and provided an ideal location for long-term continuous water level measurements.

The water level data logger and pressure transducer were manufactured by Telog Instruments of Victor, New York. The data logger was a Telog™ series 2102e-20 with a 10-psi pressure transducer which is effective in recording water level fluctuations over a range from 0 to approximately 25 feet. The recorder was set to obtain a water level measurement every ten minutes and has a data storage capacity of 148 days at that frequency of data collection. The water level data recorder was installed in the well in early July 1995 and removed in late December 1995. Installation was accomplished by mounting the unit along the inside of the well casing and lowering the pressure transducer to the bottom of the well, a distance of approximately 20 feet below the ground surface. At the bottom of the well, the transducer was submerged in about 7 feet of water. Operation of the recorder was checked periodically, and water level data from the recorder was downloaded to a portable computer in August, September, October, and December.

5.2.3 RFI Supplemental Groundwater Investigation, 1997

The RFI supplemental soils investigation activities were proposed in the "Response and Proposed Plan of Corrective Action" included as an attachment to NRC's June 13, 1997, response to NMED's May 21, 1997 letter of violation. Groundwater activities included drilling and installation of temporary monitor wells beneath the landfarm for groundwater quality sampling, placement of continuous water level recorders at several monitor well location, measurement of groundwater levels in NCL monitor wells, and groundwater sampling of well MW-54B. Groundwater sampling of MW-54B followed the same protocols as described above (Section 5.2.2.2) and will not be discussed further here. Samples from MW-54B were analyzed for the same suite of constituents which are required to be analyzed for NCL quarterly samplings.

5.2.3.1 Temporary Monitor Well Installation

During the period July 29-30, 1997, 12 temporary monitor wells were installed within the fenced area of the landfarm. The locations of the wells were selected using a random number table and a grid system based on the four NCL corner fence posts. Consecutive three-digit numbers representing easterly and northerly coordinates (in feet) from the southwest corner fence post were selected from the table until several sites were located in each of the landfarm cells A through D. The coordinates were then translated into distances from each corner fence post and the location staked. For example, boring NCL 97-A1 is located 226 feet east and 128 feet south of the northwest corner post and NCL 97-D1 is 80 feet west and 73 feet north of the southeast corner post. Each boring location is listed on the lithologic boring logs shown in Appendix B

Each well was installed using a B-61 hollow-stem auger operated by Layne Environmental Services of El Paso. A boring was first drilled to 15 feet and the auger cuttings logged. For the first several wells drilled (NCL 97-A3, NCL 97-A2, NCL 97-A1), splitspoon samples were collected from 15 to 18 feet in an attempt to locate the top of the first water-bearing zone in the NSSZ and to check for free-phase hydrocarbon in the cores. For later wells, splitspoon samples were collected from 15 to 17 feet.

The screen interval was selected based on water levels in adjacent monitor wells and the knowledge that the landfarm surface is from 1 to 2 feet higher than the wells. However, because no obvious water zone was located in the 15- to 17-foot interval for first three wells, an additional 1 foot splitspoon sample was collected before advancing the temporary screen. When the water levels were measured in the first three wells, the splitspoon sampling interval was reduced to the interval between 15 and 17 feet.

Temporary screens were advance using the PowerPunch™ direct push groundwater sampling system from GeoInsight of Clayton, California. The PowerPunch™ operates by pushing a 2 inch OD hollow drive rod and a cone tip to a pre-determined depth. Between the drive rod and the tip, a 12-inch carbon-steel tool (the PowerPunch™) is installed. To collect a water sample, 5-foot long by ¾ inch PVC screen attached to PVC casing is inserted inside the drive rod. The PowerPunch™ and drive rod (still attached to the drill rig) is retracted 5 feet exposing the screen. At that point, the drive rod is rotated two turns and is disengaged from the PowerPunch™ tool. The drive rod is removed from the hole and the tool, screen and cone tip remain in place. The PowerPunch™ tool provides an annular seal that prevents movement of fluids from upper zones to the temporary screen. After a water sample is collected, the screen is removed and the hole abandoned with the cone tip and PowerPunch™ tool remaining.

Using the direct push system, 12 temporary wells with new ¾-inch screens were installed. Because of the very slow filling of the wells, water levels were measured and samples collected from 12 to 24 hours after installation. The wells were first purged of three-well volumes using a peristaltic pump with dedicated tubing before performing groundwater sampling. Some wells recharged so slowly that multiple attempts were needed to collect a sufficient sample volume for analysis and most wells were turbid with fluids having a chalky white color. The water samples were collected, preserved, and shipped to the analytical laboratory using EPA protocols described in Section 4.2.3 of the RFI workplan. The water samples were analyzed for the same suite of constituents which are required to be analyzed for NCL quarterly samplings.

Upon completion of the sampling, the PVC well screen and casing riser was removed leaving the cone tip and PowerPunch™ tool in place. Abandonment consisted of plugging the bottom 8 feet of the hole with a cement/bentonite slurry. From 5 to 8 feet the hole was plugged with bentonite chips that were then hydrated. The remainder of the hole was plugged with clean cuttings from the intermediate portion of the bore hole.

5.2.3.2 Groundwater Elevation Measurements, 1997

As in 1995, two types of groundwater elevation measurements were obtained during the course of the RFI Supplemental Investigation. March and August 1997 measurements of water level elevations were made at the NCL wells by NRC staff or by their consultant for inclusion in this report. Continuous measurements were obtained by the installation of two water level data recorders in several monitor wells adjacent to the landfarm..

5.2.3.2.1 Continuous Elevation Measurements

At groundwater monitoring well NCL-19, the water level data logger and pressure transducer manufactured by Telog Instruments and used in 1995 was reinstalled. The transducer was linked to an electronic continuous data recorder installed in order to obtain an instantaneous profile of groundwater elevation trends over an extended period of time. The unit is described in Section 5.2.2.4 above. MW-19 is an unused, large-diameter, well is completed in the NSSZ that provides an ideal location for long-term continuous water level measurements.

The Telog™ recorder was set to obtain a water level measurement every ten minutes and has a data storage capacity of 148 days at that frequency of data collection. The water level data recorder was installed in the well in early July 1997 and removed in mid-October 1997. Operation of the recorder was checked periodically, and water level data from the recorder was downloaded to a portable computer in September and October.

A second recorder was installed in late July 1997t o measure levels in two additional wells. The second recorder is a Solinst brand Levelogger™ from Solinst Canada of Georgetown, Ontario. The Levelogger™ is a 9-inch by 7/8-inch diameter stainless steel cylinder with fully contained a pressure transducer and data storage unit. The Levelogger™ is hung from a special monitoring well cap by an ordinary steel cable and retrieved to download the stored data. The unit is programmed and data retrieved by way of an infra-red sensing unit that is connected to a personal computer. The data logger has a 10-psi pressure transducer which is effective in recording water level fluctuations over a range from 0 to approximately 16 feet. The recorder was set to obtain a water level measurement every ten minutes and has a data storage capacity of 111 days at that frequency of data collection. The Levelogger™ was installed in NCL-44 from late July through early September and then moved to NCL-32 where water levels were measured through mid October, 1997.

5.3 Statistical Analyses

Statistical analyses for soil and groundwater using the *t*-test were conducted for both chromium and lead to determine whether soil concentrations beneath the landfarm or downgradient water quality values represent a statistically significant increase in hazardous constituent concentrations. Methods for performing and evaluating the *t*-tests are found in *Statistical Analysis of Ground-Water Monitoring Data at RCRA Facilities* (USEPA, 1989), and Berk and Carey (1995). The test data and summary results are described in Section 6.1.5 for soil samples and Section 6.2.7.3 for groundwater.

To begin the statistical exercise, we assume that the background soil or groundwater data is normally distributed, i.e. has a normal distribution represented by the traditional bell-shaped curve (an assumption tested later), and a sample mean that is representative of the population mean. To utilize the *t*-test, a null hypothesis (H_0) is formulated that the mean of the soil or groundwater data sets (u_2) is equal to the true mean of the data (u_1) as represented by mean of the background data (H_0: $u_1 = u_2$). That is, the hypothesis will test that the mean of the observed sample data is not significantly different from the mean of the background data. An alternative hypothesis, H_a, is postulated that the sample and background means are not equal (H_a: $u_1 \neq u_2$). A probability value is selected (e.g. $\alpha = 0.05$) such that the probability of the true sample mean lying outside the range of the true background mean is less than 0.05 (i.e. less than 5%). With a selection of $\alpha = 0.05$, we will be confident that 95 % of the time the true sample mean will lie within the range of background values as represented by the background mean. If the sample mean is within the 95% confidence interval defined by the background data, the hypothesis of equal means is accepted and it can be stated that there is no statistically significant difference between the two means at the 95% level of significance.

Before performing the *t*-test, the distributions of the sample data were evaluated to determine whether the sample populations were normally distributed, and if the data sets used for background comparison contained outliers. The tools used to make these determinations are described in USEPA (1989), and Anderson et al., 1997. The test for a normal distribution divides the standard deviation by the sample mean. If the resultant value (called the coefficient of variation, CV) is greater than 1.0, it is likely that the data set evaluated is not normally distributed. The test for a sample outlier subtracts the sample mean from the sample value and divides the result by the sample standard deviation. If the resultant number (the *z*-statistic) is outside the range $-3 < z > 3$, the sample value is considered an outlier and eliminated from the data set under evaluation. Only background data values were evaluated for outliers; outliers in sample observations may be indicative of contamination of the sample. The results of the normalcy and outlier tests are included with discussions of the results of soil and groundwater statistical testing in Section 6.1.5 for soil samples and Section 6.2.7.3 for groundwater.

5.4 Vadose Zone Modeling

Vadose (unsaturated) zone modeling was considered for the site based on soil boring and trench observations that, once below the base of the treatment zone, hydrocarbon contamination increases vertically downwards with the greatest concentrations of these constituents found at depths in excess of 9 feet below the original land surface. Using levels of organic constituents detected in the upper interval (between the base of the unit and the depth where detections and concentrations increase) as a starting point, the model would provide attenuation information and estimate concentrations that would be found in the groundwater if the organic constituents migrated from the base of the treatment unit.

The model selected for use in this exercise was VLEACH which was developed for EPA, Region 9 in 1990. The model describes the movement of specific organic contaminants within and between three different phases: (1) As a solid dissolved in water, (2) as a gas in the vapor phase, and (3) as an adsorbed compound in the solid phase. Equilibrium between the phases occurs according to distribution coefficients defined by the user. In particular, VLEACH simulates vertical transport by advection in the liquid phase and by gaseous diffusion in the vapor phase. The processes are conceptualized as occurring in a number of distinct, user defined polygons that are vertically divided into a series of user-defined cells. The polygons may differ in soil properties, recharge rate, and depth to water. However, within each polygon homogenous conditions are assumed except for contaminant concentration , which can vary between layered cells. During each time step, the migration of the contaminant within and between cells is calculated. Hence, VLEACH can account for lateral soil heterogeneity but is limited when simulating vertical heterogeneity (Ravi, 1990).

Initially, VLEACH calculates the equilibrium distribution of contaminant mass between the liquid, gas, and sorbed phases. Transport processes are then simulated. Liquid advective transport is calculated based on values defined by the user for infiltration and soil water content. The contaminant in the vapor phase migrates into or out of adjacent cells based on the calculated concentration gradients that exist between adjacent cells. After the mass is exchanged between the cells, the total mass in each cell is recalculated and re-equilibrated between the different phases. These steps are conducted for each time step, and each polygon is simulated independently. At the end of the model simulation, the results from each polygon are compiled to determine an overall area-weighted ground-water impact for the entire modeled area.

The following VLEACH model assumptions are relevant to the current modeling scenario:

1. Linear isotherms describe the partitioning of the pollutant between the liquid, vapor and soil phases. Local or instantaneous equilibrium between these phases is assumed within each cell.

2. The vadose zone is in a steady-state condition with respect to water movement. More specifically, the moisture content profile within the vadose zone is constant. This assumption will rarely occur in the field. Although moisture gradients cannot be simulated, various moisture contents can be estimated by comparing results from several simulations that cover the common or possible ranges in soil moisture conditions.

3. Liquid phase dispersion is neglected. Hence, the migration of the contaminant will be simulated as a plug. This assumption causes higher dissolved concentrations and lower travel time predictions than would occur in reality.

4. The contaminant is not subjected to in situ production or degradation. Since organic contaminants, especially hydrocarbons, generally undergo some degree of degradation in the vadose zone, this assumption results in conservative concentration values.

5. Homogeneous soil conditions are assumed to occur within a particular polygon. This assumption will rarely occur in the field. Although spatial gradients cannot be simulated, the impact of non-uniform soils can be estimated by comparing results from several simulations covering the range of soil properties present at the site. However, initial contaminant concentrations in the soil phase can vary between cells.

6. Volatilization from the soil boundaries is either completely unimpeded or completely restricted. This assumption may be significant depending upon the depth of investigation and the soil type. In particular, after a depth of one meter, volatilization to the atmosphere will decrease significantly.

7. The model does not account for nonaqueous phase liquids or any flow conditions derived from variable density.

5.5 Groundwater Modeling

Groundwater modeling was selected to model movement and attenuation of organic constituents in the subsurface. Because the groundwater beneath the NCL has been demonstrated to exhibit elevated levels of hydrocarbons from an unrelated source, it is inappropriate to utilize those concentration levels as inputs to a fate and transport model for constituents that may have migrated from the treatment zone. Instead, worst-case hydrocarbon concentration results from the vadose zone model were used as inputs to the groundwater model.

5.5.1 Groundwater Flow Modeling

The groundwater flow model, MODFLOW was selected to simulate the local flow regime for the North Colony Landfarm Site and vicinity. MODFLOW is a modular three-dimensional finite difference groundwater flow model developed by the U.S. Geological Survey (McDonald & Harbaugh, 1984). Groundwater flow within the aquifer is simulated using a block-centered finite difference approach. Layers can be modeled as confined, unconfined or a combination of confined and unconfined. Flow such as external stresses, areal recharge, evapotranspiration, flow to drains , and flow through riverbeds, can also be simulated.

5.5.2 Contaminant transport modeling

Contaminant transport analysis was accomplished using the MT3D modular three-dimensional transport model (Zheng, 1990). MT3D is a numerical simulation code that models the fate and transport of dissolved, single-species contaminants in saturated ground-water systems. MT3D simulates advection, dispersion, mixing, and chemical reactions. MT3D calculates concentration distributions, concentration histories at selected receptor points and hydraulic sinks (for example, extraction wells), and the mass of contaminants in the ground-water system.

The chemical reaction package in MT3D which handles biodegradation and sorption was not used in the simulations. Molecular diffusion was also assumed not to occur. This makes the model results very conservative in that the only processes acting to transport the contaminants are the predominantly physical processes of advection and dispersion.

INVESTIGATION RESULTS

This section presents the results of the soils and groundwater investigation programs conducted in the vicinity of the NCL Landfarm during the RCRA investigations. Also included are the results of the statistical analyses of soils and groundwater, and vadose and saturated zone modeling study.

6.1 Soils Investigation Results

The following sections report the observations and results of the trench excavation and soil boring investigations at the NCL.

6.1.1 Observation Trenches

During the Phase I study, two sets of observation trenches were temporarily dug to visually observe subsurface conditions. The first set of four trenches was placed in the interior of the landfarm. A second set of seven trenches was placed outside the south, southwest and west boundaries of the NCL.

6.1.1.1 NCL Interior Trenches

Pursuant to the approved workplan, an observation trench was excavated in each of the four operational cells of the NCL. Visual observations of the soil profile, in conjunction with the collection of soil samples, were conducted in order to develop a more well defined characterization of conditions in the vadose zone underlying the unit. Photographs of the subsurface soil profiles for the four observation trenches are presented in Appendix A.

Trench soil sample analytical data for total chromium and lead are presented in Table 6-1 and Appendix G. Total chromium concentrations ranged from 5 to 23 mg/kg (overall average of 12.7 mg/kg), while total lead concentrations ranged from 2 to 11 mg/kg (overall average of 4.8 mg/kg).

The gross visual appearance of subsurface soil profiles in the observation trenches indicated that the oily matrix of the applied wastes had not migrated significantly beneath the upper surface of the unit. In undisturbed material, the trench soil profiles revealed a waste incorporation interval extending to a depth no greater than two feet from surface grade, being underlain by visually clean clay soils to at least six or seven feet below surface grade.

At observation Trench C, a pattern of discontinuous hydrocarbon contamination was observed. Beginning in the immediate vicinity of the 7-foot sample interval and extending downward to the base of the excavation, a mottled black staining pattern was observed in association with a hydrocarbon odor that increased in intensity with depth. Staining and hydrocarbon odors were not observed between the 7-foot interval and the surface zone of waste incorporation. The uppermost several feet of the deep stained interval revealed numerous old plant roots, and most of the localized zones of hydrocarbon mottling were centered around these residual root passageways (Photograph A-6, Appendix A). Visual evidence of hydrocarbon contamination was also confirmed by the results of PID analyses of supplementary samples collected at each sample interval (Table 6-2).

Despite the visual observations made in Trench C, neither BTEX or SVOA target constituents were detected in soil samples collected from Trench C although the analytical laboratory reported non-BTEX hydrocarbon detections at the 9-foot interval. The results of BTEX and SVOA analyses for the trench samples are presented in Table 6-2.

Landfarm subsurface soils at observation Trench D were found to have been impacted by the presence, in the northernmost end of the trench, of an old concrete structure of unknown origin and function (Photograph A-11, Appendix A). Since the landfarm was previously the site of staff housing, refinery staff speculate the structure was an old water cistern which was covered over and buried when the houses were demolished. Subsurface soils in immediate proximity exhibited hydrocarbon odors and staining. Subsequent to its discovery, the structure was excavated and the debris and oily soils were stockpiled near the western end of the unit at the periphery of landfarm cell C. The source of the material found in the cistern is undetermined.

Detection of organic constituents was reported only for samples collected from the 5- and 7-foot intervals for Trench D. Highest levels of detected organics were obtained for sample TRD-7C, in the immediate vicinity of the unidentified buried concrete structure, including the detection of benzene, ethylbenzene, xylene, and three SVOAs, including 2-methyl naphthalene, naphthalene, and phenanthrene (Table 6-2).

6.1.1.2 NCL Exterior Trenches

Trenches 1 through 4 located on the south side of the landfarm (Figure 5-2) had detectable volatile and semivolatile hydrocarbons in the soil samples. The vertical locations of the samples collected ranged from 7 to 10 ft below ground level. Staining and/odor was observed beginning at 7 to 9 feet beneath the ground surface. Laboratory results of the soil sampling detected volatile hydrocarbons (BTEX) and semi-volatile hydrocarbons in these four trenches (Tables 6-3 and 6-4). The constituents identified in the trench soil samples were also generally reported in the product sample collected from Recovery Well 7. Two constituents, anthracene and pyrene, shown as <500 ppm in the product sample are not reported because detection levels of the product are high because of matrix interference. Di-n-butylphthalate is a common laboratory artifact. No staining or discoloration, or hydrocarbon odors were seen in Trenches 5 and 6. Groundwater (but no product) was observed at the 10-foot level of Trench 3 at the time of backfilling.

Table 6-1. Observation Trench Soil Samples: Total Chromium and Lead Concentrations

Sample Location	Total Chromium (mg/Kg)	Total Lead (mg/Kg)	Sample Location	Total Chromium (mg/Kg)	Total Lead (mg/Kg)
TR A-5A	6	3	TR C-5A	14	7
TR A-5B	8	3	TR C-5B	16	8
TR A-7A	11	3	TR C-7A	14	2
TR A-7B	11	4	TR C-7B	13	5
TR A-9A	8	3	TR C-9A	12	4
TR A-9B	14	4	TR C-9B	14	4
TR B-5A	17	7	TR D-5A	19	9
TR B-5B	20	6	TR D-5B	18	11
			TR D-5C	17	8
TR B-7A	13	5	TR D-7A	18	10
TR B-7A(dup)	8	4	TR D-7B	5	2
TR B-7B	13	5	TR D-7C	5	2
TR B-9A	10	3	TR D-9A	12	4
TR B-9A(dup)	23	2	TR D-9B	11	4
TR B-9B	11	3	TR D-9C	6	4
			Trench Average:	**12.7**	**4.8**

Table 6-2. Observation Trench Soil Samples: Summary of Organic Analyses

Sample Location	PID (ppm)	Benzene (ug/Kg)	Ethylbenzene (ug/Kg)	Toluene (ug/Kg)	Xylene (ug/Kg)	Semivolatiles[a,b] (mg/Kg)
TR A-5A	2	< 6	< 6	< 6	< 6	ND
TR A-5B	2	< 5	< 5	< 5	< 5	ND
TR A-7A	1	< 5	< 5	< 5	< 5	ND
TR A-7B	2	< 5	< 5	< 5	< 5	ND
TR A-9A	0.4	< 5	< 5	< 5	< 5	ND
TR A-9B	1	< 5	< 5	< 5	< 5	ND
TR B-5A	6	< 5	< 5	< 5	< 5	ND
TR B-5B	2	< 5	< 5	< 5	< 5	ND
TR B-7A	4	< 5	< 5	< 5	< 5	ND
TR B-7A(dup)	- -	< 5	< 5	< 5	< 5	ND
TRB-7B	2.0	< 5	< 5	< 5	< 5	ND
TR B-9A	4.0	< 5	< 5	< 5	< 5	ND
TR B-9A(dup)	- -	< 5	< 5	< 5	< 5	ND
TR B-9B	0	< 5	< 5	< 5	< 5	ND
TR C-5A	12	< 5	< 5	< 5	< 5	ND
TR C-5B	27	< 5	< 5	< 5	< 5	ND
TR C-7A	12	< 5	< 5	< 5	< 5	ND
TR C-7B	12	< 5	< 5	< 5	< 5	ND
TR C-9A	428	< 5	< 5	< 5	< 5	ND
TR C-9B	171	< 5	< 5	< 5	< 5	ND
TR D-5A	6.0	< 5	< 5	< 5	< 5	ND
TR D-5B	6	< 5	< 5	< 5	< 5	ND
TR D-5C	92	< 5	14	< 5	< 5	ND
TR D-7A	12	< 5	< 5	< 5	< 5	ND
TR D-7B	10	< 5	14	< 5	< 5	ND
TR D-7C	634	255	16600	< 8	2090	1-methylnapthalene - 13.0 2-methylnapthalene - 24.0 naphthalene - 9.0 phenanthrene - 7.0
TR D-9A	15	< 5	< 5	< 5	< 5	ND
TR D-9B	5	< 5	< 5	< 5	< 5	ND
TR D-9C	323	< 5	< 5	< 5	< 5	ND

Notes:

a) Semivolatile constituent detection limits ranged from 0.5 to 3.0 mg/kg.

b) Di-n-butylphthalate also reported as sole contaminant (apparent laboratory artifact) in 8 of 29 samples

Table 6-3. NCL Upgradient Trench Sample Elevations and BTEX Concentration Data

Trench	Sample	Elevation[a] (feet)	Benzene[b] (ug/Kg)	Ethylbenzene[b] (ug/Kg)	Toluene[b] (ug/Kg)	Xylenes[c] (ug/Kg)	Total BTEX (ug/Kg)
1	TR 1-1	3,356	<21	<21	<21	68	68
	TR 1-2	3,355	<21	<21	<21	100	100
2	TR 2-1	3,355	<120	340	120	1,720	2,060
3	TR 3-1	3,353	<260	< 260	1,060	7,510	8,570
4	TR 4-1	3,354	<120	238	<120	775	1010
Recovery Trench 7		- -	3,390	307	8,150	2,260	14,100

Notes:

a) Feet above mean sea level; estimated to the nearest foot.

b) Method detection limit dependent on dilution required due to matrix interference.

c) No *o-xylene* detections reported.

Table 6-4. NCL Upgradient Trench SVOA Concentration Data

Constituent	SVOA Constituent Concentrations (mg/Kg)					
	Trench 1-1	Trench 1-2	Trench 2-1	Trench 3-1	Trench 4-1	Recovery Trench 7
acenaphthene	1.8 (1)	3.0	< 2.5	4.2	2.5	597.0
anthracene	< 2.5	< 2.5	< 2.5	2.4 [a]	1.3 [a]	< 500
di-n-butylphthalate [b]	3.4 [a]	3.4 [a]	3.4 [a]	3.4 [a]	3.4 [a]	< 500
dibenzofuran	2.2 [a]	3.1	< 2.5	5.0	< 2.5	1420.0
fluorene	3.0	4.5	2.9	6.2	4.0	1570.0
naphthalene	< 2.5	< 2.5	< 2.5	2.8	< 2.5	1170.0
2-methylnaphthalene	< 2.5	< 2.5	< 2.5	< 2.5	< 2.5	5090.0
phenanthrene	6.5	10.7	6.4	14.3	6.1	2220.0
pyrene	< 2.5	1.5 [a]	< 2.5	2.0 [a]	1.5 [a]	< 500

Notes:

a) Meets identification criteria, estimated concentration below reported detection limit.

b) Common laboratory artifact.

6.1.2 Soil Borings

6.1.2.1 Soil Boring Results, RFI Phase I Investigation

As required by the RFI workplan, fifteen shallow borings to 6.5 feet below the original land surface and eight deeper borings 15 feet below the original surface were completed at the unit during the NCL RFI Phase I study. One background boring was completed at a location immediately north of Cell A and west of NCL-32. Soil sample analytical results for metals, BTEX, and SVOAs are included in Appendix G, and are summarized in Tables 6-5 through 6-7, respectively. Boring logs are included as Appendix A. PID observations were not obtained during the soil boring sampling. Moisture impedes PID measurements and wet surface conditions were present due to frequent and heavy rainfall that occurred during soil boring sampling.

Results of the Phase I soil boring sample analyses for total chromium and lead are presented in Table 6-5. Soil total chromium concentrations ranged from 5 to 24 mg/kg (overall average of 10.0 mg/kg), and lead concentrations ranged from 2 to 11 mg/kg (overall average of 4.4 mg/kg). Background values for total chromium and lead were 8 and 4 mg/kg, respectively.

The results of the BTEX analyses for the soil boring samples obtained from the eight deeper boring locations are summarized in Table 6-6. BTEX constituents were detected in soil samples collected from six of the eight deep borings. Of the total of 41 samples that were analyzed, benzene was detected at two sample locations (C-13, 7-9 foot interval and C-15, 13-15 foot interval, at concentrations of 17 and 230 ug/kg, respectively. Ethylbenzene was detected in eleven samples at concentrations ranging from 9 to 14,400 ug/kg. Toluene was detected in three samples and one duplicate, all of which were obtained from boring location C-15, at concentrations ranging from 15 to 260 ug/kg. Xylenes were detected in eleven samples (including one duplicate) at concentrations ranging from 6 to 15,380 ug/kg.

For four of the six soil boring locations in which BTEX constituents were reported, detection events were reported at only the deepest sample interval (13-15 feet). For the remaining two boring locations, the occurrence of BTEX constituents was distributed across all five sample intervals (Boring C-13) or at four of the five sample intervals (Boring C-15).

Results of soil boring analyses for SVOA constituents are summarized in Table 6-7. In all, a total of nine SVOA constituents were reported in one or more soil boring samples. The maximum value obtained for any SVOA constituent was 41.3 mg/kg for 2-methyl naphthalene in sample C-15 at the 13-15 foot interval.

The results of the SVOA analyses were similar to those obtained for the BTEX analyses, insofar as the six deep boring locations in which BTEX constituents were detected were the same ones to yield reportable quantities of SVOA constituents. Similarly, the same four borings in which BTEX constituents were detected only at the deepest sample intervals (13-15 feet) also yielded SVOA detections only at that interval. The remaining two boring locations (C-13 and C-15) exhibited SVOA constituents in at least four of the five sample intervals.

Table 6-5. Soil Boring Samples: Total Chromium and Lead Concentrations

Sample Location and, Depth[a] (feet)	Total Chromium (mg/Kg)	Total Lead (mg/Kg)	Sample Location and Depth[a] (feet)	Total Chromium (mg/Kg)	Total Lead (mg/Kg)
BG[b] 94-06, 4-5	8	4	C-11, 5.5-6.5	11	5
			C-11, 5.5-6.5(dup)	12	5
			C-12, 5.5-6.5	23	11
A-11, 5.5-6.5	8	4	C-13, 5-7	18	8
A-12, 5.5-6.5	13	4	C-13, 7-9	11	4
A-13, 5-7	12	6	C-13, 9-11	11	4
A-13, 7-9	12	6	C-13, 11-13	6	5
A-13, 9-11	12	5	C-13, 13-15	18	4
A-13, 11-13	11	5	C-14, 5.5-6.5	12	4
A-13, 13-15	12	4	C-15, 5-7	15	8
A-14, 5.5-6.5	10	8	C-15, 5-7(dup)	18	11
A-15, 5.5-6.5	8	6	C-15, 7-9	13	6
A-16, 5-7	9	4	C-15, 9-11	12	6
A-16, 7-9	9	4	C-15, 11-13	10	6
A-16, 9-11	10	5	C-15, 13-15	10	5
A-16, 11-13	13	6	C-15, 13-15(dup)	10	5
A-16, 13-15	16	11	C-16, 5.5-6.5	11	6
A-17, 5-6	10	3	C-17, 5.5-6.5	24	10
			C-18, 5.5-6.5	9	4
B-11, 5.5-6.5	13	6	D-11, 5-7	22	10
B-12, 5.5-6.5	13	8	D-11, 7-9	9	3
B-13, 5-7	13	5	D-11, 9-11	7	2
B-13, 7-9	11	4	D-11, 11-13	14	3
B-13, 9-11	16	7	D-11, 13-15	9	4
B-13, 11-13	12	4	D-12, 5.5-6.5	18	8
B-13, 13-15	12	3	D-12, 5.5-6.5(dup)	18	8
B-14, 5.5-6.5	14	5	D-14, 5-7	19	8
			D-14, 7-9	14	5
			D-14, 9-11	9	2
			D-14, 11-13	5	2
			D-14, 13-15	10	4
			D-15, 5-7	23	9
			D-15, 7-9	12	4
			D-15, 9-11	11	4
			D-15, 11-13	8	3
			D-15. 13-15	11	4
			Boring Average:	**10.0**	**4.4**

Notes:

a) Depth from original land surface (visually approximated).

b) BG 94-06, Background Boring.

Table 6-6. Soil Boring Samples: BTEX Concentrations

Location	Depth[a] (ft)	Benzene (ug/Kg)	Ethylbenzene (ug/Kg)	Toluene (ug/Kg)	Total Xylenes (ug/Kg)	Total BTEX (ugKg)
A-13	5-7	< 6.0	< 6.0	< 6.0	< 6.0	- -
	7-9	< 6.0	< 6.0	< 6.0	< 6.0	- -
	9-11	< 6.0	< 6.0	< 6.0	< 6.0	- -
	11-13	< 6.0	< 6.0	< 6.0	< 6.0	- -
	13-15	< 6.0	1,160	< 6.0	291	1,451
A-16	5-7	< 6.0	< 6.0	< 6.0	< 6.0	- -
	7-9	< 6.0	< 6.0	< 6.0	< 6.0	- -
	9-11	< 6.0	< 6.0	< 6.0	< 6.0	- -
	11-13	< 6.0	< 6.0	< 6.0	< 6.0	- -
	13-15	< 6.0	< 6.0	< 6.0	< 6.0	- -
B-13	5-7	< 6.0	< 6.0	< 6.0	< 6.0	- -
	7-9	< 6.0	< 6.0	< 6.0	< 6.0	- -
	9-11	< 6.0	< 6.0	< 6.0	< 6.0	- -
	11-13	< 6.0	< 6.0	< 6.0	< 6.0	- -
	13-15	< 6.0	< 6.0	< 6.0	< 6.0	- -
C-13	5-7	< 6.0	26	< 6.0	6	32
	7-9	17	26	< 6.0	30	73
	9-11	< 6.0	< 6.0	< 6.0	26	26
	11-13	< 6.0	9	< 6.0	33	42
	13-15	< 6.0	< 6.0	< 6.0	21	21
C-15	5-7	< 6.0	< 6.0	< 6.0	< 6.0	- -
	7-9	< 10	33	< 10	192	225
	9-11	< 30	190	15	1330	1,535
	11-13	< 60	950	80	11,810	12,840
	13-15	230	10,700	260	11,320	22,510
	13-15 (dup)	170	14,400	210	15,380	30,160

Note:

a) Depth from original land surface (visually approximated)

Table 6-6. Soil Boring Samples: BTEX Concentrations (continued)

Location	**Depth^a (ft)**	**Benzene (ug/Kg)**	**Ethylbenzene (ug/Kg)**	**Toluene (ug/Kg)**	**Total Xylenes (ug/Kg)**	**Total BTEX (ug/Kg)**
D-11	5-7	< 6.0	< 6.0	< 6.0	< 6.0	- -
	7-9	< 6.0	< 6.0	< 6.0	< 6.0	- -
	9-11	< 6.0	< 6.0	< 6.0	< 6.0	- -
	11-13	< 6.0	< 6.0	< 6.0	< 6.0	- -
	13-15	< 10	23	< 10	< 10	23
D-14	5-7	< 6.0	< 6.0	< 6.0	< 6.0	- -
	7-9	< 6.0	< 6.0	< 6.0	< 6.0	- -
	9-11	< 6.0	< 6.0	< 6.0	< 6.0	- -
	11-13	< 6.0	< 6.0	< 6.0	< 6.0	- -
	13-15	< 10	118	< 10	< 10	118
D-15	5-7	< 10	< 10	< 10	< 10	- -
	7-9	< 6.0	< 6.0	< 6.0	< 6.0	- -
	9-11	< 6.0	< 6.0	< 6.0	< 6.0	- -
	11-13	< 6.0	< 6.0	< 6.0	< 6.0	- -
	13-15	< 600^b	3,150	< 600^b	3,200	6,350

Notes:

a) Depth from original land surface (visually approximated)

b) Method detection limit elevated due to matrix interference

Table 6-7. NCL RFI Phase I Soil Boring Samples: SVOA Concentrations (mg/kg)

Location	**A-13**	**C-13**					**C-15**				**D-11**	**D-14**	**D-15**
Depth Interval (ft)	13-15	5-7	7-9	9-11	11-13	13-15	7-9	9-11	11-13	13-15	13-15	13-15	13-15
Constituent:													
acenaphthene	< 1.2	< 1.2	< 1.1	< 1.1	0.8(a)	< 1.3	< 1.1	2.4	< 1.1	< 1.2	0.4(a)	0.8	3.6
anthracene	< 1.2	< 1.2	3.1	< 1.1	< 1.1	< 1.3	< 1.1	0.7(a)	1.1	< 1.2	< 0.6	< 0.6	2.3
dibenzofuran	1.5	4.0	5.0	2.0	< 1.1	< 1.3	1.3	1.9	3.6	5.1	0.7	1.2	5.5
fluorene	1.3	2.8	3.4	1.3	< 1.1	< 1.3	1.2	1.6	3.2	5.5	0.7	1.2	5.1
1-methylnaphthalene	8.0	< 1.1	7.0	< 1.1	1.4	1.9	4.0	14.4	17.0	34.0	1.4	5.0	29.0
2-methylnaphthalene	5.0	2.5	< 1.1	< 1.1	< 1.1	< 1.3	< 1.1	< 1.1	14.5	41.3	< 0.6	< 0.6	5.6
naphthalene	0.9(a)	< 1.2	< 1.1	< 1.1	< 1.1	< 1.3	< 1.1	0.6(a)	6.9	9.0	< 0.6	< 0.6	3.2
phenanthrene	2.9	3.7	< 1.1	0.6(a)	< 1.1	< 1.3	0.8(a)	4.1	8.3	10.9	1.6	2.7	15.4
pyrene	< 1.2	< 1.2	< 1.1	< 1.1	< 1.1	< 1.3	< 1.1	< 1.1	1.1	1.5	< 0.6	0.4(a)	2.1
Total detected SVOAs	**19.6**	**13.0**	**18.5**	**3.9**	**2.2**	**1.9**	**7.3**	**25.7**	**55.7**	**107.3**	**4.8**	**11.3**	**71.8**

Note:

a) Estimated concentration; constituent meets identification criteria, but was below detection limit.

6.1.2.2 Landfarm Survey Data

Based on the survey of the unit that was conducted during the course of the RFI Phase I study A landfarm surface elevation contour map was developed (Figure 6-1). Survey data for surface grade elevations at the observation trench locations were combined with data for estimated depth to the original land surface to calculate trench sample interval elevations (Table 6-8).

Table 6-8. Observation Trench Sample Interval Elevations

Trench	Estimated Depth to Original Land Surface (feet)	Grade Stake Elevation[a] (ft)	Trench Sample Interval Elevations		
			5 ft	7 ft	9 ft
A	1.50	3364.43	3357.93	3355.93	3353.93
B	1.67	3363.63	3356.96	3354.96	3352.96
C	0.50	3363.48	3357.98	3355.98	3353.98
D	1.50	3363.44	3356.94	3354.94	3352.94

Note:

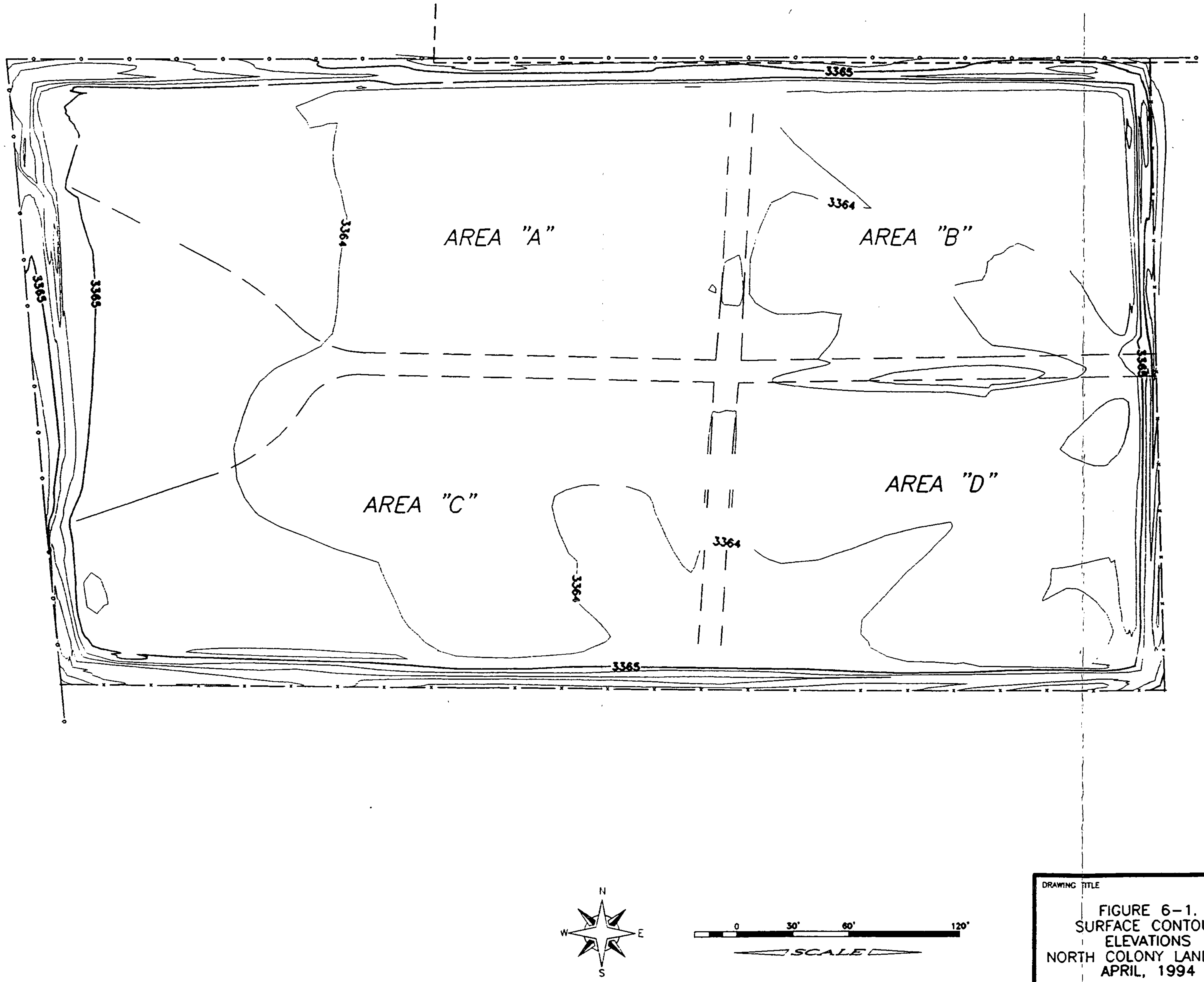
a) Elevations in feet above mean sea level

6.1.2.3 Soil Boring Results, RFI Phase II Investigation

The locations of the borings drilled during the Phase II are shown on Figure 6-2. Any detections of free-phase hydrocarbons also are shown on the figure. Boring lithologies for the individual logs reproduced in Appendix B.

Soils in the vicinity of the NCL are mainly fine grained at all depths except for the sporadic occurrence of thin discontinuous lenses of coarser grained material. Surface zones above a depth of 8 to 10 feet generally are composed of clayey silts at the surface grading to silty clay and clay at about 8 feet. At 8 feet, zones of caliche begin to be encountered with the caliche exhibiting varying degrees of cementation and hardness. However, caliche zones encountered at that depth were commonly dry, crumbly, and not so well cemented, such that sampling was impeded using the hydraulic push method. Depending on sample location, zones of clay, caliche, and caliche clay continued to total depth with occasional thin zones of coarser material.

Moisture was generally encountered at depths from 12 to 18 feet, although exact depths were difficult to ascertain in the core samples unless a coarse-grained zone was encountered. Where coarser zones were not encountered, softness in an otherwise dry clay sample generally provided an indication of moisture. The moisture was likely released to the cored hole from thin, slightly silty zones in the clays that were not visually observed in the splitspoon cores. Commonly, zones located within a few inches above or below the moist zones were completely free of moisture and logged as dry and crumbly.



DRAWING TITLE

FIGURE 6-1.
SURFACE CONTOUR
ELEVATIONS
NORTH COLONY LANDFARM
APRIL, 1994

NAVAJO REFINING CO.
P.O. DRAWER 159
ARTESIA, NEW MEXICO

DRAWN BY EJS	CHK'D BY DB	SCALE 1" = 60'-0"
DATE 11-5-97	APP'D BY -	DRAWING NUMBER FIG61.DWG

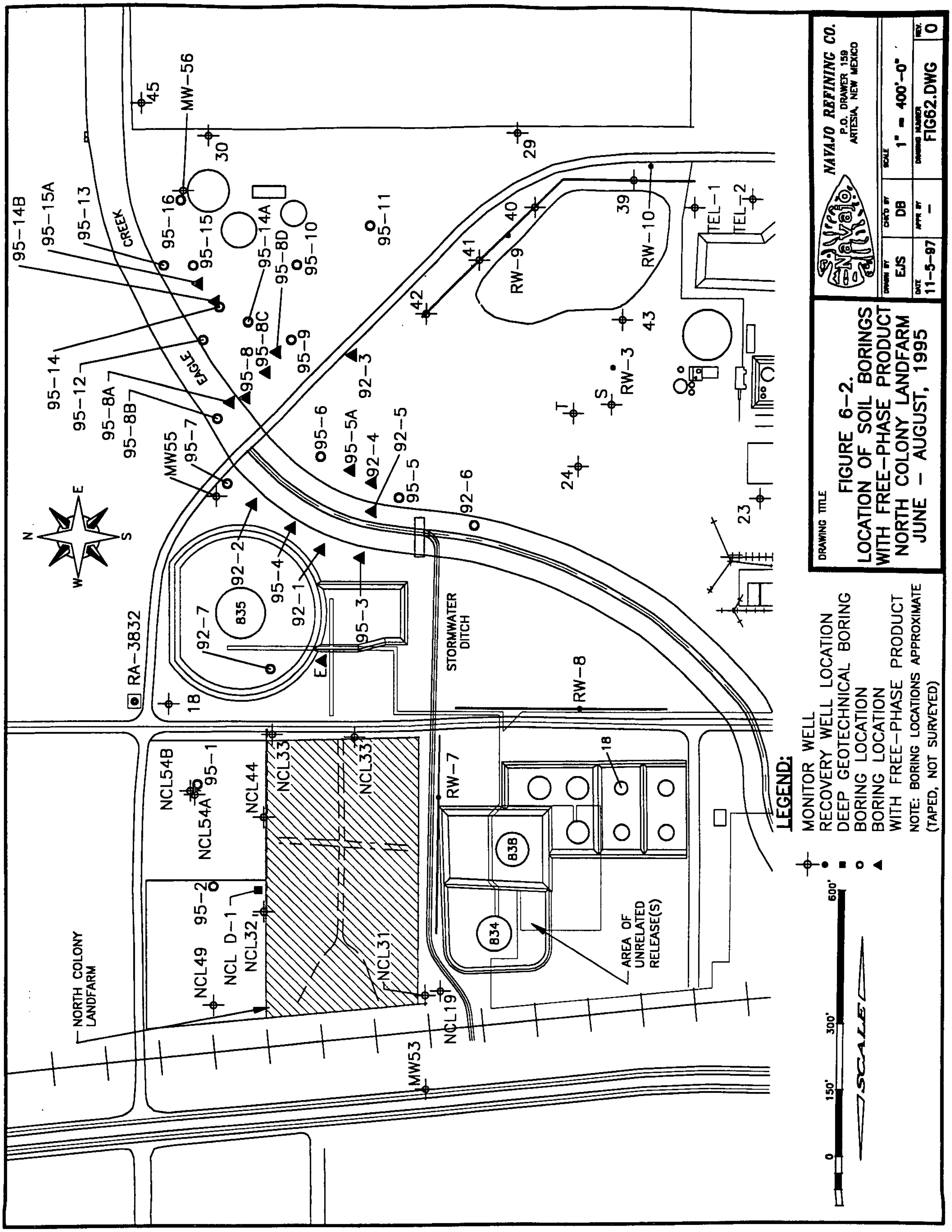
REV.
0

Coarse grained material of one type or another was encountered in 9 of the 20 coring boreholes which were logged. This material commonly consisted of a thin zone of small limestone pebbles or gravels in the clay matrix. The larger caliche gravels ranged up to about one inch in diameter and commonly were observed to exhibit varying degrees of cementation with each other. In a zone of saturation, these caliche gravels were a primary source of water to the borehole. The zones were usually very thin, and in 6 of the 9 borings, the thickness of these zones ranged from 1 to 3 inches. Two of the borings, NCL 95-13 and NCL 95-16, had greater thickness of caliche gravel. These wells, located at the far northeast corner of the investigation area (Figure 6-2), had gravel thickness of 1 and 1.5 feet at depths of 18 and 19 feet, respectively. Both borings were free of hydrocarbons, and NCL 95-16 was completed as downgradient well MW-56. Since the coarser clayey gravel zones were encountered in relatively few borings at variable depths, they were not considered to be contiguous over the zone of investigation. However, the occurrence of the shallow thin gravel zones was observed to increase in the northeast area of the investigation in the vicinity of the trickling filter used in NRC's wastewater treatment system.

In one boring (NCL 95-08C) larger gravels were encountered in the NSSZ at a depth of 21 feet. The gravels were composed of well-rounded limestone gravels up to 2 inches in diameter. The thickness of this zone is unknown since the hole was drilled with a solid-stem auger and drilling ceased when hydrocarbon was detected in the gravels. This was the only zone of its type encountered during the boring investigation; the orientation of the gravel is unknown, but it likely trends easterly in the same direction as Eagle Draw.

The placement of the monitor wells installed during the RFI Phase II study was governed by the surface configuration of the site and the location of detected contaminants. Wells MW-54, MW-55, and MW-56 were completed at three of the locations previously bored (NCL 95-01, -07, and -16, respectively), and a replacement upgradient well (MW-53) was also installed. At MW-54, drilled in mid-December 1995, a deeper zone containing coarser grained material was detected at a depth of about 30 feet at the base of what was expected to be a shallow well. Consequently the well was plugged back to a clay zone at 27 feet and completed as MW-54A, the shallow component of a two-well pair. Subsequently, well MW-54B was drilled to a depth of 47 feet. At that location, the material from 38.5 to 44 feet consisted of large rounded limestone gravels similar to those found in boring NCL 95-08C. The gravels were followed by a zone of brown, dry, stiff clay to a total depth of 47 feet. The monitor well was completed with a 10-foot screen with its base set at the bottom of the gravel zone. A geologic cross section (A-A') was prepared that shows the relationship of the monitor wells to the local geology (Figure 6-3 and 6-4). With the exception of the material at the base of MW-54B, the gravel zones are shown to be infrequent, thin, and discontinuous in both horizontal and vertical directions.

To supplement the amount of RFI subsurface information at the site, seven borings earlier drilled by Navajo in August 1992 are included in Appendix B. These borings show a similar pattern with respect to the occurrence of gravels in the subsurface. Gravels were found in only two of the seven holes with gravels in one being encountered at an elevation 8 feet higher than in the second boring. Although they were encountered at different depths, both zones were relatively thick (about one foot) and free-phase hydrocarbons were reported in the boring exhibiting the shallower gravel zone.



DRAWING TITLE
FIGURE 6-2.
LOCATION OF SOIL BORINGS
WITH FREE-PHASE PRODUCT
NORTH COLONY LANDFARM
JUNE - AUGUST, 1995

NAVAJO REFINING CO.
P.O. DRAWER 159
ARTESIA, NEW MEXICO

DRAWN BY	CHK'D BY	SCALE	
EJS	DB	1" = 400'-0"	
DATE	APPR BY	DRAWING NUMBER	REV.
11-5-97	-	FIG62.DWG	0

LEGEND:

- ⌖ MONITOR WELL
- ● RECOVERY WELL LOCATION
- ■ DEEP GEOTECHNICAL BORING
- ○ BORING LOCATION
- ▲ BORING LOCATION WITH FREE-PHASE PRODUCT

NOTE: BORING LOCATIONS APPROXIMATE (TAPED, NOT SURVEYED)

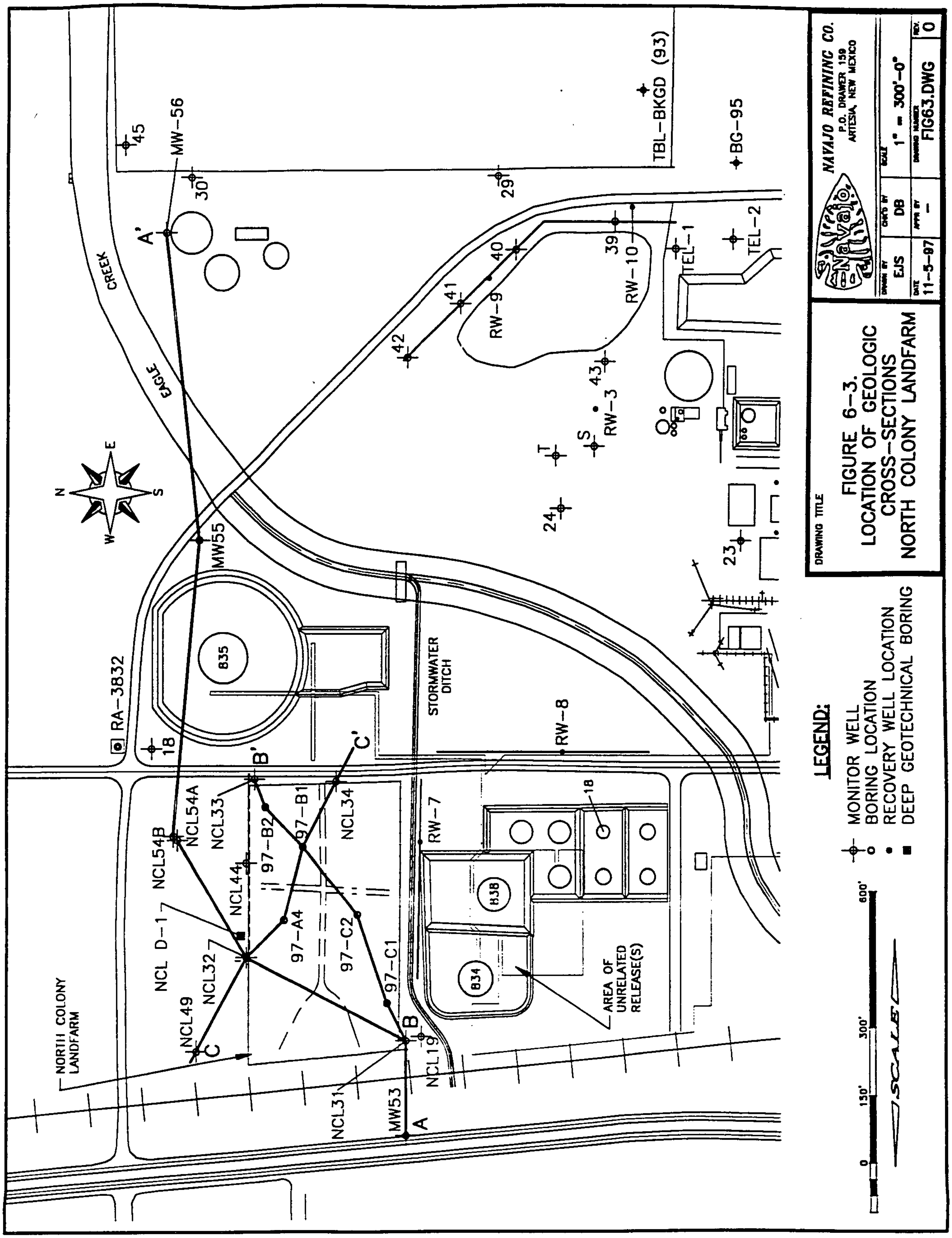
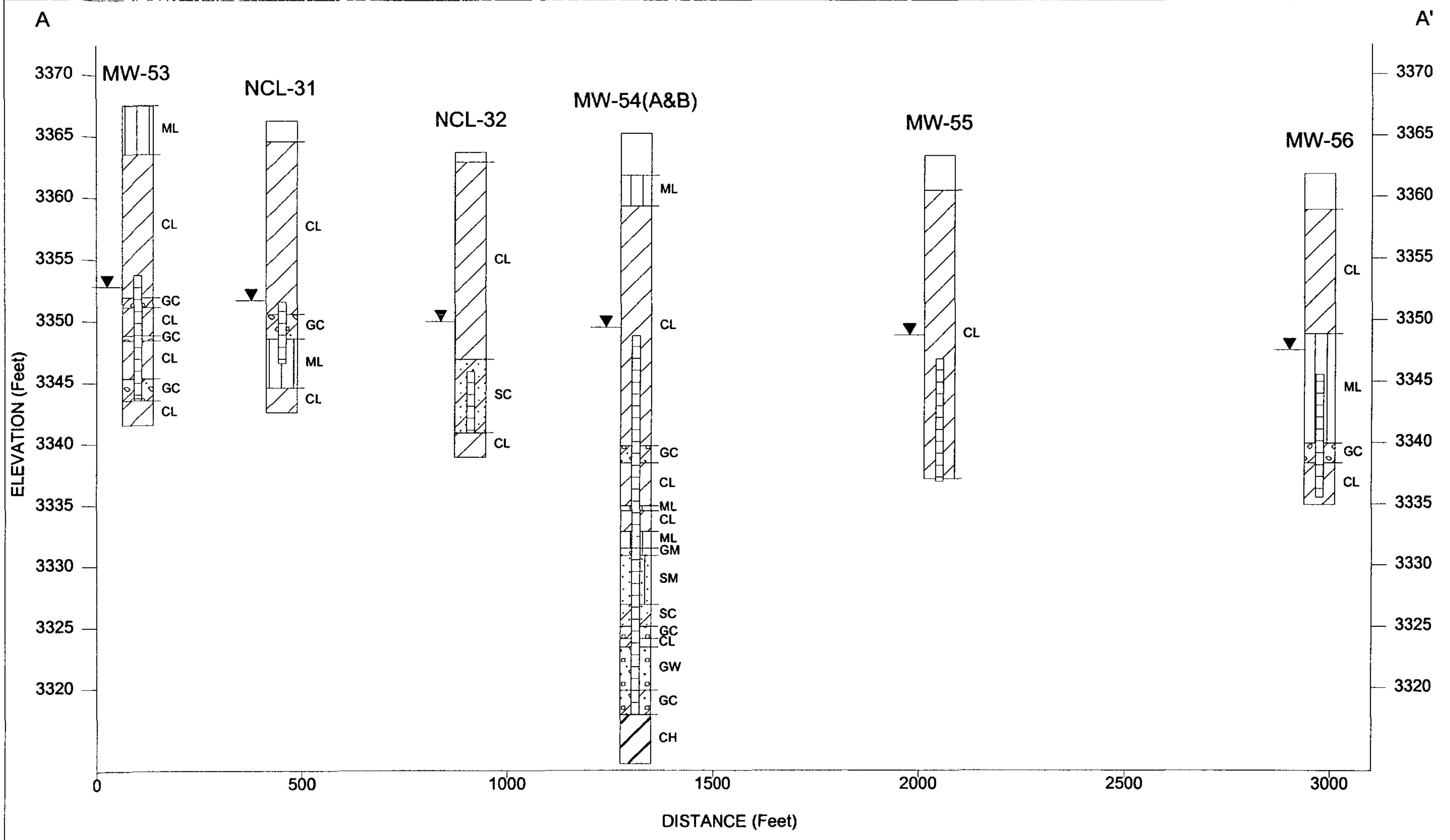


FIGURE 6-3.
LOCATION OF GEOLOGIC CROSS-SECTIONS
NORTH COLONY LANDFARM



RFI Supplemental Investigation
North Colony Landfarm
July-September, 1997

Navajo Refining Company
Artesia, New Mexico

Figure 6-4

GEOLOGIC CROSS SECTION
Section A-A'
Navajo North Colony Landfarm
Water Levels 7/31-8/2, 1997

LEGEND

GM	Silty Gravels, Silty Mixes	SC	Clayey Sands, Clay Mixes
GC	Clayey Gravels, Clay Mixes	ML	Clayey Silts, Clayey Sands
GW	Gravels, Gravel-Sand Mixes	CL	Inorganic Clays, Clay Mixes
SM	Silty Sands, Silt Mixes	CH	Fat Clays, Highly Plastic

11-11-1997 C:\MTECH46\ nav-ncl\ ncl_97_nclcros_nav-cs4.cro

6.1.2.3.1 Hydrocarbon Detection

Because the Phase II investigation was structured to locate soils that may have been impacted by releases of hydrocarbons from the vicinity of the NCL, hydrocarbons in one form or another were detected in most of the borings. Figure 6-2 shows which of the borings were observed to contain free-phase product. To assist in interpretation of the soil boring observations, Table 6-9 summarizes the occurrence of hydrocarbons detected during the Phase II portion of the RFI. For each boring, the table includes the total depth, the maximum PID reading and the interval in which it occurred, the observed contaminant range, and whether free-phase product was encountered. The observed contaminant range is based on any detections of hydrocarbons as recorded on the log form including visual, olfactory, and PID evidence of contamination.

In an attempt to determine the thickness of any free-phase product, nine of the boreholes observed to be hydrocarbon contaminated received temporary screen and casing for a 24-hour period. Of those borings receiving a temporary casing, the maximum thickness of any resulting hydrocarbon was 1/8 inch or less. Often only a skim of product and the strong odor of hydrocarbon was found on a bailer lowered into the temporary casing. Information on the temporary well installations is included with the boring logs in Appendix B.

Free-phase contamination was observed in 9 of the 24 borings completed during the Phase II activities (Table 6-9). Some evidence of contamination (discoloration, odor, or elevated PID readings) was also observed in 10 of the remaining borings. No contamination of any form was observed in 5 borings. Of the borings completed by NRC in 1992, 6 of 7 were found to have free-phase product.

Three borings completed during the first round of RFI Phase II drilling in late June 1995 were sampled for free-phase hydrocarbons. Samples were collected at borings NCL 95-01, -02, and -07 within 24 hours of completion of the borings. Analyses were performed for benzene, ethylbenzene, toluene, and xylenes. These analyses, together with the results of the borehole drilling, were used as a guide to monitor well placement. Ethylbenzene at 0.045 mg/L in boring NCL 95-01 was the only free-phase hydrocarbon detected in the June sampling. Two monitor wells (MW-54A and -54B) were drilled and installed at the location in December 1995 to monitor any northward movement of free-phase constituents.

6.1.2.4 Soil Boring Results, 1997 RFI Supplemental Investigation

6.1.2.4.1 Background Soil Samples

Five additional background soil samples were collected north of landfarm Cell A in the area between monitor wells NCL-32 and NCL-49 to provide a larger population for statistical analysis. These samples were combined with the samples collected in 1990 and 1994 to provide a total of 15 samples for statistical analysis and comparison with samples taken from beneath the base of the treatment unit at the same depth interval of from 5 to 7 feet.

Table 6-9. Summary of Soil Boring Observations, NCL RFI Phase II.

Boring	Total Depth (ft)	Max PID Reading (ppm)	Max PID Interval (ft)	Observed Contaminant Range(ft)	Free-Phase Product?
1995 RFI Phase II Borings					
NCL 95-01	20	908	16-18	15-20	No
NCL 95-02	26	< 10	- -	None	No
NCL 95-03	23	1,229	5-7	5-18	Yes
NCL 95-04	24	1,098	12-14	3-20	Yes
NCL 95-05	28	1,102	10-12	10-27	No
NCL 95-05A	25	NA	NA	NA	Yes
NCL 95-06	26	1,154	12-14	13-23	No
NCL 95-07	22	(See Note)	NA	None	No
NCL 95-08	24	1,064	12-14	10-20	Yes
NCL 95-08A	15	NA	NA	3-5	No
NCL 95-08B	15	94	8-9	5-15	Yes
NCL 95-08C	25	78	16-18	NA	Yes
NCL 95-08D	25	70	15-17	NA	Yes
NCL 95-09	26	264	16-18	15-22	No
NCL 95-10	26	115	16-18	14-20	No
NCL 95-11	25	NA	NA	15-20	No
NCL 95-12	27	132	12-14	10-27	No
NCL 95-13	22	< 10	- -	None	No
NCL 95-14	22	112	16-18	14-20	No
NCL 95-14A	25	NA	NA	None	No
NCL 95-14B	20	NA	NA	NA	Yes
NCL 95-15	20	118	18-20	10-20	No
NCL 95-15A	20	51	18-20	NA	Yes
NCL 95-16	24	<10	NA	None	No
1992 Navajo Refinery Borings					
NCL 92-01	20	NA	NA	8-19	Yes
NCL 92-02	20	NA	NA	14-20	Yes
NCL 92-03	24	NA	NA	14-24	Yes
NCL 92-04	24	NA	NA	11-24	Yes
NCL 92-05	24	NA	NA	16-24	Yes
NCL 92-06	24	NA	NA	5-24	Yes
NCL 92-07	24	NA	NA	15-24	No

Notes:

a) NA - Information not available

b) At NCL 95-07 PID malfunctioned due to moisture or vapor carryover from previous sample.

The tabulated results of the soil background sampling are shown in Table 6-10 for the 5 to 7, 7 to 9, and 9 to 11 feet depth intervals. Chromium values range from a low of 4.19 mg/Kg in that interval to a maximum of 14.6 mg/Kg with a mean of 8.99 mg/Kg. The range of values for lead in the same interval is from 1.92 to 42 mg/Kg with a mean of 5.62 mg/Kg. As discussed in Section 6.1.4, the maximum lead value of 42 mg/Kg was found to be a statistical outlier and was eliminated from use in calculating the mean and other statistical calculations. Values for chromium and lead at 7 to 9 and 9 to 11 feet were comparable to those at the shallower interval and also could be used in statistical analyses although the background sample size at these lower intervals is limited.

6.1.2.4.2 Monitor Well Soil Samples

Because soil samples were not collected for laboratory analysis and evaluation at the time of installation of new monitor wells MW-53, 54(A and B), 55 and 56, the locations of wells MW-54, -55 and -56 were revisited and soil borings were drilled between 14 and 18 feet downgradient of the current well locations. The results of the analyses are shown in Tables 6-11 and 6-12.

Results for chromium and lead metals are similar to soil background readings shown previously in Table 6-10. The average for both chromium and lead over all intervals is 9.9 and 6.5 mg/Kg, respectively. These values are only slightly higher than the background averages. The maximum value for chromium was 27.6 mg/Kg at 9 to 11 feet in MW-55, and the maximum for lead was 23.8 mg/Kg at the same interval at the MW-54 location. A review of the logs for both wells reveals no anomalous lithologic conditions in that interval.

For organics, the results generally do not show elevated levels of constituents except at the 18 to 20 feet interval in MW-54, and the 5 to 7 feet interval in MW-56. At MW-54, ethylbenzene at 8.2 ug/Kg was detected. An odor was noted at the 18-foot depth in the 1995 drilling log. This location is partially downgradient from NCL-44 which had measurable levels of hydrocarbons in groundwater from at least 1990 to 1996 when detections in NCL-44 ceased. MW-54A has had four hydrocarbon detections since installation: one each of ethylbenzene and xylene, and two detections of 2-methyl-naphthalene. At less than 15 ug/L, all groundwater detections are within EPA drinking water maximum contaminant levels (MCL's) or EPA health advisory limits.

In the vicinity of MW-56, a layer of organic hydrocarbon sludge was found at a depth of 5 to 9 feet below the ground surface. This material was black and odoriferous and analytical results show a total BTEX concentration of 44,000 ug/Kg. This substance was not found at the time of drilling of MW-56 in 1995. The well is approximately 18 feet upgradient from the sludge location. The material appears weathered and there was no indication of recent surface disturbance. The area of MW-56 is adjacent to an old and abandoned city wastewater treatment plant on a site now owned by NRC. Based on other drilling performed in the area that found shallow subsurface hydrocarbons and the fact that the surrounding area has been a center of oil production for over 70 years, it is likely that this material was buried sometime in the distant past by either the city, the refinery, or some unknown third party. Even though the material is less than 20 feet away from MW-56, no detections of hydrocarbons have been found in the well since

Table 6-10. Soil Background Sampling, Chromium and Lead, North Colony Landfarm

Location	Date Collected	Chromium (mg/Kg)	Lead (mg/Kg)	Chromium (mg/Kg)	Lead (mg/Kg)	Chromium (mg/Kg)	Lead (mg/Kg)
		Depth 5 - 5.5 feet					
BG-01	15-Jun-90	6.8	7	--	--	--	--
BG-02	15-Jun-90	6.7	5	--	--	--	--
BG-03	15-Jun-90	8.1	7	--	--	--	--
BG-04	15-Jun-90	5.8	7	--	--	--	--
BG-05	15-Jun-90	5.9	4	--	--	--	--
BG-06	15-Jun-90	12.1	8	--	--	--	--
BG-07	15-Jun-90	13.0	10	--	--	--	--
BG-08	15-Jun-90	13.4	42[a]	--	--	--	--
		Depth 4 - 5 feet					
BG 94-06	11-May-94	8	4	--	--	--	--
		Depth 5 - 7 feet		**Depth 7 - 9 feet**		**Depth 9 - 11 feet**	
BG-97-01	01-Aug-97	6.51	4.11	9.92	4.18	13.00	6.14
BG-97-02	01-Aug-97	6.51	3.97	NS	NS	8.26	2.14
BG-97-03	01-Aug-97	4.19	1.92	5.75	2.91	13.7	5.59
BG-97-04	01-Aug-97	10.8	4.45	9.13	5.09	5.81	2.47
BG-97-05	01-Aug-97	12.4	5.38	12.2	8.62	7.76	3.75
BG-97-05 (dup1)	01-Aug-97	14.6	6.82	--	--	--	--
BG-97-05 (dup2)	01-Aug-97	--	--	--	--	11.5	4.54
Average (mg/Kg):		**8.99**	**5.62**	**9.25**	**5.20**	**10.01**	**4.11**

Notes:

a) Statistical outlier; mean calculated without use of this value.
b) Reporting limits 1990: Chromium, 0.4 mg/Kg; lead 1 mg/Kg
c) Reporting limits 1994: Chromium, 2 mg/Kg; lead 1 mg/Kg.
d) Reporting limits 1997: Chromium, 1.15 - 1.30 mg/Kg; lead 0.345 - 0.390 mg/Kg.
e) See Figure 6-1 for boring locations; laboratory analytical data sheets provided in appendices.

Table 6-11. Metals Analyses, Monitor Well Soils, North Colony Landfarm

Location, Depth (feet)	**Chromium (mg/Kg)**	**Reporting limit (mg/Kg)**	**Lead (mg/Kg)**	**Reporting limit (mg/Kg)**
MW-54,				
5-7	9.03	1.20	3.25	0.360
9-11	5.25	1.15	23.8	0.345
18-20	9.05	1.25	4.85	0.375
23-25	7.54	1.22	4.23	0.366
MW-55,				
5-7	6.24	1.16	3.19	0.348
9-11	27.6	1.33	5.31	0.399
13-15	11.1	1.22	4.66	0.366
18-20	7.03	1.27	2.96	0.381
23-25	5.14	1.30	2.62	0.390
MW-54,				
18-20	11.5	1.25	9.86	0.375
Average, all intervals:	**9.9**		**6.5**	

Note:

a) Sample date August 1, 1997

b) Laboratory analytical data sheets provided in appendices.

Table 6-12. Volatiles/Semi-Volatiles Analyses, Monitor Well Soils, North Colony Landfarm

Location, Depth (feet)	Benzene (ug/Kg)	Toluene (ug/Kg)	Ethyl-benzene (ug/Kg)	Total Xylenes (ug/Kg)	Acetone[a] (ug/Kg)	Methylene Chloride[a] (ug/Kg)	Semi-volatiles (ug/Kg)
MW-54							
5-7	<6.1	<6.1	<6.1	<6.1	23.8	21.8	ND
9-11	<5.76	<5.76	<5.76	<5.76	19.8	19.7	ND
13-15	<5.95	<5.95	<5.95	<5.95	71.8	18.2	ND
18-20	<6.25	<6.25	8.2	<6.25	18.0	20.9	ND
23-25	<6.1	<6.1	<6.1	<6.1	16.7	22.0	ND
MW-55							
5-7	<5.8	<5.8	<5.8	<5.8	19.1	11.5	ND
9-11	<6.65	<6.65	<6.65	<6.65	21.7	10.9	ND
13-15	<6.10	<6.10	<6.10	<6.10	21.0	20.1	ND
18-20	<6.35	<6.35	<6.35	<6.35	16.1	15.9	ND
18-20 (dup)	<6.15	<6.15	<6.15	<6.15	22.1	21.9	ND
23-25	<6.5	<6.5	<6.5	<6.5	14.8	11.5	ND
MW-56							
5-7	<919	<919	21,500	19,500	2,480	1,450	NS
9-11	<5.8	<5.8	<5.8	<5.8	100	10.8	NS
13-15	<5.9	<5.9	<5.9	<5.9	71	18.2	NS
18-20	<6.25	<6.25	<6.25	<6.25	26	19.2	ND
Trip Blank	<5.0	<5.0	<5.0	<5.0	<10.0	<10.0	- -

Notes:

a) Analyte is a common solvent; its presence may be an artifact of sample collection, transport, or analysis.
b) Date Collected: August 1, 1997.
c) Volatiles by EPA SW-846 method 8240, semi-volatiles by EPA SW-846 method 8270.
d) Abbreviations: ND – not detected, NS – not sampled.
e) Reporting limits for 31 other volatiles generally ranged from 5.75 to 13.3 ug/Kg.
f) Reporting limits varied for each constituent and each sample location; 68 semi-volatiles generally ranged from 383 to 1,330 ug/Kg.
g) Laboratory analytical data sheets provided in appendices.

groundwater sampling was initiated in the new well in 1996. The lack of current groundwater contamination and the lack of evidence indicating a preexisting problem is indicative of the effectiveness of the clay zone, located from 5 to 10 feet below the surface, in preventing downward migration of semi-solid hydrocarbon materials.

6.1.2.4.3 Temporary Well Soil Samples

Temporary monitor wells were emplaced beneath the NCL unit as described in Section 5.2.3.1. Although the main purpose of the installations were collection of water quality samples, hole lithology was logged from the cuttings and from splitspoon samples. The drillers placed cuttings from 2-foot depth intervals on the surface for inspection. Split-spoon samples were collected from 15 to 17 feet for examination in an attempt to ascertain the presence of saturated zones. None of the boreholes initially contained water and the logs reflect only slightly moist soils in several of the wells. Photographs taken of the cuttings and splitspoon samples, and the borehole logs are presented in Appendices A and B.

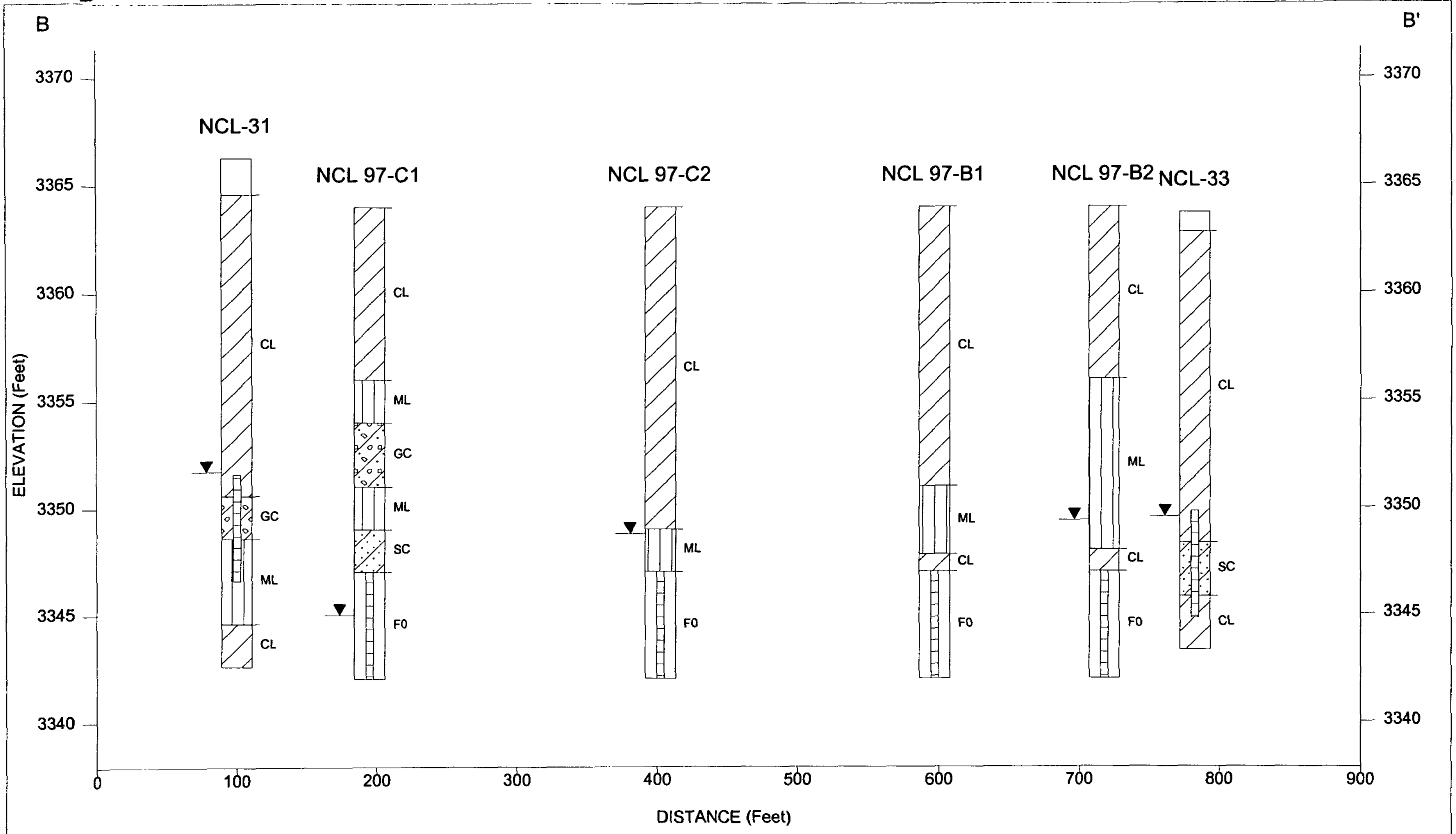
In general, clearly discernible coarse-grained zones were not present in the 12 borings. Exceptions were borings 97-A1 (2.5 inch zone of clay with caliche at 16 feet), 97-A4 (2-foot zone of clay and caliche at 15 to 17 feet containing some fine-grained sand and a strong diesel hydrocarbon odor), 97-C1 (3-foot zone at 10 to 13 feet with a blue-gray gravelly clay and strong diesel hydrocarbon odor, and a lower 2-foot zone of fine grained clayey sand from 15 to 17 feet with little odor), and 97-C3 (5-foot thick zone of clayey sand from 7 to 12 feet containing a strong hydrocarbon odor).

The variability of the subsurface layers and the predominance of clayey materials is seen in Cross-sections B-B' and C-C' (Figures 6-5, and 6-6) which show lithologies beneath the landfarm. Cross-section B-B' is drawn from southwest to northeast generally along the hydraulic gradient and shows no continuous coarse-grained layer. Well 97-B1 is dry, and the water level elevation in 97-C-1 is lower than the other wells. Cross-section C-C' exhibits more coarse grained lithology. Because the predominate sediment transport direction in the area of the refinery is northeast, a cross-section perpendicular to the direction of flow likely would intersect the thin northeastward trending fluvial channels and show more grain-size variability. On the other hand, a cross-section in the direction of flow may be oriented along or within the fine-grained linear features and show less change in grain size. In summary, the more permeable zones are shown to be infrequent, thin, and discontinuous in both horizontal and vertical directions. These results are consistent with the Phase I trench observations and the Phase II boring investigation.

6.1.3 Deep Geotechnical Boring Results

In order to characterize the near-surface geology in the vicinity of the NCL, a deep boring (NCL-D-1) was completed during the RFI Phase I investigation to a depth of 100 feet outside the unit boundary and adjacent to NCL-32 (Figure 5-1). Soil samples retrieved from the boring at 5-foot intervals were examined and logged, as described in the NCL RFI workplan. The boring log for the deep geotechnical boring is presented in Appendix B. Photographs taken during the drilling of the hole are shown in Appendix A.

Observations made at the time of the deep boring revealed that the near-surface saturated zone at this location consists of an interconnected network of thin caliche gravel seams interbedded with clayey sand. Visual and olfactory evidence of hydrocarbon contamination was observed in association with the gravel seams at a depth interval ranging from 13.5-16.5 feet. below surface grade. The gravel seams, which were observed to have an average thickness of approximately 6 inches, extended to a final depth of 37.5 feet., with interbedding materials transitioning from clayey sand to silty clay to clay. During the drilling in 1995 of MW-54B, located 300 feet northeast of NCL-D-1, the gravel seams were observed to terminate slightly deeper at a depth of 44 feet.



RFI Supplemental Investigation
North Colony Landfarm
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Navajo Refining Company
Artesia, New Mexico

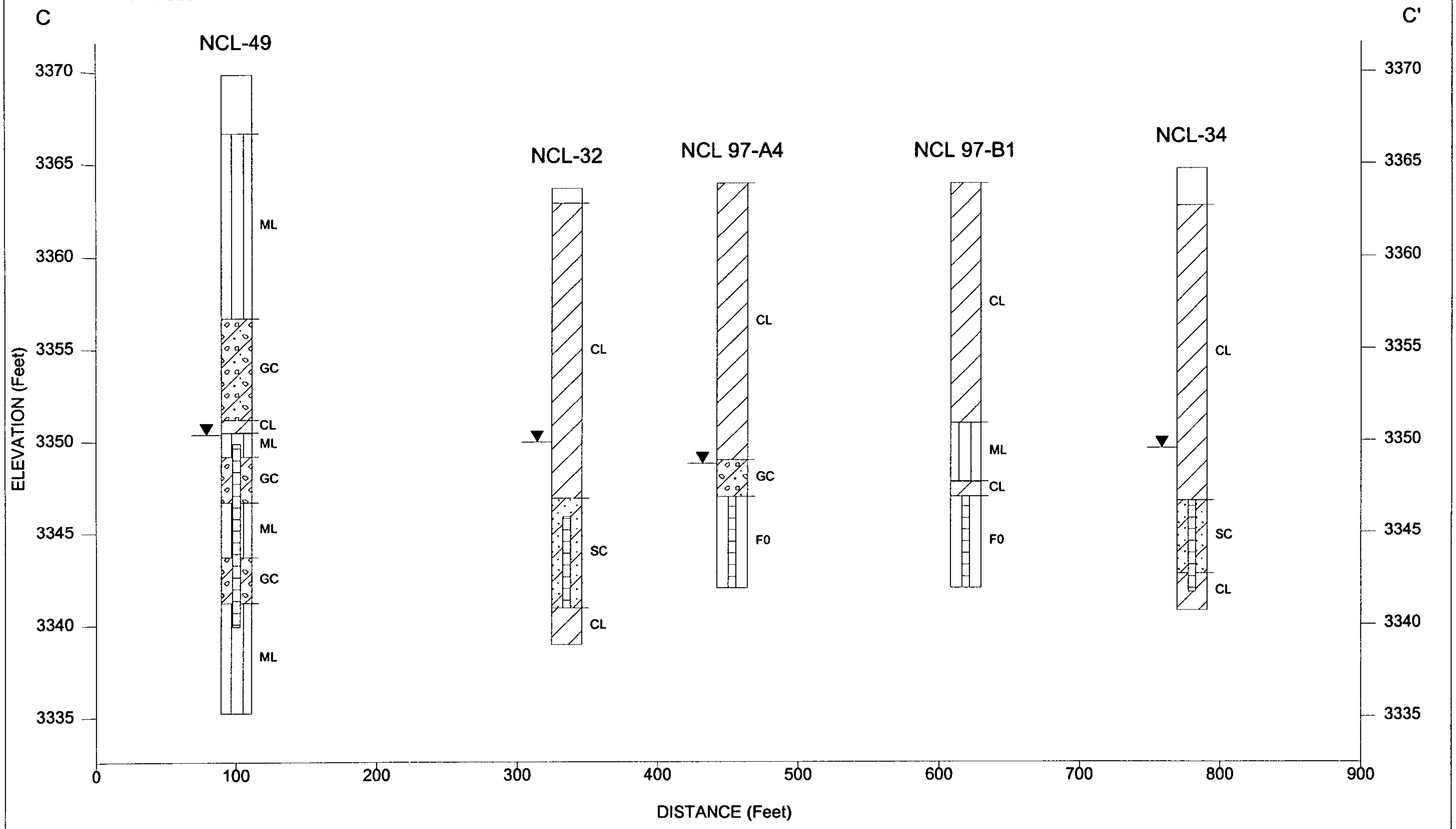
Figure 6-5

GEOLOGIC CROSS SECTION
Section B-B'
Navajo North Colony Landfarm
Water Levels 7/31-8/2, 1997

LEGEND

GM	Silty Gravels, Silty Mixes	SC	Clayey Sands, Clay Mixes
GC	Clayey Gravels, Clay Mixes	ML	Clayey Silts, Clayey Sands
GW	Gravels, Gravel-Sand Mixes	CL	Inorganic Clays, Clay Mixes
SM	Silty Sands, Silt Mixes	CH	Fat Clays, Highly Plastic .

11-11-1997 C:\MTECH46\ nav-ncl\ ncl_97_nclcros_nav-cs2.cro



RFI Supplemental Investigation
North Colony Landfarm
July-September, 1997

Navajo Refining Company
Artesia, New Mexico

Figure 6-6

GEOLOGIC CROSS SECTION
Section C-C'
Navajo North Colony Landfarm
Water Levels 7/31-8/2, 1997

LEGEND

GM	Silty Gravels, Silty Mixes	SC	Clayey Sands, Clay Mixes
GC	Clayey Gravels, Clay Mixes	ML	Clayey Silts, Clayey Sands
GW	Gravels, Gravel-Sand Mixes	CL	Inorganic Clays, Clay Mixes
SM	Silty Sands, Silt Mixes	CH	Fat Clays, Highly Plastic

11-11-1997 C:\MTECH46\ nav-ncl\ ncl_97_nclcros_nav-cs3.cro

Below 37.5 feet., geological materials consisted primarily of dry, very hard clays, limestone and some silty sands to the final boring depth of 100 feet. (Photographs A-13, A-14, Appendix A). No evidence of groundwater-bearing strata was indicated from 37.5 to 100 feet (Appendix B).

The observations are in agreement with previous borehole logs produced by geotechnical engineers drilling for foundation information for tanks and refining units. In the past four years two deep borings (to 85 and 101 feet) have been drilled and logged by registered professional engineers using the same ASTM nomenclature as was used in the current investigation. Neither boring encountered water beneath the NSSZ to total depth. The lower zones generally consisted of clay with occasional gravels interspersed sparsely in the clay. In the lower zones, free water was encountered only as moisture surrounding isolated gravel pieces in the clay matrix. The geotechnical logs for these two borings are presented in Appendix B.

6.1.4 Statistical Analysis of Soil Samples

6.1.4.1 Selection of Data for Statistical Testing

The selection of the proper data for testing is an important step in validating the results of a statistical test. To determine representative soil background concentrations for chromium and lead metals, data from recent and past soil tests were collected and compiled. The resultant data sets are presented in Tables 6-10 and 6-13. For the most accurate comparison of background data with sample data, the data should be from the same sample interval. For the comparison with NCL soil data taken at the base of the treatment zone, background samples in the range from 5 to 7 feet below the surface were selected with one additional sample from the 4 to 5 feet interval chosen (Table 6-10).

6.1.4.2 Preliminary Statistical Tests

Prior to conducting the *t*-test, statistical tests to check for normal distributions and data outliers were performed as described in Section 5.3. To test for normal distributions, the sample standard deviation is divided by the sample mean; if the ratio exceeds 1.0, there is evidence the data are not normally distributed. The soil background and sample observation data set populations were found to be normal.

An assessment for statistical outliers was also performed. This test evaluates the possibility that a value in a sample set is not from the sample set population and may be removed from subsequent statistical calculation. For each sample value, the test subtracts the sample mean from the value and this value is divided by the standard deviation. The resultant score is called the *z*-statistic. If the *z*-score is <-3 or >3, the sample value is considered an outlier.

No outliers were identified in the data set utilized for chromium soil analysis. An outlier of 42 ug/kg was identified within the background soil sample population for lead and was removed form the analysis. Removing this assumed outlier value effectively produces a more conservative background soil sample set for use in the data comparisons.

Table 6-13. Soil Sample Data Set Used in Chromium and Lead Statistical Tests, North Colony Landfarm

Location	Chromium (mg/Kg)	Lead (mg/Kg)	Location	Chromium (mg/Kg)	Lead (mg/Kg)
Landfarm Cell A, 1990 Sampling:			**Landfarm Cell C, 1990 Sampling:**		
A-1	7.5	7	C-1	16.6	9
A-2	8.2	6	C-2	13.3	8
A-3	5.9	7	C-3	7.2	4
A-4	14.0	4	C-4	8.9	9
A-5	4.9	5	C-5	8.9	4
A-5(dup)	4.5	6	C-6	11.6	9
A-6	6.5	6	C-7	10.3	9
A-7	5.7	4	C-8	9.6	6
A-8	8.0	7	C-9	6.8	6
A-9	13.8	8	C-10	8.7	5
A-10	3.2	2	C-10(dup)	6.3	6
Landfarm Cell A, 1994 Sampling:			**Landfarm Cell C, 1994 Sampling:**		
A-11	8	4	C-11	11	5
A-12	13	4	C-11(dup)	12	5
A-13	12	6	C-12	23	11
A-14	10	8	C-13	18	8
A-15	8	6	C-14	12	4
A-16	9	4	C-15	15	8
A-17	10	3	C-16	11	6
			C-17	24	10
			C-18	10	4
Landfarm Cell B, 1990 Sampling:			**Landfarm Cell D, 1990 Sampling:**		
B-1	9.5	8	D-1	6.4	5
B-2	14.0	6	D-2	12.3	8
B-3	8.6	6	D-3	8.3	6
B-4	9.2	8	D-4	7.3	3
B-5	9.6	8	D-5	9.4	6
B-5(dup)	13.9	9	D-6	7.3	5
B-6	5.8	6	D-7	8.0	6
B-7	18.7	7	D-8	7.5	6
B-8	9.1	7	D-9	7.7	8
B-9	11.5	16	D-10	8.5	7
B-10	9.1	7	D-10(dup)	9.0	7
Landfarm Cell B, 1994 Sampling:			**Landfarm Cell D, 1994 Sampling:**		
B-11	13	6	D-11	22	10
B-12	13	8	D-12	18	8
B-13	13	5	D-12(dup)	18	8
B-14	14	5	D-14	19	8
			D-15	23	9

6.1.4.3 Soil Sample Statistical Test Results

The two sample *t*-test assuming equal and unequal variances was performed for chromium and lead soil data sets consisting of subsets of background and sample data from beneath the landfarm. Results of *t*-tests for chromium and lead are shown in Table 6-14 while the statistical data sets included in Appendix D.

For both chromium and lead, results of the *t*-tests indicate that the absolute value of the *t*-statistics are consistently less than the critical values. Therefore, the null hypothesis (Ho: $u_1 = u_2$) was accepted. Regardless of the assumptions of equal or unequal variance, the statistical analyses show soil chromium and lead not to be present at sample locations beneath the base of the NCL treatment unit at levels elevated above ambient or background conditions that are statistically significant at the 95% confidence interval.

6.1.5 Vadose Zone Modeling

As described previously in Section 5-4, the VLEACH model describes the movement of specific organic contaminants within and between three different phases: (1) as a solid dissolved in water, (2) as a gas in the vapor phase, and (3) as an adsorbed compound in the solid phase.

Results of soil analyses in the July 1994 Volume I RFI Report, RCRA Facility Investigation, North Colony Landfarm, Navajo Refinery, were reviewed to identify the most elevated volatiles and semivolatiles. This assessment was limited to a depth from 5 to 9 feet. Based on the review, benzene at a concentration of 17 ug/kg detected at a depth of 7 to 9 feet in boring C-13 was selected to model transport in the unsaturated zone. Other constituents selected were ethylbenzene at a concentration of 33 ug/kg, xylene at a concentration of 192 ug/kg, and 2-methyl naphthalene at a concentration of 7 mg/kg were used for model input.

The selected parameters listed in Table 6-15 and additional parameters of precipitation, recharge, organic soil content and porosity were used in the VLEACH model to estimate the impact due to mobilization and migration, assuming these organic contaminants are sorbed to soil in the vadose zone. The model was assumed to have four soil layers, each three feet thick.

6.1.5.1 Vadose Zone Modeling Results

VLEACH documentation including input and output files are included in Appendix E. Table 6-16 summarizes results of the VLEACH sensitivity analysis. Model sensitive parameters including organic content and porosity were varied in a series of model simulations. VLEACH output provides concentration of soil water just above the top of the saturated zone. In order to determine groundwater concentrations from the model simulation, the Summers analytical equation, developed by EPA (1980), was used. This equation takes the soil water concentration results and inputs into them into a mixing equation for determination of the groundwater concentrations.

Table 6-14. Results of Soil Chromium and Lead Statistical Analyses, North Colony Landfarm

Soil Chromium Statistical Analyses

t-Test: Two-Sample Assuming Equal Variances:

	Chromium Sample (mg/Kg)	***Chromium Background (mg/Kg)***
Mean	11.0159	8.9873
Variance	21.3705	11.3181
Observations	69	15
Pooled Variance	19.6542	
Hypothesized Mean Difference	0	
df	82	
t Stat	**1.6062**	
P(T<=t) one-tail	0.0560	
t Critical one-tail	1.6636	
P(T<=t) two-tail	0.1121	
t Critical two-tail	**1.9893**	

t-Test: Two-Sample Assuming Unequal Variances:

	Chromium Sample (mg/Kg)	***Chromium Background (mg/Kg)***
Mean	11.0159	8.9873
Variance	21.3705	11.3181
Observations	69	15
Hypothesized Mean Difference	0	
df	27	
t Stat	**1.9664**	
P(T<=t) one-tail	0.0298	
t Critical one-tail	1.7033	
P(T<=t) two-tail	0.0596	
t Critical two-tail	**2.0518**	

Soil Lead Statistical Analyses

t-Test: Two-Sample Assuming Equal Variances:

	Lead Sample (mg/Kg)	***Lead Background (mg/Kg)***
Mean	6.5942	5.61781
Variance	4.8329	4.4426
Observations	69	14
Pooled Variance	4.7703	
Hypothesized Mean Difference	0	
df	81	
t Stat	**1.5250**	
P(T<=t) one-tail	0.0656	
t Critical one-tail	1.6639	
P(T<=t) two-tail	0.1311	
t Critical two-tail	**1.9897**	

t-Test: Two-Sample Assuming Unequal Variances:

	Lead Sample (mg/Kg)	***Lead Background (mg/Kg)***
Mean	6.5942	5.6178
Variance	4.8329	4.4426
Observations	69	14
Hypothesized Mean Difference	0	
df	19	
t Stat	**1.5686**	
P(T<=t) one-tail	0.0666	
t Critical one-tail	1.7291	
P(T<=t) two-tail	0.1332	
t Critical two-tail	**2.0930**	

Model-estimated soil water concentrations just above the top of the vadose zone and resultant groundwater concentrations using the Summers equations are shown in Table 6-16. VLEACH simulations were run for a 30-year period and the results generally indicate that concentrations decrease over the 30 year period. To add further conservatism to the analysis, the more elevated initial soil water concentrations at time zero, instead of the lower concentration after 30-years of leaching, were used to calculate the groundwater concentration.

Results of the VLEACH sensitivity analysis indicate that model predicted concentrations in soil water and groundwater are below applicable groundwater standards for the organic parameters run in the analysis. The analysis was considered conservative because the most elevated concentrations of volatiles and semivolatiles detected in the upper unsaturated soils were used in the model. In addition, the heterogeneous layers of caliche and silty clay are not considered by the model. Finally, actual recharge in the vicinity of the landfarm is well below one foot, the modeled value. An average of only about 13 inches of rainfall occurs in the Artesia area on an annual basis and evapotranspiration rates are between 66 and 72 inches per year. Because the annual net moisture deficit is 53 to 59 inches, very little of the precipitation is available for direct recharge through soil.

Table 6-15. Properties of Volatile and Semi-Volatile Compounds Used in Vadose Zone Modeling, North Colony Land Farm.

Constituent Property	**Benzene**	**Ethyl Benzene**	**Xylene**	**2 Methyl Naphthalene**
Organic Carbon Distribution Coefficient, (K_{OC})(ml/g)	64.56	676.1	691.83	8,511
Henry's Constant, (K_H)(Dimensionless)	0.22	0.32	0.28	2.05
Water Solubility (mg/l)	1,780	152	200	25.4
Free Air Diffusion Coefficient (m^{-2}/d)	0.79	0.61	0.66	0.5

Reference: (Ravi, 1990)

Table 6-16. Vadose Zone Sensitivity Analysis, North Colony Landfarm

VLEACH Input	**Benzene 17 ug/Kg**		**Ethylbenzene 33 ug/Kg**		**Xylene 192 ug/Kg**		**2 Methyl Naphthalene 7 ug/Kg**	
	Soil water ug/L	Ground-water ug/L	Soil water ug/L	Ground-water ug/L	Soil water ug/L	Ground-water ug/L	Soil water ug/L	Ground-water ug/L
Recharge = 1 foot Organic Content = 0.4 Porosity = 0.4 3, 4-foot Layers	0.65	0.71	0.12	0.18	0.69	0.75	0.002	0.065
Recharge = 1 foot Organic Content = 0.1 Porosity = 0.25 3, 4-foot Layers	2.6	2.6	0.49	0.54	2.8	2.8	0.008	0.07
Recharge = 1 foot Organic Content = 0.4 Porosity = 0.25 3, 4-foot Layers	0.65	0.71	0.12	0.18	0.69	0.70	0.008	0.07
Recharge = 1 foot Organic Content = 0.1 Porosity = 0.4 3, 4-foot Layers	2.6	2.6	0.48	0.54	2.8	2.8	0.008	0.07
Recharge = 1 foot Organic Content = 0.2 Porosity = 0.4 3, 4-foot Layers	1.3	1.4	0.24	0.31	2.8	2.8	0.004	0.004
Recharge = 1 foot Organic Content = 0.2 Porosity = 0.25 3, 4-foot Layers	1.3	1.4	0.24	0.30	1.4	1.5	0.004	0.06

6.2 Groundwater Investigation Results

Like the soils study presented earlier in this section, the hydrogeological investigation at the NCL consisted of several elements that were performed during the various RFI studies. Groundwater elevations in new and existing monitor wells were measured during the RFI Phase I and Phase II studies and during the current supplemental work. The data from these observations was used to determine changes in groundwater levels, and to produce water level elevation maps needed to establish groundwater flow direction and hydraulic gradient. In addition, data loggers were installed in 1995 and 1997 to obtain continuous groundwater level measurements in an effort to better characterize the hydraulic regime and monitor well impacts to precipitation. In 1995 localized hydraulic conductivities were determined through the analysis of "slug" test data collected at two of the newly installed wells. In 1997 the hydraulic conductivity data was combined with results from earlier studies and included with other physical parameters as inputs for a groundwater transport model to predict the fate of organic constituents in the subsurface. Additional water quality data was obtained in 1997 for use in defining the extent of the dissolved and/or free-phase hydrocarbon plume underneath the facility.

6.2.1 Groundwater Elevations

Groundwater elevations in the vicinity of the NCL are routinely measured during collection of quarterly water quality samples as required by the RCRA permit, more frequently as necessary. During the RFI investigation process, additional water level measurements were performed including continuous measurements during a 6-month period in summer and fall 1995, and during a 90-day period in late summer 1997.

6.2.1.1 Periodic Elevation Measurements

The water level elevations in the wells were monitored periodically during the investigations. This provided data used in the construction of the water level contour maps (Section 6.2.2). Also, the water level elevations, and more importantly, the magnitude of water level changes, were used to evaluate the response of the NSSZ under the NCL to hydraulic stress.

Table 6-17 presents a summary of long-term water level changes in monitor wells near the NCL in 1995. A general decline in groundwater levels from September to December is indicated. Water level decreases under the landfarm (as measured by NCL-33 and NCL-31) during this time period range from 2.2 to about 4.1 feet. The average decrease is approximately 3.3 feet. By contrast, the decrease from August to December in newly installed wells MW-55 and MW-56 is only about 0.8 feet which may indicate that hydrogeologic conditions in the vicinity of the latter two wells differ from the area of the landfarm. The reasons for a possible change are discussed in Section 6.2.2

6.2.1.2 Continuous Elevation Measurements

Observations from soil borings and excavation trenches completed during the RFI Phase I yielded strong evidence to indicate that extensive vadose zone contamination beneath the NCL was the result of an unrelated petroleum product release. At many RFI Phase I locations on the unit, environmental observations and data demonstrated the upward migration of contaminants from the NSSZ towards the base of the unit treatment zone. Moreover, inspection of the sidewall profiles of RFI Phase I trench excavations revealed numerous instances in which petroleum product was apparently forced into relatively impermeable clay formations below the unit. During such events, migration of product occurred via restricted preferential pathways.

Table 6-17. Changes in Water Levels at Monitor Wells in the Vicinity of the North Colony Landfarm, September to December, 1985

Well Name	Depth to water (feet)	Date Measured	Depth to Water (feet)	Date Measured	Change in Water Level (feet)	Number of Days
NCL-31	12.60	9/13/95	16.66	12/23/95	-4.06	101
NCL-32	11.93	9/13/95	15.33	12/23/95	-3.40	101
NCL-33	13.71	9/13/95	15.93	12/1/95	-2.22	79
NCL-34	13.65	9/13/95	16.81	12/1/95	-3.16	79
NCL-44	12.25	9/13/95	15.27	12/23/95	-3.02	101
NCL-49	17.55	9/13/95	21.31	12/23/95	-3.76	101
MW-53	14.24	6/29/95	17.10	12/23/95	-2.86	177
MW-55	15.36	8/9/95	16.15	12/23/95	-0.79	136
MW-56	14.40	8/9/95	15.19	12/23/95	-0.79	136

The observed intrusion of hydrocarbon materials into the relatively tight clays was observed to occur at subsurface elevations which were well above the commonly observed potentiometric elevation of the NSSZ, and the radiative diffusion of hydrocarbons from those preferential pathways into the confining matrix was observed to be very limited. These observations were believed to indicate the occurrence of historic episodes during which the NSSZ experienced a relatively intense but transient increase in hydraulic gradient. This potential mechanism for upward transport of hydrocarbon product towards the base of the NCL was first hypothesized in the RFI Phase I report.

Although monitoring of groundwater elevations on a periodic basis provides an accurate snapshot of the hydrologic system at fixed point in time, the detection of rapid potentiometric fluctuations, such as might be caused by precipitation, irrigation, pumping, etc., is more appropriately assessed by means of continuous groundwater elevation monitoring. Therefore, in early July 1995, a data logger as described in Section 5.2.2.4 was installed adjacent to the NCL in unused MW-19. Data from the recorder was downloaded and copied into a PC-driven graphical plotting program. The resultant graph is presented in Figure 6-7.

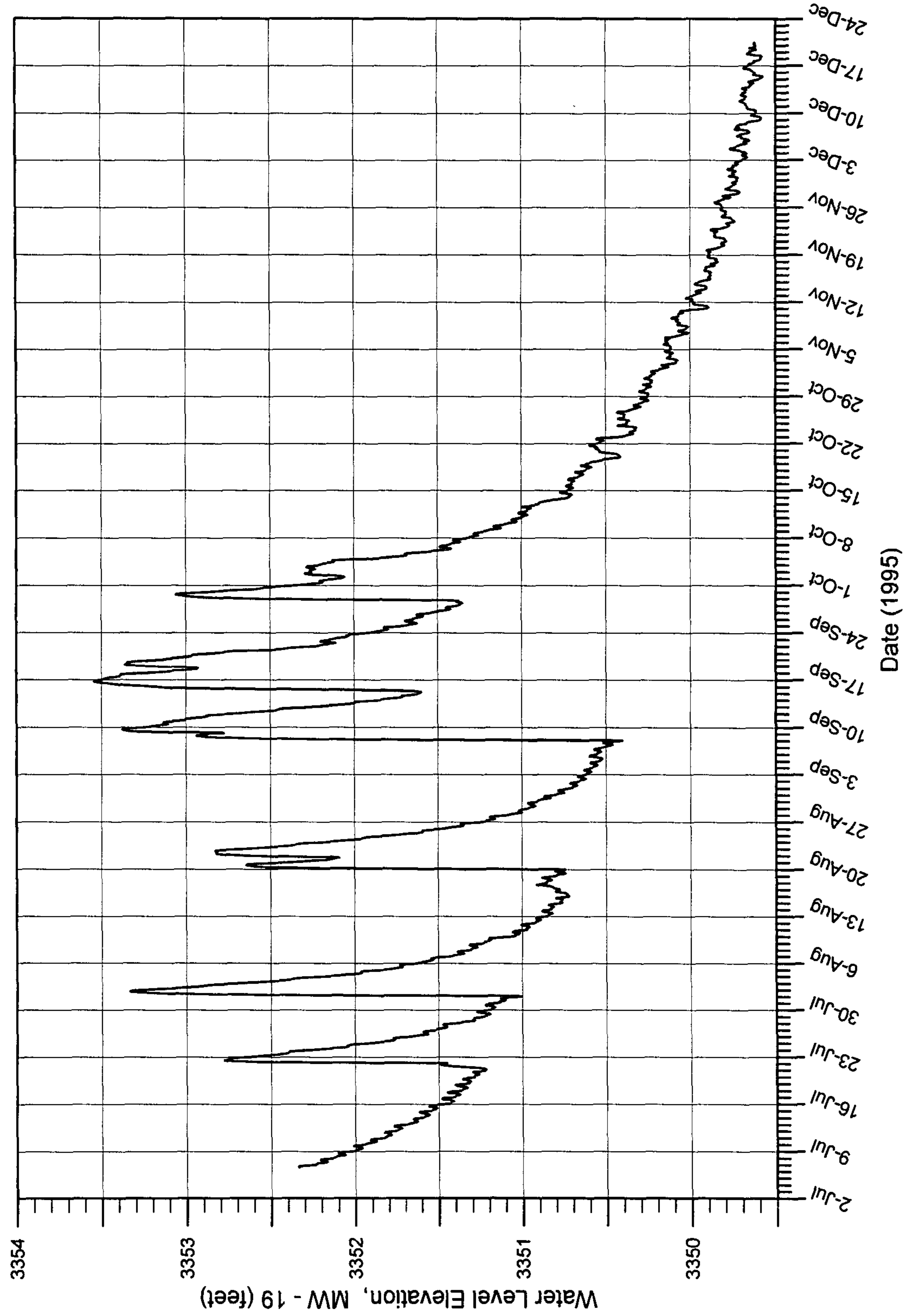


Figure 6-7. Six-Month Water Level Elevations, North Colony Landfarm, MW-19, July - December, 1995

The plotted data clearly show highly variable and rapid fluctuations in water levels over the period of investigation. Water levels declined approximately 3 feet from early July through late December. Of greater importance are the dramatic rises in water levels that were observed on at least six occasions during this period. Water level rises of 1 to 2 feet in a 12-hour period were common. The most spectacular response occurred on September 8, 1995, when water levels rose about 3 feet in one day. The return to initial conditions (defined as water level elevations existing at a time immediately preceding the increase), typically took about 10 days (provided no additional stimulus occurred).

Two alternative hypotheses were proposed in RFI Phase II report that could account for the changes in water levels. The first was a response to local precipitation, and the second was a response to irrigation of City of Artesia parks by treated city wastewater effluent. Initial data from mid-July to mid-August tentatively supported the irrigation scenario since the rise in water levels could be interpreted to be a response to periodic irrigation on a schedule from 10 days to 2 weeks apart. However, inquiry found the city irrigates on almost a daily basis and no unusually large applications of the effluent are applied on a schedule which reflected the observed response in MW-19.

Acquisition of rainfall records was constrained by the fact that no official station is maintained within the City of Artesia. However, precipitation is recorded on a daily basis at two sites nearby. The Artesia Municipal Airport, located 5 miles west of the refinery, and the New Mexico State University Agricultural Science Center, 7 miles south of the NCL site, both provided rainfall records. The precipitation data was correlated with the water level elevation data and plotted to determine the impact of precipitation on the groundwater system.

The resultant graph of water levels and precipitation is shown in Figure 6-8. An obvious correlation can be seen between precipitation events and water level increases. Because summer precipitation in the Southwestern United States is primarily convective in nature, rainfall occurs from finite-diameter storm cells that commonly drop the majority of their moisture close to the cell. This effect often produces heavy rainfall in one location while very little is deposited a few miles away. Therefore, while neither the Artesia airport or the university station precipitation records correlate completely with the increases seen in the monitor well, the combination of both produces excellent correlation of precipitation and water level increases.

The exercise was repeated in 1997 for collection of data at multiple NCL observation wells simultaneously. Two water level data recorders were installed. The first was reinstalled in MW-19 on July 11 and remained in that well until October 10. The second data recorder was installed in NCL-44 on July 29, removed on September 2, and placed in NCL-32 that same day. It remained in that well until retrieval on October 9. These to wells are located on the north-central and northeast side of the landfarm and are generally downgradient from MW-19. Daily precipitation data was only available from the NMSU Agricultural Science Center and is combined with the water level data for presentation on Figure 6-9.

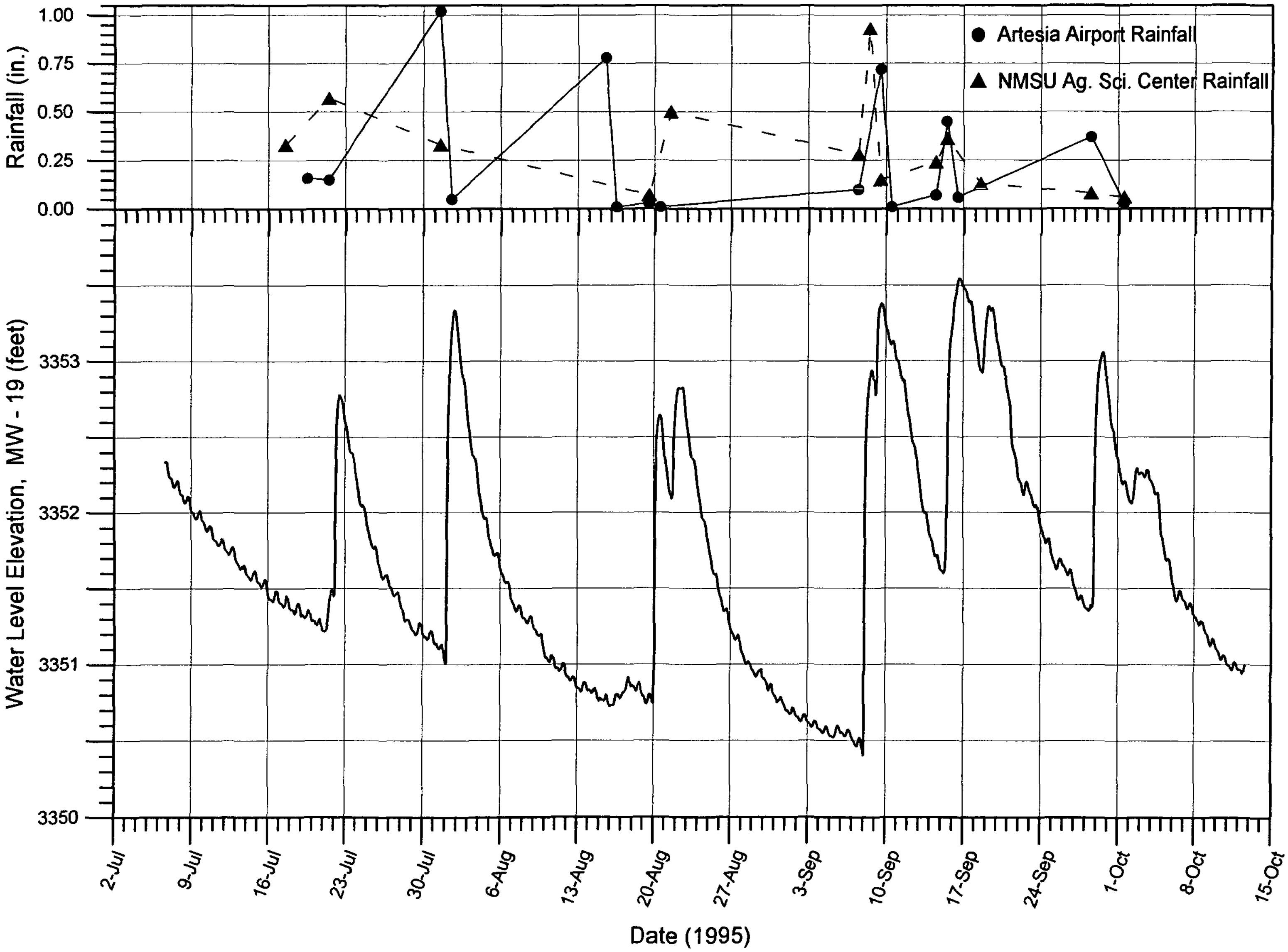


Figure 6-8. Water Level-Rainfall Relationship, North Colony Landfarm, MW-19, July - October, 1995

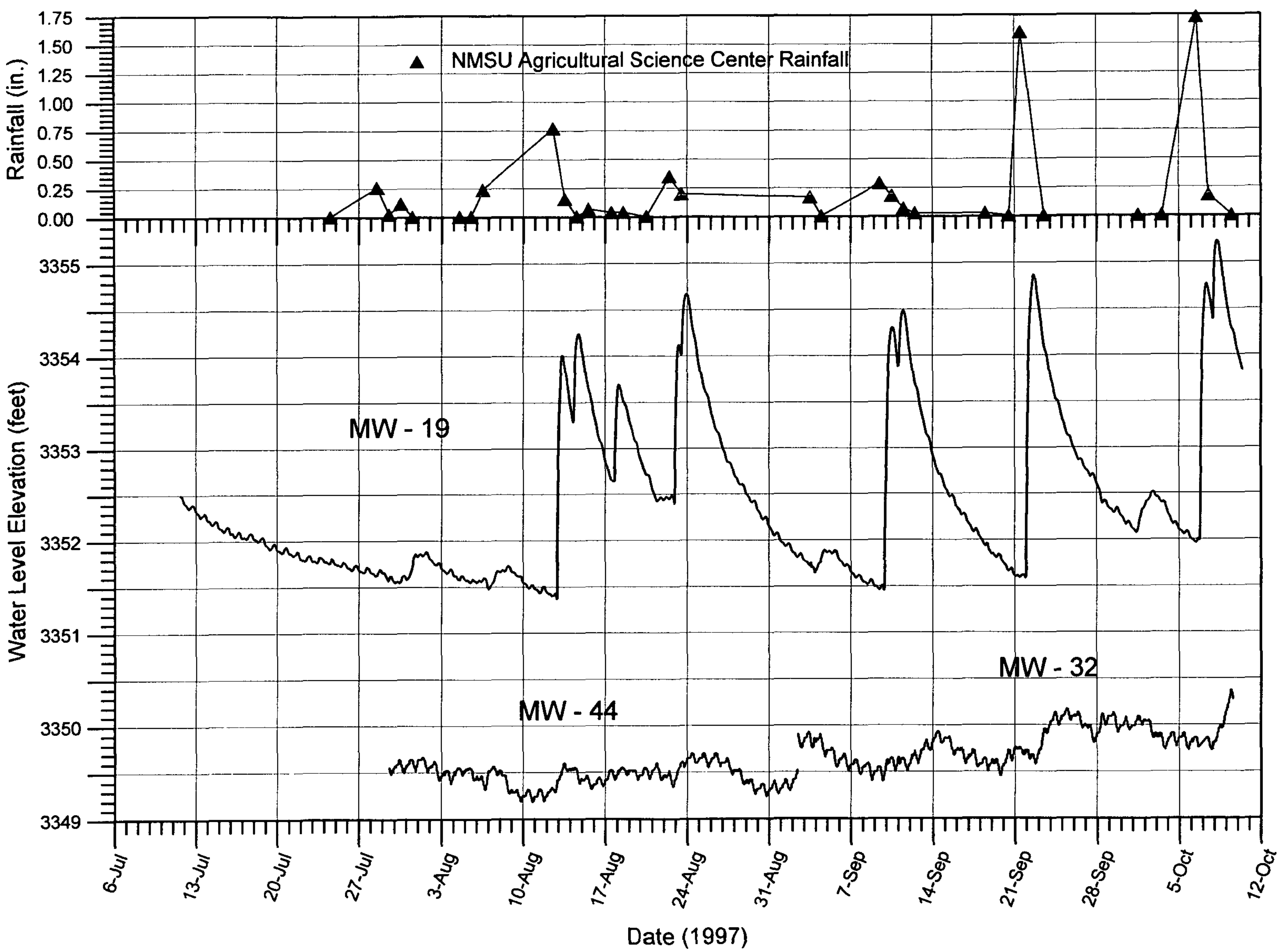


Figure 6-9. Water Level-Rainfall Relationship, North Colony Landfarm, MW-19, -32, and -44, July - October, 1997

In 1997, the same pattern of immediate and significant response to precipitation is again seen in well MW-19. Although increases in water levels during several August and September periods do not appear to directly correlate with the magnitude of the precipitation recorded at the university station, summer rainfall events are extremely variable with respect to the areal distribution of precipitation. A better comparison can be made by noting what dates some amount of precipitation was recorded at the rainfall station and comparing dates of precipitation with increases in water levels in MW-19.

A modification in the graph's y-axis scale allows more detailed comparison of changes in MW-19 with the other wells (Figure 6-10). Both wells NCL-44 and NCL-32 show increases in water level in response to changes in MW-19. The response in these two wells is subdued and delayed. On August 12 MW-19 rose 2.5 feet in one day while NCL-44 shows a 0.4-foot increase within two days. Similarly, MW-19 shows another water level elevation spike on August 23-24 followed by a long decline in water levels until September 9, while NCL-44 peaks three days later before beginning its decline. When the recorder is installed in NCL-32, a similar pattern is established. The magnitude of water level changes is slightly greater in NCL-32 but the changes take place over a longer period of time. For example, MW-19 has a 3-foot water level rise on September 9, but it takes 5 days until September 14 before NCL-32 peaks with a 0.5-foot increase. From September 10 to 13, and from September 22 to 26, water levels in well NCL 32 are increasing while MW-19 levels are dropping. Interpretation of these patterns indicates that water levels reach equilibrium by redistribution of moisture from the area of upgradient well MW-19 to the downgradient wells through movement of water underneath the landfarm. As will be seen in the next section, this scenario is supported by water level contour maps which show the direction of groundwater movement to be north-northeasterly.

The exact location of the source of water that recharges MW-19 is unknown. The City of Artesia is directly upgradient from the NCL and no obvious nearby infiltration source, such as a retention basin or city park pond was identified. A shallow unlined city stormwater drainage ditch is located adjacent to NCL. Limited trenching performed along the ditch during the NCL Phase I investigation and reported in Section 6.1.1.2 found that clay overburden present in the ditch location was similar to that observed directly under the landfarm. However, since the ditch is concreted in the city and concentrates rainfall runoff, it is possible that a relatively small permeable recharge area may exist at the juncture of the lined and unlined portion of the ditch. This is given some credence by the fact that both highway and railroad structures occur at the same location and the ditch was no doubt excavated at that locale to remove the overlying clay and provide foundation structural stability. This, combined with stormwater scouring at the exit point of the concreted ditch, may provide a permeable temporary storage site and serve as a source of subsurface infiltration. If this location is not the source of the water, the next possible upgradient source is Eagle Draw in an area in the city where it has been modified from an incised channel into a broad swale that serves as a park planted with grass, landscaped, and irrigated with wastewater effluent. If the recharge is from Eagle Draw and the direction of flow remains constant, the closest upgradient location for such infiltration to occur is at distance of about 4,000 feet in the vicinity of the 10th Street crossing of Eagle Draw.

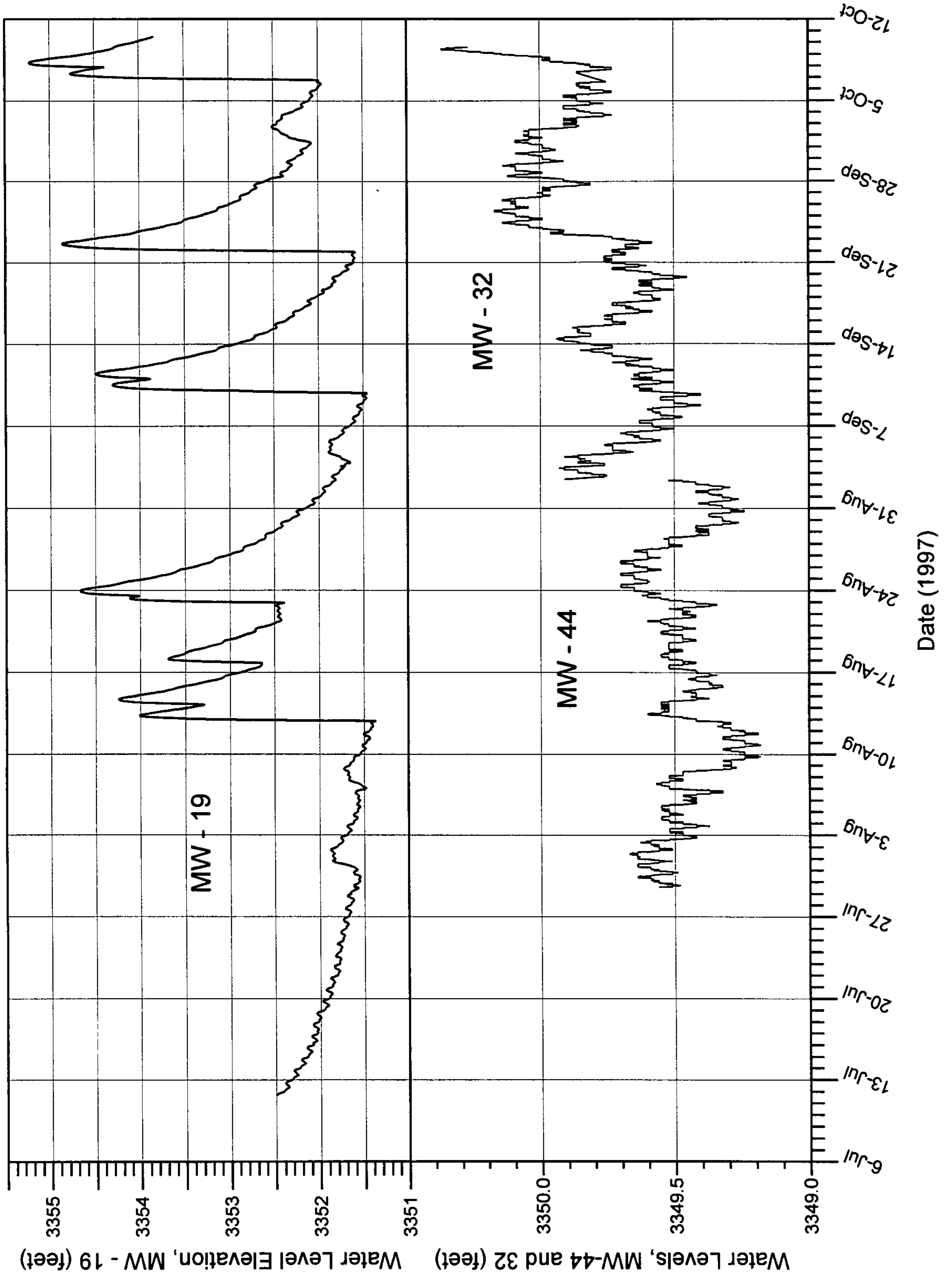


Figure 6-10. Hydrograph Comparison, North Colony Landfarm, MW-19, -32, and -44, July - October, 1997

6.2.2 Groundwater Flow Direction and Gradient

Prior to the preparation of groundwater contour maps, surface and casing elevation data for the existing and new wells were compared to verify the correct elevations. After analysis of data from several well elevation surveys conducted during this and previous investigations, the data from the survey of the most recently installed wells was adjusted downwards slightly. This adjustment eliminated inconsistencies between the surveys and matched data from the more extensive survey of the NCL conducted in 1994.

The depth-to-water elevations measured during the RFI studies were used to produce five groundwater contour maps which show groundwater conditions under several varying sets of hydrologic circumstances. For example, the measurements and the maps show groundwater levels in late summer 1995 during a time of somewhat frequent rainfall, again in December 1995 after a prolonged dry period.

Water level contour maps for the vicinity of the NCL were constructed using the groundwater elevation information shown in Table 6-18. The resultant maps are shown in Figures 6-11 through 6-15, respectively. Water flow is generally north-northeasterly on the maps, although contours at the north end of the maps show movement to be more easterly. The northeasterly direction of flow in this area of the refinery follows the orientation of Eagle Draw in the vicinity of the landfarm. Groundwater movement in other areas of the refinery has been shown to flow in a more easterly direction.

The groundwater contour maps presented in Figures 6-12 and 6-13 show several features which are critical to understanding the groundwater system in the vicinity of the NCL. The water level map for September 13 shows potentiometric surface elevations under the NCL ranging from 3,350.5 to 3,353.5 feet while the range for December 23 is from 3,348 to 3,349.5 ft. On September 13, water level elevations under the NCL decrease by 3 feet over a horizontal distance of approximately 620 feet from the vicinity of the southwest corner of the landfarm to the northeast corner. This results in an average hydraulic gradient of about 0.0048 feet/feet across the landfarm. On December 23, water levels under the landfarm decrease by 1.5 feet from southwest to northeast across a distance of approximately 720 feet, which produces a gradient of about 0.0021 feet/feet.

Additional comparison between the December 23 maps shows the numeric value of hydraulic gradient to be decreasing from west to east. The gradient decreases from 0.0025 feet/feet in the vicinity of NCL-31 to 0.0011 feet/feet near MW-56. This means that the driving force for water and contaminant movement is lessened by a factor of two as water moves northeastward, which in turn reduces groundwater seepage velocities. The information shown on the maps is presented in tabular form in Table 6-19, which summarizes the 1995 hydraulic gradient changes. Similar gradient changes were noted in review of the August 1997 map (Figure 6-15), while the spring 1997 map shows a much flatter aspect (Figure 6-14).

Table 6-18. Groundwater Elevations in the Vicinity of the North Colony Landfarm, RFI Investigation

Well Name	TOC Elevation (feet)	06-01-94 Depth to water (feet)	Water Level Elevation (feet)	09-13-95 Depth to water (feet)	Water Level Elevation (feet)	12-23-95 Depth to water (feet)	Water Level Elevation (feet)	03-25-97 Depth to water (feet)	Water Level Elevation (feet)	08-02-97 Depth to water (feet)	Water Level Elevation (feet)
18	3364.13	- -	- -	- -	- -	16.52	3347.61	- -	- -	14.74	3349.39
19	3366.70	- -	- -	- -	- -	17.07	3349.63	- -	- -	15.02	3351.68
NCL-31	3366.30	11.84	3354.46	12.60	3353.70	16.66	3349.64	- -	- -	14.58	3351.72
NCL-32	3363.72	11.94	3351.78	11.93	3351.79	15.33	3348.39	13.04	3350.68	13.74	3349.98
NCL-33	3363.71	12.16	3351.55	13.71	3350.00	- -	- -	13.27	3350.44	14.15	3349.56
NCL-34	3364.77	12.90	3351.87	13.71	3351.06	- -	- -	13.89	3350.88	15.15	3349.62
NCL-44	3363.25	11.82	3351.43	12.25	3351.00	15.27	3347.98	12.86	3350.39	13.73	3349.52
NCL-49	3369.91	17.97	3351.94	17.55	3352.36	21.31	3348.60	19.12	3350.79	19.52	3350.39
53	3367.53	- -	- -	- -	- -	17.10	3350.43	14.75	3352.78	14.70	3352.83
54A	3365.24	- -	- -	- -	- -	17.47	3347.77	14.58	3350.66	15.76	3349.48
54B	3365.22	- -	- -	- -	- -	17.44	3347.78	- -	- -	15.74	3349.48
55	3363.43	- -	- -	- -	- -	16.15	3347.28	13.11	3350.32	14.58	3348.85
56	3361.91	- -	- -	- -	- -	15.19	3346.72	11.82	3350.09	14.32	3347.59

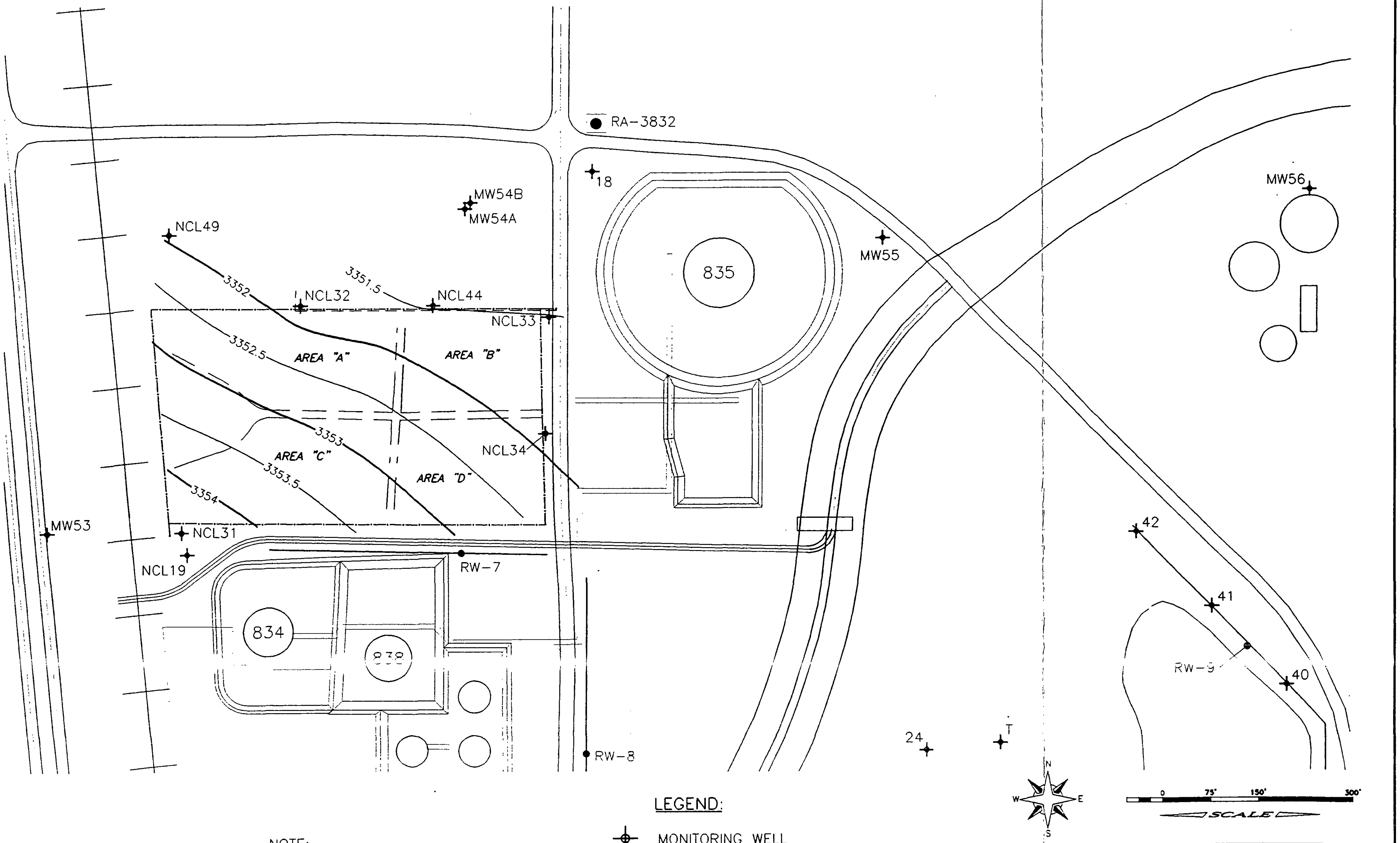
Notes:

Elevations are corrected elevations as follows:

a) Elevations for wells 53, 54A, 54B, 55 and 56 (J.West survey) corrected by subtracting 0.14 ft.

b) Elevation for well 19 (Navajo information) corrected by adding 0.08 ft.

c) Elevation in MW-34 corrected for product thickness.



NOTE:
MW-53 THROUGH MW-56 NOT
DRILLED AND/OR SURVEYED
UNTIL DECEMBER 1995.

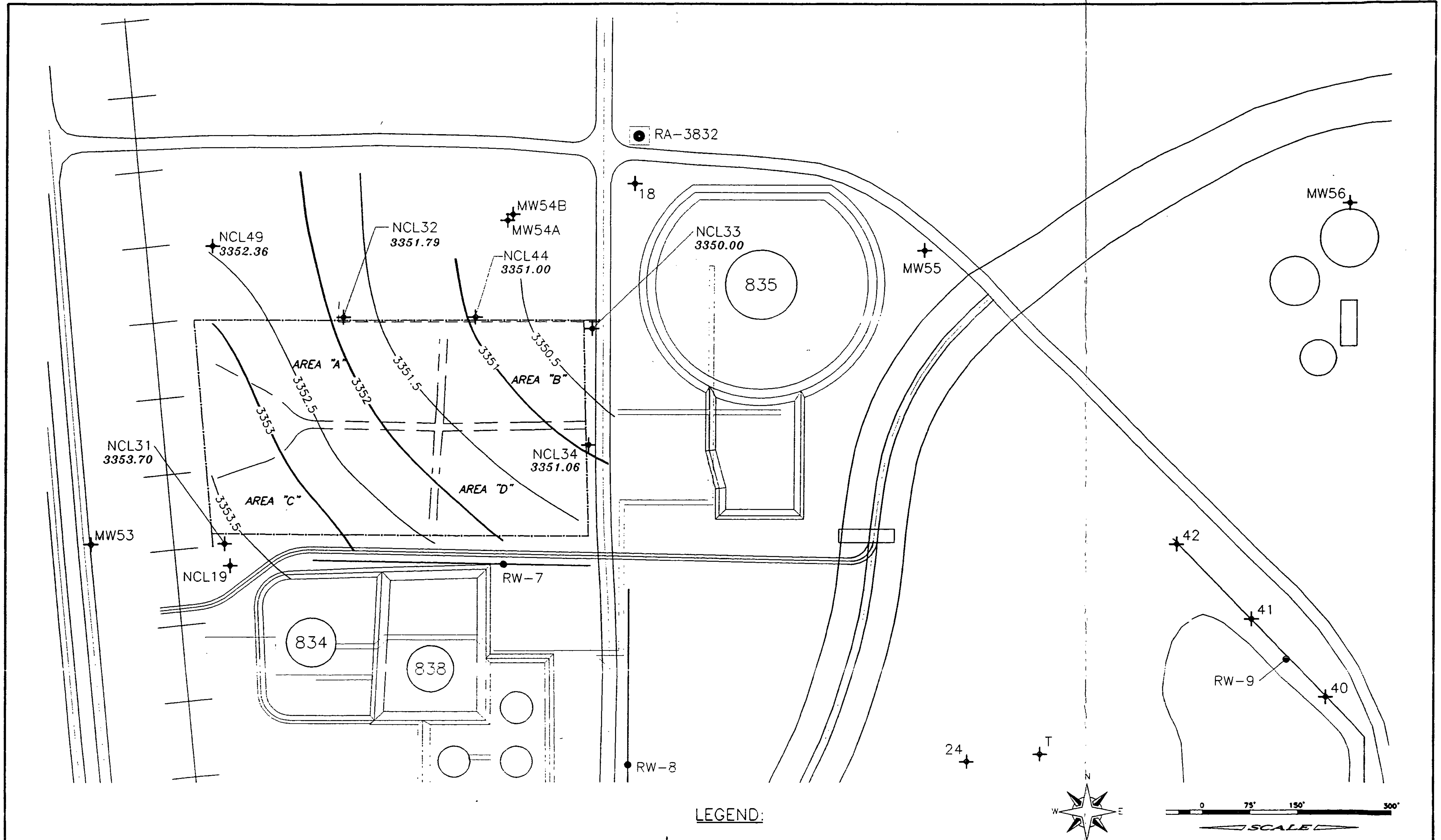
LEGEND:

⌖	MONITORING WELL
●	WATER WELL - DEEP, ARTESIAN AQUIFER
RA-3832	STATE ENGINEER OFFICE WELL NUMBER, ROSWELL ARTESIAN BASIN
—3354—	WATER LEVEL CONTOUR INTERVAL 0.5'

DRAWING TITLE
FIGURE 6-11.
GROUNDWATER ELEVATION
CONTOUR MAP
NORTH COLONY LANDFARM
JUNE 1, 1994

NAVAJO REFINING CO.
P.O. DRAWER 159
ARTESIA, NEW MEXICO

DRAWN BY	CHK'D BY	SCALE	
EJS	DB	1" = 150'-0"	
DATE	APPR BY	DRAWING NUMBER	REV.
11-5-97	-	FIG611.DWG	0



LEGEND:

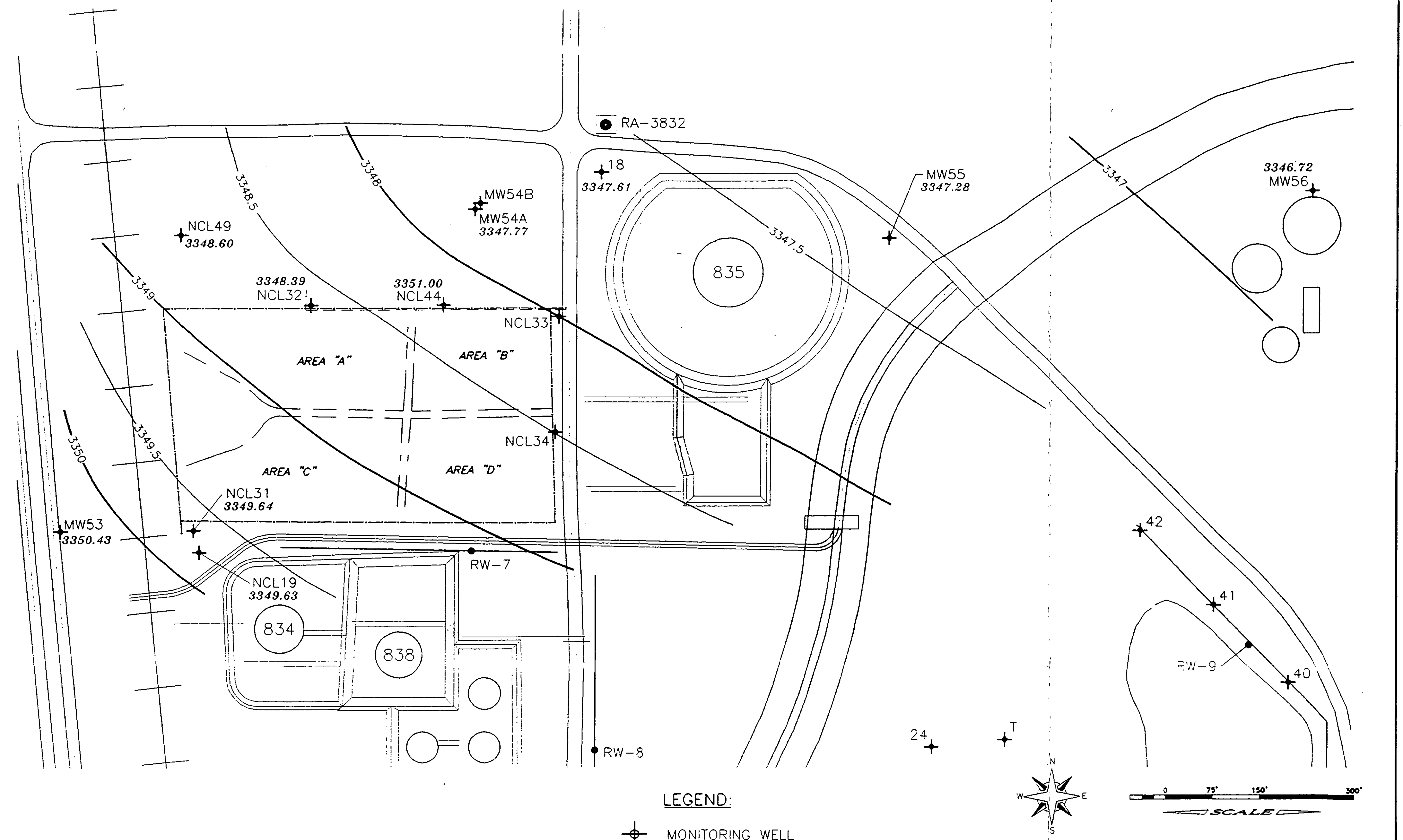
- MONITORING WELL
- WATER WELL - DEEP, ARTESIAN AQUIFER
- RA-3832 STATE ENGINEER OFFICE WELL NUMBER, ROSWELL ARTESIAN BASIN
- 3352 WATER LEVEL CONTOUR INTERVAL 0.5'

NOTE:
MW-53 THROUGH MW-56 NOT
DRILLED AND/OR SURVEYED
UNTIL DECEMBER 1995.

DRAWING TITLE
FIGURE 6-12.
GROUNDWATER ELEVATION
CONTOUR MAP
NORTH COLONY LANDFARM
SEPTEMBER 13, 1995

NAVAJO REFINING CO.
P.O. DRAWER 159
ARTESIA, NEW MEXICO

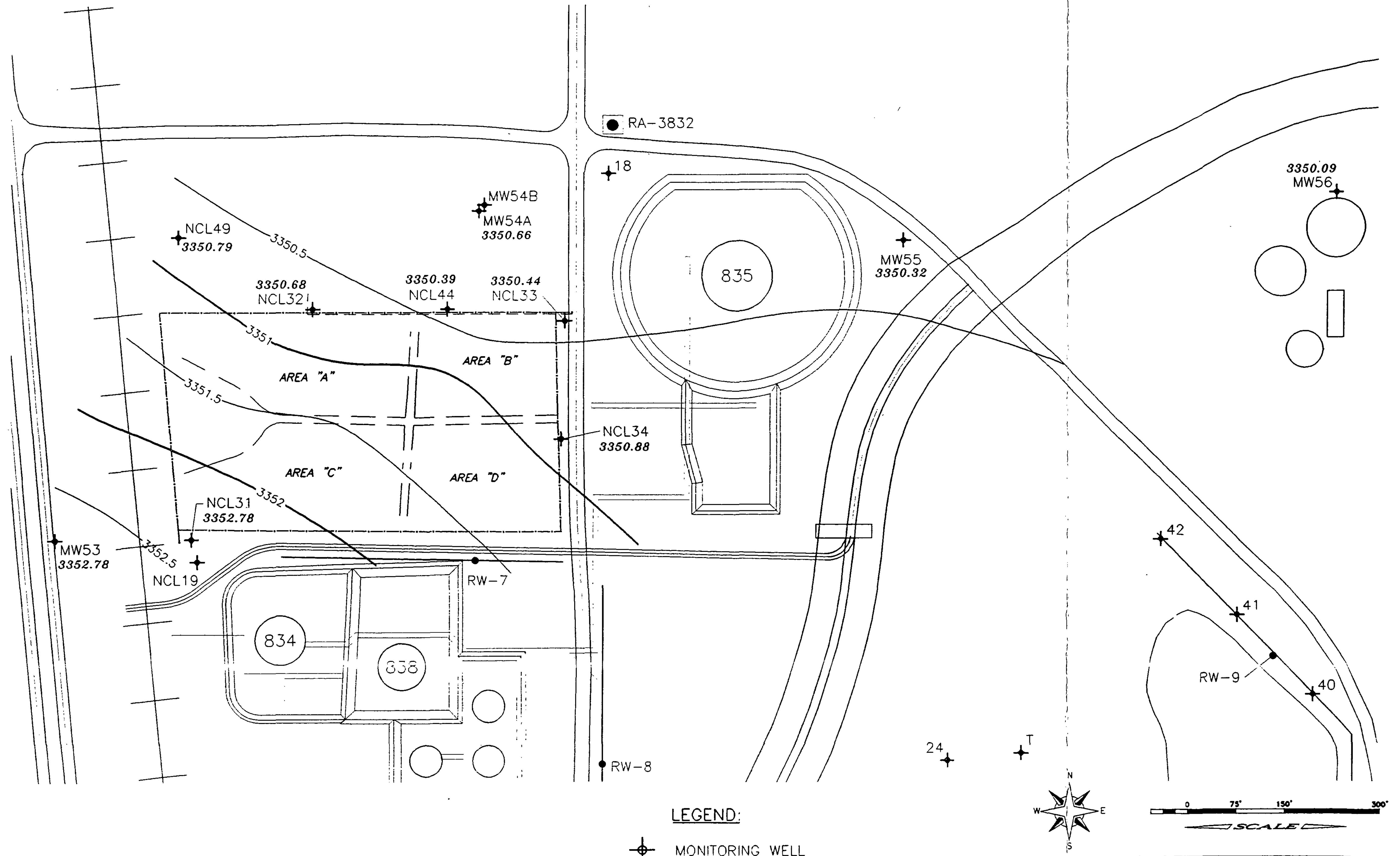
DRAWN BY	CHK'D BY	SCALE	
EJS	DB	1" = 150'-0"	
DATE	APPR BY	DRAWING NUMBER	REV.
11-5-97	-	FIG612.DWG	0



LEGEND:

- MONITORING WELL
- ● WATER WELL - DEEP, ARTESIAN AQUIFER
- RA-3832 STATE ENGINEER OFFICE WELL NUMBER, ROSWELL ARTESIAN BASIN
- —3348— WATER LEVEL CONTOUR INTERVAL 0.5'

DRAWING TITLE	NAVAJO REFINING CO. P.O. DRAWER 159 ARTESIA, NEW MEXICO		
FIGURE 6-13. GROUNDWATER ELEVATION CONTOUR MAP NORTH COLONY LANDFARM DECEMBER 23, 1995	DRAWN BY EJS	CHK'D BY DB	SCALE 1" = 150'-0"
	DATE 11-7-97	APPR BY -	DRAWING NUMBER FIG613.DWG — REV. 0



LEGEND:

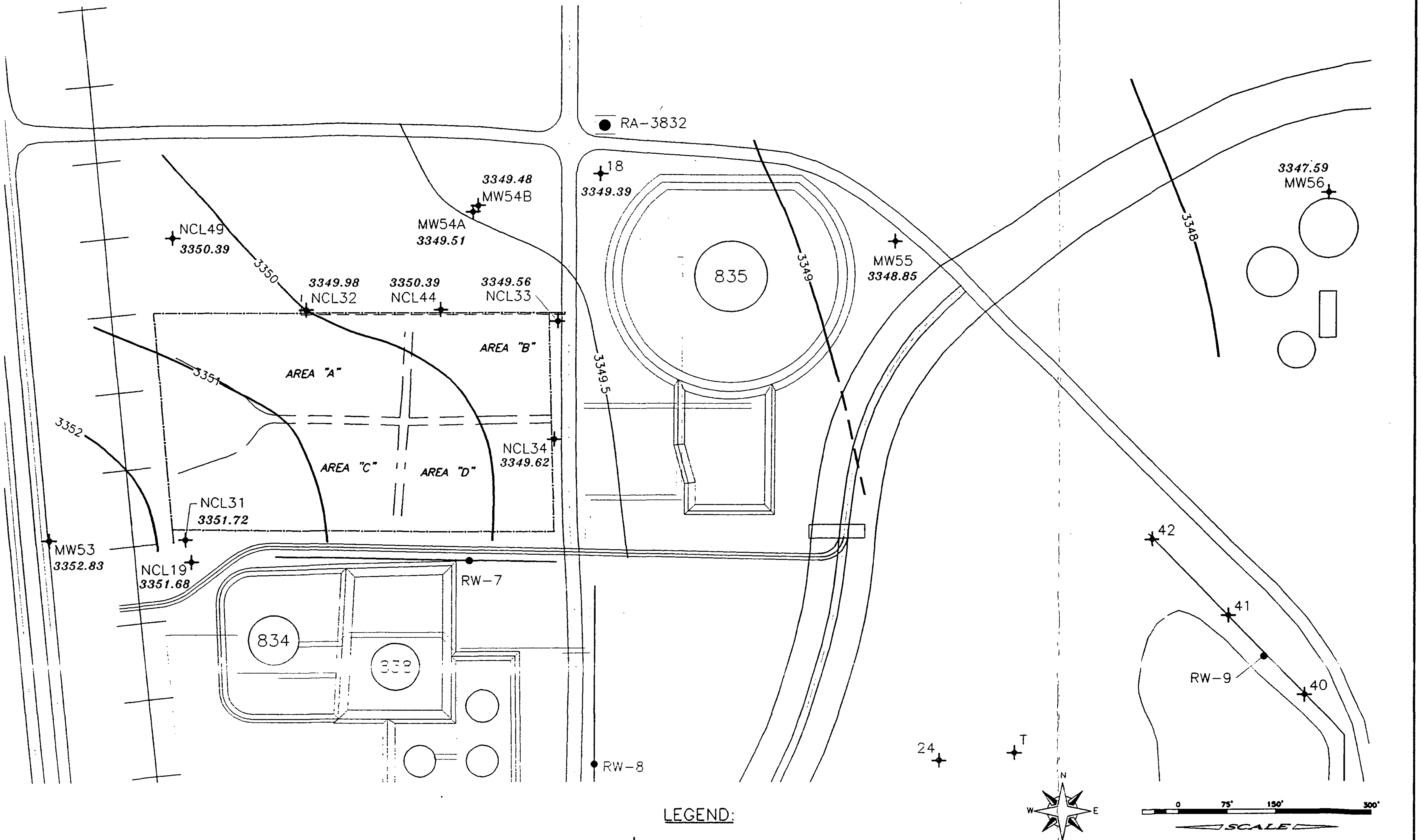
- MONITORING WELL
- WATER WELL – DEEP, ARTESIAN AQUIFER
- RA-3832 STATE ENGINEER OFFICE WELL NUMBER, ROSWELL ARTESIAN BASIN
- 3351 WATER LEVEL CONTOUR INTERVAL 0.5'

DRAWING TITLE

FIGURE 6-14.
GROUNDWATER ELEVATION
CONTOUR MAP
NORTH COLONY LANDFARM
MARCH 25-27, 1997

NAVAJO REFINING CO.
P.O. DRAWER 159
ARTESIA, NEW MEXICO

DRAWN BY	CHK'D BY	SCALE	
EJS	DB	1" = 150'-0"	
DATE	APPR BY	DRAWING NUMBER	REV.
11-5-97	-	FIG614.DWG	0



LEGEND:

⌖	MONITORING WELL
●	WATER WELL – DEEP, ARTESIAN AQUIFER
RA-3832	STATE ENGINEER OFFICE WELL NUMBER, ROSWELL ARTESIAN BASIN
—3354—	WATER LEVEL CONTOUR INTERVAL AS SHOWN

DRAWING TITLE

FIGURE 6-15.
GROUNDWATER ELEVATION
CONTOUR MAP
NORTH COLONY LANDFARM
AUGUST 2, 1997

NAVAJO REFINING CO.
P.O. DRAWER 159
ARTESIA, NEW MEXICO

DRAWN BY	CHK'D BY	SCALE
EJS	DB	1" = 150'-0"
DATE	APP'D BY	DRAWING NUMBER
11-5-97	–	FIG615.DWG

REV. 0

Table 6-19. Observed values of groundwater hydraulic gradient in the vicinity of the North Colony Landfarm, RFI Phase II.

Date	Gradient (ft/ft)	Descriptive location
9/13/95	0.0048	Average across area of landfarm
12/23/95	0.0025	Vicinity of NCL-31
12/23/95	0.0021	Average across area of landfarm
12/23/95	0.0014	Between NCL-33 and MW-55
12/23/95	0.0011	Between MW-55 and MW-56
8/02/97	0.0050	East of NCL-31
8/02/97	0.0017	Between MW-55 and MW-56

Several explanations are possible for the reduction in hydraulic gradient from southwest to northeast across the area. Steep gradients can occur near a source of recharge where a high hydraulic potential (either a pressure or elevation head) is quickly reduced due to friction losses as the water passes through the porous material. If the source of recharge to the NSSZ is near the NCL, the reduction in hydraulic head as the water moves into the NSSZ and downgradient can produce gradient changes of the type observed. Also, flat gradients can occur in areas where groundwater withdrawal has lowered groundwater elevations upgradient from the location where the flat gradient is observed. In the vicinity of the NCL several product and contaminated groundwater recovery efforts are being pursued (Figure 6-2) which likely have the effect of lowering nearby water levels.

Two other possible reasons for the changing hydraulic gradients are worth noting. An increase in formation hydraulic conductivity or an increase in the thickness of the transmissive zones allows an increased flow of water at the same gradient, or movement of the same mass of water with less hydraulic pressure required as a driving force. Based on review of the boring logs, it appears that material of greater permeability is present in the vicinity of MW-56 and that zones containing this material are thicker.

6.2.3 Vertical Flow Gradients

Groundwater elevations in the paired wells MW-54A and -54B were compared to determine whether a vertical gradient was present (Table 6-18). In 1995, the elevation of groundwater in MW-54B, the deeper well, was at a slightly higher elevation (3,347.78 feet) than groundwater in MW-54A (3,347.77 feet). This indicates a very slight upward vertical gradient. However, the values differ by such a small value (0.01 feet) that they could be affected by normal errors in surveying, measurement, or both. Measurements of both wells in August 1997 resulted in equal groundwater elevations. Therefore, it is concluded that occurrence of a positive or negative vertical gradient can not be definitely ascertained at this location using the current set of measurements.

6.2.4 Hydraulic Conductivity Tests

Tests were conducted on December 22, 1995, to determine the in situ hydraulic conductivity of the saturated zones opposite newly drilled monitor wells MW-54A and MW-54B. The wells were tested using the "slug test" procedure. The sealed length of pipe of known volume was quickly inserted in the well, and the subsequent displacement and time for recovery of water levels were registered on a data recorder. The equipment and methodology used in conducting the test was described in Section 5.2.2.3. This section describes the procedures used in analyzing the data and compares the results to earlier hydraulic conductivity testing performed in the vicinity of the NCL.

Depending on aquifer properties, slug test results are evaluated using one of two procedures. H. Bouwer and R.C. Rice (Bouwer and Rice, 1976) developed a procedure for analysis of slug test data from unconfined aquifers. Water in confined (artesian) aquifers is analyzed using a procedure developed by H. Cooper and others in 1967 (Cooper, et al., 1967). The Bouwer and Rice methodology was later judged applicable to confined and semi-confined aquifers (Bouwer, 1989). Because of its simplicity, the Bouwer and Rice slug test method is a frequently used evaluation tool in groundwater studies. At the paired MW-54 wells, the use of both the Bouwer and Rice and the Cooper methods were appropriate for evaluation of information collected during the current investigation.

The Bouwer and Rice equation and test parameters used in calculating the hydraulic conductivities are presented in Appendix F which also includes graphs of the slug test data. Data collected during the two tests conducted at each well are graphically displayed on a semi-logarithmic plot with displacement plotted on the vertical logarithmic axis and time plotted on the horizontal axis. For the straight line portion of each graph, two points are selected for inclusion in the equation and then hydraulic conductivity (K) was calculated. The resultant values are shown on each graphical plot (Appendix F) and summarized in Table 6-20.

The Cooper method for determining transmissivity is also graphical in nature. In this method, the vertical axis is linear and plots the ratio of displacement at time t to the maximum displacement at time $t = 0$. Time is plotted on the logarithmic horizontal axis. Curve fitting is performed using a specified set of type curves from which the aquifer parameters can be determined. The Cooper method produced good curve matches in the deeper well (MW-54B), but was unsuitable for analysis of transmissivity in the shallow well. Because water in MW-54B was confined entirely within the formation due to the method of well construction, it responded in true artesian fashion to hydraulic pressure changes during the test. These conditions enabled use of the Cooper curve matching technique with excellent results. The aquifer parameters derived from these tests also are included in Table 6-20.

Table 6-20. Results of slug-test evaluation, NCL monitor wells MW-54A and MW-54B, RFI Phase II.

Test ID	Well	Test Type	K (ft/min.)	K (cm/sec)	T (ft^2/min.)	b (calc) feet	Comment - Section of Data Plot Selected for Curve Matching
0	MW-54B	Slug-In	**0.008135**	**4.13E-03**	1.50E-01	18.4	Early time, steep
0	MW-54B	Slug-In	0.001267	6.44E-04	1.50E-01	118.0	
1	MW-54B	Slug-Out	**0.008136**	**4.13E-03**	1.32E-01	16.2	Early time, steep
1	MW-54B	Slug-Out	0.003118	1.58E-03	1.32E-01	42.2	
1	MW-54B	Slug-Out	0.001626	8.26E-04	1.32E-01	80.9	
2	MW-54A	Slug-In	**0.00078**	**3.96E-04**	N/A	N/A	Late time, flatter
3	MW-54A	Slug-Out	**0.001094**	**5.56E-04**	N/A	N/A	Late time, flatter
4	MW-54A	Slug-In	**0.000782**	**3.97E-04**	N/A	N/A	Late time, flatter
K (avg.), MW-54B = 0.00814 ft/minute, 4.15E-03 cm/second							
K (avg.), MW-54A = 0.000938 ft/minute, 4.78E-04 cm/second							

Notes:

Graphical data plots used to determine aquifer parameters are shown in Appendix C

Test date: December 22, 1995

K = Hydraulic Conductivity

T = Transmissivity

b = Aquifer thickness = T/K

Bold - indicates values used to calculate average K

A technique to compare the results of the two methods is to divide the transmissivity (units of feet squared per minute) by the hydraulic conductivity (units of feet per minute) to determine the theoretical saturated aquifer thickness. If the calculated thickness is close to the actual value (as determined by the lithologic log and screen placement), the hydraulic conductivity values may be accepted as a realistic estimate of conductivity in the formation zone opposite the screen. In this instance, the calculated thickness using early-time hydraulic conductivity data ranges between 16 and 18 feet, which is close to the actual thickness of the interval tested.

6.2.5 Groundwater Movement and Flow Rate

The seepage velocity of the groundwater system can be determined from the hydraulic conductivity, hydraulic gradient, and effective porosity of the aquifer. Hydraulic conductivity determinations were discussed above. The hydraulic gradient is typically measured from a groundwater contour map or a potentiometric surface map such as those presented in Figures 6-11 through 6-15. The September and December 1995 groundwater-flow gradients (Table 6-19) were used in the calculation of a range of seepage velocities for comparison and evaluation.

The effective porosity can be estimated from the intrinsic porosity of the aquifer. Although the intrinsic porosity is the actual pore volume of the aquifer matrix, it is usually not representative of the actual porosity that governs the flow of water through the matrix because of the influence of isolated pore spaces, grain angularity, and other factors. The effective porosity of the aquifer is a corrected porosity that more closely represents true flow conditions. Effective porosity can be several orders of magnitude lower than the intrinsic porosity in consolidated aquifers, but the effective porosity of an unconfined alluvial aquifer is typically 10 to 100 percent of the intrinsic porosity (Fetter, 1988). In alluvial sediments, this usually results in an effective porosity of 0.25 to 0.30. The 1982 Geraghty & Miller study determined intrinsic porosity in the very low permeability clay core samples taken during monitor well installation. The values for four samples range from 0.33 to 0.49, with an average of 0.44. In the absence of site-specific porosity data for the permeable zones, the effective porosity was assumed to be 0.25, which is representative of porosities found in this lithologic environment.

The seepage velocity of the groundwater system in the vicinity of the NCL was calculated using an effective porosity of 25 percent according to the following equation:

$$\mathbf{v = Ki/n_e}$$

where:

$\mathbf{v}$ = seepage velocity (ft/min),
$\mathbf{K}$ = hydraulic conductivity (ft/min),
$\mathbf{i}$ = hydraulic gradient (ft/ft), and
$\mathbf{n_e}$ = effective porosity (unitless)

The hydraulic conductivities (K) determined from slug tests conducted for the current investigation were compared with hydraulic conductivities determined during the 1982 Geraghty & Miller study. That study concentrated on evaluating laboratory permeability of the clay cores; field tests to determine in situ hydraulic conductivity were not conducted. K values for the clay cores were on the order of 10^{-6} cm/sec. However, a sample from MW-38, a well located east of the NCL near NRC's TEL Weathering Area, resulted in a calculated K of 10^{-3} cm/sec based on a grain size analysis of the sample. This value is intermediate between the two values determined for the MW-54 wells.

The range of seepage velocities for the permeable zones in the vicinity of the NCL is shown in Table 6-21. Included in the table are hydraulic conductivity data for the two MW-54 wells and the MW-38 well. Seepage velocities in fine-grained material similar to that observed in MW-54A are on the order of 2 to 10 feet per year. By way of contrast, seepage velocities in the zone intercepted by deeper well MW-54B are about 10 times those calculated for MW-54A. Estimated seepage velocities for MW-38 are intermediate to those determined in the MW-54 well pair.

The wide range in seepage velocities reflects the complexity of the hydrologic system in the vicinity of the NCL. Significant flow occurs only in the coarser grained water-bearing seams that are typically limited in vertical and horizontal extent, and are interbedded with extensive zones of low permeability silts and clays. High permeability zones do not predominate in the vicinity of the hydrocarbon-impacted soils. The lower permeability materials, together with the presence of thick clay zones which greatly restrict vertical downward movement of contaminants, act to contain much of the released product. However, where hydrocarbon fluids have reached a higher permeability zone, movement is expedited. For example, the location of the maximum extent of hydrocarbon material northeast of the tank farm (probable source of the release) is about 1600 feet downgradient. If the release occurred up to 20 years ago, the seepage velocity needed to move the product (assuming product moves at the same rate as the groundwater) is 80 feet per year, which is met only in zones of coarse grained materials. The occasional and sporadic occurrence of coarser permeable materials in the area of the release limits the types of hydrocarbon recovery operations that can be successfully used in the area to recovery trenches which bisect the infrequently distributed permeable zones.

Table 6-21. Estimated range of seepage velocities for permeable lithologic zones in the vicinity of the North Colony Landfarm, RFI Phase II.

Date	Gradient	Location	Seepage Velocity (ft/min)	Seepage Velocity (ft/year)
Seepage Velocities using K = 9.38E-4 ft/min (K at MW-54A, 12/95)				
9/13/95	0.0048	Average gradient across Landfarm	1.8E-5	9.5
12/23/95	0.0025	Vicinity of NCL-31	9.4E-6	4.9
12/23/95	0.0021	Average gradient across Landfarm	7.9E-6	4.1
12/23/95	0.0014	Between NCL-33 and MW-55	5.3E-6	2.8
12/23/95	0.0011	Between MW-55 and MW-56	4.1E-6	2.2
Seepage Velocities using K = 1.96E-3 ft/min (K at MW-38, 12/82 NCL report, Geraghty & Miller)				
9/13/95	0.0048	Average gradient across Landfarm	3.8E-5	20
12/23/95	0.0025	Vicinity of NCL-31	2.0E-5	10
12/23/95	0.0021	Average gradient across Landfarm	1.6E-5	8.7
12/23/95	0.0014	Between NCL-33 and MW-55	1.1E-5	5.8
12/23/95	0.0011	Between MW-55 and MW-56	8.6E-6	4.5
Seepage Velocities using K = 8.14E-3 ft/min (K at MW-54B, 12/95)				
9/13/95	0.0048	Average gradient across Landfarm	1.6E-5	82
12/23/95	0.0025	Vicinity of NCL-31	8.1E-5	43
12/23/95	0.0021	Average gradient across Landfarm	6.8E-5	36
12/23/95	0.0014	Between NCL-33 and MW-55	4.6E-5	24
12/23/95	0.0011	Between MW-55 and MW-56	3.6E-5	19

Seepage velocities calculated using:
$v = Ki/n_e$
where:
v = seepage velocity (ft/min),
K = hydraulic conductivity (ft/min),
i = hydraulic gradient (ft/ft), and
n_e = effective porosity (unitless) = 0.025 (assumed)

6.2.6 Results of Groundwater Flow and Contaminant Transport Modeling

6.2.6.1 Groundwater Flow Modeling

The groundwater flow model, MODFLOW was selected to simulate the local flow regime for the North Colony Landfarm Site and vicinity. The site conceptual model was simplified so that the grid was limited to one layer. The modeled area was 2,800 feet by 1,400 feet. The individual cells were 50 feet long in the X (east-west) direction and 50 feet wide in the Y (north-south) direction. Therefore the dimensions of the grid are 56 cells in the X direction and 28 cells in the Y direction. Thickness of the layer was assumed to be approximately 5 feet. Selected groundwater flow and contaminant transport model input is included in Table 6-22.

It was conservatively assumed that the one layer model was homogenous and isotropic. Also, the layer is conservatively assumed to be unconfined and without an upward hydraulic gradient. A hydraulic conductivity of approximately 1 x 10^{-3} centimeters per second or 2.8 feet/day was used. The coefficient of storage was estimated at approximately 0.01.

The groundwater flow model was calibrated using March, 1997 ground water elevation data. The average gradient across the entire modeled area is approximately 0.001 while the modeled gradient in the vicinity of the site was approximately 0.002. To simulate recharge, a series of injection wells were added across the entire landfarm area to represent seepage into the thin zone of saturation at a constant rate. Groundwater flow and injection (seepage) was simulated under transient conditions for 30 years. The graphical result of the steady state groundwater flow simulation is shown in Figure 6-16. Examples of model output are included in Appendix F.

Table 6-22. Groundwater and Contaminant Transport Model Inputs, North Colony Landfarm

Parameter	Modeled Value or Range
Hydraulic Conductivity (K, 10^{-3} cm/s):	2.8 feet/day
Coefficient of Storage (dimensionless):	0.01
Porosity (dimensionless):	0.35
Dispersion (feet):	
Longitudinal	10 feet
Horizontal	0.2 feet
Vertical	0.02 feet
Source and Concentration (ug/L):	Benzene, 2.6 ug/L
Layer Thickness (feet):	5 feet

Figure 6-16. Steady State Groundwater Flow Model Simulation, North Colony Landfarm

6.2.6.2 Contaminant transport modeling

Contaminant transport analysis was accomplished using the MT3D modular three-dimensional transport model (Zheng, 1990). MT3D simulates advection, dispersion, mixing, and chemical reactions. The chemical reaction package which handles biodegradation and sorption was not used in the MT3D simulations. Molecular diffusion was also assumed not to occur. This is conservative in that the only processes acting to transport the contaminants are the predominantly physical processes of advection and dispersion.

Inputs to the contaminant transport model, which also simulated 30-years of movement, are shown in Table 6-22. The porosity for the silty clay was set to 0.35 based on field and laboratory observations. The longitudinal dispersion coefficient used was 10 for a uniform silty sand with a horizontal to longitudinal ratio of 0.2, and a vertical to longitudinal ratio of 0.02 (Zheng, 1990).

To evaluate groundwater impacts, a benzene concentration of 2.6 ug/L in soil water determined from vadose zone modeling results (Section 6.1.6) was used as a constant source concentration injected across the entire site for 30 years. Benzene and xylene were the two constituents that had the highest vadose zone concentrations as predicted by the vadose zone model. However, Benzene was selected for groundwater modeling because it is much more of a concern in drinking water and the predicted vadose zone concentration, though less than the drinking water standard of 5 ug/L, is of the same order of magnitude.

Graphical results of the modeling simulation are shown in Figure 6-17 and sample calculations are shown in Appendix F. The modeling results show that if the benzene seeped into the groundwater from the base of the landfarm treatment zone such that benzene was present in the groundwater at a concentration of 2.6-ug/L everywhere beneath the landfarm and the concentration was maintained (e.g. through constant seepage) for 30-years, then benzene concentrations would be less than 0.05 ug/L (i.e. less than 50 parts per trillion) at a maximum distance of approximately 180 feet from the landfarm in the easterly and northerly directions (Figure 6-17). Again, the chemical reaction portion of the modeling package (which handles biodegradation and sorption) was not utilized in the simulations; the only processes acting to transport and lessen contaminant concentrations are the predominantly physical processes of advection and dispersion which makes the results extremely conservative.

6.2.7 Groundwater Quality

This section provides a discussion of water quality results from the wells drilled and installed during the RFI Phase II study and the temporary monitor wells installed for the RFI supplemental investigation. Statistical analyses were performed on chromium and lead metal to determine the likelihood that downgradient wells have been impacted by any possible releases from the landfarm unit. NCL water quality sampling results beginning in 1990 were collected, reviewed, and are tabulated for this report. The resultant data sheets are presented in Appendix D.

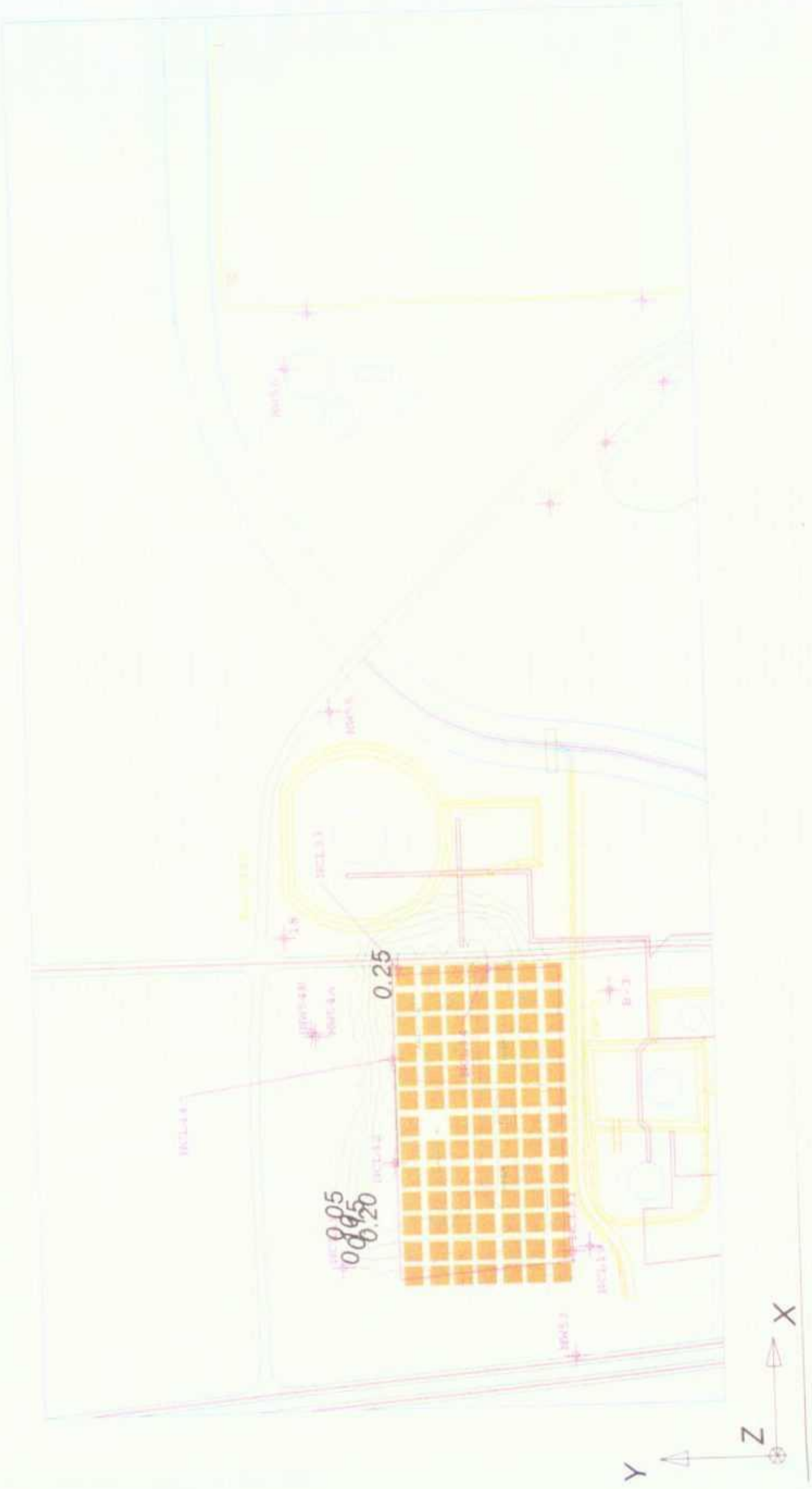


Figure 6-17. Thirty-Year Benzene Contaminant Transport Simulation, North Colony Landfarm

6.2.7.1 Groundwater Analytical Results

The laboratory analytical results of the groundwater sampling analyses performed on the new monitor wells installed during the RFI Phase II study are presented in Appendix G and summarized in Table 6-23. Groundwater samples were analyzed for volatile and semivolatile organic constituents, metals, and general water chemistry parameters.

Table 6-23. Laboratory Analytical Data Summary, Groundwater Monitoring Wells Sampled During the NCL RFI Phase II, 1996.

	Monitoring Well					
	MW-18 (6/29/95)	**MW-53** (6/29/95)	**MW-54A** (12/22/95)	**MW-54B** (12/22/95)	**MW-55** (8/9/95	**MW-56** (8/9/95)
Volatiles [a,b]						
benzene (5 ug/L)	<5	<5	<5	<5	<5	<5
toluene (1,000 ug/L)	<5	<5	<5	<5	<5	<5
ethylbenzene (700 ug/L)	<5	<5	6	<5	<5	<5
xylenes (10,000 ug/L)	<5	<5	<5	<5	<5	<5
other	NA	<5 to <200	<5 to <200	<5 to <200	<5 to <100	<5 to <100
Semivolatiles [c]	NA	<10 to <25	<50 to <630	<10 to <30	<10 to <25	<10 to <25
Metals [a,d]						
chromium (100 ug/L)	NA	7	<5	<5	14	13
lead (15 ug/L)	NA	<10	<10	<10	<10	<10
General Chemistry [a]						
pH	NA	7.4	7.7	8.1	7.1	6.9
total dissolved solids[e] (mg/L)	NA	2,500	1,970	2,100	2,160	4,900
sulfates (400 mg/L)	NA	1,130	745	1,000	901	2,170

Notes:

All concentrations are reported in ug/L except General Chemistry mg/L..

a) Constituent values, where shown, are Safe Drinking Water Act final or proposed health-based concentration limits.

b) Volatile constituent analyses included 30 additional Method 8240 constituents; data sheets are reproduced in appendices.

c) Semivolatile constituent analyses included 65 Method 8270 constituents; data sheets are reproduced in appendices.

d) Analyses included 19 metals, evaluated as total metal concentrations; data sheets are reproduced in appendices.

e) EPA recommended non-health-based standard for TDS is 500 mg/L.

For all groundwater samples from the new wells, concentrations for target organic and inorganic constituents were below Safe Drinking Water Act final or proposed health-based concentration limits (Table 6-23). All target organic volatiles and semi-volatiles were below reported detection limits, except for a detection of ethylbenzene in MW-54A at a concentration of 6 ug/L, which, essentially, is at the detection limit. General chemistry parameters for the well network indicate poor water quality characteristics, with total dissolved solids ranging from 1,970 to 4,900 mg/l, and total sulfates ranging from 745 to 2,170 mg/l. The analytical results indicate that the downgradient well network is appropriately situated outside the boundary of the hydrocarbon product plume, and can provide early detection of any dissolved-phase hydrocarbon constituents.

6.2.7.2 Water Quality Results at the Temporary Monitor Wells

This section describes sampling results from the temporary monitoring wells installed at the NCL location. The wells were installed as described in Section 5.2.3.1. The wells were allowed to equilibrate for approximately 24 hours prior to sampling. Two wells, 97-B1 and 97-C3 were dry 24 hours following installation. Most others required time to recover after purging 3-well volumes from the ¾-inch casing. Sampling was performed using a peristaltic pump with clean tubing. Even though the wells were purged slowly prior to sampling, the water samples generally were turbid and exhibited a white chalky color. Sample collection, preservation, and chain-of custody protocols were followed. At the laboratory, samples were analyzed for the same chemical constituents as those performed on quarterly samples from the NCL. Analysis results for volatile and semi-volatile hydrocarbons are shown in Tables 6-24 and 6-25, respectively. Data sheets for these and other sampled constituents are included in Appendix G.

Concentration results for the volatile constituents were plotted on a NCL drawing and concentration contour maps for total BTEX and benzene prepared (Figure 6-18 and 6-19). The maps show a dissolved hydrocarbon plume trending north-northeasterly with the highest concentrations of contaminants occurring along the south boundary of the landfarm. For comparison, dissolved hydrocarbon concentrations in water from Recovery Well 7 (and associated trench) are shown. Given that the predominant direction of flow is northeasterly in the vicinity of the landfarm, the two drawings clearly show that contaminants have migrated to beneath the landfarm from the south, and that the origin of the dissolved hydrocarbons is a source or sources located to the south of the NCL. This is an area which has served as a location for refined hydrocarbon product storage since the earliest days of the refinery, and from which known product releases have occurred. Further discussion of this subject is provided in Section 7.

6.2.7.3 Results of Statistical Testing of Groundwater Sample Analyses

Statistical testing was performed on chromium and lead groundwater sample data collected from the NCL monitoring well network. For this exercise water quality data beginning the 4th quarter of 1995 were selected as the starting point for comparison of background and downgradient wells. This was because a new background well (MW-53) installed during the summer of 1995 was used in the analysis and only data collected at the same time as data from MW-53 was compared.

Outliers were identified in samples collected from downgradient NCL-34 for both lead and chromium data. These outliers were removed as these detection's are related to a source other than the landfarm. Omitting data from well 34 from the analysis, the data sets were all found to be parameteric (i.e. exhibit a normal distribution) using the test in EPA 1989, *Statistical Analysis of Ground-Water Monitoring Data at RCRA Facilities.* The two sample *t*-test assuming unequal variances was performed for the chromium and lead data sets consisting of subsets of background and downgradient data. Results of t-tests for chromium and lead are shown in Tables 6-26 to 6-28.

For both chromium and lead, results of the *t*-tests indicated that the absolute value of the *t*-statistics are consistently less than the critical values. Therefore, the null hypothesis (Ho: $u_1 = u_2$) was accepted indicating that background data and sample data are from the same population set. Regardless of the assumptions of equal or unequal variance, the analyses show that chromium and lead are not present at site locations at statistically significant elevated levels with respect to ambient or background conditions.

Table 6-24. Volatile Hydrocarbon Concentrations in Groundwater, NCL Landfarm, July 1997

Location	Depth collected (feet)	Benzene (ug/L)	Ethyl-benzene (ug/L)	Toluene (ug/L)	Total xylenes (ug/L)	Total BTEX (ug/L)	Acetone[a] (ug/L)	2-Butanone (MEK) (ug/L)	Methylene chloride[a] (ug/L)
NCL-97-A1	18-23	<5.0	<5.0	<5.0	<5.0	<5.0	12.8	ND	ND
NCL-97-A2	15.5-20.5	ND	ND	ND	ND	ND	132	29.3	ND
NCL-97-A3	17.5-22.5	ND	ND	ND	5.00	5.00	31.2	ND	ND
NCL-97-A4	17-22	ND	31.1	ND	9.81	40.9	ND	ND	ND
NCL-97-B1	17-22	- -	- -	- -	- -	- -	- -	- -	- -
NCL-97-B2	17-22	ND	53.8	ND	ND	53.8	111	18.2	ND
NCL-97-B3	17-22	37.6	73.7	ND	44.9	156	78.1	29.1	ND
NCL-97-C1	17-22	19	388	ND	66.1	473	198	69.9	14
NCL-97-C2	17-22	564	383	ND	181	1,128	54.3	ND	ND
NCL-97-C2 (dup)	17-22	509	361	ND	152	1,022	ND	ND	ND
NCL-97-C3	- -	- -	- -	- -	- -	- -	- -	- -	- -
NCL-97-D1	17-22	13.1	124	ND	ND	137	168	59	ND
NCL-97-D2	17-22	34.9	50	5.69	20.5	111	109	24.7	ND
Trip Blank (IMI-006)		ND	ND	ND	ND	ND	ND	ND	14.2
Trip Blank (ILY-012)		ND	ND	ND	ND	ND	ND	ND	17.7

Notes:

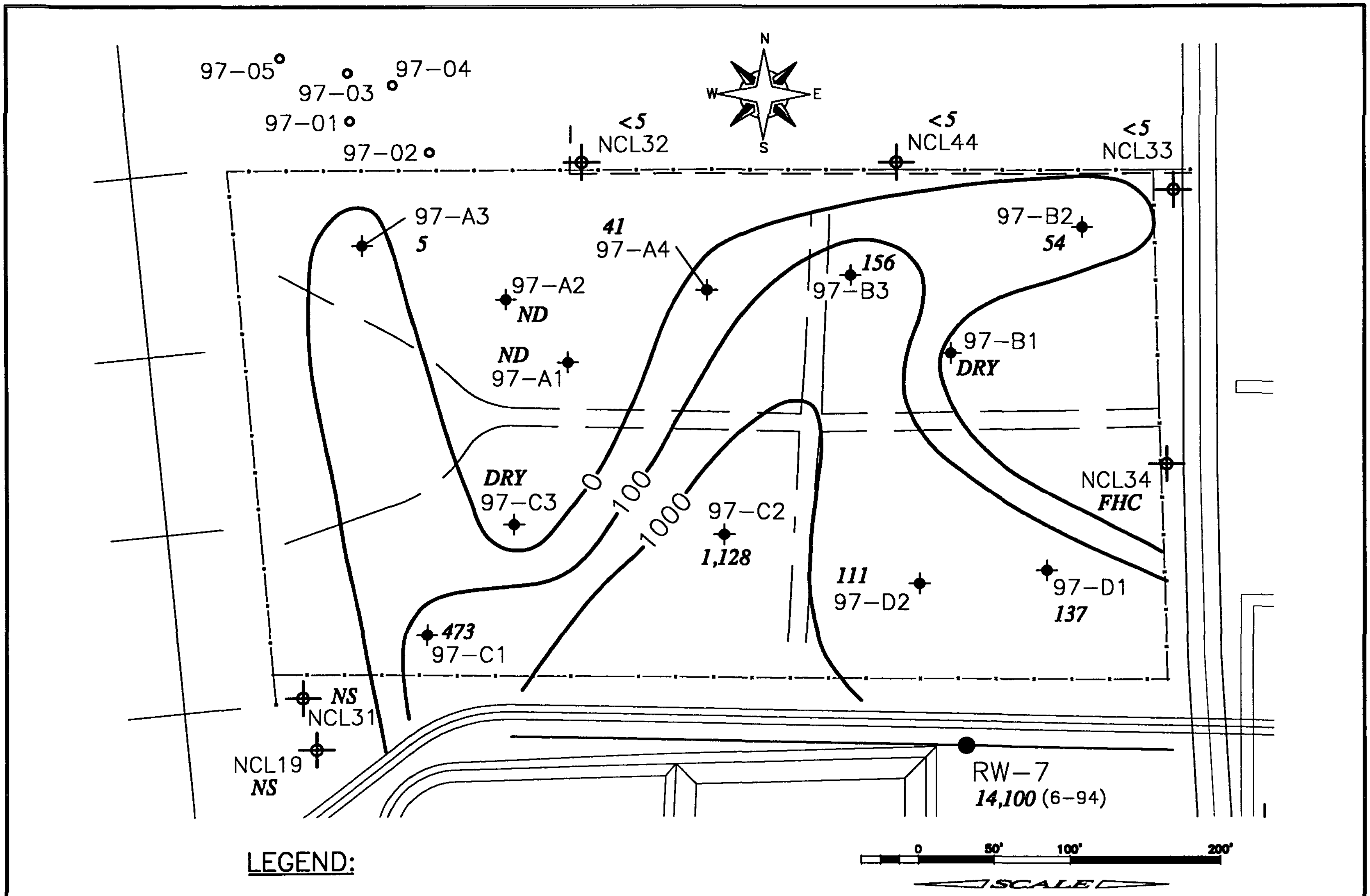
a) Analyte is a common solvent; its presence may be an artifact of sample collection, transport or analysis.
b) Sample dates July 29-31, 1997. Abbreviations: ND - Not detected.
c) Borings B1 and C3 were dry when measured 24 hours after drilling.
d) Volatiles by EPA SW-846 method 8240. Reporting limits: BTEX, 5-25 ug/L; 28 other volatiles 5–50 ug/L; data sheets reproduced in appendices.

Table 6-25. Semi-Volatile Hydrocarbon Detections in Groundwater, NCL Landfarm, July 1997

Location	Depth Collected (feet)	Dibenzo-furan (ug/L)	Fluorene (ug/L)	2-Methyl-naphthalene[a] (ug/L)	4-Methyl-phenol (p-Cresol) (ug/L)	Naphthalene[a] (ug/L)
NCL-97-A1	18-23	ND	ND	ND	ND	ND
NCL-97-A2	15.5-20.5	ND	ND	ND	19.8	ND
NCL-97-A3	17.5-22.5	ND	ND	ND	ND	ND
NCL-97-A4	17-22	ND	ND	13.3	ND	ND
NCL-97-B2	17-22	ND	ND	50.6	ND	ND
NCL-97-B3	17-22	ND	ND	ND	ND	ND
NCL-97-C1	17-22	ND	ND	ND	ND	ND
NCL-97-C2	17-22	19.4	13.0	218	ND	113
NCL-97-C2(dup 1)	17-22	20.0	13.3	229	ND	115
NCL-97-D1	17-22	ND	ND	124	ND	ND
NCL-97-D2	17-22	ND	ND	ND	ND	ND

Notes:

a) The analysis was performed at a dilution due to a high analyte concentration.
b) Sample dates July 29-31, 1997. Abbreviations: ND - Not detected.
c) Borings B1 and C3 were dry when measured 24 hours after drilling.
d) Semi-volatiles by EPA SW-846 method 8270. Reporting limits: Detected constituents, 10.6-109 ug/L; 62 other semi-volatiles 10.6-327 ug/L; data sheets reproduced in appendices.



LEGEND:

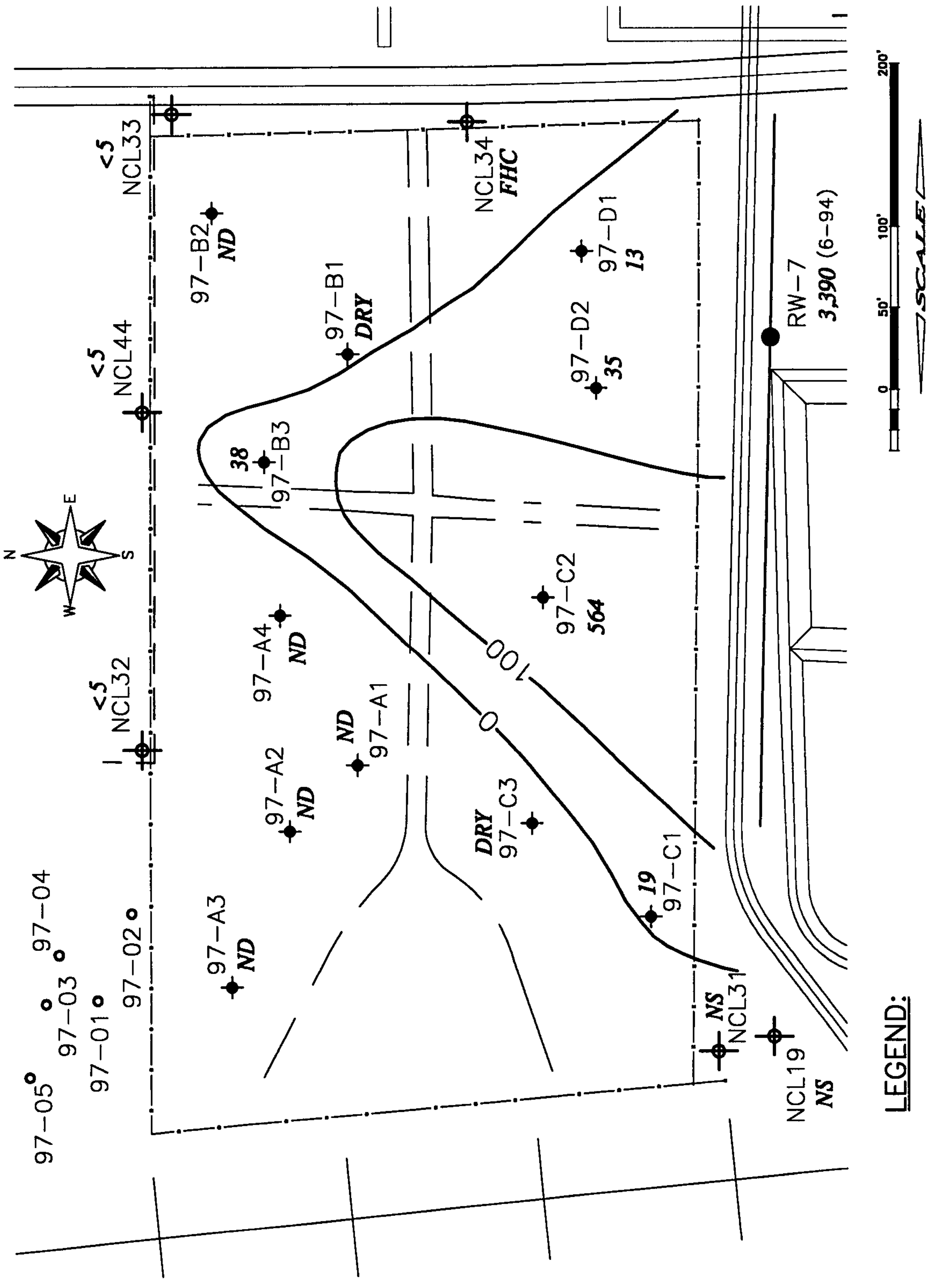
⌖	MONITORING WELL	ND	NOT DETECTED
		NS	NOT SAMPLED
●	RECOVERY WELL	FHC	FREE-PHASE HYDROCARBON
○	BACKGROUND BORING LOCATION	✦	SOIL BORING
		1,128	TOTAL BTEX (ug/L)

DRAWING TITLE

FIGURE 6-18.
TOTAL BTEX MAP
NORTH COLONY LANDFARM
JULY - AUGUST, 1997

NAVAJO REFINING CO.
P.O. DRAWER 159
ARTESIA, NEW MEXICO

DRAWN BY	CHK'D BY	SCALE	
EJS	DB	1" = 100'-0"	
DATE	APPR BY	DRAWING NUMBER	REV.
11-5-97	-	FIG618.DWG	0



NAVAJO REFINING CO.
P.O. DRAWER 159
ARTESIA, NEW MEXICO

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EJS	DB	1" = 100'-0"
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DRAWING TITLE

FIGURE 6-19.
BENZENE MAP
NORTH COLONY LANDFARM
JULY - AUGUST, 1997

LEGEND:

ND	NOT DETECTED
NS	NOT SAMPLED
FHC	FREE-PHASE HYDROCARBON
✦	SOIL BORING
3,390	TOTAL BENZENE (ug/L)
⌖	MONITORING WELL
●	RECOVERY WELL
○	BACKGROUND BORING LOCATION

Table 6-26. Summary of *t-test* Results Comparing Chromium and Lead Concentrations from All Wells with Concentrations from Background Well 53, North Colony Landfarm

Groundwater Chromium Statistical Analyses			**Groundwater Lead Statistical Analyses**		
t-Test: Two-Sample Assuming Unequal Variances:			**t-Test: Two-Sample Assuming Unequal Variances:**		
	Chromium non-BG wells (ug/L)	***Chromium Background wells (ug/L)***		***Lead non-BG wells (ug/L)***	***Lead Background wells (ug/L)***
Mean	12.70	9.31	Mean	7.21	5.79
Variance	70.82	14.21	Variance	95.6	9.83
Observations	56	8	Observations	51	8
Hypothesized Mean Difference	0		Hypothesized Mean Difference	0	
df	19		df	34	
t Stat	**1.94**		**t Stat**	**0.81**	
P(T<=t) two-tail	0.066775		P(T<=t) two-tail	0.425426	
t Critical two-tail	**2.09**		**t Critical two-tail**	**2.02243**	

Table 6-27. Summary of *t-test* Results Comparing Chromium Concentrations from Individual Wells with Concentrations from Background Well 53 (Assuming Unequal Variances), North Colony Landfarm

Well	Location	Mean	Variance	Observations	t-Statistic	t-Critical Two-Tail
32	Background	9.31	14.21	8	0.5880	2.1603
	Downgradient	8.28	18.90	7		
33	Background	9.31	14.21	8	-1.7704	2.3646
	Downgradient	16.49	102.49	7		
34	Background	9.31	14.21	8	2.0150	2.5706
	Downgradient	37.77	1587	6		
44	Background	9.31	14.21	8	-1.0203	2.1604
	Downgradient	11.3	14.13	7		
49	Background	9.31	14.21	8	-0.5131	2.3060
	Downgradient	11.33	95.66	7		
54-A	Background	9.31	14.21	8	-0.9082	2.1604
	Downgradient	10.83	7.07	7		
55	Background	9.31	14.21	8	-0.3553	2.1788
	Downgradient	9.88	5.84	8		
56	Background	9.31	14.21	8	-1.4324	2.2281
	Downgradient	13.9	67.85	8		

Table 6-28. Summary of *t-test* Results Comparing Lead Concentrations from Individual Wells with Concentrations from Background Well 53 (Assuming Unequal Variances), North Colony Landfarm

Well	Location	Mean	Variance	Observations	t-Statistic	t-Critical Two-Tail
32	Background	5.79	9.83	8	1.4861	2.2281
	Downgradient	3.99	1.63	7		
33	Background	5.79	9.83	8	-1.2653	2.3060
	Downgradient	9.91	65.77	7		
34	Background	5.79	9.83	8	-2.3644	2.5706
	Downgradient	53.95	2481	6		
44	Background	5.79	9.83	8	-0.5798	2.3646
	Downgradient	7.73	69.64	7		
49	Background	5.79	9.83	8	1.7702	2.3060
	Downgradient	3.74	0.811	7		
54-A	Background	5.79	9.83	8	0.6963	2.1604
	Downgradient	4.82	4.90	7		
55	Background	5.79	9.83	8	1.0064	2.1604
	Downgradient	4.38	5.98	8		
56	Background	5.79	9.83	8	-1.2556	2.3646
	Downgradient	15.18	437.09	8		

7.0 DISCUSSION

The combined results of the RFI Phase I, Phase II and the Supplemental Investigation provide a coherent framework from which to view the subsurface environmental setting in the vicinity of the NCL. The findings of the Phase I study determined that soils within 10 to 15 feet of the surface consisted of fine-grained silts and clay which provide resistance to fluid migration. These sediments form the upper boundary of the near-surface saturated zone (NSSZ) materials which the Phase I findings suggested was variable in lithology and distribution, and likely existed under semi-confined hydraulic conditions. The results of the Phase II and Supplemental Investigation efforts have subsequently provided strong confirmation of the initial suppositions regarding the nature of the subsurface soils and the NSSZ.

7.1 Soils Investigation

During the RFI Phase I investigation in 1994, 4 observation trenches and 23 soil borings, including 15 shallow borings (to 6.5 feet) and eight deeper (to 15 feet) borings were completed at the NCL. An additional shallow background boring was completed. During the 1997 supplemental investigation, the 1994 chromium and lead sample results were statistically compared with previous analyses of NCL soils and background samples from the NCL (Core Laboratories, 1990). Maximum chromium and lead soil concentrations detected from these studies were 24 and 16 mg/Kg, respectively.

The results of the statistical comparison indicate that there have not been statistically significant releases of either chromium or lead from the base of the unit, and that unit soils pose no risk to underlying groundwater due to the release of either chromium or lead constituents. Even if the statistics had indicated that some small release had occurred, the low maximum values detected indicate that a problem would not exist. For example, the maximum value for lead detected at the base of the NCL treatment zone is 25 times less than the value that EPA has selected as the residential screening level. 1n 1994, the EPA Office of Solid Waste released a detailed directive on risk assessment and cleanup of lead-containing soils at residential sites. The directive recommends that soil lead levels less than 400 mg/Kg be considered safe for residential use (EPA, 1994).

The evaluation of organic constituent data for subsurface soils of the unit is complicated by the fact that the near-surface saturated zone underlying the unit has been impacted by one or more hydrocarbon plumes originating from upgradient source(s) that are not associated with unit operations (Section 6.1.1.2). It is highly probable that many, if not all, of the organic constituents contained in refinery wastes applied to the NCL are also common to the petroleum product(s) contained in the near-surface hydrocarbon plume.

Apparent hydrocarbon contamination was visually observed at observation Trench C extending to the base of the excavation, at a depth of approximately 12 feet Starting in the immediate vicinity of the 7-foot sample interval and extending downward to the base of the excavation, a mottled black staining pattern was observed in association with a strong hydrocarbon odor. The uppermost several feet of the stained interval revealed numerous old plant roots, and it was observed that a majority of the local zones of hydrocarbon mottling were centered around these residual root passageways. Staining and hydrocarbon odors were not observed in the vertical extent of clay soils extending between the 7-foot depth upwards to the surface zone of waste incorporation. The visual evidence of hydrocarbon contamination was further confirmed by the results of the PID analyses (Table 6-2). These observations appear to be indicative of a contaminant source located in the vicinity of the deeper near-surface saturated zone, as opposed to a downward-migrating release from the base of the NCL unit.

Visual and/or olfactory evidence of apparent hydrocarbon contamination to depths as great as 18 feet below surface grade was also reported for 13 of the 23 soil borings (Table 7-1, Figures 7-1 to Figure 7-4). However, for eight of the 13 soil borings in which hydrocarbon contamination was indicated at depth, significant discontinuities were observed in the vertical contamination profile, again suggesting the presence of an off-site near-surface plume may be contributing significantly to hydrocarbon contamination in subsurface soils at the unit. At the eight borings in which contaminant profile discontinuities were observed, hydrocarbon-impacted soils within the treatment zone were subtended by an interval of uncontaminated soils. These apparently clean soils were in turn underlain by a second, deeper zone of hydrocarbon-contaminated soils. Soil borings fitting this profile included A-13, A-16, C-12, C-14, C-17. C-18, D-11, and D-12. In these borings, the linear extent of apparently uncontaminated soils intervening between the disjunct hydrocarbon-contaminated zones ranged from 1.5 to 12 feet, with an overall average of 6.3 feet.

Of the remaining five soil borings in which evidence of apparent hydrocarbon contamination was found to extend to significant depth below the base of the unit, the hydrocarbon-impacted soils were visually observed to extend continuously to the maximum boring depth. Soil borings in this category included C-11, C-13, C-15, D-14, and D-15. Boring C-11 was a shallow boring (10 feet maximum depth) from which obtained samples were evaluated only for chromium and lead. As a result, definitive conclusions can not be reached concerning the presence of hydrocarbon constituents at this boring location. Borings D-14 and D-15 were deeper borings from which samples obtained from the base of the unit to a final depth of 15 feet were subsequently analyzed for BTEX and SVOA constituents. At these boring locations, the presence of hazardous organic constituents was confirmed only at the lowest sample interval (13 to 15 feet). The detection of hazardous organic constituents reported at depth in borings D-14 and D-15, in the absence of similar detections in overlying sample intervals, is most plausibly accounted for by the proximity of the near-surface petroleum product plume to the lowest sample interval depth. At deeper boring location C-15, BTEX and SVOA contaminants were found at sample intervals between 7 and 15 feet. Finally, at deeper boring location C-13, observed evidence of hydrocarbon contamination throughout the profile was confirmed by laboratory analytical testing. BTEX and/or SVOA contaminants were reported in all sample intervals.

Table 7-1. Criteria Used in Vadose Zone Diagrams

Area A Boring ID, TD, Sample Depth		VOA Samples: H/C Contamination?, benzene, total BTEX	SVOA Samples: H/C Contamination?	Drilling Log Contamination Comments
A-11	10 ft.			
	5.5 - 6.5 ft.	NS	NS	No H/C odor or discoloration 2.5 - 10 ft.
A-12	10 ft.			
	5.5 - 6.5 ft.	NS	NS	No H/C odor or discoloration 2.5 - 10 ft.
A-13	19 ft.			
	5 - 7 ft.	ND	ND	
	7 - 9 ft.	ND	ND	
	9 - 11 ft.	ND	ND	
	11 - 13 ft.	ND	ND	No H/C odor or discoloration 3 - 13 ft.
	13 - 15 ft.	Yes, ND, 1451	Yes	H/C odor from 13 - 18 ft, no odor 18 - 19 ft.
A-14	10 ft.			
	5.5 - 6.5 ft.	NS	NS	No H/C odor or discoloration 2.5 - 10 ft.
A-15	10 ft.			
	5.5 - 6.5 ft.	NS	NS	No H/C odor or discoloration 2 - 10 ft.
A-16	19 ft.			
	5 - 7 ft.	ND	ND	
	7 - 9 ft.	ND	ND	No H/C odor or discoloration 3 - 14 ft.
	9 - 11 ft.	ND	ND	
	11 - 13 ft.	ND	ND	H/C odor and discoloration 14 - 15.5 ft.
	13 - 15 ft.	ND	ND	No H/C odor or discoloration 15.5 - 19 ft.
A-17	10 ft.			
	5.5 - 6.5 ft.	NS	NS	No H/C odor or discoloration 3 - 10 ft.

Area B Boring ID, TD, Sample Depth		VOA Samples: H/C Contamination?, benzene, total BTEX	SVOA Samples: H/C Contamination?	Drilling Log Contamination Comments
B-11	10 ft.			
	5.5 - 6.5 ft	NS	NS	No H/C odor or discoloration 4.5 - 10 ft.
B-12	10 ft.			
	5.5 - 6.5 ft.	NS	NS	No H/C odor or discoloration 3 - 10 ft.
B-13	15 ft.			
	5 - 7 ft.	ND	ND	
	7 - 9 ft.	ND	ND	
	9 - 11 ft.	ND	ND	
	11 - 13 ft.	ND	ND	No H/C odor or discoloration 3.5 - 15 ft.
	13 - 15 ft.	ND	ND	
B-14	10 ft.			
	5.5 - 6.5 ft.	NS	NS	No H/C odor or discoloration 4 - 10 ft.

Abbreviations:

TD – total depth; H/C – hydrocarbon, NS – not sampled, ND – not detected.

Table 7-1. Criteria Used in Vadose Zone Diagrams (continued)

Area C Boring ID, TD, Sample Depth	VOA Samples: H/C Contamination?, benzene, total BTEX	SVOA Samples: H/C Contamination?	Drilling Log Contamination Comments
C-11 10 ft.			
5.5 - 6.5 ft.	NS	NS	Gray H/C discoloration to 7 ft.
5.5-6.5 ft.(dup.)	NS	NS	Weak H/C odor 7 - 10 ft., no discoloration
C-12 10 ft.			
5.5 - 6.5 ft.	NS	NS	No H/C odor or discoloration 4.5 - 8 ft. H/C odor and discoloration 8 - 10 ft.
C-13 15 ft.			
5 - 7 ft.	Yes, ND, 32	Yes	
7 - 9 ft.	Yes, 17, 73	Yes	H/C discoloration throughout, black to gray
9 - 11 ft.	Yes, ND, 26	Yes	with depth. H/C odor weakens to 7 ft., then
11 - 13 ft.	Yes, ND, 42	Yes, trace	increases to 15 ft.
13 - 15 ft.	Yes, ND, 21	Yes	
C-14 10 ft.			
5.5 - 6.5 ft.	NS	NS	No H/C odor 4.5-5 ft. H/C odor at 6 ft., increases to total depth at 10.
C-15 15 ft.			
5 - 7 ft.	ND	ND	H/C odor and discoloration decreases with
5 - 7 ft.(dup.)	ND	ND	depth, then increases toward 5 ft.
7 - 9 ft.	Yes, ND, 225	Yes	
9 - 11 ft.	Yes, ND, 1535	Yes	
11 - 13 ft.	Yes, ND, 12840	Yes	H/C odor and discoloration increases with
13 - 15 ft.	Yes, 230, 22510	Yes	depth from 5 - 15 ft.
13 - 15 ft.(dup.)	Yes, 170, 29990	Yes	
C-16 10 ft.			
5.5 - 6.5 ft.	NS	NS	No H/C odor or discoloration below 2.5 ft.
C-17 10 ft.			
5.5 - 6.5 ft.	NS	NS	No H/C odor or discoloration 4.5 - 9 ft., odor and discoloration reappear 9-10 ft.
C-18 10 ft.			
5.5 - 6.5 ft.	NS	NS	No H/C odor or discoloration 2 - 7.5 ft. Discoloration and odor increase 7.5 - 10 ft.

Table 7-1. Criteria Used in Vadose Zone Diagrams (concluded)

Area D Boring ID, TD, Sample Depth	VOA Samples: H/C Contamination?, benzene, total BTEX	SVOA Samples: H/C Contamination?	Drilling Log Contamination Comments
D-11 15 ft.			
5 - 7 ft.	ND	ND	
7 - 9 ft.	ND	ND	No H/C odor or discoloration 3 - 14 ft.
9 - 11 ft.	ND	ND	
11 - 13 ft.	ND	ND	
13 - 15 ft.	Yes, ND, 23	Yes	H/C odor and discoloration 14 - 15 ft.
D-12 10 ft.			
5.5 - 6.5 ft.	NS	NS	No H/C odor or discoloration 4 - 6.5 ft.
5.5-6.5 ft.(dup.)	NS	NS	Slight odor and discoloration 6.5 - 10 ft.
D-13			
5.5 - 6.5 ft.	NS	NS	No boring performed, trench location
D-14 15 ft.			
5 - 7 ft.	ND	ND	No H/C odor or discoloration 1 - 4 ft.
7 - 9 ft.	ND	ND	
9 - 11 ft.	ND	ND	Increasing H/C odor and discoloration
11 - 13 ft.	ND	ND	from 4 - 15 ft.
13 - 15 ft.	Yes, ND, 118	Yes	
D-15 15 ft.			
5 - 7 ft.	ND	ND	No H/C odor or discoloration 1.5 - 6 ft.
7 - 9 ft.	ND	ND	Hydrocarbon discoloration 6 - 10 ft.
9 - 11 ft.	ND	ND	Moderate H/C odor at 9 ft.
11 - 13 ft.	ND	ND	H/C odor increases from 10 - 15 ft.
13 - 15 ft.	Yes, ND, 6350	Yes	

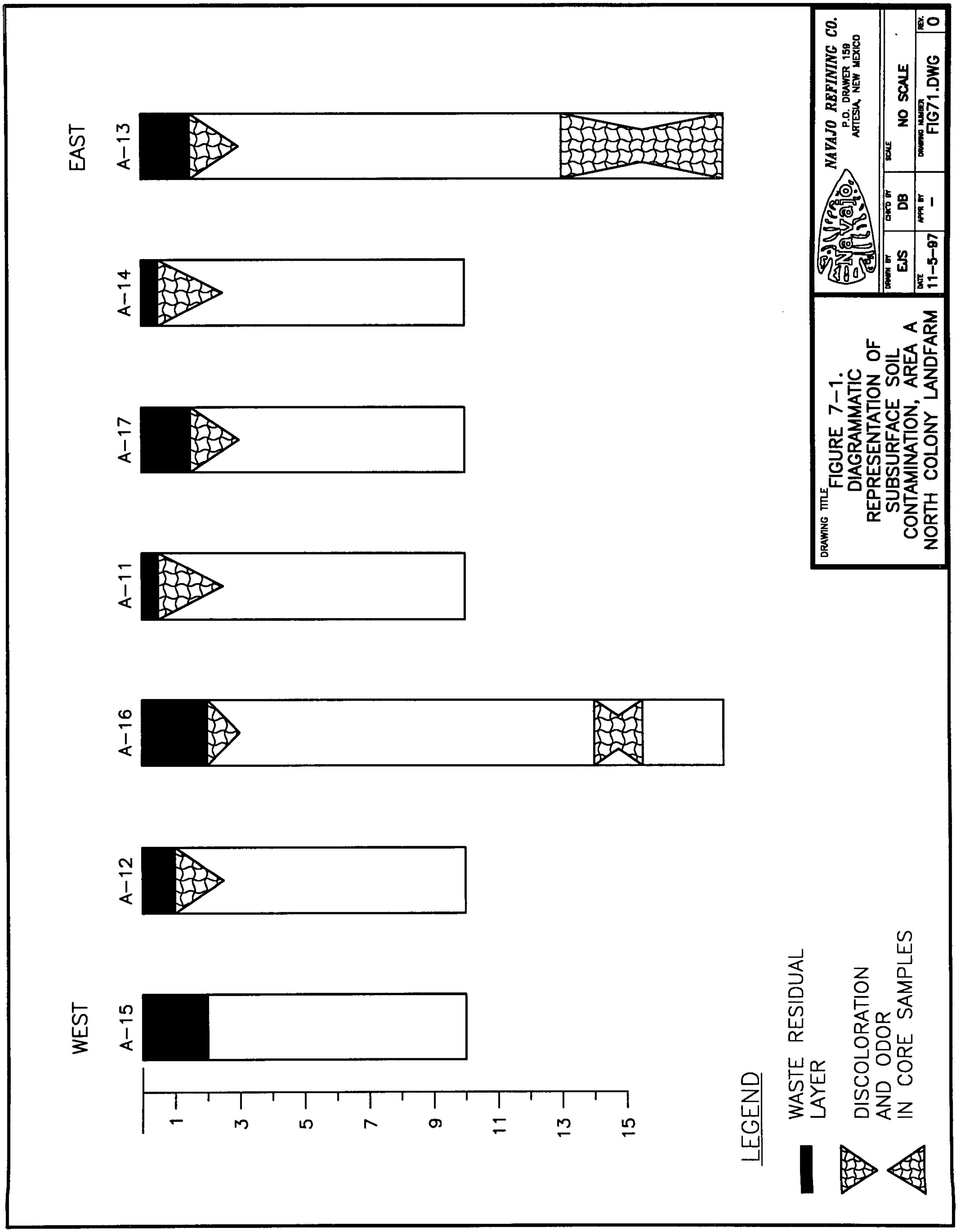

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FIGURE 7-1.
DIAGRAMMATIC
REPRESENTATION OF
SUBSURFACE SOIL
CONTAMINATION, AREA A
NORTH COLONY LANDFARM

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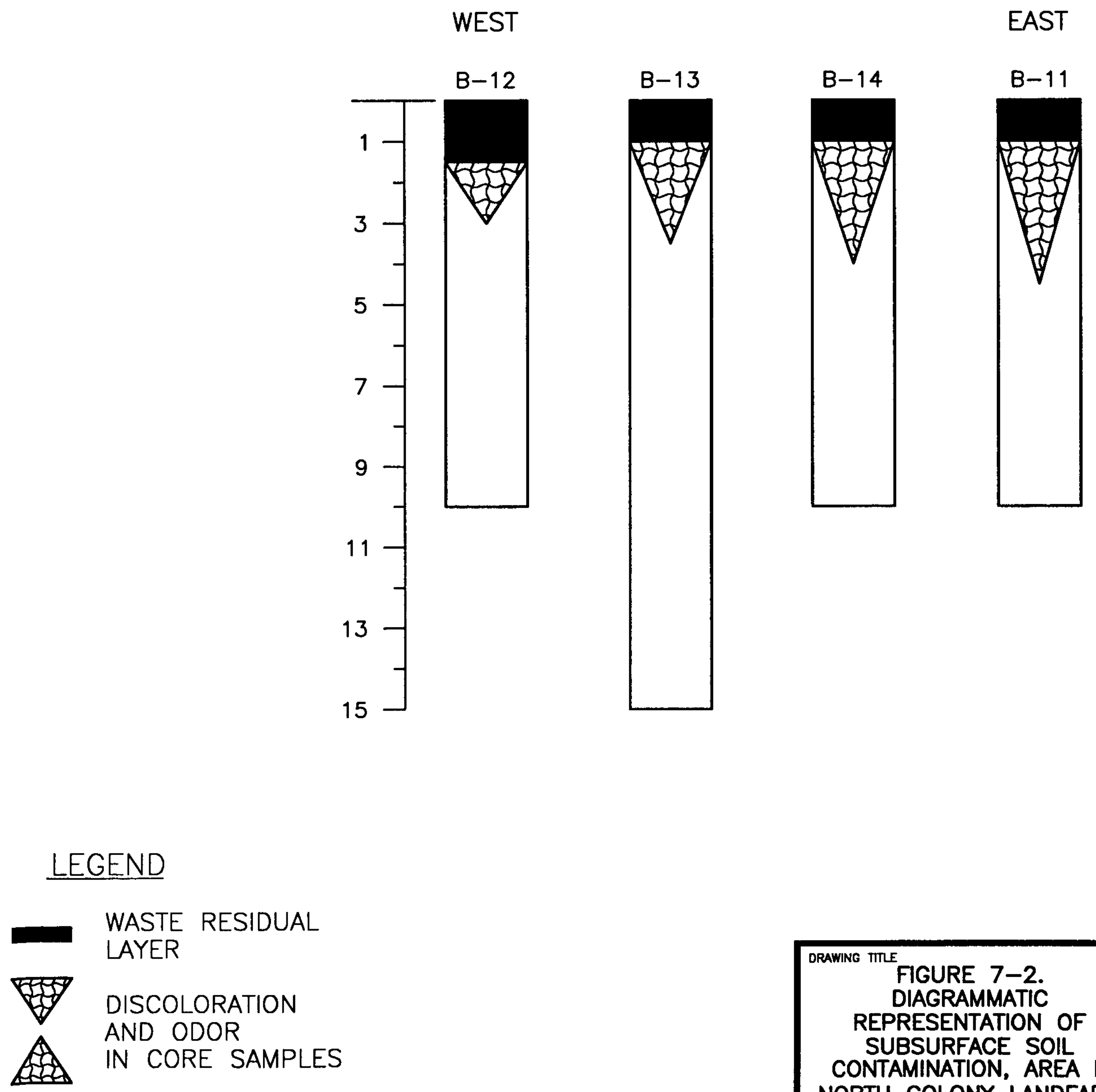

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FIGURE 7−2.
DIAGRAMMATIC REPRESENTATION OF SUBSURFACE SOIL CONTAMINATION, AREA B NORTH COLONY LANDFARM

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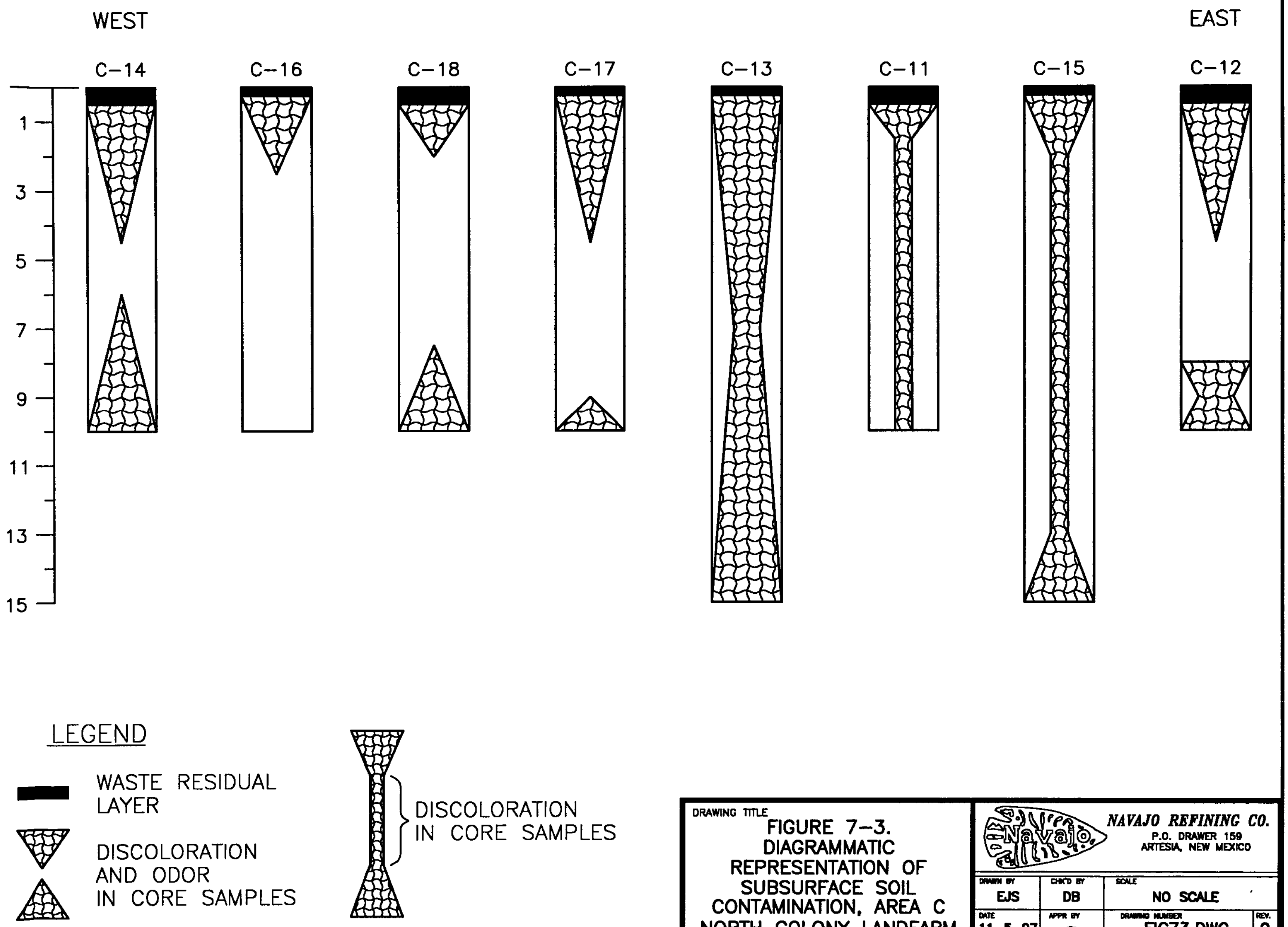

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FIGURE 7−3.
DIAGRAMMATIC REPRESENTATION OF SUBSURFACE SOIL CONTAMINATION, AREA C NORTH COLONY LANDFARM

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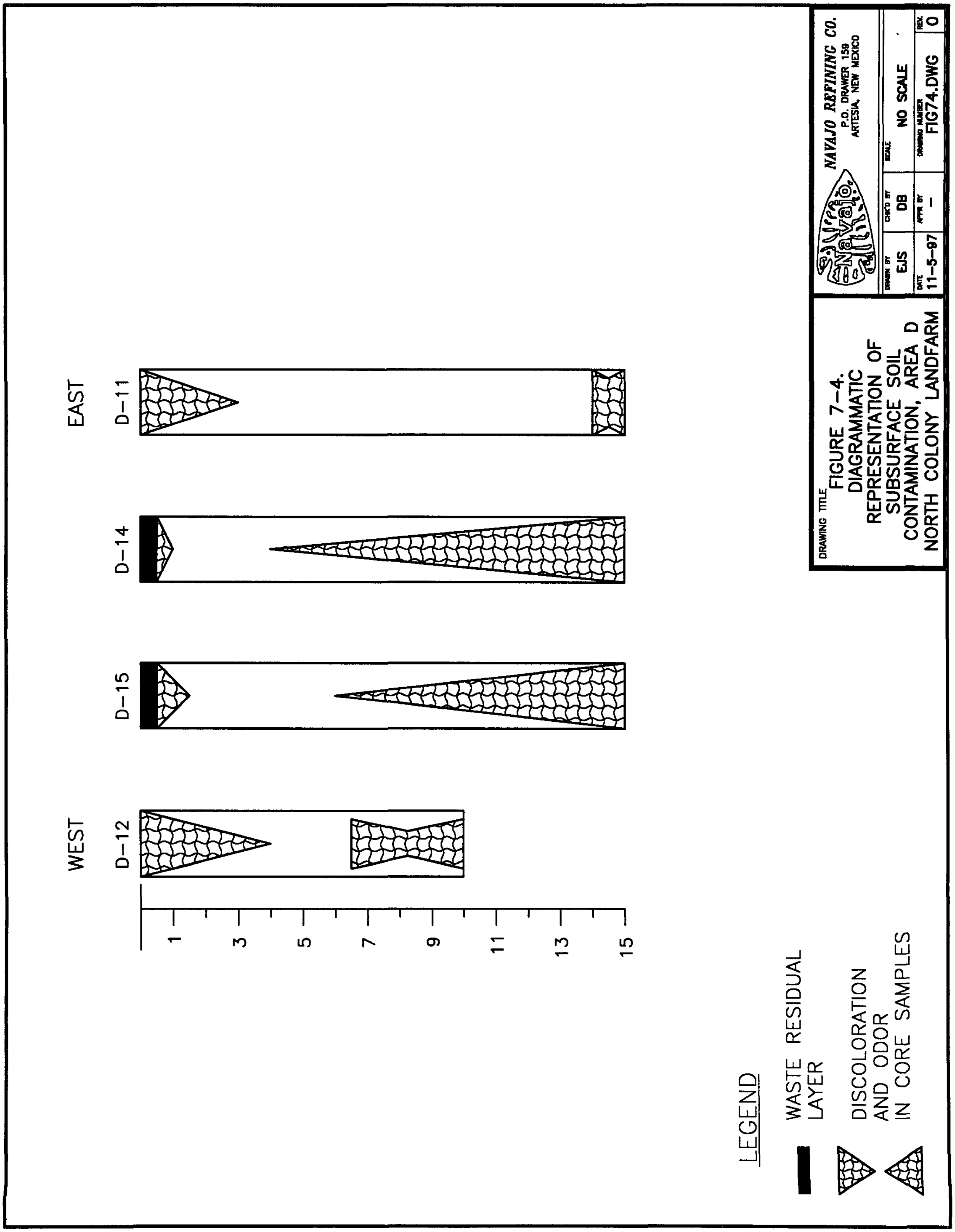

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FIGURE 7-4:
DIAGRAMMATIC REPRESENTATION OF SUBSURFACE SOIL CONTAMINATION, AREA D
NORTH COLONY LANDFARM

Sample analytical results for Phase I boring C-15 provide the strongest indication that petroleum product originating in the near-surface saturated zone could be transported within close proximity of the base of the unit. The contaminant concentration profile exhibited by boring C-15, as revealed by the sample analytical results (Tables 6-6 and 6-7), is indicative of a hydrocarbon contaminant source originating in the vicinity of the deepest sample interval (13 to 15 feet). Thereafter, as sample intervals are considered in ascending sequence, reported overall hydrocarbon constituent concentrations become increasingly attenuated, such that the total BTEX concentration for the 7 to 9 feet interval was less than 1% of the BTEX concentration obtained for the 13 to 15 feet interval, and no BTEX constituents were reported for the uppermost (5-7 feet) sample interval. Similarly, when taken as the sum of all SVOA constituents, total SVOA concentrations for C-15 soil samples also exhibited a consistent attenuation trend when considered in ascending sequence. No SVOA constituents were detected at the 5 to 7 feet interval, and the total SVOA concentration reported for the 7 to 9 feet interval sample was less than 7% of the total SVOA concentration at the 13 to 15 feet interval (Table 6-7).

Similar relationships were found in the 1997 Supplemental Investigation. Soil cuttings from 12-borings drilled for installation of temporary monitor wells showed landfarm materials and a mixture of these materials and native soils to a depth of about 5 feet. Below this depth a clean zone of silty clays and clayey silts exist to a depth of about 10 to 12 feet (Section 6.1.2.4.3, photograph log Appendix A). At this depth, the soil contains more silt, and variable amounts of coarser grained sediment. Depending on the location within the landfarm thin pebble seams and caliche layers are also present. At the south center area of the landfarm (cells C and D), these thin zones also exhibit gray and blue gray discoloration and strong hydrocarbon odors. Although the deeper cuttings exhibited visual and olfactory contamination and water samples from the borings contained dissolved phase hydrocarbons, no free-phase hydrocarbon product was located under the landfarm.

Due to the nature of the subsurface stratigraphy underlying the NCL, upward migration petroleum product from the near-surface saturated zone to the base of the unit appears to be tenable. During installation of groundwater monitoring wells at the NCL (Geraghty & Miller, December 1982), the upper water bearing zone was characterized as a confined pebble seam under artesian pressure. Observations made during the subsequent RFI investigations suggest that, during episodes when groundwater elevations are at peak levels, artesian pressure may force near-surface groundwater to move into overlying confining strata through existing channels such as old root passages and the discontinuous network of caliche gravel seams underlying the unit. This mechanism is discussed further in Section 7-3.

Any such vertically upwards migration of contaminants could be further facilitated by additional physical mechanisms, including capillary tension or gradient-driven dispersion of organic contaminants partitioned into the gaseous phase. Capillary tension is maximized in finer grained soils and moisture can commonly migrate upwards several feet above an unconfined water table. Under artesian conditions, the upward gradient effects of artesian head and capillary tension are additive. Gradient-driven dispersion of organic contaminants in the gaseous phase are commonly observed in locations where subsurface leaks have occurred such as underground storage tanks at gasoline stations. At these locations, vapors accumulating in crawl spaces or basements of nearby structures pose an explosive hazard. Although thick clays can retard upward movement, the clayey silts located in some areas of the landfarm appear sufficiently permeable to allow upward transport of gaseous hydrocarbon components from the subsurface hydrocarbon product plume.

The results of the 1994 offsite NCL trenching plus a previous investigation (Shomaker, 1990) have documented the occurrence of hydrocarbon contaminated soils directly upgradient of the North Colony Landfarm along virtually the entire length of the south fence line. One apparent source of the contamination was leaky underground piping at a product storage tank south of the landfarm. Because the area where the tank is located has been in use as a product storage and loading area since the earliest days of the refinery, the possibility of still earlier releases at the tank storage area cannot be discounted. The tank storage area is located between the landfarm and Eagle Draw (Figure 6-2) which is the major drainageway in the Artesia area.

An additional location containing free-phase hydrocarbon exists in the vicinity of NCL-34. This monitor well has been observed to contain petroleum product for several years, and until recently it was thought to be diesel fuel because of its proximity to the diesel fuel recovery trenches on the south side of the NCL. A sample of the product collected for the current investigation reveals the product consists of 70 to 80 percent weathered crude oil with the remaining 20 to 30 percent more recent diesel (Core Labs, 1997). The diesel portion of the product is thought to have migrated from the area of the tank farm. The crude oil is more of a mystery although the area immediately to the east of the landfarm has been a crude oil unloading area for many years. Older photographs of the area show a small crude tank to the immediate east of the NCL that no longer exists today.

7.2 Deep Geotechnical Boring

Based on lithologic information obtained from the deep geotechnical boring drilled during the Phase I RFI and the two earlier deep borings discussed in Section 6.1.3, a location map (Figure 7-5) and cross-section (Figure 7-6) were prepared to illustrate deeper subsurface relationships in the vicinity of the NCL. Based on review of the available data, in the immediate area of the landfarm, the next major water bearing zone beneath the NSSZ is at a depth in excess of 100 feet. Also, the lithologic information provided by the three boring logs strongly supports a conclusion that deeper groundwater in the vicinity of the deep boreholes is isolated from the shallow NSSZ in the area beneath the landfarm.

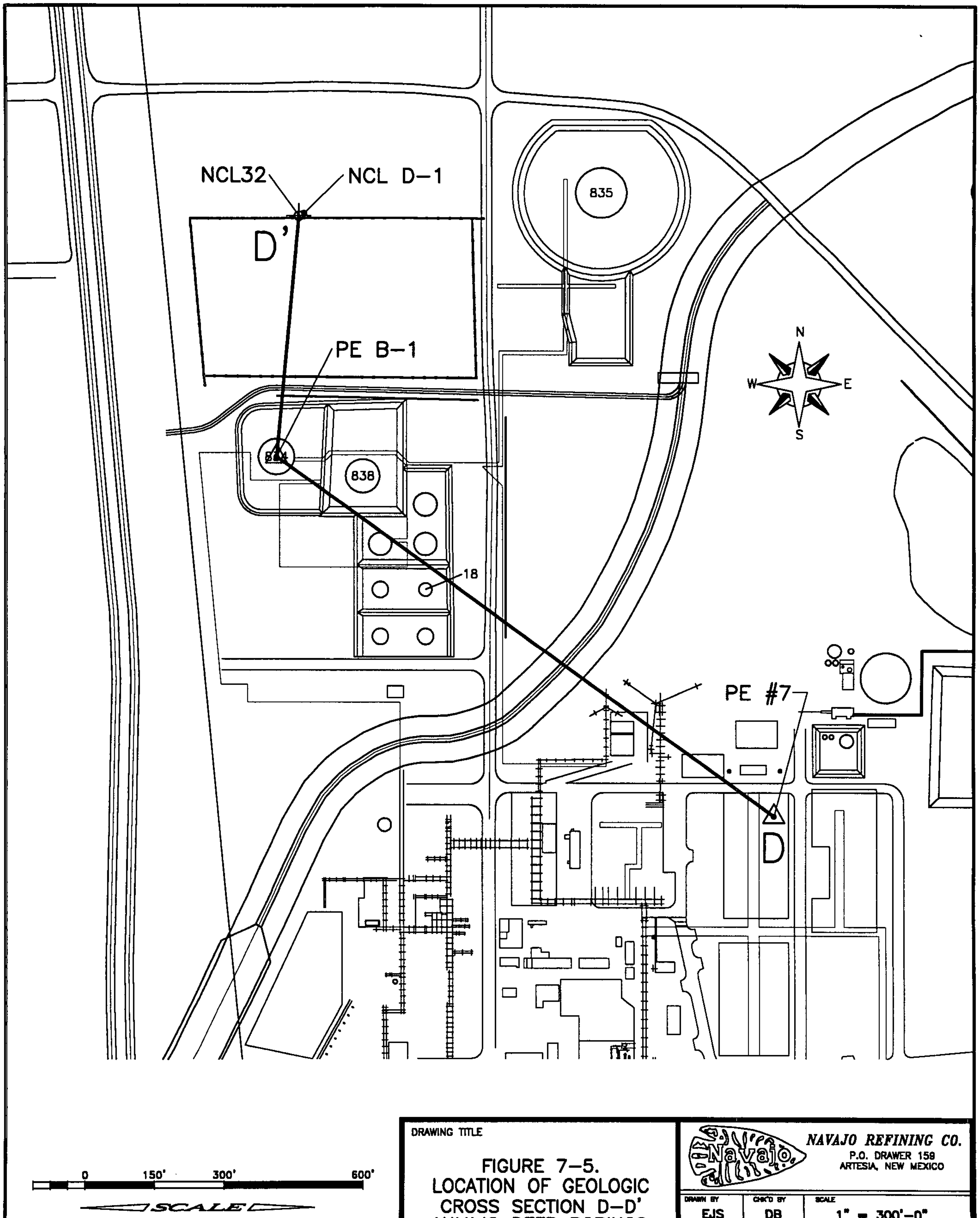

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FIGURE 7-5.
LOCATION OF GEOLOGIC
CROSS SECTION D-D'
NAVAJO DEEP BORINGS

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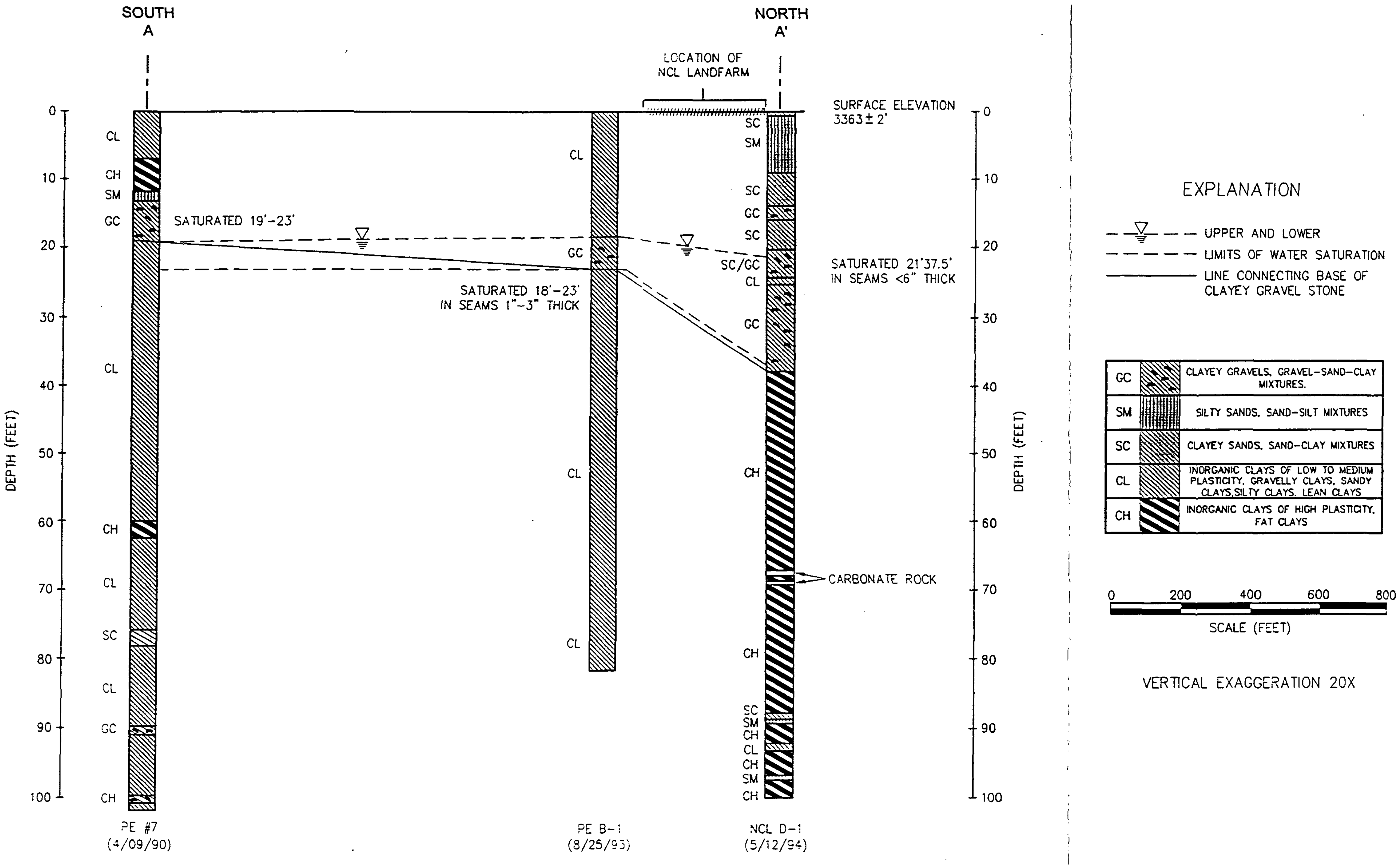

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FIGURE 7-6.
DEEP BORING GEOLOGIC
CROSS SECTION D-D'
VICINITY OF
NORTH COLONY LANDFARM

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7.3 Groundwater Investigation

The RFI investigations have demonstrated that the NSSZ is a highly variable network of interconnected, but sporadically distributed saturated zones. This fact is perhaps most clearly demonstrated by observations made at Phase II boring locations NCL 95-14 and 14B (Table 6-9, Figure 6-2, and Appendix B), which were separated by a distance of about 4 feet. Despite their near proximity, the borings were strikingly dissimilar in terms of the occurrence of hydrocarbons. Specifically, NCL 95-14B contained free-phase product while NCL 95-14 evidenced no hydrocarbon product, and showed only a moderate odor and slightly elevated PID readings at a depth of 17.6 to 17.9 feet.

Similar observations were noted in the 1997 RFI Supplemental investigation. Two of the 12 borings (97-B1, 97-C3) remained dry after 24 hours while adjacent borings beneath the landfarm at the same depth contained sufficient water for sampling.

The variable nature of the NSSZ hydraulic system is further indicated by the broad range of estimated seepage velocities for the NSSZ which were obtained using various wells evaluated over different groundwater elevation measurement dates (Table 6-21). The wide range in seepage velocities reflects the complexity of the hydrologic system in the vicinity of the NCL. Seepage velocity is controlled by the permeability of less frequently encountered high-permeability gravel and sand zones that finger out in advance of the main body of the plume. Under the assumed subsurface regime, hydrocarbon product behind the leading edge of the plume gradually infiltrates remaining available pore space via more restricted and tortuous pathways.

Significant groundwater flow occurs only in the coarse grained water-bearing seams that are typically limited in vertical and horizontal extent, and which are interbedded with extensive zones of low permeability silts and clays. High permeability zones do not predominate in the vicinity of the hydrocarbon-impacted soils. The lower permeability materials, together with the presence of thick clay zones which greatly restrict vertical downward movement of contaminants, act to contain the released product. However, where hydrocarbon fluids have reached a higher permeability zone, movement is expedited. The occasional and sporadic occurrence of coarser permeable materials in the area of the release limits the types of hydrocarbon recovery operations that can be successfully used in the area to recovery trenches which bisect the infrequently distributed permeable zones.

The other key finding of the RFI Phase II and the 1997 supplemental efforts involves the apparent validation of the semi-confined nature of the NSSZ, which was originally postulated on the basis of RFI Phase I results. The continuous groundwater elevation monitoring data collected in 1995 and 1997 and presented in Figures 6-7 through 6-10 are highly consistent with the NCL soil boring program results, as well as with the observed hydrocarbon contaminant profiles in the vadose zone above the NSSZ. The significance of this finding is that the driving force to move contaminants horizontally beneath the unit and vertically upwards has been confirmed.

In response to localized precipitation events the upgradient areas along the northwest boundary of the landfarm receives a hydraulic head pulse that results in an increase of over 3 feet in a several hour period. This pulse, in a reduced form on the order of 0.5 feet, is transmitted under the landfarm to the other wells over a period of several days. The pulse mechanism provides the hydraulic driving force the moving contaminants along the southern boundary of the landfarm northeasterly under the landfarm.

Historically, water levels have been much greater under all areas of the landfarm. Figure 2 of the 1982 Geraghty & Miller report (Appendix H) shows the October 1982 potentiometric surface is approximately 2 ft. higher than that measured in 1994, 1995, or 1997. The specific reason for the significant decline in overall water levels is unknown. They may be regional or more directly related to recovery of hydrocarbon product and water from Recovery Well 7 and its associated recovery trench. However, as discussed above and notwithstanding the use of the recovery trench, the pulse mechanism phenomena continues to be observed and impacts water movement under the NCL.

7.4 Water Quality

The result of the 1997 RFI supplemental investigation did not detect the presence of free-phase hydrocarbons under the landfarm, although dissolved-phase water contamination and residual soil contamination was encountered. The hydrogeological and chemical results provide confirming evidence that the contamination originated from the vicinity of several above-grade storage tank areas to the south of the NCL.

Water quality under that landfarm appears to have improved in past several years. In the early 1990's significant concentrations of dissolved-phase hydrocarbons were detected in monitor wells NCL-31, NCL-33 and NCL-44. Before its use was discontinued in 1995, NCL-31 showed no detections of dissolved-phase hydrocarbons. More recently, current sampling results from NCL-33 and NCL-44 have shown no detections of any dissolved phase hydrocarbons at the method detection level for the past two sampling episodes. Benzene has not been detected in these two wells in the past two years and total BTEX concentrations are less than 15 ug/L. Improvement in water quality is likely due to the presence of the hydrocarbon recovery system along the south NCL boundary and the hydraulic pulse mechanism described above. It can be interpreted that improvement in water quality is due to the physical mechanisms described above plus naturally occurring attenuation and biodegradation processes which are being enhanced by the physical movement of fresh recharge water under the site.

Although it is not possible to conclusively demonstrate that a release of hydrocarbons from the NCL has not occurred, now that a driving force mechanism has been verified and its magnitude confirmed, there is a much greater likelihood that the hydrocarbon contaminants observed at depth in the vadose zone beneath the landfarm are from a hydrocarbon release unrelated to surface activities at NCL. Even if a release from the base of the landfarm treatment unit has occurred, there is nothing to distinguish any contaminants which may have been contributed by the NCL from those contaminants contained in the upgradient release. To assist in assessing the impact on groundwater of a hypothetical release from the NCL, we have performed worst-case vadose zone modeling for maximum concentrations of organic constituents detected in the soil sampling episodes. The results of the modeling, presented in Section 6.1..5, do not show exceedances of EPA MCL standards in the underlying groundwater, including benzene.

The NSSZ does not represent a feasible drinking water source, due to its poor quality and limited productivity potential. Potential for human exposure to hydrocarbon-impacted groundwater is further diminished due to the semi-confined nature of the contaminants within the NSSZ, and the significant interval of impermeable strata intervening between the NSSZ and lower groundwater zones.

8.0 RFI CONCLUSIONS AND RECOMMENDATIONS

8.1 RFI Conclusions

The RFI Phase I, Phase II, and Supplemental investigations have provided detailed information on near-surface soil and groundwater conditions at the North Colony Landfarm (NCL), and have generated significant data on the characteristics and concentration of hazardous constituents found beneath the site. The results of the three investigations demonstrate that, at worst, only minimal releases of hazardous waste constituents have occurred from the waste treatment unit. The investigation results provide evidence to support the following specific and general conclusions:

1. The clay soils prevalent in the upper treatment zone of the unit have effectively immobilized metal constituents. As demonstrated by statistical comparison of background and landfarm soil samples, concentrations for chromium and lead in soils underlying the base of the unit essentially represent background conditions, and pose no environmental risk to groundwater underlying the unit.

2. Similarly, statistical comparison was performed on water sampling results from up- and down-gradient monitor wells. No statistically significant variations in chromium and lead metal concentrations in groundwater were determined. Monitor well NCL-34, containing a mixture of crude and diesel oil free-phase hydrocarbons, exhibits highly variable and elevated metals concentrations, and was not included in the statistical analysis.

3. Vadose (unsaturated) zone modeling was performed to predict concentrations of hazardous organic constituents in groundwater beneath the unit. The modeling results determined that concentrations contributed by organic constituents detected in soil immediately below the treatment zone would in all cases be less than EPA maximum contaminant levels (MCL) for drinking water. For benzene, the model predicts a concentration of 2.6 micrograms per liter (ug/L) in the groundwater which is less than the 5.0 ug/L MCL. The modeling was performed using conservative assumptions (e.g. instantaneous solution of the contaminant mass into water and immediate transport to underlying groundwater). Concentrations utilized as inputs to the model were the maximum detected values as determined from analyses of samples of soil borings at the landfarm, even though some values detected (such as for benzene) may have been from unrelated hydrocarbon releases.

4. Using the vadose zone modeling concentration results as inputs, saturated zone modeling was performed using conservative assumptions to determine fate and transport of the modeled hazardous organic constituents in groundwater. The model predicts that for any hazardous constituents that may have been released from the unit and that may have reached the groundwater, concentrations would be dissipated within 200 feet downgradient of the unit boundary and within the refinery property. For the benzene

example starting at 2.6 ug/L, concentrations of less than 0.05 ug/L (i.e. less than 50 parts per trillion) are predicted at a distance of less than 200 feet.

5. The first water-bearing zone beneath the NCL (the Near Surface Saturated Zone (NSSZ)) is a highly variable network of interconnected, but sporadically distributed saturated zones. Significant groundwater flow occurs only in the coarse grained water-bearing seams that are typically limited in vertical and horizontal extent, and which are interbedded with extensive zones of low permeability silts and clays. Because of this variability, fluids were not observed in several soil borings (some temporarily screened) within and adjacent to the landfarm while other nearby borings completed at the same elevation contained water and in some instances hydrocarbon product.

6. Groundwater elevations beneath the landfarm show considerable variation in response to localized precipitation. The likely source for this water is infiltration from rainfall runoff in the adjacent stormwater drainage ditch which borders the NCL south boundary. Water levels in one upgradient well were observed to rise 3 feet during several 12-hour periods in 1995 and 1997. Increases in downgradient wells were about 0.5 feet during this time..

7. Comparison of groundwater level measurements in monitor wells at the landfarm show water levels beneath the landfarm in October 1982 were from 5 to 6 feet higher than levels measured in 1995 and 1997. The 1982 levels were within 0.5 to 1 feet of the 7-feet sample interval in the trenches excavated in April 1994 for the Phase I study. Higher water levels transmit any dissolved and free-phase hydrocarbons which may be present in the NSSZ closer to the base of the treatment unit. This may lead to uncertainty as to the source of any constituents detected in sampling of soil from borings or observation trenches.

8. Benzene and total BTEX maps drawn from groundwater data collected from temporary screened borings beneath the unit show a source of hydrocarbons to the south and upgradient of the NCL. The NSSZ underlying the unit is known to have been impacted by two or more petroleum product plumes that have migrated under the site from several possible sources located adjacent to and/or upgradient (i.e. south) of the unit.

9. Based on the nature of free-phase hydrocarbon materials recovered from existing interception trenches and monitoring wells in the vicinity of the NCL, the petroleum products associated with the unrelated releases appear to consist of a combination of biologically degraded crude oil and a diesel-like product. As such, it is likely that most if not all of the hydrocarbon constituents present in the hydrocarbon-impacted area of the NSSZ are also common to the refinery wastes formerly applied to the NCL.

10. The significant and rapid changes in water levels observed in up- and down- gradient NCL monitor wells in response to precipitation support semi-confined hydrogeologic conditions in the vicinity of the site. The importance of this finding is that a pulse mechanism exists which is primary physical mechanism moving water and contaminants horizontally through the NSSZ beneath the unit and vertically upwards in response to

high hydraulic head changes. Secondary mechanisms are capillary action in fine grained soils and possibly gaseous diffusion of volatiles.

11. Several monitor wells previously contaminated with elevated concentrations of dissolved phase hydrocarbons in the early 1990's now generally show no detectable hydrocarbons. These wells include former up-gradient well NCL-31, and downgradient wells NCL-33 and NCL-44. It is likely that the interception trench (RW-7) installed immediately south of the unit, plus the pulse mechanism described above are acting to assist in natural remediation of the groundwater under the west and central portions of the unit.

12. Releases, if any, of hazardous constituents from the base of the NCL unit have probably been limited with respect to the affected area and quantity of released constituents. The observations and data obtained during the RFI studies indicate that hydrocarbon constituents associated with the upgradient plume that is present over a large area of the NSSZ underlying the NCL are far more likely to have impacted subsurface soils below the unit, than NCL unit constituents have impacted the groundwater. Therefore, it is concluded that future efforts intended to ensure the protection of human health and the environment will be most effectively directed towards delineation, interception, and treatment or recovery of the hydrocarbon product contained in the NSSZ present in the vicinity of the unit.

13. Due to petroleum products originating from a source or sources external to the NCL, and the apparent migration of these materials into strata beneath the NCL, some uncertainty may remain regarding the interpretation of observations and results regarding the fate of organic constituents having similar characteristics which were applied on the unit. However, the overall evidence obtained from examination of the soil profiles in the NCL observation trenches and soil borings, the results of the groundwater sampling of the temporary wells installed within the unit, and evaluation of the statistical analysis and groundwater modeling results provide compelling documentation that the occurrence of the preponderance, if not the totality, of the hydrocarbon contamination detected in subsurface soils and groundwater at depth below the base of the unit is attributable to transport of off-site petroleum product in the NSSZ, and is not the result of releases of applied refinery waste constituents from the base of the unit.

14. The NSSZ does not represent a feasible drinking water source, due to its poor quality and limited productivity potential. Potential for human exposure to hydrocarbon-impacted groundwater is further diminished due to the semi-confined nature of the contaminants within the NSSZ, and the significant interval of impermeable strata intervening between the NSSZ and lower groundwater zones.

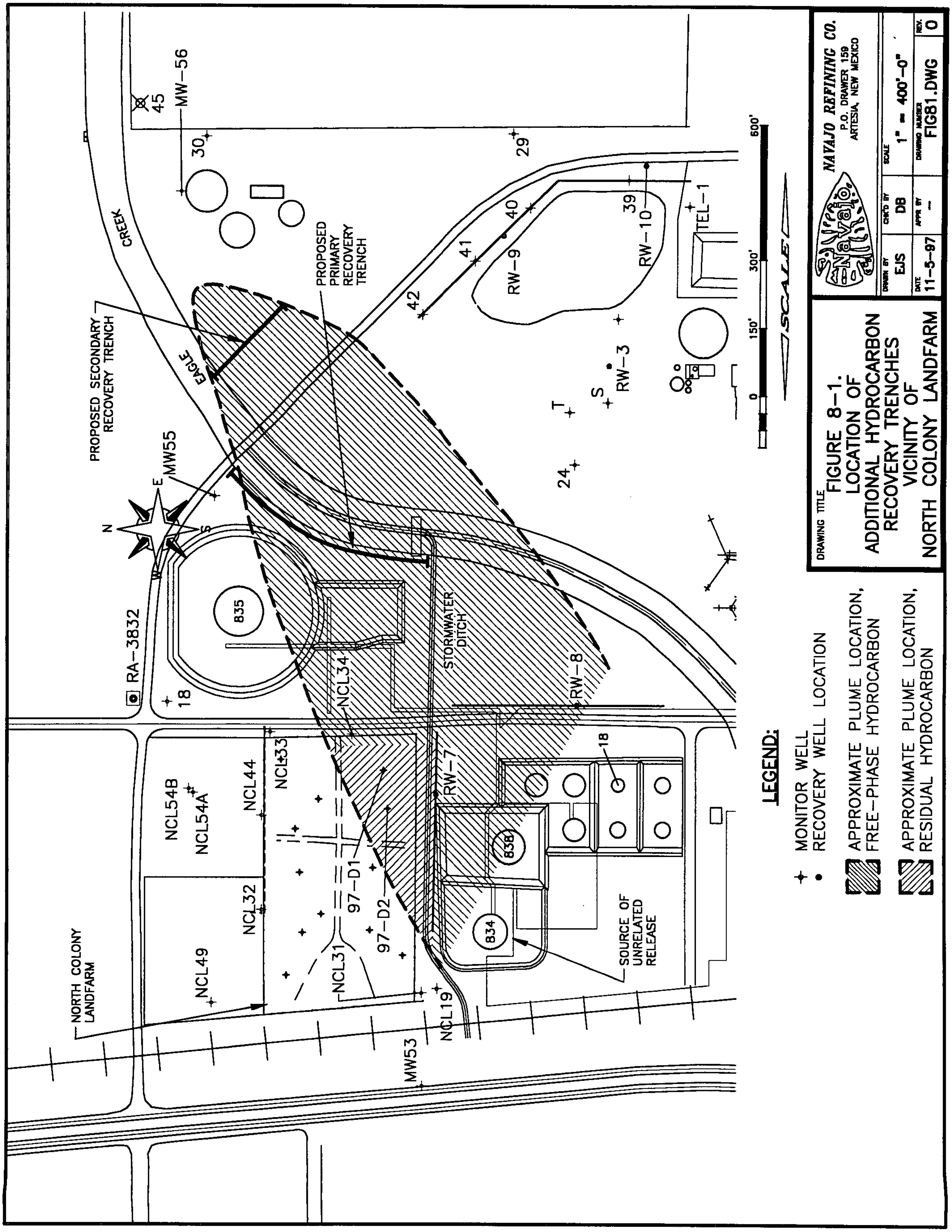
8.2 Recommendations

Due to the variable, disjunct nature of the NSSZ, the construction of interception trenches across the path of the petroleum product plume represents the only feasible corrective measures alternative. Based on the configuration of the free-phase product plume and its relationship to above-ground features, the Phase II report recommended construction of interception trenches for the containment and recovery of the hydrocarbon product. NRC is currently proceeding with design of the recovery systems and selection of a contractor, and expects to have new installations on-line within 90 days.

The proposed system consists of primary and secondary recovery trenches. Locations for the proposed trenches are presented in Figure 8-1. The primary trench will be located in the area west of Eagle Draw in which the occurrence of free-phase hydrocarbon in the boreholes was most frequently encountered. The location of this trench will supplement the existing recovery operations at RW-7 and RW-8. The secondary trench will be located near the leading tip of the plume and is expected to recover lesser amounts of hydrocarbon and contaminated water since not all borings in that area were found to have been impacted by the product. The location of this trench is also dictated by existing refinery structures and pipeline and utility considerations. However, by cutting off the source of product and water, the trench is expected to cause downgradient fluid movement to greatly decrease and it should significantly diminish hydrocarbon movement. The presence of new monitor well MW-56 will provide timely notice of imminent approach of any hydrocarbon constituents.

The location of the trenches likewise will intercept and recover and surface releases from the NCL, however unlikely, that may have migrated vertically downwards and contacted the plume. The magnitude of any releases from the NCL has been evaluated previously and are, at worst, minimal. The monitor wells installed in 1995 along the northern and eastern boundaries of the hydrocarbon plume will allow for timely detection of changes in water quality, and the data collected will assist in making any necessary modifications to the trench recovery system proposed for installation.

In addition to the trenches, it is suggested that hydrocarbon recovery be initiated at NCL-34 using a skimmer system. The diameter of the well (2 inches) will limit available recovery options, but the product in that well continues to be pervasive. Due to the well's proximity to the landfarm, some portion of the hydrocarbon product no doubt extends under the site and should be removed so as to facilitate any further investigation which might be necessary as well as to prevent future downgradient hydrocarbon movement.



LEGEND:

- ✛ MONITOR WELL
- ● RECOVERY WELL LOCATION
- ▨ APPROXIMATE PLUME LOCATION, FREE-PHASE HYDROCARBON
- ▨ APPROXIMATE PLUME LOCATION, RESIDUAL HYDROCARBON

DRAWING TITLE
FIGURE 8-1.
LOCATION OF
ADDITIONAL HYDROCARBON
RECOVERY TRENCHES
VICINITY OF
NORTH COLONY LANDFARM

NAVAJO REFINING CO.
P.O. DRAWER 159
ARTESIA, NEW MEXICO

DRAWN BY	CHK'D BY	SCALE	
EJS	DB	1" = 400'-0"	
DATE	APPR BY	DRAWING NUMBER	REV.
11-5-97	-	FIG81.DWG	0

9.0 REFERENCES

Allen, E., et al., 1995. *Metal Speciation and Contamination of Soil*, Lewis Publishers, Ann Arbor, Michigan.

Anderson, D.R., Sweeney, D.J., and T.A. Williams, 1997. *Essentials of Statistics for Business and Economics*, West Publishing Co., Minneapolis, MN.

A. T. Kearney Inc., and Harding Lawson Associates, 1986. "Preliminary Assessment Report, Navajo Refining Company, Artesia, New Mexico," prepared for U.S. EPA, Region VI, Dallas, TX, Contract No. 68-01-7038, April 14.

Berk, K. N., and P. Carey. 1995. *Data Analysis with Microsoft Excel 5.0 for Windows*, Course Technology Inc.

Bouwer, H., 1989. "The Bouwer and Rice Slug Test -- an Update." *Ground Water*, vol. 27, no. 3, pp. 304-309.

Bouwer, H., and R.C. Rice, 1976. "A Slug Test Method for Determining Hydraulic Conductivity of Unconfined Aquifers with Completely or Partially Penetrating Wells." *Water Resources Research*, vol. 12, no. 3, pp. 423-428.

Calabrese, E.J., 1992. *Hydrocarbon Contaminated Soils and Groundwater*, Volumes 2 and Volume 3, Lewis Publishers, Ann Arbor, Michigan.

Cooper, H.H., Jr., J.D. Bredehoeft, and I.S. Papadopulos, 1967. "Response of a Finite Diameter Well to an Instantaneous Charge of Water." *Water Resources Research*, vol. 3, pp. 263-269.

Core Laboratories, 1990. Analytical Report 900982 for Navajo Refining, Aurora, CO, July 27.

Core Laboratories, 1997. Analytical Report 974143-1 for Navajo Refining, Houston, TX, July 27.

Fetter, C.W., 1988. *Applied Hydrogeology*. 2nd edition. Merrill Publishing, Columbus, Ohio.

Fiedler, A. G., and Nye, S. S., 1933. "Geology and Ground-Water Resources of the Roswell Artesian Basin, New Mexico," U.S. Geological Survey Water Supply Paper 639, U.S. Govt. Printing Office, Washington, DC.

Geraghty & Miller Inc., 1982. "Installation of Groundwater Monitoring System at the Navajo Refining Company, Artesia, New Mexico," 25 p., four appendices, Houston, TX.

Hendrickson, G. E., and R. S. Jones, 1952. “Geology and Ground-Water Resources of Eddy County, New Mexico,” Groundwater Report, 3, New Mexico Bureau of Mines & Mineral Resources, Socorro, NM.

International Technology Corporation, 1989. “Hydrogeologic Assessment of Navajo Refinery: Compilation and Review of Investigations Through 1988,” report to Navajo Refining Company, Artesia, NM.

Kelley, V. C., 1971. “Geology of Pecos Country, Southeastern New Mexico,” New Mexico Bureau of Mines & Mineral Resources - Memoir 24, University of New Mexico Printing Plant, Socorro, NM.

K.W. Brown Environmental Services, 1993. “RCRA Facility Investigation Three-Mile Ditch and Evaporation Ponds, Phase II (Revised), Navajo Refinery, Artesia, New Mexico.” Prepared for submittal to U.S. EPA, Region VI, Dallas, TX, five volumes, College Station, TX, November.

LATA, 1996. “RCRA Facility Investigation, Phase II Report, North Colony Landfarm, Navajo Refinery, Artesia, New Mexico”, Prepared for Navajo refining Company, Artesia , New Mexico.

Lesage, S., and R. Jackson, 1992. *Groundwater Contamination and Analysis at Hazardous Waste Sites,* Marcel Dekker Inc., New York, New York.

Lyford, F. P., 1973. “Valley Fill in the Roswell-Artesia Area, New Mexico,” Open File Report 73-163, USGS Open File Services, Denver, CO.

Mathess, G. 1982. *The properties of Groundwater*, John Wiley and Sons, New York, New York.

McDonald, M. G. and A. W. Harbaugh, 1988. “A Modular Three-Dimensional Finite Difference Ground-Water Flow Model”. Prepared by the U.S. Department of the Interior, U.S. Geological Survey. Reston, Virginia.

Mclean, J., and B. Bledsoe. 1992. “Ground Water Issues, Behavior of Metals in Soils”, USEPA, Superfund Technology Support Center for Ground Water, Robert S. Kerr Environmental Research Laboratory, Ada Oklahoma.

Morgan, A. M., 1938. “Geology and Shallow-Water Resources of the Roswell Artesian Basin”, New Mexico State Engineer Bulletin No. 5, Santa Fe, NM.

Navajo Refining Co., 1990. January 19 letter from Zeke Sherman, NRC to NMED responding to 11/08/89 NMED information request and providing analytical results of soil cores taken at NCL in November, 1989.

Navajo Refining Co., 1990. July 13 letter from Zeke Sherman, NRC to NMED responding to 04/20/90 NMED administrative order, providing analytical results of soil cores taken at NCL in July, 1989, and providing statistical analysis of the results.

New Mexico Bureau of Mines & Mineral Resources, 1990. July 6, 1990 letter from W. C. Haneberg, Engineering Geologist, submitting results of chemical and mechanical analysis of core samples collected at the NRC.

New Mexico Water Quality Control Commission, 1995. "Water Quality Standards for Interstate and Intrastate Streams in New Mexico". New Mexico Water Quality Control Commission, Santa Fe.

National Oceanic and Atmospheric Administration, 1982. "Monthly Normals of Temperature, Precipitation, and Heating and Cooling Degree Days, 1951-1980", Natural Climatic Data Center, Asheville, NC.

RE/SPEC, Inc., 1993. "RCRA Facility Investigation Work Plan (Revised) North Colony Landfarm, Navajo Refining Company Artesia, New Mexico", Amended 3/94, submitted to New Mexico Environment Department, Santa Fe, 100 p.

Ravi, V., and J. Johnson. 1990. “VLEACH, A One-Dimensional Finite Difference Vadose Zone Leaching Model”, USEPA Region IX.

RE/SPEC Inc., 1994. “Volume I, RCRA Facility Investigation, North Colony Landfarm, Navajo Refinery, Artesia, New Mexico”, Topical Report RSI-0537, Prepared for Navajo refining Company, Artesia, New Mexico.

RE/SPEC, Inc., 1994. “RCRA Facility Investigation, North Colony Landfarm, Navajo Refining Company Artesia, New Mexico.” Topical Report RSI-0537, Prepared for submittal to New Mexico Environment Department, Santa Fe, July.

RE/SPEC, Inc., 1995. “RCRA Facility Investigation Phase I & II Work Plan (Revised), North Colony Landfarm, Navajo Refining Company Artesia, New Mexico.” Prepared for submittal to New Mexico Environment Department, Santa Fe, February.

Shomaker, J. W. Inc., 1990. “North Colony Landfarm - Alternative Source Demonstration, Navajo Refining Company”, April 9 Submittal to NM Environmental Improvement Division, Santa Fe, NM, 23p.

Shomaker, J. W. Inc., 1990. “Report of Investigation and Monitoring Work Completed at the TEL and North Colony Landfarm Sites From June 14 to 19, 1990”, Submittal to Navajo Refining Company, Artesia, NM, July 24.

U.S. Department of Agriculture Soil Conservation Service, 1971. “Soil Survey Eddy County Area”, New Mexico, U.S. Government Printing Office, Washington, DC.

USEPA, 1980. "Methodology to Evaluate the Potential for Ground Water Contamination from Geothermal Fluid Releases", Industrial Environmental Research Laboratory, Office of Research and Development, U.S. Environmental Protection Agency, Cincinnati, Ohio.

USEPA, 1988. "Superfund Exposure Assessment Manual", Office of Remedial Response, Washington, D.C.

USEPA, 1989. "Statistical Analysis of Ground-Water Monitoring Data at RCRA Facilities, Interim Final Guidance". Office of Solid Waste Management Division, USEPA, Washington, D.C.

Welder, G. E., 1983. "Geohydrologic Framework of the Roswell Ground-Water Basin, Chaves and Eddy Counties, New Mexico", USGS Technical Report 42, University of New Mexico Printing Plant, Socorro, NM.

Zheng C., 1990. "MT3D, A Modular Three-Dimensional Transport Model for Simulation of Advection, Dispersion, and Chemical Reaction of Contaminants in Groundwater Systems", USEPA, Robert S. Kerr Environmental Research Laboratory, Ada, Oklahoma.

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Appendix A

Appendix A

APPENDIX A

PHOTOGRAPHIC LOGS

RFI Phase I Photographs, 1994
(found on following pages A-2 to A-5)

Photograph	Description
A-1	Observation Trench A, 5 ft sample interval locations TRA-5A and TRA-5B
A-2	Observation Trench A, 7 ft sample interval locations TRA-7A and TRA-7B, and 9 ft sample interval locations TRA-9A and TRA-9B
A-3	Observation Trench B, 5 ft sample interval locations TRB-5A and TRB-5B
A-4	Observation Trench B, 7 ft sample interval locations TRB-7A and TRB-7B, and 9 ft sample interval locations TRB-9A and TRB-9B, April 1994.
A-5	Observation Trench C, 5 ft sample interval locations TRC-5A and TRC-5B, April 1994
A-6	Observation Trench C, 7 ft sample interval locations TRC-7A and TRC-7B, and 9 ft sample interval locations TRC-9A and TRC-9B.
A-7	Observation Trench D, 5 ft sample interval location TRD-5C. Note hydrocarbon staining associated with unidentified buried structure.
A-8	Observation Trench D 5 ft sample interval locations TRD-5A and TRD-5B.
A-9	Observation Trench D, 7 ft sample interval location TRD-7C and 9 ft sample interval location TRD-9C.
A-10	Observation Trench D, 7 ft sample interval locations TRD-7A and TRD-7B, and 9 ft sample interval locations TRD-9A and TRD-9B.
A-11	Oily soils and debris excavated at location of unidentified buried structure in NCL landfarm cell D.
A-12	NCL D-1 deep boring, brown and white clayey sand with carbonate seams (20-24 ft), silty clay below
A-13	NCL D-1 deep boring, brown dry hard clay, collected in the clay interval from 69 to 87.5 ft
A-14	NCL D-1 deep boring, close-up of clay in photograph A-13

Photo A-1

Photo A-2

Photo A-3

Photo A-4

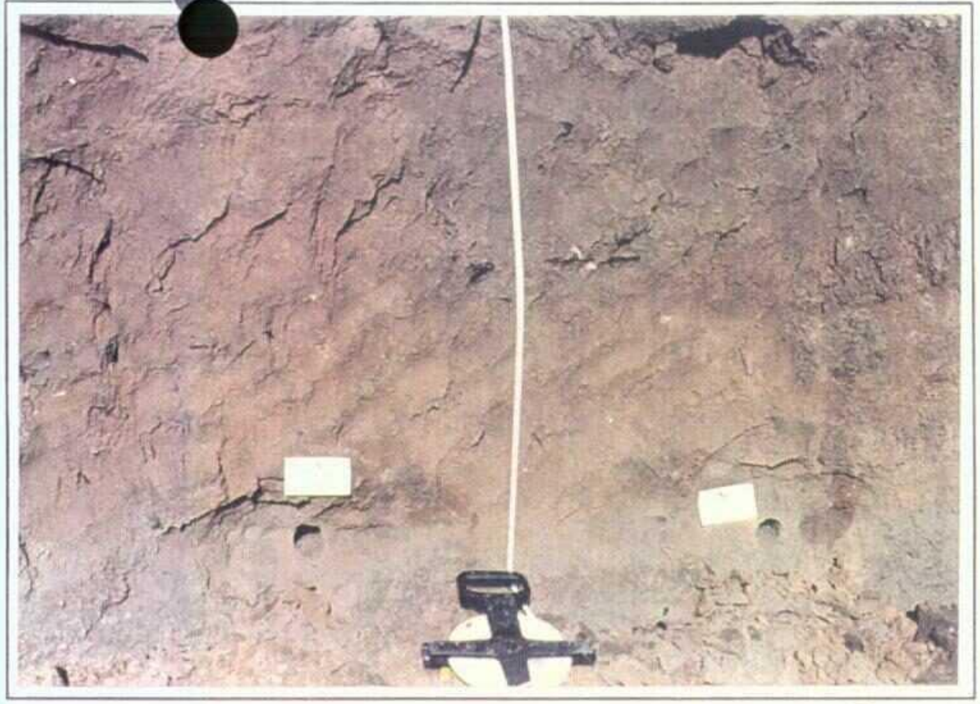
Photo A-5

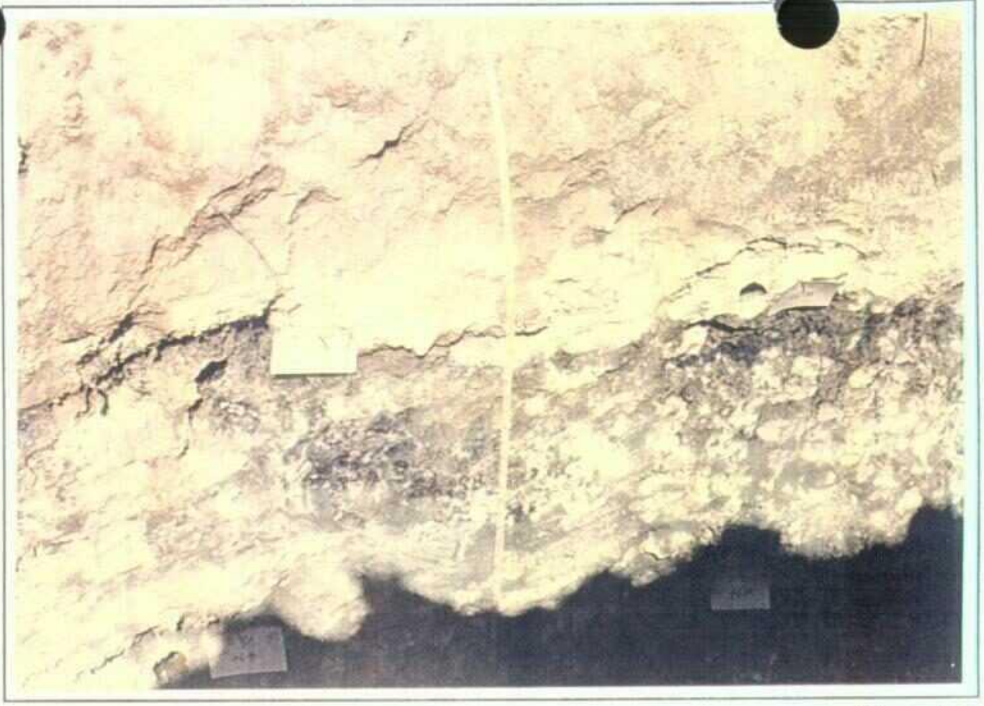
Photo A-6


Photo A-7


Photo A-8

Photo A-9

Photo A-10

Photo A-11

Photo A-12

Photo A-13

Photo A-14

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Photograph A-15: North Colony Landfarm soil sampling location, view southeast, refinery North Division process area in background

Photograph A-16: Boring 97-B1, Overview

Photograph A-17: Boring 97-B1, left 2-5 ft.; right 0-1 ft.

Photograph A-18: Boring 97-B1, left 8-10 ft.; right 5-8 ft.

Photograph A-19: Boring 97-B1, left 13-15 ft.; right 10-13 ft.

Photograph A-20: Boring 97-B2, Overview

Photograph A-21: Boring 97-B2, left, 3-5 ft.; right, 0-3 ft.

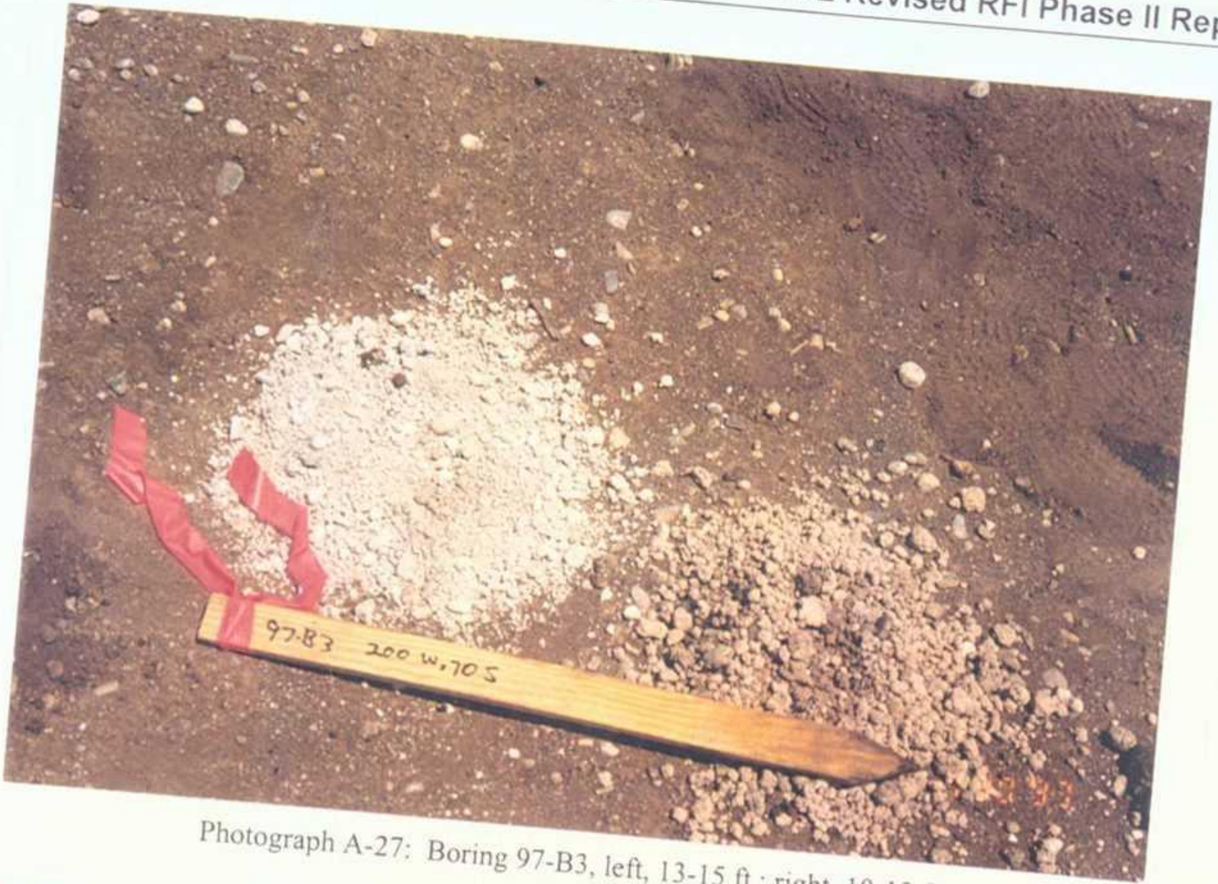
Photograph A-22: Boring 97-B2, left, 8-10 ft.; right, 5-8 ft.

Photograph A-23: Boring 97-B2, left, 13-15 ft.; right, 10-13 ft.

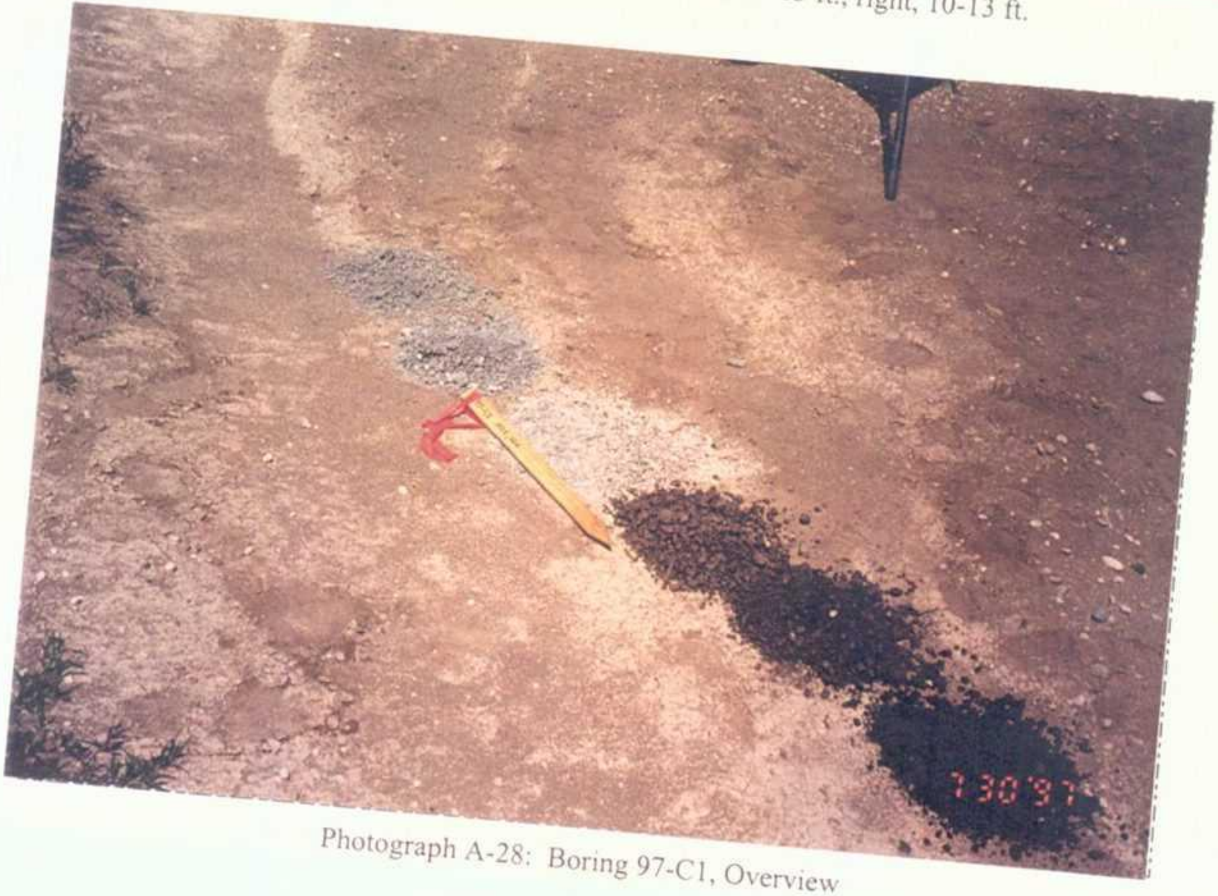
Photograph A-24: Boring 97-B2, Splitspoon, left, 17 ft.; right, 15 ft.

Photograph A-25: Boring 97-B3, Overview

Photograph A-26: Boring 97-B3, left, 8-10 ft.; right, 5-8 ft.



Photograph A-27: Boring 97-B3, left, 13-15 ft.; right, 10-13 ft.



Photograph A-28: Boring 97-C1, Overview

Photograph A-29: Boring 97-C1, left, 5-8 ft.; center, 2-5 ft.; right, 0-2 ft.

Photograph A-30: Boring 97-C1, far left, 10-13 ft.; left, 8-10 ft.; right, 5-8 ft.; far right 2-5 ft.

Photograph A-31: Boring 97-C1, left, 13-15 ft.; right, 10-13 ft.

Photograph A-32: Boring 97-C2, Overview

Photograph A-33: Boring 97-C2, left, 2-5 ft.; right, 0-2ft.

Photograph A-34: Boring 97-C2, left, 9-13 ft.; center, 7-9 ft.; right, 5-7 ft.

Photograph A-35: Boring 97-C2, left, 13-15 ft.; right, 9-13 ft.

Photograph A-36: Boring 97-D1, Overview

Photograph A-37: Boring 97-D1, left, 5-7 ft.; center, 2-5 ft.; right, 0-2 ft.

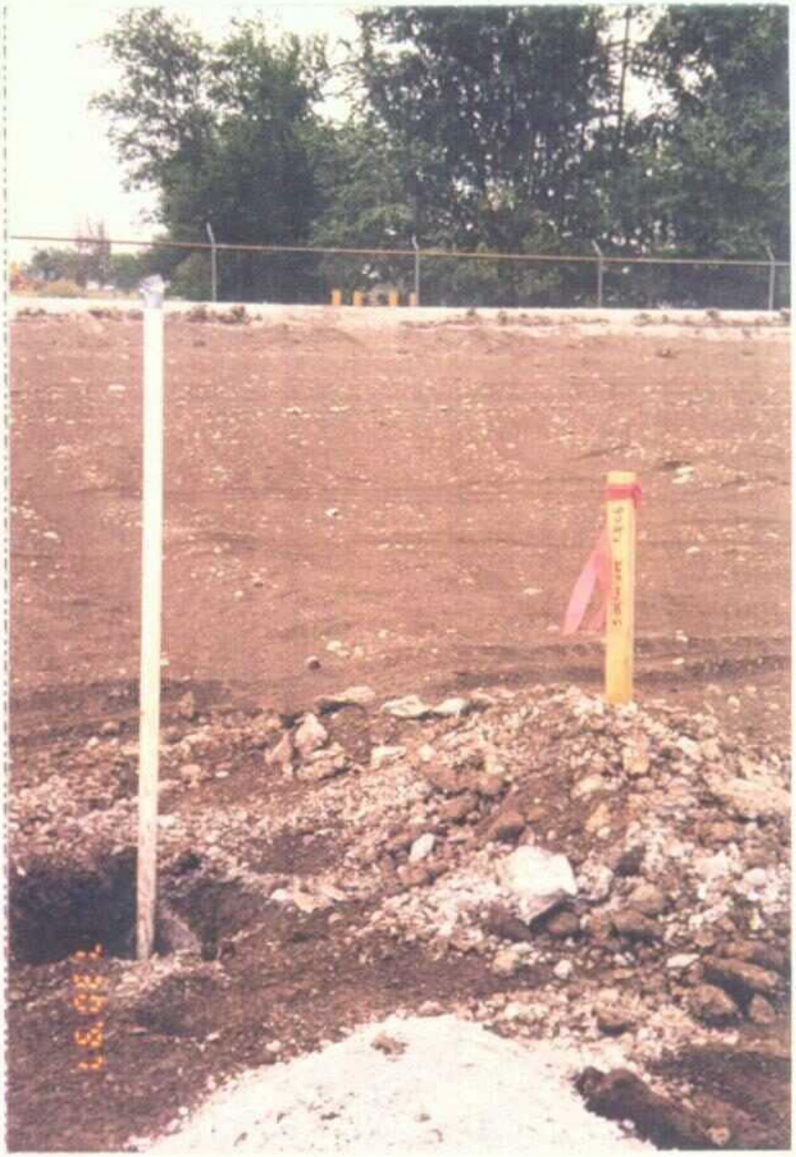
Photograph A-38: Boring 97-D1, left, 12-15 ft.; center, 10-12 ft.; right, 7-10 ft.

Photograph A-39: Boring 97-D1, Splitspoon; left 17 ft; right, 15 ft.

Photograph A-40: Boring 97-D2, Overview

Photograph A-41: Boring 97-D2, left, 5-7 ft.; center, 2-5 ft.; right, 0-2 ft.

Photograph A-42: Boring 97-D2, left top, 14-15.5 ft.; left bottom, 12-14 ft.; center, 10-12 ft.; right top, 9-10 ft.; right bottom, 7-8 ft.



Photograph A-43: Temporary well installation at 97-B3,
NCL-44 in background

Photograph A-44: Boring BG 97-05, left, 7 ft.; right, 9 ft.

Photograph A-45: Boring BG 97-05, left, 9 ft.; right, 11 ft.

Photograph A-46: Background soil sampling location, view south, NCL and above-ground storage tank area in background.

Photograph A-47: Background soil sampling location, view southwest, NCL in background

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Appendix B

Appendix B

APPENDIX B

LITHOLOGIC LOGS

APPENDIX B1

RFI PHASE I SHALLOW BORING LITHOLOGIC LOGS

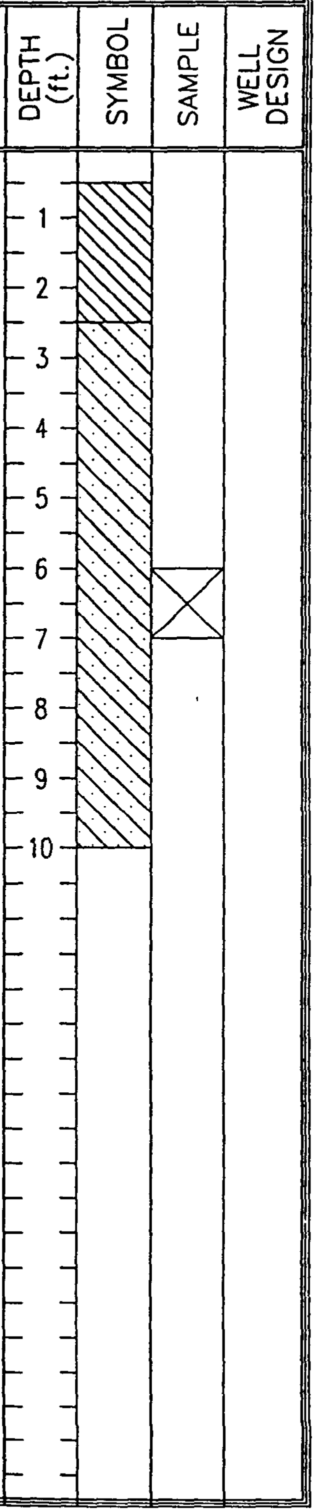
BORING LOG

PROJECT: 622093002-252 (NR-A11)
CLIENT: Navajo Refinery
BORING NUMBER: A-11
EXCAVATED POND:
FIRST ENCOUNTERED WATER:
DATE COMPLETED: 05/09/94

SHEET: 1 of 1
DRILLED BY: Precision Eng.
LOGGED BY: PWC
SURF. ELEV:
TOTAL DEPTH: 10'

DESCRIPTION

0-0.5'	Waste Residual Layer
0.5-2.5'	CLAY, black hydrocarbon discoloration grading to grey with depth, slightly moist, stiff, strong hydrocarbon odor weakens with depth.
2.5-10.0'	CLAYEY SAND, light brown, dry, dense, no hydrocarbon odor - some white mottling (caliche) from 8-10' - percent sand increases with depth



KWBES

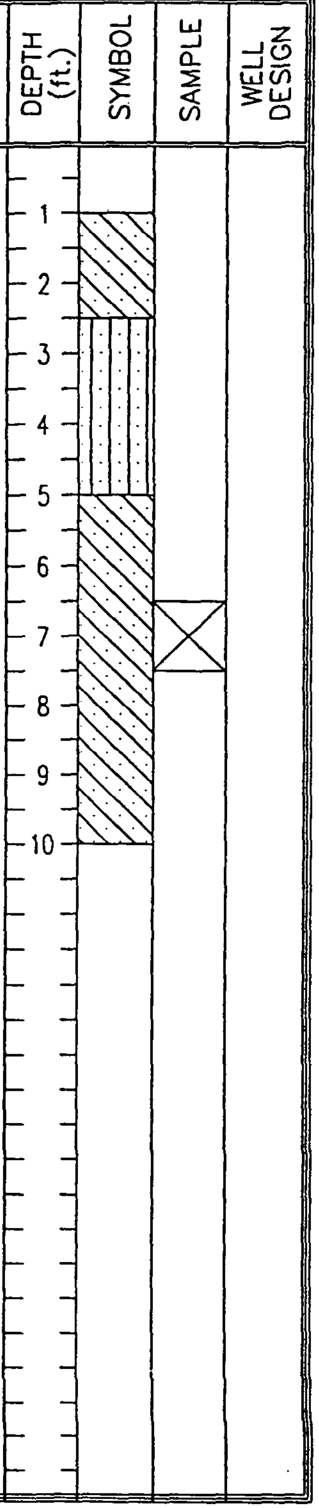
BORING LOG

PROJECT: 622093002-252 (NR-A12)
CLIENT: Navajo Refinery
BORING NUMBER: A-12
EXCAVATED POND:
FIRST ENCOUNTERED WATER:
DATE COMPLETED: 05/09/94

SHEET: 1 of 1
DRILLED BY: Precision Eng.
LOGGED BY: PWC
SURF. ELEV:
TOTAL DEPTH: 10.0'

DESCRIPTION

0-1.0'	Waste Residual Layer
1.0-2.5'	CLAYEY SAND, brown with grey hydrocarbon discoloration, slightly moist, dense, strong hydrocarbon odor weakens with depth.
2.5-5.0'	SITLY SAND, tan, dry, dense, no hydrocarbon odor.
5.0-10.0'	CLAYEY SAND, light brown with white mottling, dry, dense. -white mottling increases with depth -caliche pebbles noted near 7.0'



KWBES

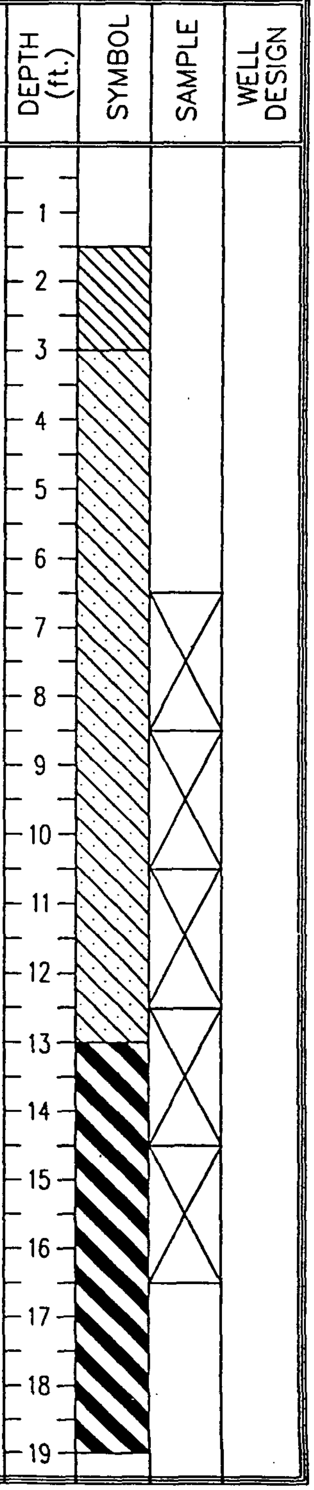
BORING LOG

PROJECT: 62209302.252 (A13)
CLIENT: Navajo Refinery
BORING NUMBER: A13
EXCAVATED POND:
FIRST ENCOUNTERED WATER:
DATE COMPLETED: 05/10/94

SHEET: 1 of 1
DRILLED BY: Precision Eng.
LOGGED BY: PWC
SURF. ELEV:
TOTAL DEPTH: 19.0'

DESCRIPTION

0–1.5'	Waste Residual Layer.
1.5–3.0'	CLAY, black hydrocarbon discoloration grading to grey, slightly moist, stiff, strong hydrocarbon odor weakens with depth.
3.0–13.0'	CLAYEY SAND, light grey to light brown, slightly moist, dense, no hydrocarbon odor.
13.0–19.0'	CLAY, grey with small pockets of fine white sand, hydrocarbon odor noted, slightly moist, stiff. – caliche gravel seams noted between 15.0' and 18.0' – gravel 1/2–1.0" diameter – gravel seams are pathway for contaminant – no hydrocarbon odor from 18.0' to 19.0'



KWBES

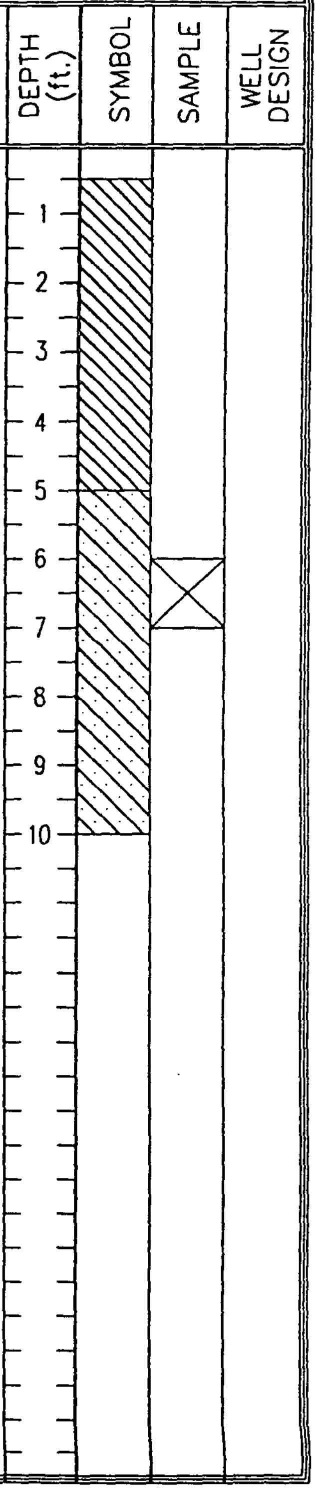
BORING LOG

PROJECT: 62209302.252 (A14)
CLIENT: Navajo Refinery
BORING NUMBER: A14
EXCAVATED POND:
FIRST ENCOUNTERED WATER:
DATE COMPLETED: 05/10/94

SHEET: 1 of 1
DRILLED BY: Precision Eng.
LOGGED BY: PWC
SURF. ELEV:
TOTAL DEPTH: 10.0'

DESCRIPTION

0-0.5'	Waste Residual Layer.
0.5-2.5'	SANDY CLAY, black hydrocarbon discoloration grading to grey with depth, slightly moist, stiff, strong hydrocarbon odor weakens with depth.
2.5-5.0'	SANDY CLAY, light brown, dry, stiff, no hydrocarbon odor.
5.0-10.0'	CLAYEY SAND, light brown to brown, slightly moist, stiff.



KWBES

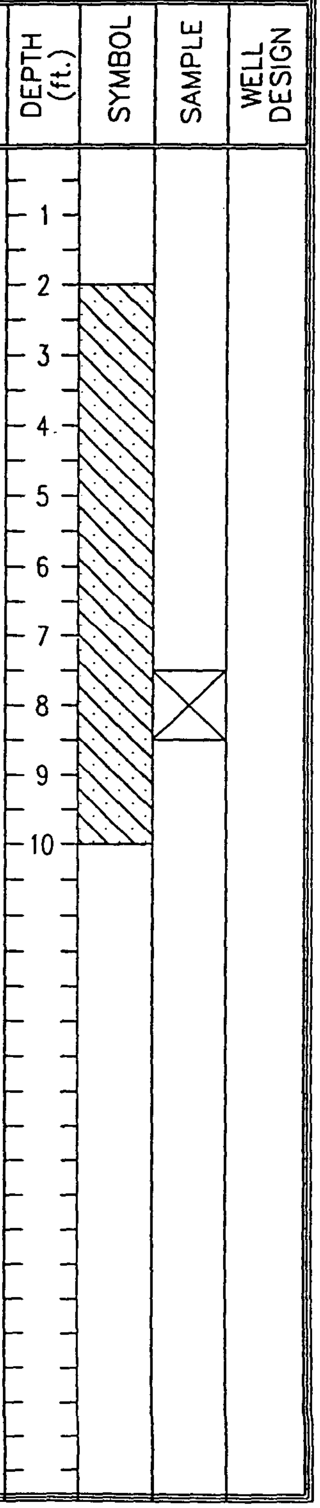
BORING LOG

PROJECT: 622093002-252 (NR-A15)
CLIENT: Novajo Refinery
BORING NUMBER: A-15
EXCAVATED POND:
FIRST ENCOUNTERED WATER:
DATE COMPLETED: 05/09/94

SHEET: 1 of 1
DRILLED BY: Precision Eng.
LOGGED BY: PWC
SURF. ELEV:
TOTAL DEPTH: 10'

DESCRIPTION

0-2.0'	Waste Residual Layer
2.0-10.0'	CLAYEY SAND, tan, slightly moist to dry, dense. -white mottling caused by carbonate replacement begins @ 4.0' and increases with depth.



KWBES

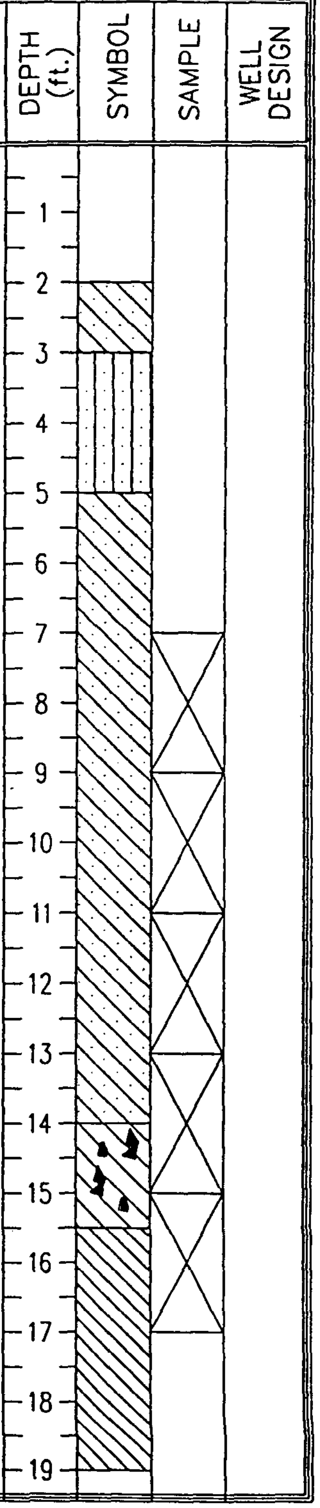
BORING LOG

PROJECT: 622093002-252 (NR-A16)
CLIENT: Navajo Refinery
BORING NUMBER: A-16
EXCAVATED POND:
FIRST ENCOUNTERED WATER:
DATE COMPLETED: 05/10/94

SHEET: 1 of 1
DRILLED BY: Precision Eng.
LOGGED BY: PWC
SURF. ELEV:
TOTAL DEPTH: 19.0'

DESCRIPTION

0-2.0'	Waste Residual Layer
2.0-3.0'	CLAYEY SAND, black hydrocarbon discoloration, slightly moist, dense, strong hydrocarbon odor weakens with depth.
3.0-5.0'	SILTY SAND, tan, dry, dense, no hydrocarbon odor. -white mottling (caliche)
5.0-14.0'	CLAYEY SAND, tan to brown, slightly moist, dense.
14.0-15.5'	CLAYEY GRAVEL, caliche gravel-sand-clay mix, moist, dense. -strong hydrocarbon odor and black discoloration
15.5-19.0'	SANDY CLAY, brown, slightly moist, firm to stiff. -no hydrocarbon odor or discoloration



KWBES

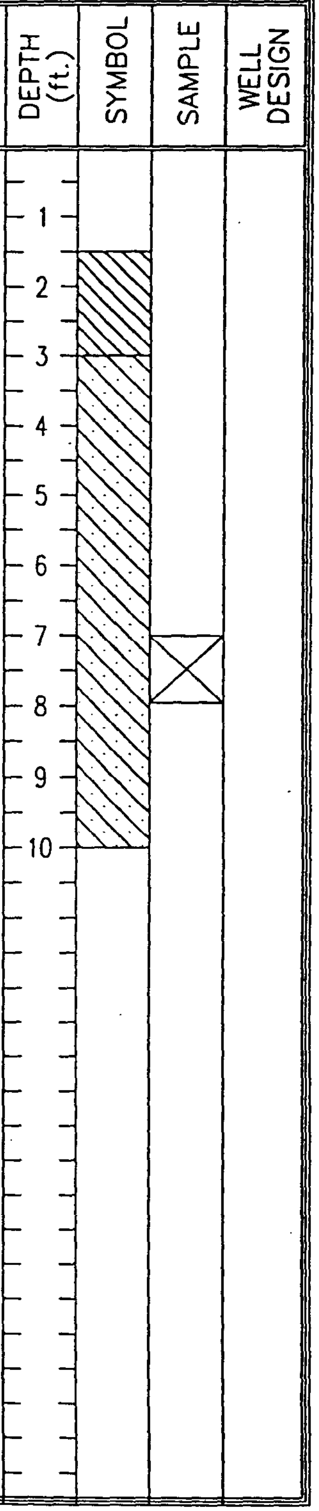
BORING LOG

PROJECT: 622093002-252 (NR-A17)
CLIENT: Novajo Refinery
BORING NUMBER: A-17
EXCAVATED POND:
FIRST ENCOUNTERED WATER:
DATE COMPLETED: 05/10/94

SHEET: 1 of 1
DRILLED BY: Precision Eng.
LOGGED BY: PWC
SURF. ELEV:
TOTAL DEPTH: 10.0'

DESCRIPTION

0-1.5'	Woter Residuol Layer
1.5-3.0'	CLAY, black hydrocarbon discoloration, slightly moist, stiff, strong hydrocarbon odor weakens with depth.
3.0-10.0'	CLAYEY SAND, brown to light brown, slightly moist to dry, dense, no hydrocarbon odor. -occasional small pockets of fine white sand -caliche pebbles noted from 5.0-10.0'



KWBES

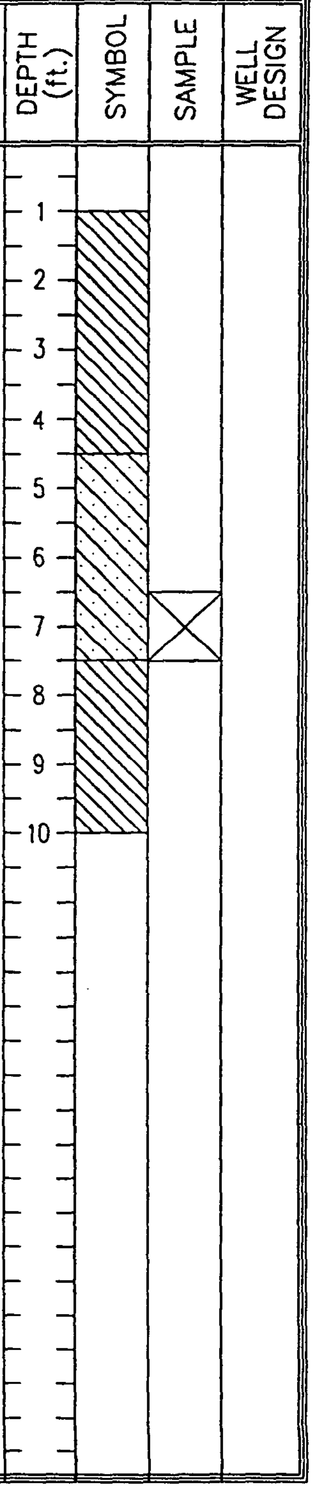
BORING LOG

PROJECT: 62209302.252 (B11)
CLIENT: Navajo Refinery
BORING NUMBER: B11
EXCAVATED POND:
FIRST ENCOUNTERED WATER:
DATE COMPLETED: 05/10/94

SHEET: 1 of 1
DRILLED BY: Precision Eng.
LOGGED BY: PWC
SURF. ELEV:
TOTAL DEPTH: 10.0'

DESCRIPTION

0-1.0'	Waste Residual Layer.
1.0-4.5'	CLAY, black hydrocarbon discoloration grading to natural brown color by 2.75', slightly moist, stiff, strong hydrocarbon odor weakens with depth.
4.5-7.5'	CLAYEY SAND, brown to light grey, dry to slightly moist, dense, no hydrocarbon odor.
7.5-10.0'	SANDY CLAY, light grey, dry, stiff - orange ferruginous staining noted - small caliche pebbles noted



KWBES

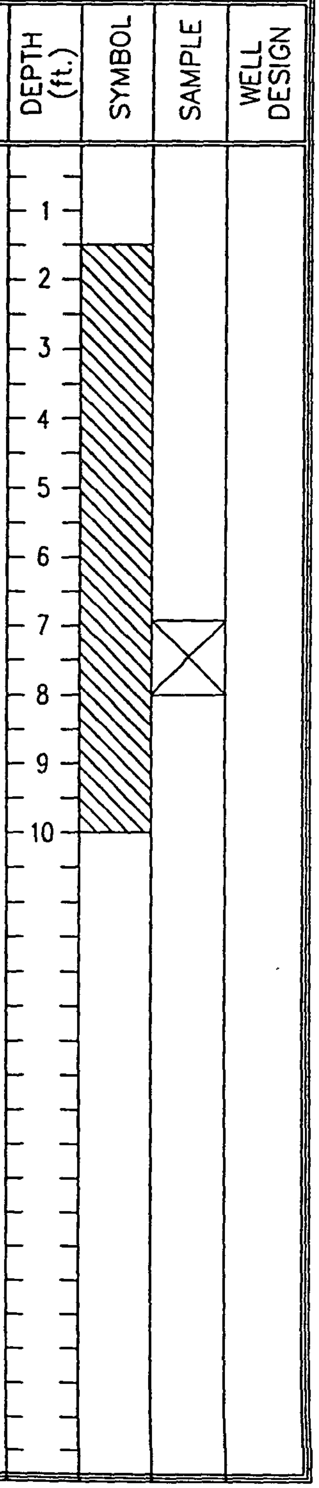
BORING LOG

PROJECT: 62209302.252 (B12)
CLIENT: Navajo Refinery
BORING NUMBER: B12
EXCAVATED POND:
FIRST ENCOUNTERED WATER:
DATE COMPLETED: 05/10/94

SHEET: 1 of 1
DRILLED BY: Precision Eng.
LOGGED BY: PWC
SURF. ELEV:
TOTAL DEPTH: 10.0'

DESCRIPTION

0-1.5'	Waste Residual Layer.
1.5-9.0'	CLAY, black hydrocarbon discoloration grading to natural brown color by 3.0', slightly moist to dry, stiff, strong hydrocarbon odor weakens with depth. - percent sand content increases with depth.
9.0-10.0'	CLAYEY SAND; light grey to light brown, slightly moist, dense, no hydrocarbon odor.



KWBES

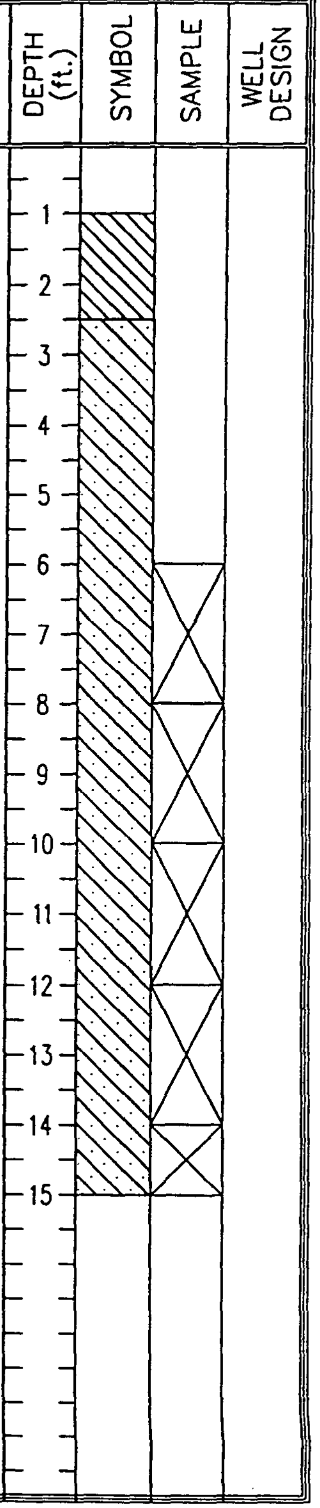
BORING LOG

PROJECT: 622093002-252 (NR-B13)
CLIENT: Navajo Refinery
BORING NUMBER: B-13
EXCAVATED POND:
FIRST ENCOUNTERED WATER:
DATE COMPLETED: 05/10/94

SHEET: 1 of 1
DRILLED BY: Precision Eng.
LOGGED BY: PWC
SURF. ELEV:
TOTAL DEPTH: 15.0'

DESCRIPTION

0-1.0'	Waste Residual Layer
1.0-2.5'	CLAY, black hydrocarbon discoloration, slightly moist, stiff, strong hydrocarbon odor weakens with depth.
2.5-3.5'	CLAYEY SAND, brown with grey hydrocarbon discoloration slightly moist, medium dense, weak hydrocarbon odor.
3.5-15.0'	CLAYEY SAND, brown, slightly moist, dense to very dense. -color changes to greenish grey between 7.0' and 9.5', no hydrocarbon odor -color change to grey with streaks of white carbonate sand form 11.0-15.0' -no hydrocarbons detected by visual or olfactory check



KWBES

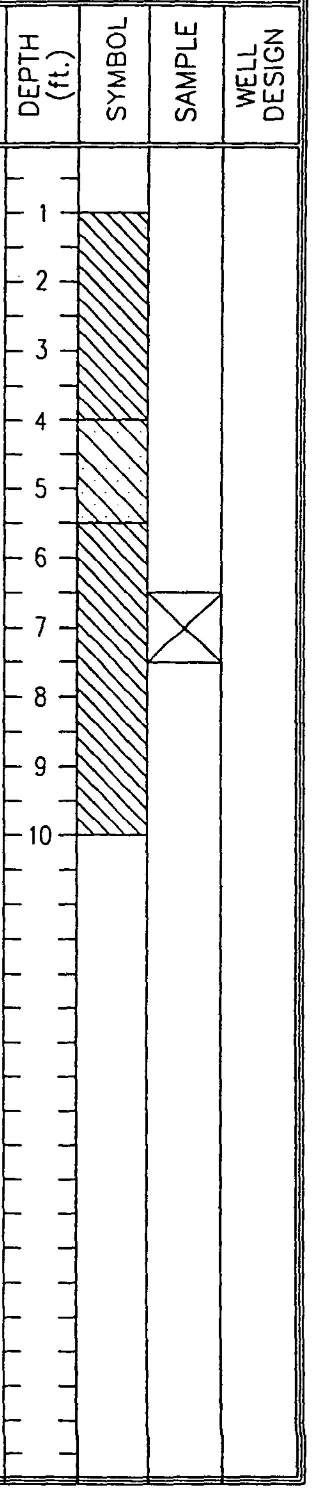
BORING LOG

PROJECT: 62209302.252 (B14)
CLIENT: Navajo Refinery
BORING NUMBER: B14
EXCAVATED POND:
FIRST ENCOUNTERED WATER:
DATE COMPLETED: 05/10/94

SHEET: 1 of 1
DRILLED BY: Precision Eng.
LOGGED BY: PWC
SURF. ELEV:
TOTAL DEPTH: 10.0'

DESCRIPTION

0–1.0'	Waste Residual Layer.
1.0–4.0'	CLAY/ SANDY CLAY, black hydrocarbon discoloration grading to light grey color, slightly moist, stiff, strong hydrocarbon odor weakens with depth.
4.0–5.5'	CLAYEY SAND, tan, slightly moist, dense, no hydrocarbon odor.
5.5–10.0'	SILTY/ SANDY CLAY, grey to greenish grey, stiff, slightly moist. – no hydrocarbon discoloration or odor



KWBES

BORING LOG

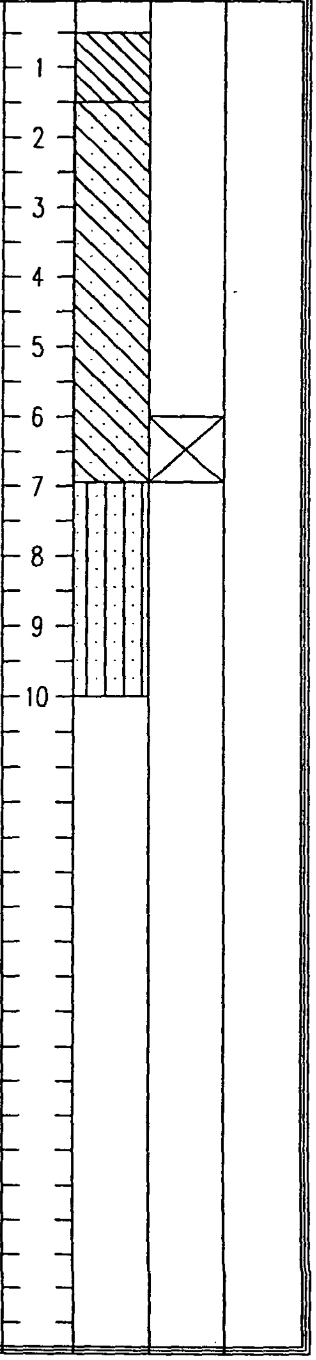
PROJECT: 622093002-252 (NR-C11)
CLIENT: Navajo Refinery
BORING NUMBER: C-11
EXCAVATED POND:
FIRST ENCOUNTERED WATER:
DATE COMPLETED: 05/11/94

SHEET: 1 of 1
DRILLED BY: Precision Eng.
LOGGED BY: PWC
SURF. ELEV:
TOTAL DEPTH: 10.0'

DESCRIPTION

0-0.5'	Waste Residual Layer
0.5-1.5'	CLAY, black hydrocarbon discoloration grading to grey with depth, slightly moist, stiff, strong hydrocarbon odor weakens with depth.
1.5-7.0'	CLAYEY SAND, brown with grey hydrocarbon discoloration mottling, dry, dense. -grey color lightens with depth
7.0-10.0'	SILTY SAND, grey hydrocarbon discoloration, dry, very dense, weak hydrocarbon odor. -carbonate replacement increases with depth

DEPTH (ft.) | SYMBOL | SAMPLE | WELL DESIGN



KWBES

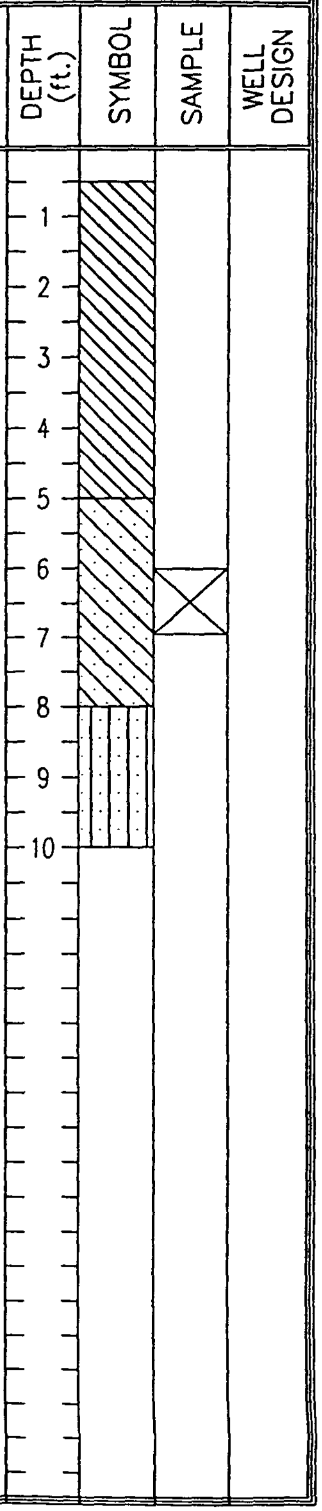
BORING LOG

PROJECT: 622093002-252 (NR-C12)
CLIENT: Navajo Refinery
BORING NUMBER: C-12
EXCAVATED POND:
FIRST ENCOUNTERED WATER:
DATE COMPLETED: 05/11/94

SHEET: 1 of 1
DRILLED BY: Precision Eng.
LOGGED BY: PWC
SURF. ELEV:
TOTAL DEPTH: 10.0'

DESCRIPTION

0-0.5'	Waste Residual Layer
0.5-5.0'	SANDY/SILTY CLAY, black hydrocarbon discoloration grading to grey with depth, slightly moist, stiff, strong hydrocarbon odor weakens with depth. -natural brown color noted from 4.5-5.0'
5.0-8.0'	SANDY CLAY, brown, slightly moist, stiff, no hydrocarbon odor. -milky white streaks of carbonate in column
8.0-10.0'	SILTY SAND, greenish grey hydrocarbon discoloration, dry, dense, moderate hydorcarbon odor.



KWBES

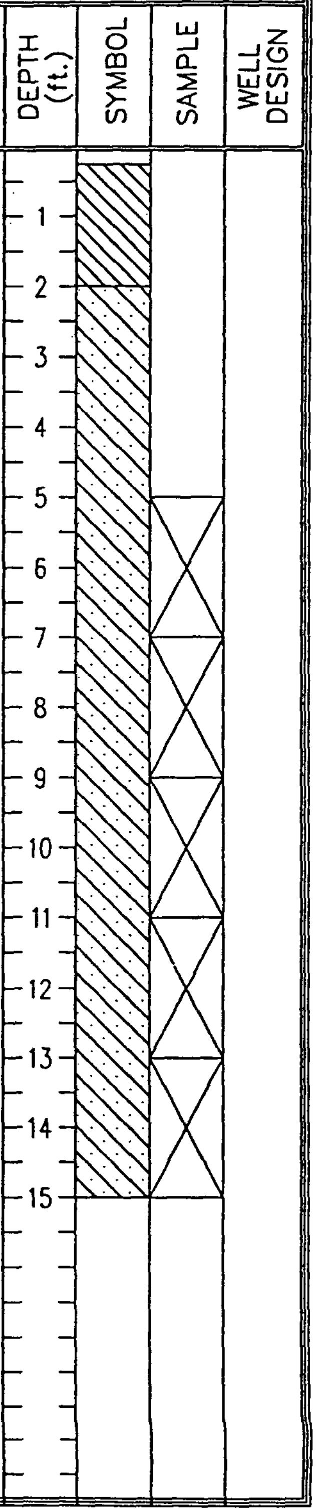
BORING LOG

PROJECT: 622093002-252 (NR-C13)
CLIENT: Navajo Refinery
BORING NUMBER: C-13
EXCAVATED POND:
FIRST ENCOUNTERED WATER:
DATE COMPLETED: 05/11/94

SHEET: 1 of 1
DRILLED BY: Precision Eng.
LOGGED BY: PWC
SURF. ELEV:
TOTAL DEPTH: 15.0'

DESCRIPTION

0-0.25'	Waste Residual Layer
0.25'-2.0'	CLAY, black hydrocarbon discoloration grading to grey with depth, slightly moist, stiff, strong hydrocarbon odor weakens with depth.
2.0-15.0'	CLAYEY SAND, grey hydrocarbon discolorations grading to dark grey with depth, dry, dense to very dense. -gypsum replacment starts @ 8.0' and increases with depth producing a milky white mottling -hydrocarbon odor initially weakens to 7.0' then increases in strength



KWBES

BORING LOG

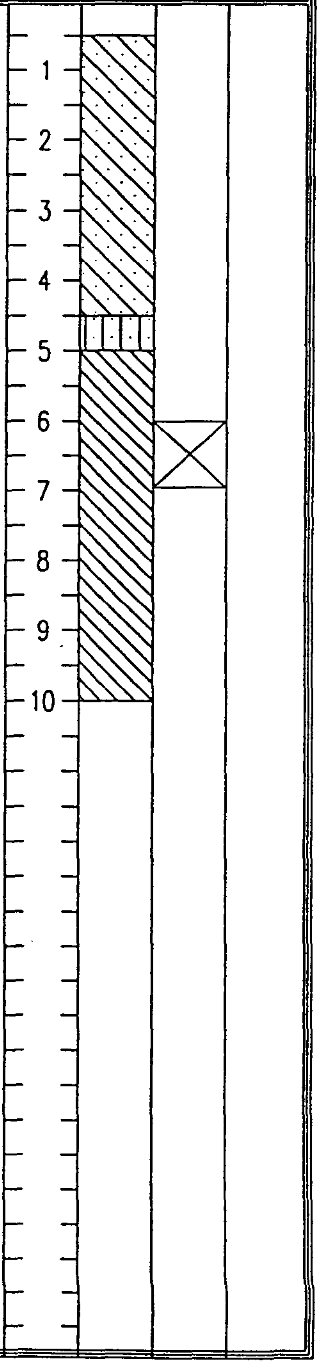
PROJECT: 622093002-252 (NR-C14)
CLIENT: Navajo Refinery
BORING NUMBER: C-14
EXCAVATED POND:
FIRST ENCOUNTERED WATER:
DATE COMPLETED: 05/11/94

SHEET: 1 of 1
DRILLED BY: Precision Eng.
LOGGED BY: PWC
SURF. ELEV:
TOTAL DEPTH: 10.0'

DESCRIPTION

DEPTH (ft.) | SYMBOL | SAMPLE | WELL DESIGN

0-0.5'	Waste Residual Layer
0.5-4.5'	CLAYEY SAND, black hydrocarbon discoloration grading to grey with depth, slightly moist, dense, strong hydorcarbon odor weakens with depth.
4.5-5.0'	SILTY SAND, light grey, dry, very dense, no hydrocarbon odor.
5.0-10.0'	SANDY CLAY, grey to light grey, dry, soft. -hydrocarbon odor detected @ 6.0' and increases in strength with depth



KWBES

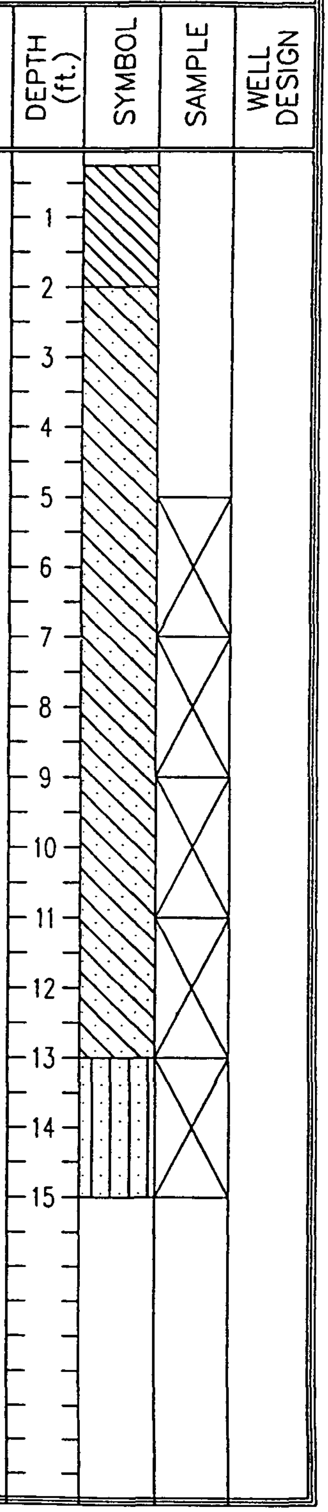
BORING LOG

PROJECT: 622093002-252 (NR-C15)
CLIENT: Navajo Refinery
BORING NUMBER: C-15
EXCAVATED POND:
FIRST ENCOUNTERED WATER:
DATE COMPLETED: 05/11/94

SHEET: 1 of 1
DRILLED BY: Precision Eng.
LOGGED BY: PWC
SURF. ELEV:
TOTAL DEPTH: 15.0'

DESCRIPTION

0-0.25'	Waste Residual layer
0.25'-2.0'	CLAY, black hydrocarbon discoloration grading to grey with depth, slightly moist, stiff, strong hydrocarbon odor weakens with depth.
2.0-5.0'	CLAYEY SAND, brown with grey hydrocarbon mottling, slightly moist, dense. -hydrocarbon discoloration and odor decreases initially with depth then increase towards 5.0'
5.0-13.0'	CLAYEY SAND, grey hydrocarbon discoloration, slightly moist, medium dense.
13.0-15.0'	SITLY SAND, grey hydrocarbon discoloration, dry, very dense. -carbonate replacement increases with depth, strong hydrocarbon odor



KWBES

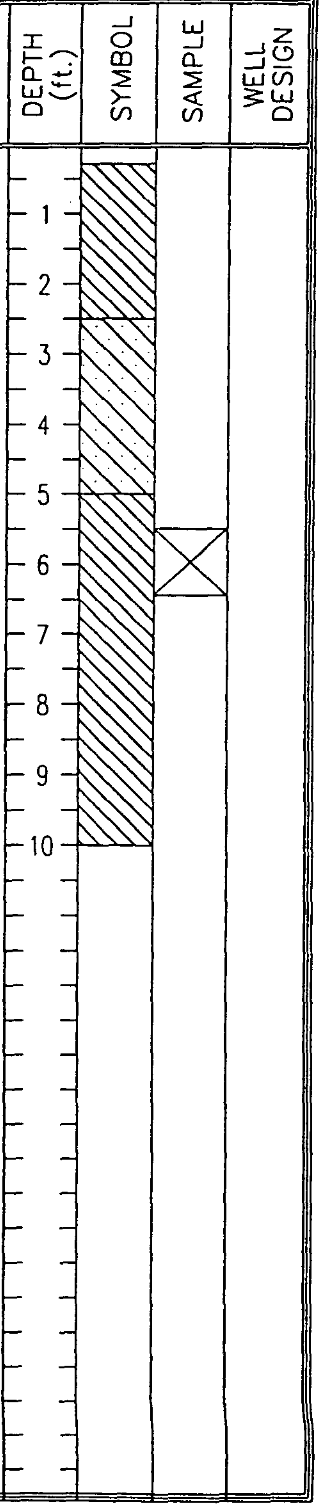
BORING LOG

PROJECT: 622093002-252 (NR-C16)
CLIENT: Navajo Refinery
BORING NUMBER: C-16
EXCAVATED POND:
FIRST ENCOUNTERED WATER:
DATE COMPLETED: 05/11/94

SHEET: 1 of 1
DRILLED BY: Precision Eng.
LOGGED BY: PWC
SURF. ELEV:
TOTAL DEPTH: 10.0'

DESCRIPTION

0-0.25'	Waste Residual Layer
0.25-2.5'	CLAY, black hydrocarbon discoloration grading to grey with depth, slightly moist, stiff, strong hydrocarbon odor weakens with depth.
2.5-5.0'	CLAYEY SAND, brown to light brown, dry, dense, no hydrocarbon odor.
5.0-10.0'	SILTY CLAY, greenish grey, slightly moist, stiff. -caliche replacement increases with depth giving a milky mottling to the clay



KWBES

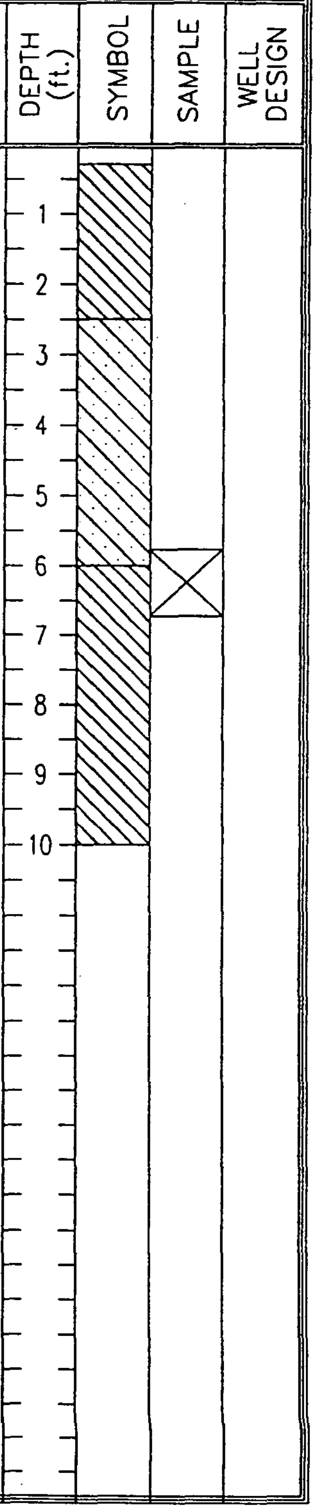
BORING LOG

PROJECT: 622093002-252 (NR-C17)
CLIENT: Navajo Refinery
BORING NUMBER: C-17
EXCAVATED POND:
FIRST ENCOUNTERED WATER:
DATE COMPLETED: 05/11/94

SHEET: 1 of 1
DRILLED BY: Precision Eng.
LOGGED BY: PWC
SURF. ELEV:
TOTAL DEPTH: 10.0'

DESCRIPTION

0-0.25'	Waste Residual Layer
0.25-2.5'	CLAY, black hydrocarbon discoloration grading to grey with depth, slightly moist, stiff, strong hydrocarbon odor weakens with depth.
2.5-4.5'	CLAYEY SAND, grey hydrocarbon discoloration, slightly moist, dense, weak hydrocarbon odor.
4.5-6.0'	CLAYEY SAND, brown, slightly moist, dense. -no hydrocarbon discoloration or odor
6.0-10.0'	SILTY/SANDY CLAY, greenish grey, slightly moist, stiff to soft. -caliche replacement increases with depth -hydrocarbon discoloration (black) and odor reappear @ 9.0' and increase with depth



KWBES

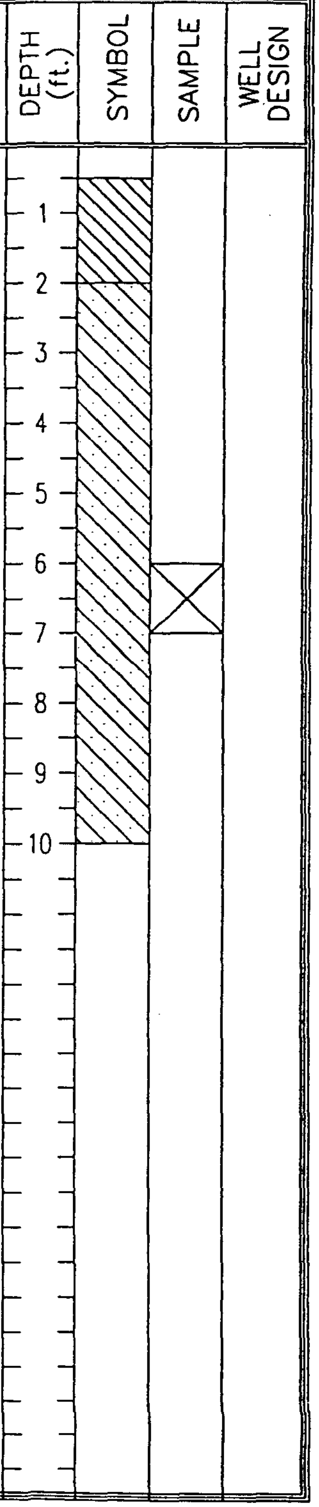
BORING LOG

PROJECT: 622093002-252 (NR-C18)
CLIENT: Navajo Refinery
BORING NUMBER: C-18
EXCAVATED POND:
FIRST ENCOUNTERED WATER:
DATE COMPLETED: 05/11/94

SHEET: 1 of 1
DRILLED BY: Precision Eng.
LOGGED BY: PWC
SURF. ELEV:
TOTAL DEPTH: 10.0'

DESCRIPTION

0–0.5'	Waste Residual Layer
0.5–2.0'	CLAY, black hydrocarbon discoloration grading to grey with depth, slightly moist, stiff to hard. -strong hydrocarbon odor weakens with depth
2.0–7.5'	CLAYEY SAND brown to light brown, dry, dense, no hydrocarbon odor.
7.5–10.0'	CLAYEY SAND, greenish grey, slightly moist, dense. -hydrocarbon odor begins @ 7.5' and strength increases with depth -gypsum replacement gives milky white streaking to clayey sand



KWBES

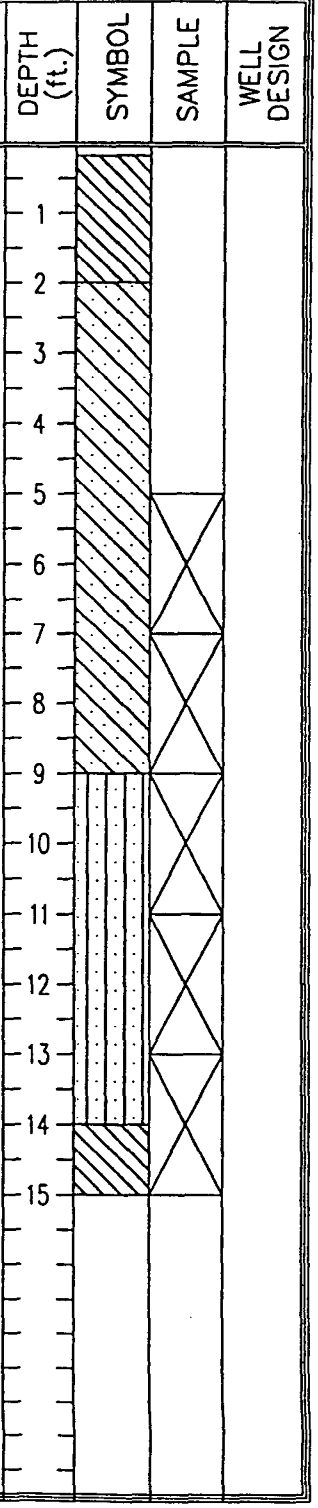
BORING LOG

PROJECT: 622093002-252 (NR-D11)
CLIENT: Navajo Refinery
BORING NUMBER: D-11
EXCAVATED POND:
FIRST ENCOUNTERED WATER:
DATE COMPLETED: 05/11/94

SHEET: 1 of 1
DRILLED BY: Precision Eng.
LOGGED BY: PWC
SURF. ELEV:
TOTAL DEPTH: 15.0'

DESCRIPTION

0-1"	Waste Residual Layer
1"-2.0'	CLAY, black hydrocarbon discoloration grading to grey with depth, moist, stiff, strong hydrocarbon odor.
2.0-9.0'	CLAYEY SAND, brown, dry to slightly moist, dense. -hydrocarbon odor weakens and disappears by 3.0' below grade
9.0-14.0'	SILTY SAND, light grey with milky white mottling, dry, dense. -carbonate replacement provides milky white color -mottling increases with depth
14.0-15.0'	SILTY CLAY, black and grey hydrocarbon discoloration, slightly moist, firm. -strong hydrocarbon odor



KWBES

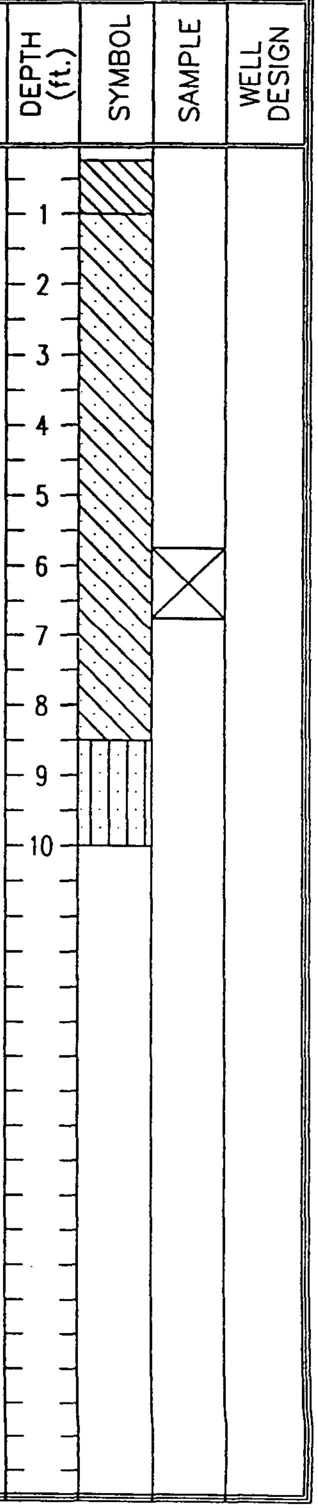
BORING LOG

PROJECT: 622093002-252 (NR-D12)
CLIENT: Navajo Refinery
BORING NUMBER: D-12
EXCAVATED POND:
FIRST ENCOUNTERED WATER:
DATE COMPLETED: 05/11/94

SHEET: 1 of 1
DRILLED BY: Precision Eng.
LOGGED BY: PWC
SURF. ELEV:
TOTAL DEPTH: 10.0'

DESCRIPTION

0-2"	Waste Residual Layer
2"-1.0'	CLAY, black hydrocarbon discoloration grading to grey with depth, slightly moist, stiff, strong hydrocarbon odor.
1.0-6.5'	CLAYEY SAND, brown with grey hydrocarbon mottling to 4.0' then brown, dry, dense. -hydrocarbon odor disappears below 4.0'
6.5-8.5'	CLAYEY SAND, grey hydrocarbon discoloration, dry, dense. -weak hydrocarbon odor
8.5-10.0'	SILTY SAND, light grey hydrocarbon discoloration, dry, very dense. -weak hydrocarbon odor -carbonate replacement noted



KWBES

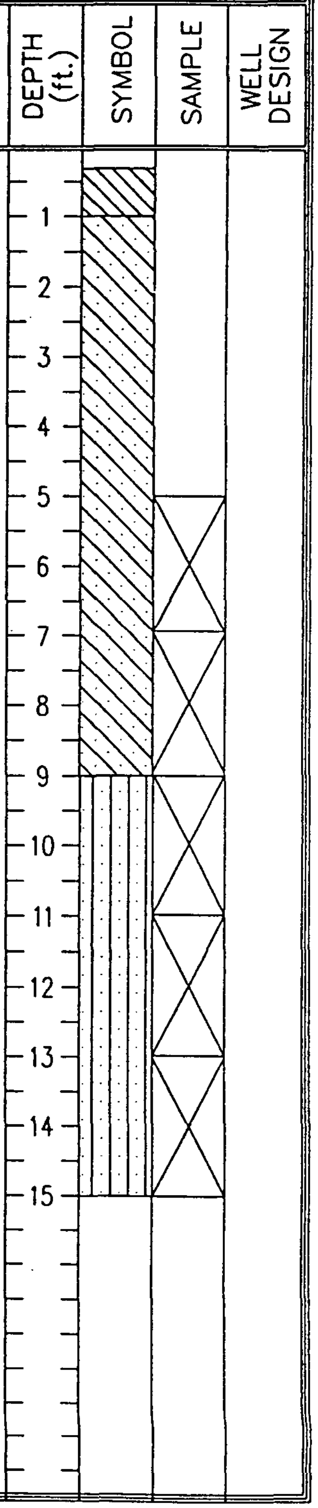
BORING LOG

PROJECT: 622093002-252 (NR-D14)
CLIENT: Navajo Refinery
BORING NUMBER: D-14
EXCAVATED POND:
FIRST ENCOUNTERED WATER:
DATE COMPLETED: 05/11/94

SHEET: 1 of 1
DRILLED BY: Precision Eng.
LOGGED BY: PWC
SURF. ELEV:
TOTAL DEPTH: 15.0'

DESCRIPTION

0-4"	Waste Residual Layer
4"-1.0'	CLAY, black hydrocarbon discoloration slightly moist, stiff, strong hydrocarbon odor weakens with depth.
1.0-5.0'	CLAYEY SAND, brown, slightly moist, dense. -no hydrocarbon odor detected until 4.0' then increases in strength with depth
5.0-9.0'	CLAYEY SAND, brown to 6.0' then grading into a grey hydrocarbon discoloration, dry, dense. -hydrocarbon odor strengthens with depth
9.0-10.0'	SILTY SAND, milky white to light grey, dry, very dense. -carbonate replacement provides milky white color -moderate hydrocarbon odor
10.0-15.0'	SILTY SAND, milky white and grey to 14.0' then greenish grey hydrocarbon discoloration, slightly moist, dense. -thin caliche pebble seam throughout column -hydrocarbon odor very strong near 15.0'



KWBES

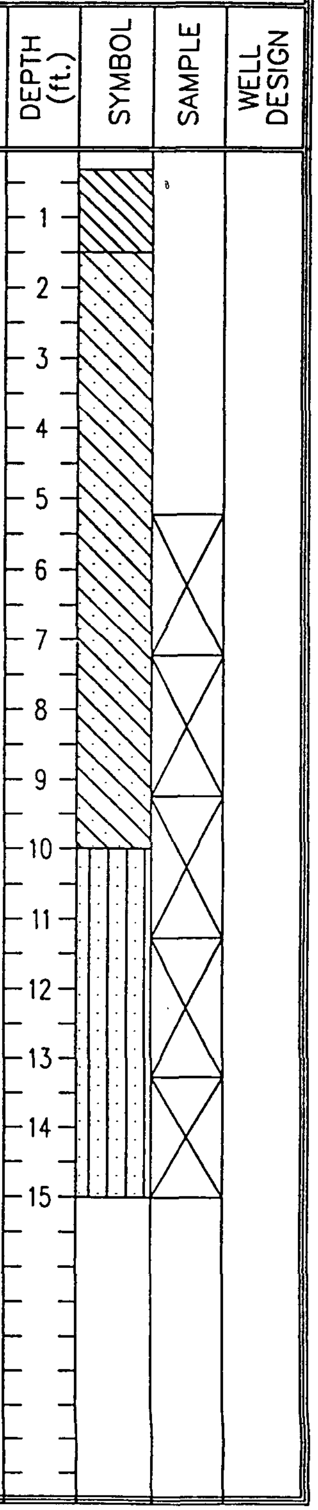
BORING LOG

PROJECT: 622093002-252 (NR-D15)
CLIENT: Navajo Refinery
BORING NUMBER: D-15
EXCAVATED POND:
FIRST ENCOUNTERED WATER:
DATE COMPLETED: 05/11/94

SHEET: 1 of 1
DRILLED BY: Precision Eng.
LOGGED BY: PWC
SURF. ELEV:
TOTAL DEPTH: 15.0'

DESCRIPTION

0-4"	Waste Residual Layer
4"-1.5'	CLAY, black hydrocarbon discoloration, slightly moist, stiff, strong hydrocarbon odor weakens with depth.
1.5-9.0'	CLAYEY SAND, brown to 6.0' then grey hydrocarbon discoloration dominates matrix, slightly moist, dense.
9.0-10.0'	CLAYEY/SILTY SAND, transition zone, grey hydrocarbon discoloration, dry, dense, moderate hydrocarbon odor. -carbonate replacement gives milky color mottling
10.0-15.0'	SILTY SAND, light grey hydrocarbon discoloration mottled with milky white carbonate seems, dry, very dense. -hydrocarbon odor strengthens with depth



KWBES

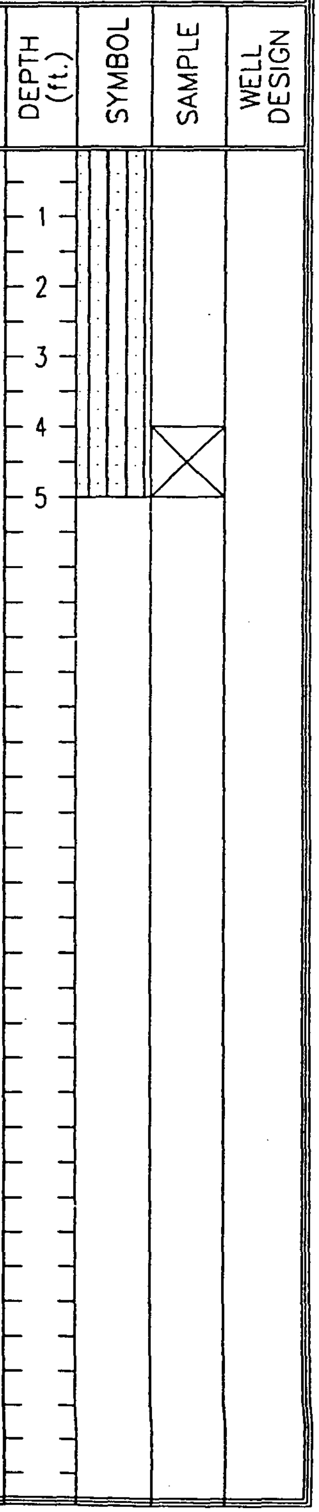
BORING LOG

PROJECT: 622093002-252 (NR-BG6)
CLIENT: Navajo Refinery
BORING NUMBER: BG-6
EXCAVATED POND:
FIRST ENCOUNTERED WATER:
DATE COMPLETED: 05/11/94

SHEET: 1 of 1
DRILLED BY: Precision Eng.
LOGGED BY: PWC
SURF. ELEV:
TOTAL DEPTH: 5.0'

DESCRIPTION

0-5.0' SITLY SAND, tan, dry, loose to dense.
-carbonate replacement starts @ 4.0'



KWBES

RE/SPEC INC.
RESEARCH / SPECIALISTS

SOIL BOREHOLE LOG

Page 1 of 1

PROJECT NO.: 327 LOGGED BY: DGB
CLIENT NAME: Navajo Refinery
APPROX. SURFACE ELEV.: 3363.54
DRILLING METHOD: Backhoe
FIELD COORDINATES: See map (Figure E-1)
GROUNDWATER: DEPTH N/A

BORING NO.: Trench 1
DATE: 6/21/94
DATE STARTED.: 6/21/94
DATE COMPLETED: 6/21/94
DATE/TIME: 10:15 - 11:02

DEPTH ( )	SAMPLE TYPE & NO.	BLOWS ON SAMPLER PER ( )	RECOVERY ( )	DESCRIPTION	USCS SYMBOL	MEASURED CONSISTENCY (TSF)	REMARKS
				0-1.5' surface soil and debris, brown clayey sand.	SC		
				1.5-5.5' clayey silt, brown moist at top, no odor.	ML		
5				5.5-8.5' silty clay, gray, occasional caliche pebbles, moist, strong hydrocarbon odor starting approx. 7 ft.	CL		
				Sample TR1-1 from backhoe bucket ~7-7.5 ft., 10:57 AM.			
10				Sample TR1-2 from backhoe bucket ~8-8.5 ft., 11:02 AM.			

R/S RE/SPEC INC.
RESEARCH SPECIALISTS

SOIL BOREHOLE LOG

Page 1 of 1

PROJECT NO.: 327 LOGGED BY: DGB
CLIENT NAME: Navajo Refinery
APPROX. SURFACE ELEV.: 3363.96
DRILLING METHOD: Backhoe
FIELD COORDINATES: See map (Figure E-1)
GROUNDWATER: DEPTH N/A

BORING NO.: Trench 2
DATE: 6/21/94
DATE STARTED.: 6/21/94
DATE COMPLETED: 6/21/94
DATE/TIME: 11:15 - 11:27

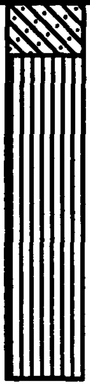
DEPTH ( )	SAMPLE TYPE & NO.	BLOWS ON SAMPLER PER ( )	RECOVERY ( )	DESCRIPTION	USCS SYMBOL	MEASURED CONSISTENCY (TSF)	REMARKS
				0-1.5' surface soil, brown clayey sand.	SC		▨
				1.5-5.5' clayey silt, brown moist at top, no odor.	ML		▥
5				5.5-9.4' silty clay, gray, occasional caliche pebbles, moist, odor and severe hydrocarbon staining approx. 8 ft. Sample TR2-1 from backhoe bucket ~9 ft., 11:27 AM.	CL		▧
10							

R/S RE/SPEC INC.
RESEARCH SPECIALISTS

SOIL BOREHOLE LOG

Page 1 of 1

PROJECT NO.: 327 LOGGED BY: DGB
CLIENT NAME: Navajo Refinery
BORING NO.: Trench 3
APPROX. SURFACE ELEV.: 3363.00
DATE: 6/21/94
DRILLING METHOD: Backhoe
DATE STARTED.: 6/21/94
FIELD COORDINATES: See map (Figure E-1)
DATE COMPLETED: 6/21/94
GROUNDWATER: DEPTH 10.2 ft.
DATE/TIME: 11:36 - 11:50

DEPTH ( )	SAMPLE TYPE & NO.	BLOWS ON SAMPLER PER ( )	RECOVERY ( )	DESCRIPTION	USCS SYMBOL	MEASURED CONSISTENCY (TSF)	REMARKS
				0-1.5' surface soil, brown clayey sand.	SC		
				1.5-5.5' clayey silt, brown slightly moist.	ML		
5				5-10.2' sandy silt grading to clayey silt, gray with caliche pebbles turning darker and moist with depth.			
				Strong hydrocarbon odor and darker gray beginning ~7.5 ft.			
10				Sample TR3-1 from backhoe bucket ~10 ft., 11:50 AM.			

RE/SPEC INC.
RESEARCH SPECIALISTS

SOIL BOREHOLE LOG

Page 1 of 1

PROJECT NO.: 327 LOGGED BY: DGB
CLIENT NAME: Navajo Refinery
APPROX. SURFACE ELEV.: 3364.09
DRILLING METHOD: Backhoe
FIELD COORDINATES: See map (Figure E-1)
GROUNDWATER: DEPTH N/A

BORING NO.: Trench 4
DATE: 6/21/94
DATE STARTED.: 6/21/94
DATE COMPLETED: 6/21/94
DATE/TIME: 13:10 - 13:37

DEPTH ( )	SAMPLE TYPE & NO.	BLOWS ON SAMPLER PER ( )	RECOVERY ( )	DESCRIPTION	USCS SYMBOL	MEASURED CONSISTENCY (TSF)	REMARKS
				0-1.5' surface soil, brown clayey sand.	SC		
5				1.5-6.4' clayey silt, brown, moist.	ML		
10				6.4-10.4' silty clay, gray with increasing sand and caliche pebbles/gravel with depth, stained hydrocarbon, gray, at ~9 ft. Sample TR4-1 from backhoe bucket ~10 ft., 1337. Strong hydrocarbon odor.	CL		

RE/SPEC INC.
RESEARCH SPECIALISTS

SOIL BOREHOLE LOG

Page 1 of 1

PROJECT NO.: 327 LOGGED BY: DGB
CLIENT NAME: Navajo Refinery
APPROX. SURFACE ELEV.: 3365.55
DRILLING METHOD: Backhoe
FIELD COORDINATES: See map (Figure E-1)
GROUNDWATER: DEPTH N/A

BORING NO.: Trench 5
DATE: 6/21/94
DATE STARTED.: 6/21/94
DATE COMPLETED: 6/21/94
DATE/TIME: 13:40 - 14:30

DEPTH ( )	SAMPLE TYPE & NO.	BLOWS ON SAMPLER PER ( )	RECOVERY ( )	DESCRIPTION	USCS SYMBOL	MEASURED CONSISTENCY (TSF)	REMARKS
				0-0.5' surface soil, debris. 0.5-6' sandy clay, brown. 6-11.4' silty clay, light brown with caliche pebbles. No hydrocarbon odor or stain seen. No sample collected.	SC		▨
5					ML		▨
10					CL		▨

RE/SPEC INC.
RESEARCH SPECIALISTS

SOIL BOREHOLE LOG

Page 1 of 1

PROJECT NO.: 327 LOGGED BY: DGB
CLIENT NAME: Navajo Refinery
APPROX. SURFACE ELEV.: 3354
DRILLING METHOD: Backhoe
FIELD COORDINATES: See map (Figure E-1)
GROUNDWATER: DEPTH N/A
BORING NO.: Trench 6
DATE: 6/21/94
DATE STARTED.: 6/21/94
DATE COMPLETED: 6/21/94
DATE/TIME: 14:37 - 15:00

DEPTH ( )	SAMPLE TYPE & NO.	BLOWS ON SAMPLER PER ( )	RECOVERY ( )	DESCRIPTION	USCS SYMBOL	MEASURED CONSISTENCY (TSF)	REMARKS
5 10				Surface to 11.75'- silty clay, yellowish brown, calcite (or gypsum) crystals seen in clay. Frequent pebbles increasing with depth. No hydrocarbon odor or staining seen. No sample collected.	CL		▨

APPENDIX B2

RFI PHASE I DEEP BORING LITHOLOGIC LOGS

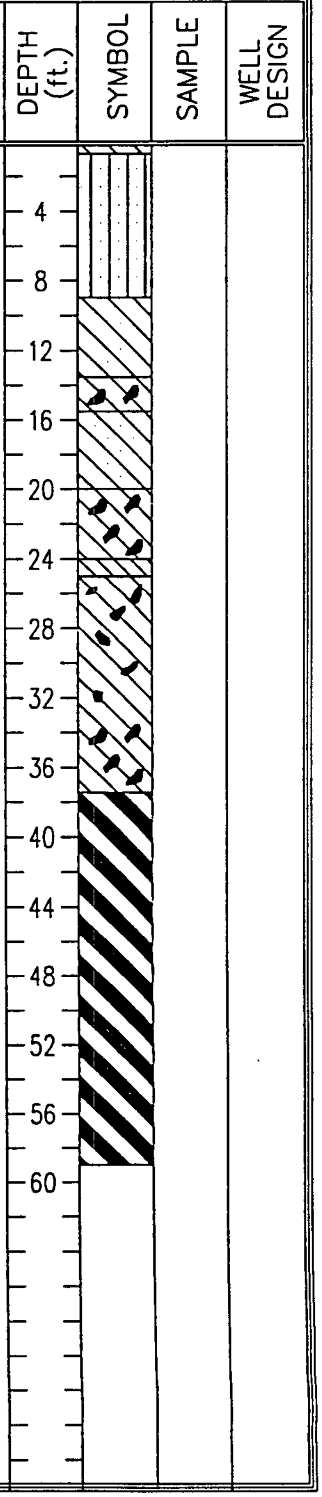
BORING LOG

PROJECT: 622093002-252 (NR-DB)
CLIENT: Navajo Refinery
BORING NUMBER: Deep Boring
EXCAVATED POND:
FIRST ENCOUNTERED WATER: 21.0'
DATE COMPLETED: 05/12/94

SHEET: 1 of 2
DRILLED BY: Precision Eng.
LOGGED BY: PWC
SURF. ELEV:
TOTAL DEPTH: 100'

DESCRIPTION

0-0.5'	Top Soil - brown clayey sand, roots and root systems, moist, dense.
0.5-9.0'	SITLY SAND, tan, dry, loose to medium dense. -carbonate replacement beginning @ 5.0' -milky white carbonate sands and pebbles increase in frequency with depth
9.0-13.5'	CLAYEY SAND, brown with milky white carbonate mottling, slightly moist, dense.
13.5-15.5'	CLAYEY SAND interbedded with carbonate gravels, brown and white with grey hydrocarbon motting associated with gravel seam, moist, medium dense sand. -gravel provides pathway for moisture -hydrocarbon smell moderate
15.5-20.0'	CLAYEY SAND, brown, moist to slightly moist, dense. -hydrocarbon odor disappears from soil @ 16.5'
20.0-24.0'	CLAYEY SAND interbedded with carbonate gravel seams, brown and white, very moist to saturated @ 21.0', dense.
24.0-25.0'	SITLY CLAY, brown, moist, firm.
25.0-37.5'	CLAY interbedded with carbonate gravel seams, clay is brown, gravel is white, clay is moist with saturation along gravel seams, clay is firm to stiff, gravel seams are typically less then 6" in thickness and interbedded with the clay between 1.0-2.0' intervals. -Note: saturated zones appear to be interconnected from 20.0-37.5'
37.5-59.0'	CLAY, brown, dry, very stiff. -occasionally carbonate pebbles and gravel are noted in the column, dry.



KWBES

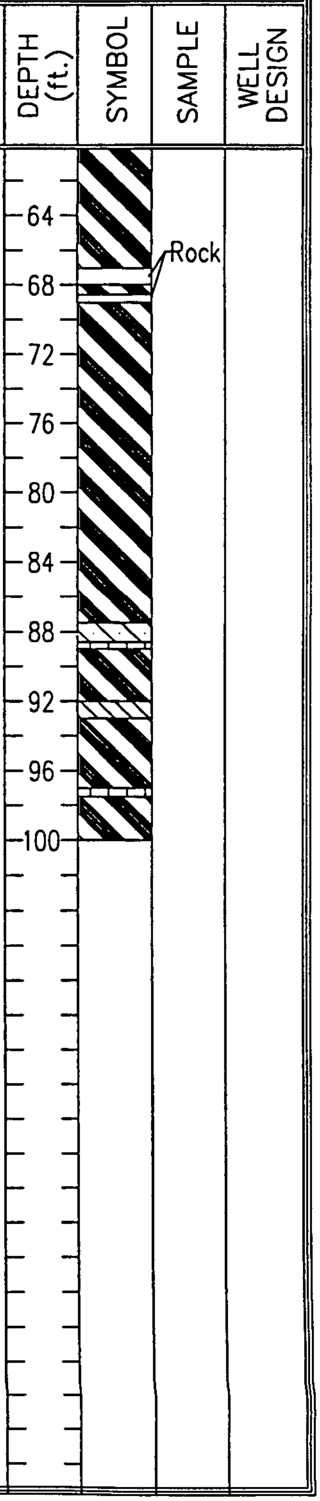
BORING LOG

PROJECT: 622093002-252 (NR-DB)
CLIENT: Navajo Refinery
BORING NUMBER: Deep Boring
EXCAVATED POND:
FIRST ENCOUNTERED WATER: 21.0'
DATE COMPLETED: 05/12/94

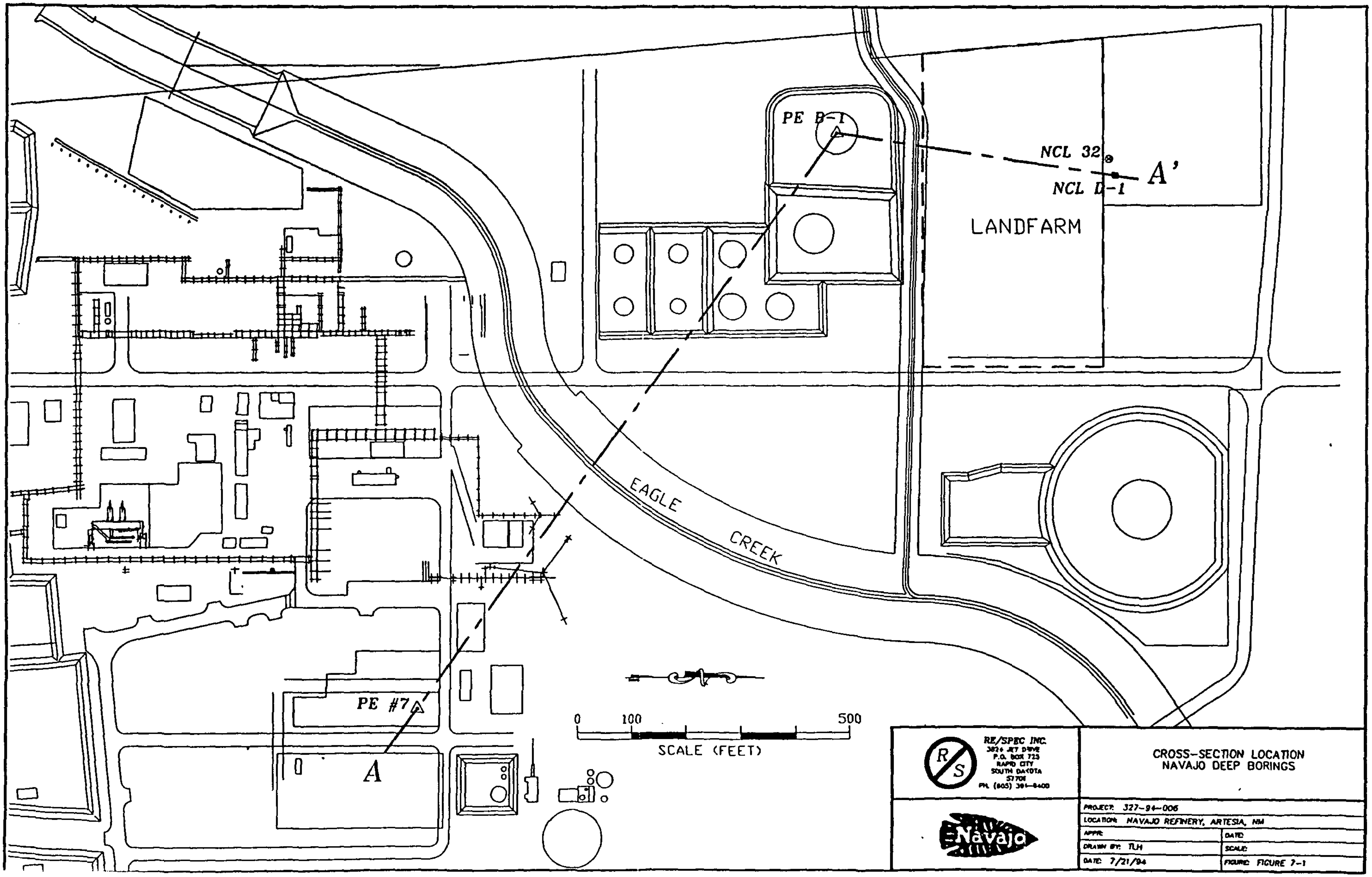
SHEET: 2 of 2
DRILLED BY: Precision Eng.
LOGGED BY: PWC
SURF. ELEV:
TOTAL DEPTH: 100'

DESCRIPTION

59.0-67.0'	CLAY, greenish grey grading to brown, dry, very hard. -occasionally carbonate pebbles noted in column, dry
67.0-68.0'	Carbonate Rock, white, auger refusal, drilled with bit, dry.
68.0-68.5'	CLAY, brown, dry, very hard.
68.5-69.0'	Carbonate Rock, white, auger refusal, drilled with bit, dry.
69.0-87.5'	CLAY, brown, dry, hard. -occasionally carbonate pebbles noted in column, dry
87.5-88.5'	CLAYEY SAND, brown, dry, very dense.
88.5-89.0'	SILTY SAND, brown, dry, very dense.
89.0-92.0'	CLAY, brown, dry, hard.
92.0-93.0'	SITLY CLAY, brown, slightly moist, firm.
93.0-97.0'	CLAY, brown, dry, hard.
97.0-97.5'	SILTY SAND, brown, slightly moist, very dense.
97.5-100.0'	CLAY, brown, dry, hard.



KWBES



RE/SPEC INC.
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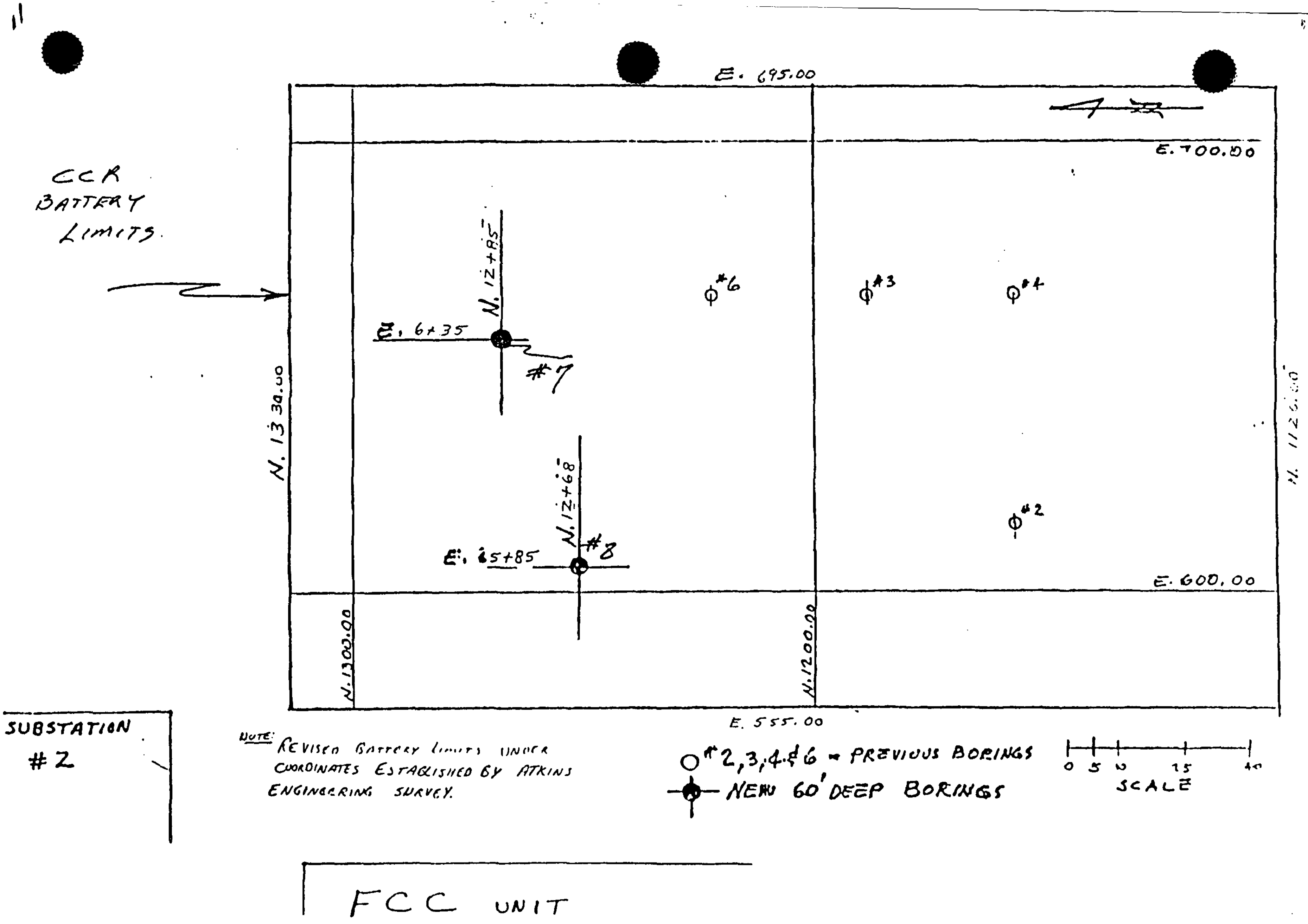
RAPID CITY
SOUTH DAKOTA
57701
PH. (605) 394-6400

CROSS-SECTION LOCATION
NAVAJO DEEP BORINGS

PROJECT: 327-94-006	
LOCATION: NAVAJO REFINERY, ARTESIA, NM	
APPR:	DATE:
DRAWN BY: TLH	SCALE:
DATE: 7/21/94	FIGURE: FIGURE 7-1



NOTE: REVISED BATTERY LIMITS UNDER COORDINATES ESTABLISHED BY ATKINS ENGINEERING SURVEY.

Precision Engineering Location Sketch Map for Boring PE #7 (Refer to Figure 7-1)

SHEET 1 OF 8 PRECISION ENGINEERING, INC. File No. 89-117

ing Location: SEE SITE PLAN LOG OF TEST BORINGS Location Artesia, NM

Elevation Existing

Boring Number: SEVEN Water Level 14.5 Date: 4/09/90

LAB #	DEPTH	BLOWS/N	PLOT	SCALE	SAMPLE	MATERIAL CHARACTERISTICS (MOISTURE,CONDITION,COLOR,GRAINSIZE,ETC.)	%M	LL	PI	CLASS.
	0.0 - 4.0		\-\			CLAY, SILTY, SOFT, MOIST, ORANGE BROWN TO DARK	11.4			
			\-\			BROWN, HYDROCARBON ODOR				
			\-\							
			\-\							
			\-\	2.5						
			\-\							
			\-\							
			\-\							
	4.0 - 7.0		\-\			CLAY, SILTY, FIRM, MOIST, BROWN w/WHITE GYPSI-				
			\-\	5		FEROUS MOTTLING, STRONG HYDROCARBON ODOR				
			\-\			GRADES FROM ABOVE INTO MOTTLED MATERIAL				
			\-\							
			\-\							
			\-\							
	7.0 - 12.0		\-\			CLAY, GREY TO BLACK, VERY STIFF, HYDROCARBON				
			\-\			ODOR, MOIST				
			\-\							
			\-\							
			\-\							
			\-\	10						
			\-\			BLUE-GRAY, HARD				
			\-\							
			\-\							
			\-\							
	12.0-13.0		o_o			SAND, SILTY, MODERATELY DENSE, BLUE-GREY,				
			o o			HYDROCARBON ODOR				
	13.0-19.0		\-\			CLAY, GREY TO BLUE, STIFF, HYDROCARBON ODOR				
			\-\			SCATTERED FINE GRAVEL				
			\-\							
			\-\	15						
			\-\							
			\-\							
			\-\							
			\-\							
			\-\							
			\-\							
			\-\			ENCOUNTERED HIGH MOISTURE CONDITIONS @ 19.0'				
			\-\			WET				
	19.0-50.0		\\\			CLAY, STIFF, BROWN TO PINK, WEAK CARBONATE				
			\\\	20		INDURATION (CCI 1 OR LESS), LESS CARBONATE				
			\\\			PRODUCES DARKER RED COLOR IN CLAY, WATER				
			\\\			BEARING TO APPROX 23'. WATER APPEARS PERCHED.				
			\\\							
			\\\							
			\\\							
			\\\							
			\\\							
			\\\			CONTINUED ON NEXT PAGE				
			\\\							

Size & Type of Boring: 5-5/8" OD Hollow Stemmed Auger Logged By: RJ

EET 2 OF 8 PRECISION ENGINEERING, INC. File No. 89-117

ring Location: SEE SITE PLAN

LOG OF TEST BORINGS

Location Artesia, NM

Elevation Existing

Boring Number: SEVEN

Water Level 14.5 Date: 4/09/90

LAB #	DEPTH	BLOWS/N	PLOT	SCALE	SAMPLE	MATERIAL CHARACTERISTICS (MOISTURE,CONDITION,COLOR,GRAINSIZE,ETC.)	%M	LL	PI	CLASS.
			\\\\	25		CARBONATE NODULES IN THE CLAY MATRIX APPEAR TO	11.4			
			\\\\			BE DERIVED AS THE RESULT OF A DEGRADING				
			\\\\			GEOMORPHIC SURFACE.				
			\\\\			CARBONATE INDURATION VARIES SIGNIFICANTLY BUT				
			\\\\			GENERALLY HAS CCI OF 1 TO 2 WHERE PRESENT.				
			\\\\			INDURATED ZONES ARE .25 TO 1 FOOT THICK. MORE				
			\\\\			COMMONLY .25'.				
			\\\\	30						
			\\\\	35						
			\\\\	40						
			\\\\	45						
			\\\\			CONTINUED ON NEXT PAGE				

SHEET 3 OF 8

PRECISION ENGINEERING, INC.

File No. 89-117

Boring Location: SEE SITE PLAN

LOG OF TEST BORINGS

Location Artesia, NM

Elevation Existing

Boring Number: SEVEN

Water Level 14.5 Date: 4/09/90

LAB #	DEPTH	BLOWS/N	PLOT	SCALE	SAMPLE	MATERIAL CHARACTERISTICS (MOISTURE,CONDITION,COLOR,GRAINSIZE,ETC.)	%M	LL	PI	CLASS.
			\\\	50						
13153	50.0-51.5	8-9-16	\\\		S	CLAY, SLIGHTLY SILTY, SANDY, WET, REDDISH	21.0	35	20	CL/A-6
			\-\		S	BROWN, VERY STIFF, CCI OF BOTTOM 4" OF SAMPLE				
			\\\		S	IS 1-2. POCKET PENETROMETER AVERAGE (PPA) .75				
			\-\							
			\\\							
			\-\							
			\\\							
			\-\							
			\\\	55						
13154	55.0-56.4	SHELBY	\-\		U	RECOVERY 94%, PPA=1.0, CC1=0	31.7	44	27	CL/A-7-6
			\\\		U					
			\-\		U					
			\\\							
			\-\							
			\\\							
			\-\							
			\\\							
			\-\							
			\\\	60						
13155	60.0-61.5	6-9-9	\-\		S	STIFF, CCI 0-1, SCATTERED CALCAREOUS NODULES	26.6	52	35	CH/A-7-6
			\\\		S					
			\-\		S					
			\\\							
			\-\							
			\\\							
			\-\							
			\\\							
			\-\							
			\\\	65						
13156	65.0-66.5	6-8-8	\-\		S	PPA-1.5, CCI 0-1	28.7	28	12	CL/A-6
			\\\		S					
			\-\		S					
			\\\							
			\-\							
			\\\							
			\-\							
			\\\							
			\-\							
			\\\	70						
13157	70.0-71.1	SHELBY	\o\		U	CLAY, SLIGHTLY SANDY, REDDISH LIGHT BROWN,	17.9	31	17	CL/A-6
			\\\		U	MOIST, SOME CALCAREOUS NODULES PISOLITE SIZE,				
			\o\			CCI OF THE MASS 0-1, PPA=1.5				
			\\\							
			\o\							
			\\\							
			\o\							
			\\\			CONTINUED ON NEXT PAGE				
			\o\							

Size & Type of Boring: 5-5/8" OD Hollow Stemmed Auger

Logged By: PLJ

SHEET 4 OF 8
PRECISION ENGINEERING, INC.
File No. 89-117

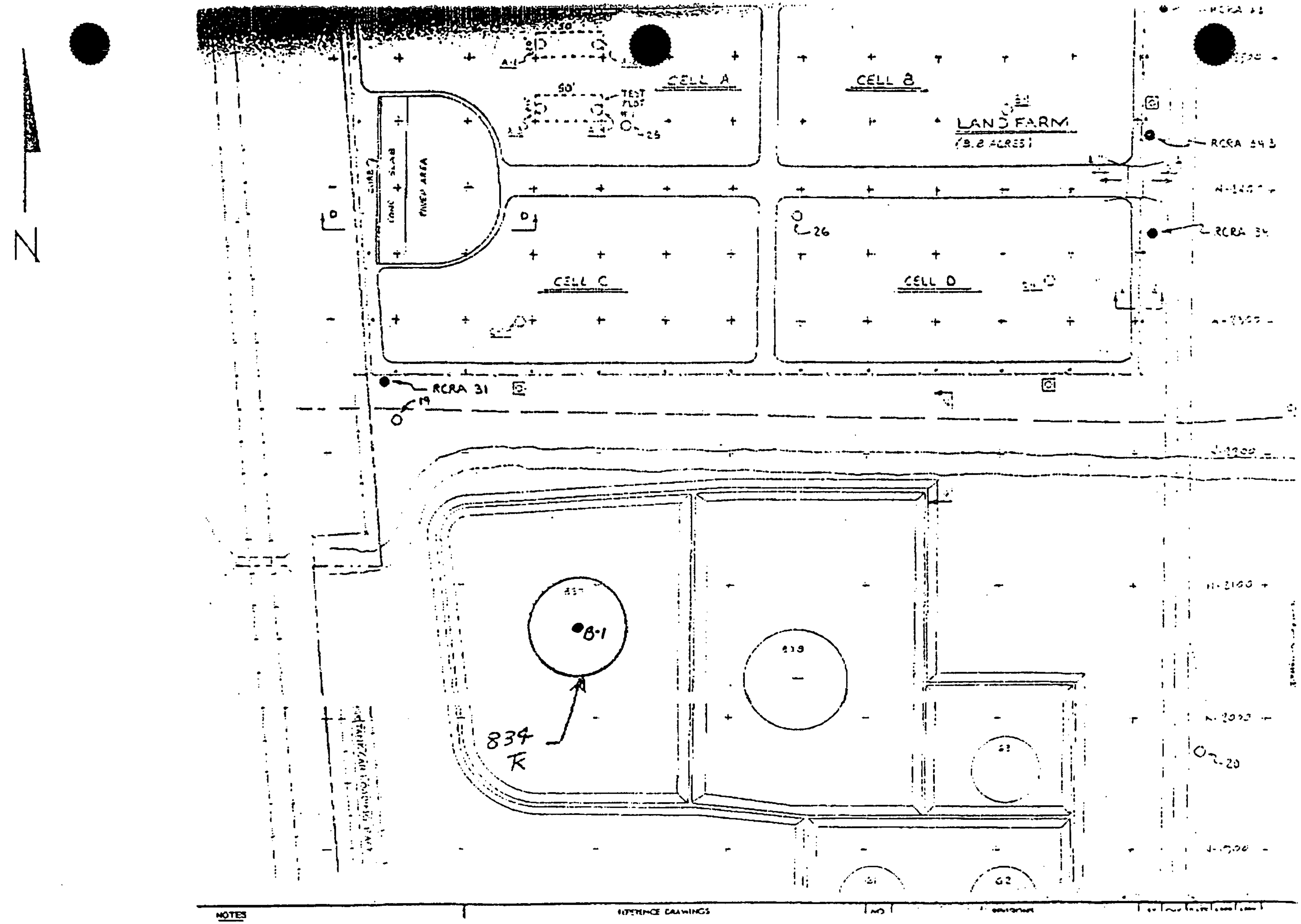
ing Location: SEE SITE PLAN
LOG OF TEST BORINGS
Location Artesia, NM

Elevation Existing

Boring Number: SEVEN
Water Level 14.5
Date: 4/10/90

LAB #	DEPTH	BLOWS/N	PLOT	SCALE	SAMPLE	MATERIAL CHARACTERISTICS (MOISTURE,CONDITION,COLOR,GRAINSIZE,ETC.)	%M	LL	PI	CLASS.
			\\\\	75						
13158	75.0-75.9	(	\o\		S	CLAY, SANDY AS DESCRIBED BEFORE, PPA=3.0	19.1	30	18	CL/A-6
		(8-9-16	\\\\		S					
	75.9-76.5	(	o\o		S	SAND, CLAYEY, RUST RED, MOIST, MEDIUM DENSE	17.5	22	10	SC/A-4
			o\o			PPA=1.5				
			o\o							
	78.0		o\o							
			\\\\			CLAY, HARD, REDDISH BROWN, ALTERNATING LAYERS				
			\\\\			OF CARBONATE CEMENTATION 3-4" THICK AT 12-18"				
			\\\\	80		FREQUENCY, NODULAR CARBONATE THROUGHOUT, CCI				
13159	80.0-81.2	10-22-100	\\\\		S	OF NODULES 3, PPA OF CLAY 2.25, PPA OF INDUR-	24.0	28	10	CL/A-4
		(2.5)	\\\\		S	ATED MATERIAL 75. CARBONATE CAUSES "SILTY"				
			\\\\		S	FEEL.				
			\\\\							
			\\\\							
			\\\\							
			\\\\							
			\\\\							
			\\\\							
			\\\\	85						
13160	85.0-86.5	14-16-18	\\\\		S	HARD, CCI 0-1, SCATTERED CALCAREOUS NODULES	12.7	40	25	CL/A-6
			\\\\		S	PPA=2.25				
			\\\\		S					
			\\\\							
			\\\\							
			\\\\							
			\\\\							
			\\\\							
			\\\\							
			\\\\	90						
13161	90.0-90.5	SHELBY	\\\\		U	HARD PPA=2.0, POOR SAMPLE, CARBONATE NODULES	30.0	40	22	GC/A-2-6
13162NR	90.5-90.8	100(3.0")	\\\\		S	PRESENT, CLASSIFICATION GOVERNED BY CARBONATE				
			\\\\			NODULES IN CLAY MATRIX.				
			\\\\							
			\\\\							
			\\\\							
			\\\\							
			\\\\							
			\\\\							
			\\\\	95						
13163	95.0-96.5	10-15-18	\\\\		S	PPA=2.25, WHERE CARBONATE INDURATED CCI=2	17.6			
			\\\\		S					
			\\\\		S					
			\\\\							
			\\\\							
			\\\\							
13164	100.0-100.7	SHELBY	\\\\		U	CCI 2, PPA=2.25, POOR SAMPLE-CARBONATE NODULES	28.0	78	49	CH/A-7-6
13165	100.0-102.2	14-15-20	\\\\		S	PPA=2.75, CCI 1, SOME BLUE-GREY MOTTLING	22.9	39	15	CL/A-6
	TD-102.2		\\\\		S	APPEARS SILTIER THAN ABOVE				

Size & Type of Boring: 5-5/8" OD Hollow Stemmed Auger
Logged By: WHK



Precision Engineering Location Sketch Map for Boring B-1. (Refer to Figure 7-1)

SHEET 1 OF 2

PRECISION ENGINEERING, INC.

File No. 93-118

Boring Location Center point of Tank

LOG OF TEST BORINGS

Location ARTESIA, N.M.

Elevation EXISTING

Boring Number: ONE

Water Level 10.9(see note) Date: 08/25/93

LAB #	DEPTH	BLOWS/N	PLOT	SCALE	SAMPLE	MATERIAL CHARACTERISTICS (MOISTURE,CONDITION,COLOR,GRAINSIZE,ETC.)	%M	LL	PI	CLASS.
	0.0 - 1.5	3-3-4	//////		S	CLAY, SILTY, FIRM, DARK GREY, WET, STRONG				CL
			//////		S	HYDROCARBON ODOR				
			//////							
			//////							
	4.0		/-//-/			CLAY, SILTY, SANDY, STIFF, LIGHT GREY				
	5.0 - 6.5	5-7-11	/-//-/	5	S	HYDROCARBON ODOR, MOIST, CRUMBLES EASILY,				CL
			/-//-/		S	PPR=2.75				
			/-//-/							
			/-//-/							
			/-//-/							
	10.0 - 11.5	4-10-16	/-//-/	10	S	AS ABOVE WITH VISIBLE CARBONATE NODULES,				
			/-//-/		S	CRUMBLY, SLIGHTLY MORE SAND, CCI=2, PPR>4.5,				
			/-//-/			STRONG HYDROCARBON ODOR, VERY STIFF				
	13.5		/-//-/			DARK GREY ZONE FROM 13.5-14.5'				
			/-//-/							
	15.0 - 16.5	7-7-9	/-//-/	15	S	WHITE AND LIGHT GREY MOTTLED, WETTER THAN				CL
			/-//-/		S	ABOVE, LESS SAND, HAS HYDROCARBON ODOR, CCI=3				
			/-//-/			VERY EASILY CRUMBLED DESPITE CCI				
	18.0		/¯//¯/			CLAY, VERY STIFF, THIN CARBONATE GRAVEL				
			/¯//¯/			(CALICHE) ZONES ARE WATER BEARING, GRAVEL 1-3"				
	20.0 - 21.2	10-12-11	/¯//¯/	20	S	THICK SPACED APPROX. 8"., RED BROWN COLOR,				CL
			/¯//¯/		S	CCI=1, PPR=2.5, VERY STIFF, WEAK HYDROCARBON				
			/¯//¯/			ODOR.				
	23.0		/¯//¯/			OUT OF WATER BEARING GRAVELS @ 23.0??				
			//////			CLAY, FIRM, RED BROWN, WET (NOT WATER BEARING)				
	25.0-26.5	4-4-7	//////	25	S	SOME SCATTERED CARBONATE PISOLITES IN CLAY				CL
			//////		S	LITTLE OR NO SAND AND SILT				
			//////							
			//////							
			//////							
	30.0 - 31.5	3-3-4	//////	30	S	AS ABOVE, NO HYDROCARBON ODOR, WET, (NOT WATER				CL
			//////		S	BEARING)				
			//////							
			//////							
			//////							
			//////	35						
			//////							
			//////							
			//////							
			//////							
	40.0 - 41.5	7-6-5	/://:/	40	S	CLAY, SANDY, WET BUT NOT WATER BEARING, RED				CL
			/://:/		S	BROWN, NO ODOR, PPR=2.75, CCI=0				
			/://:/							
			//////			LITTLE SAND AT 44'				
			//////			CONTINUED				

Size & Type of Boring: 7-5/8" OD Hollow Stemmed Auger

Logged By: WHK

SHEET 2 OF 2

PRECISION ENGINEERING, INC.

LOG OF TEST BORINGS

File No. 93-118

Boring Location Center point of Tank

Location ARTESIA, NM

Elevation EXISTING

Boring Number: ONE-CONTINUED

Water Level 10.9 (NOTE) Date: 8/25/93

LAB #	DEPTH	BLOWS/N	PLOT	SCALE	SAMPLE	MATERIAL CHARACTERISTICS (MOISTURE,CONDITION,COLOR,GRAINSIZE,ETC.)	%M	LL	PI	CLASS.
			//////	45	S	CONTINUED FROM PAGE 1				
			//////		S					
			//////							
			//////							
			//////							
	50.0 - 51.5	4-4-5	//////	50	S	PPR=3.25,CCI=3, OCCATIONAL CARBONATE NODULES				CL
			//////		S	BUT RARE, WET BUT NOT WATER BEARING				
			//////							
			//////							
			//////							
			//////	55						
			//////							
			//////							
			//////							
			//////							
	60.0 - 61.5	4-4-5	//////	60	S	VERY SLIGHLY SANDY, AS ABOVE, NO ODOR, PPR=3.0				CL
			//////		S	FIRM				
			//////							
			//////							
			//////							
			//////	65						
			//////							
			//////							
			//////							
			//////							
	70.0 - 71.5	6-11-9	/://:/	70	S	**CLAY**, SANDY, STIFF, RED BROWN, SOME CARBONATE				CL
			/://:/		S	LENSES, CCI=0, PPR=1.25, WET BUT NOT WATER				
			/://:/			BEARING				
			/://:/							
			/://:/							
			/://:/	75						
			/://:/							
			/://:/							
			/¯//¯/			**CLAY**, HARD, RED BROWN, WET, WATER BEARING				
			/¯//¯/			CARBONATE GRAVELS FORM PARTINGS IN THE CLAY				
	80.0 - 81.5	5-23-18	/¯//¯/	80	S	BODY				CL
			/¯//¯/		S					
			/¯//¯/							
	TOTAL DEPTH 81.5'					**NOTE:** WATER LEVEL ENCOUNTERED AT 18' AT TIME OF DRILLING, 16 HOURS LATER WATER LEVEL MEASURED AT 10.9'. BORING PLUGGED AFTER WATER MEASUREMENTS WITH 6% BENTONITE/CEMENT GROUT INJECTED BY 1" TREMMIE AT 80'. GROUTED TO THE SURFACE, COVERED WITH CUTTINGS.				

Size & Type of Boring: 7-5/8" OD Hollow Stemmed Auger

Logged By: WHK

APPENDIX B3

RFI PHASE II BORING LITHOLOGIC LOGS
(Including 1992 NCL Boring Logs)

LOG OF BORING NCL 95-01

(Page 1 of 1)

RFI Phase II
North Colony Landfarm
Navajo Refining Company
Artesia, New Mexico

Date Started: : 06/23/95
Time Started : 1345
Date Completed : 06/23/95
Hole Diameter: : 2"
Drilling Method: : Hydraulic push
Sampling Method: : 2'x3/4"ID Splitspoon
Drilled By: : Pool Environmental
Logged By: : D.G. Boyer

Depth in Feet	Samples	Blows per 2 ft.	Recovery (ft)	GRAPHIC	USCS	DESCRIPTION	Contact depth	PID Interval (ft)	PID (ppm)
0	1		1.5	▥	ML	Clayey silt, brown, lighter with depth, calcite grains	2.5	0 - 5	3
	2	43	2	▨	CL	Clay, light brown to chalk color, dry, crumbly, plastic when wetted			
5				▨				5 - 10	1
	3	19	2	▨		Clay, light brown, slightly moist at bottom, some fine-grained caliche zones at 9 ft. (zones approx. 2 in. thick, chalk color)			
10	4	53	2	▨		Clay, light brown, dry, crumbly, plastic when wetted			
	5	37	2	▨		Clay, light brown, dry 12-12.5 ft., plastic 12.5 to 14 ft.		10 - 15	5
15	6		2	▨		Clay, light brown, some chalk color zones, some with dark brown (iron?) staining, slightly moist and plastic at 14 ft., water on drive shoe			
	7	54	2	▨		Silty clay, moist at 16 ft., chalky clay at 17 ft., slight hydrocarbon (?) odor	16	15 - 20	908
	8		2	▨		Clay, light brown, slightly moist, some chalky coloring but no caliche	18		
20									
25									
30									

Notes:
Depth to water (DTW) 17.8 ft. @ 1800 hr.; DTW 13.8 ft.

LOG OF BORING NCL 95-02

(Page 1 of 1)

RFI Phase II
North Colony Landfarm
Navajo Refining Company
Artesia, New Mexico

Date Started:	: 06/23/95	Drilling Method:	: Hydraulic push
Time Started	: 1600	Sampling Method:	: 2'x3/4"ID Splitspoon
Date Completed	: 06/23/95	Drilled By:	: Pool Environmental
Hole Diameter:	: 2"	Logged By:	: D.G. Boyer

Depth in Feet	Samples	Blows per 2 ft.	Recovery (ft)	GRAPHIC	USCS	DESCRIPTION	Contact depth	PID Interval (ft)	PID (ppm)
0	1		1.5			Clay, black, soft, no H/C odor			
	2		2			Clay, light brown, some caliche flakes		0 - 5	7
5									
	3		2			Clay, light brown, some calcite crystals		8 - 10	7
10					CL				
	4		2			Clay, light brown to chalk color, plastic, slightly moist		13 - 15	4
15									
	5		2			Moist at 18.2 ft., otherwise same as above		18 - 20	6
20	6		2						
	7		2		CH	Clay, light brown to chalk color, slightly moist, plastic, expansive at 22 ft.	22	20 - 24	6
	8		1			Increasing fine gravel 25 to 25.8 ft.			
25	9		1		GC	25.8-26.1 ft. Fine gravel, slightly moist, punch refusal	25.8	25 - 26	5
30									
35									

Notes: Moisture on probe at 26 ft, no free water, but moisture entering hole at conclusion of drilling. DTW 14.6 ft. @1715, 6/24. Total depth (TD) 17.2 ft. BTEX water sample taken 6/24/95, pH=7, EC=3000 umhos @22C.

Plugged back hole with medium bentonite chips, hydrated with 5 gallons fresh water. Photoionization Detector (PID) readings are from jar headspace analysis of grab samples taken from the splitspoon at the designated intervals.

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Navajo

LOG OF BORING NCL 95-03

(Page 1 of 1)

RFI Phase II
North Colony Landfarm
Navajo Refining Company
Artesia, New Mexico

Date Started: : 06/24/95
Time Started : 0730
Date Completed : 06/24/95
Hole Diameter: : 2"
Drilling Method: : Hydraulic push
Sampling Method: : 2'x3/4"ID Splitspoon
Drilled By: : Pool Environmental
Logged By: : D.G. Boyer

Depth in Feet	Samples	Blows per 2 ft.	Recovery (ft)	GRAPHIC	USCS	DESCRIPTION	Contact depth	PID Interval (ft)	PID (ppm)
0						No information			
5	1		2			Clay, medium brown, hard, slightly plastic, grading to gray at 6.5 ft., hydrocarbon (H/C) odor below transition		5 - 7	1229
	2		2			Clay, gray with some lighter colored areas, dry, crumbly, strong H/C odor		7 - 9	996
10	3		2		CL	Clay, dark gray to black, caliche clay from 10.5 - 11 ft, dry, crumbly, H/C odor		9 - 11	1088
	4		2					11 - 13	717
	5		2			Increasing moisture from 14 to 15 ft.		13 - 15	852
15					GC	14.8 - 15 ft. Caliche gravel and clay, gravel to 1/2 in., H/C product along side of splitspoon	14.8 15		
	6		0 & 2		ML	Clayey silt, dark gray, H/C odor. Less gray and decreasing odor from 17 to 17.5 ft.		15 - 17	679
	7		0 & 2			Clay, light brown, plastic Clay, light brown, slightly reddish, uniform, hard, no odor	17.5	17 - 19	136
20	8		2		CL			19 - 21	53
	9		2					21 - 23	55
25									
30									

Notes:
No recovery 15-17 and 17-19 ft., moved over 0.5 ft., pushed to 15 ft. DTW 13.8 ft. @1600, 6/24, product thickness too thin to measure. Hole collasped below 14 ft.

Plugged back hole with medium bentonite chips, hydrated with 5 gallons fresh water. Photoionization Detector (PID) readings are from jar headspace analysis of grab samples taken from the splitspoon at the designated intervals .

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LOG OF BORING NCL 95-04

(Page 1 of 1)

RFI Phase II
North Colony Landfarm
Navajo Refining Company
Artesia, New Mexico

Date Started:	: 06/24/95	Drilling Method:	: Hydraulic push
Time Started	: 1000	Sampling Method:	: 2'x3/4"ID Splitspoon
Date Completed	: 06/24/95	Drilled By:	: Pool Environmental
Hole Diameter:	: 2"	Logged By:	: D.G. Boyer

Depth in Feet	Samples	Blows per 2 ft.	Recovery (ft)	GRAPHIC	USCS	DESCRIPTION	Contact depth	PID Interval (ft)	PID (ppm)
0						No information			
5	1		2	▨	CL	Clay, dark brown, plastic, no odor		3 - 5	27
	2		2			Clay, light brown to chalk color, some brown mottling		8 - 10	19
10	3		2			Clay, chalky color to 11 ft., brown-stained 11-11.5 ft., 11.5-12 ft. strong H/C odor		10 - 12	59
	4		2			Clay, gray and black. 13-14 ft., silty clay, gray and black with calcite crystals from 13.5-14 ft., strong H/C odor.		12 - 14	1098
15	5		2			Silty clay, gray. 15.5-16 ft., clay, medium brown, some gray and caliche mottling, 3/4 in. rock at 15.5 ft. H/C product on outside of core.		14 - 16	946
	6		2			Silty clay, gray-brown with H/C odor. 17-18 ft., clay, brown to chalk color, some silt, H/C odor		16 - 18	870
	7		2			Silty clay with H/C odor. 19.5-20 ft., caliche clay, some gravel, slight H/C odor.		18 - 20	1033
20	8		2			Clay, medium brown to chalk color, brown from 20.5 to 21.5 ft., moist, no H/C odor.		20 - 22	45
	9		2			Clay, light brown to chalk color, some silt, moist at 22 ft., no H/C odor		22 - 24	29
25									
30									

Notes:
Product and water at 15.6 ft. @1600 6/24, total depth 17.6 ft.
Product thickness too thin to measure.
Plugged back hole with medium bentonite chips, hydrated with 5 gallons fresh water.
Photoionization Detector (PID) readings are from jar headspace analysis of grab samples taken from the splitspoon at the designated intervals.

LOG OF BORING NCL 95-05

(Page 1 of 1)

RFI Phase II
North Colony Landfarm
Navajo Refining Company
Artesia, New Mexico

Date Started:	: 06/24/95	Drilling Method:	: Hydraulic push
Time Started	: 1115	Sampling Method:	: 2'x3/4"ID Splitspoon
Date Completed	: 06/24/95	Drilled By:	: Pool Environmental
Hole Diameter:	: 2"	Logged By:	: D.G. Boyer

Depth in Feet	Samples	Blows per 2 ft.	Recovery (ft)	GRAPHIC	USCS	DESCRIPTION	Contact depth	PID Interval (ft)	PID (ppm)
0						No information			
5	1		2			Silty clay, dark brown with some chalky color, no odor		4 - 6	18
	2		2			Clay,medium to light brown, no odor		8 - 10	17
10	3		2			Clay, dark brown, discoloring to dark gray and black. 10.6-12 ft., black hydrocarbon-impregnated soil, no liquid, strong H/C odor.		10 - 12	1102
	4		2			Silty clay, gray with black mottling, strong H/C odor, dry.		12 - 15	609
15	5		2		CL	Same as above, some interior areas have light brown coloring, some visible grains (calcite?) that are crushable.		15 - 17	560
	6		2			Same as above.		17 - 19	859
20	7	93	2			Same as above. 20.5-21 ft., clay, gray, plastic, H/C odor.		19 - 21	585
	8		2			Same as above, H/C odor.		21 - 23	545
	9		2			Clay, grading to light gray with more silt. 24.7-25 ft., clay grading to brown at 25 ft., green reduction zone at 24.8 ft., slight H/C odor.		23 - 25	282
25	10		1			Clay, gray, slight odor		25 - 26	323
	11		2			Clay, light brown to light gray, reduction zone 27.0-27.1 ft., no odor		26 - 28	120
30									
35									

Notes:

Water at 18.0 ft. @1530 6/25, caved below 20 ft.
Plugged back hole with medium bentonite chips, hydrated with 5 gallons fresh water. Photoionization Detector (PID) readings are from jar headspace analysis of grab samples taken from the splitspoon at the designated intervals.

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LOG OF BORING NCL 95-05A

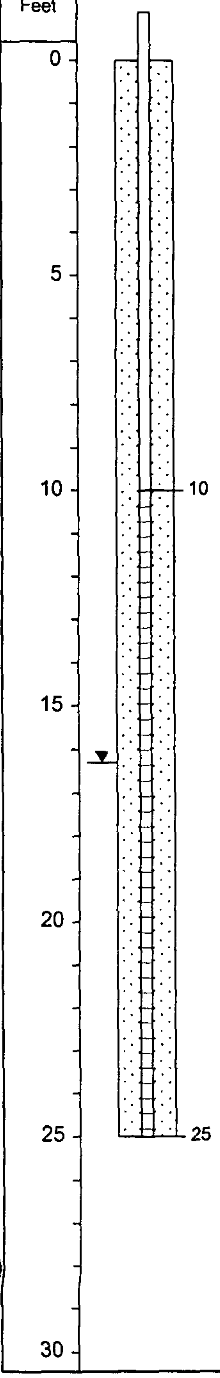
(Page 1 of 1)

RFI Phase II
North Colony Landfarm
Navajo Refining Company
Artesia, New Mexico

Date Started:	: 07/31/95	Drilling Method:	: Solid Stem Auger
Time Started	: 1330	Sampling Method:	: None
Date Completed	: 07/31/95	Drilled By:	: Pool Environmental
Hole Diameter:	: 3.5 "	Logged By:	: D.G. Boyer

Depth in Feet

Well: NCL 95-05A



DESCRIPTION

NCL 95-05A located approximately midway between NCL 95-05 and NCL 95-06. Bored 25 ft., installed 15 ft. of screen and 10 ft. of temporary PVC casing for H/C product search. Hole was not logged. Drillers reported product on drill augers.

Depth to water 16.3 ft. BLS on 8/2/95. No product seen in bailer.

Plugged back hole with medium bentonite chips, hydrated with 5 gallons fresh water.

LOG OF BORING NCL 95-06

(Page 1 of 1)

RFI Phase II
North Colony Landfarm
Navajo Refining Company
Artesia, New Mexico

Date Started: : 06/24/95
Time Started : 1340
Date Completed : 06/24/95
Hole Diameter: : 2"
Drilling Method: : Hydraulic push
Sampling Method: : 2'x3/4"ID Splitspoon
Drilled By: : Pool Environmental
Logged By: : D.G. Boyer

Depth in Feet	Samples	Blows per 2 ft.	Recovery (ft)	GRAPHIC	USCS	DESCRIPTION	Contact depth	PID Interval (ft)	PID (ppm)
0						No information			
	1		0.7	▨	CL	Clay, light brown to chalk color, dry, crumbly, some silt, no PID reading			
5									
	2		1.2			Clay, dark brown, slightly moist, no odor		8 - 10	55
10	3		1.6			Same as above		10 - 12	45
	4		2			Same as above. 13-13.2 ft. Rreduction zone, black. 13.2-14 ft. Clay, dark gray, some silt, dry, crumbly, strong H/C odor.		12 - 14	1154
15	5		2			Same as above. Grading to light gray clay from 14.3-16 ft., hydrocarbon odor throughout.		14 - 16	1111
	6		2			Clay, light gray with H/C odor. 17.2-18 ft., clay, gray with caliche.		16 - 18	765
	7	93	2			Clay, gray with caliche, darker at 20 ft.		18 - 20	600
20	8		2			Clay, light gray, more plastic at 20.9 ft., H/C odor decreasing with depth.		20 - 22	590
	9		2			Clay, light gray. 22.5-24 ft., clay, brown, becoming lighter with depth. H/C odor to 22.5 ft., slight or none below 22.5 ft.		22 - 24	929
25	10		2			Clay, light brown, plastic, no H/C odor, moist at 25.6 ft.		24 - 26	90
30									

Notes:
Dry at 18.6 ft. @1500 6/25, caved below. Plugged back hole with medium bentonite chips, hydrated with 5 gallons fresh water.
Photoionization Detector (PID) readings are from jar headspace analysis of grab samples taken from the splitspoon at the designated intervals.

LOG OF BORING NCL 95-07 (MW-55)

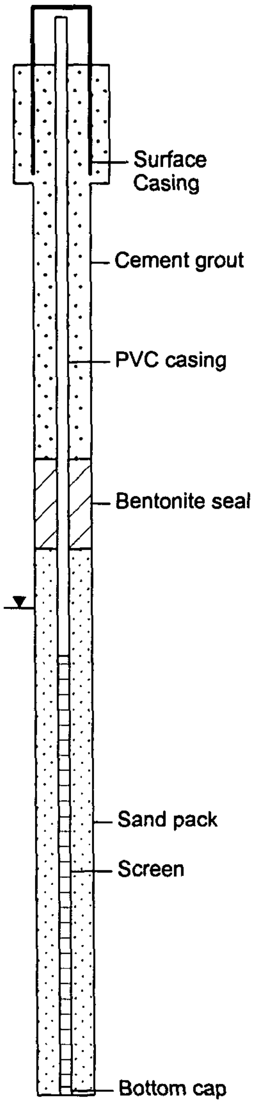
(Page 1 of 1)

RFI Phase II
North Colony Landfarm
Navajo Refining Company
Artesia, New Mexico

Date Started:	: 06/25/95	Drilling Method:	: Hydraulic push
Time Started	: 1215	Sampling Method:	: 2'x3/4"ID Splitspoon
Date Completed	: 06/25/95	Drilled By:	: Pool Environmental
Hole Diameter:	: 2"	Logged By:	: D.G. Boyer

Depth in Feet	Samples	DESCRIPTION	GRAPHIC	USCS
0		No information		
5	1	3-5 ft. Clay, brown with white streaks, lighter brown at 4.2 ft., no odor, 1.2 ft. recovery	▨	CL
	2	8-10 ft. Silty clay to clayey silt, brown to chalk color, dry, crumbly, caliche clay at 8 ft., some brown staining on core surface, 1.7 ft. recovery	▨	
10	3	10-12 ft. Silty clay to clayey silt, light brown with soft zones every few inches, extensive small crystals (calcite?) where soft, 2 ft. recovery	▨	
	4	12-14 ft. Silty clay to clayey silt, light brown, fewer zones with crystals, 1 ft. recovery	▨	
15	5	14-16 ft. Silty clay to clayey silt, light brown, no caliche zones, lighter color and softer at 16 ft., 2 ft. recovery	▨	
	6	16-18 ft. Clay, very light brown, hard, 2 ft. recovery	▨	
	7	18-20 ft. Silty clay, brown, some lighter color zones, no caliche, 2 ft. recovery	▨	
20	8	20-22 ft. Same as above, 2 ft. recovery	▨	
25 30		Notes: No odor in any core sample Depth to water at 17.3 ft. BLS @1600 6/25. Plugged back NCL 95-07 hole with medium bentonite chips, hydrated with 5 gallons fresh water. Photoionization Detector (PID) readings are from jar headspace analysis of grab samples taken from drill cuttings at designated intervals. On 8/08/95, hole was redrilled and completed as MW-55 with DTW of 12.3 ft. BLS.		

Well: MW-55
Elev.: 3363.57



Well Construction Information

DRILLING INFORMATION

Date completed	: 8/08/95
Hole diameter	: 8 1/4 in.
Depth Hole BLS	: 23.9 ft.
Drilling Method	: HSA
Drilled by	: Pool Environmental
Logged by	: D. G. Boyer

CASING, SCREEN & CAP

Material, joints	: PVC, threaded
Diameter	: 2 in. ID
Screen type	: Johnson Slotted
Screen length	: 10 ft.
Screen opening	: 0.010 slot
Scrn. placement	: 13.7 - 23.7 ft. BLS
Bottom Cap	: 0.2 ft PVC
Protector Casing	: Above-ground steel
Lock Key #	: P-493

SEALS & SAND PACK

Cement seal type	: Cement with 5 % : powered bentonite
Seal placement	: 0 - 9.1 ft. BLS
Annular seal type	: Med. bentonite : chips, ("Pure Gold")
Seal placement	: 9.1 - 11.2 ft. BLS
Sand pack type	: 10-20 CSSI silica
Sand placement	: 11.2 - 23.9 ft. BLS

ELEVATIONS

Ground elevation	: 3360.75 ft.
Inner casing, top	: 3363.57 ft.
Outer casing, top	: 3363.97 ft.

NOTES

PID Readings (ppm):

0-3 ft.	Not measured
3-5 ft.	30
8-10 ft.	49
10-12 ft.	45
12-14 ft.	29
14-16 ft.	34
16-18 ft.	22
18-20 ft.	18
20-22 ft.	18

(Note: PID likely impacted by moisture or exhibited carry-over from previous sample)

COMPLETION NOTES:

Driller bailed 22 gallons 8/8
Developed with pump 8/9/95
Purged 30 gallons prior to sampling, pumped at 1.5 gpm with pump intake at 20 ft.
Purge info. @25gal, 0855: 22 C, 2800 umhos, pH 7
Depth to water prior to sampling: 15.36 ft. below top inner casing.

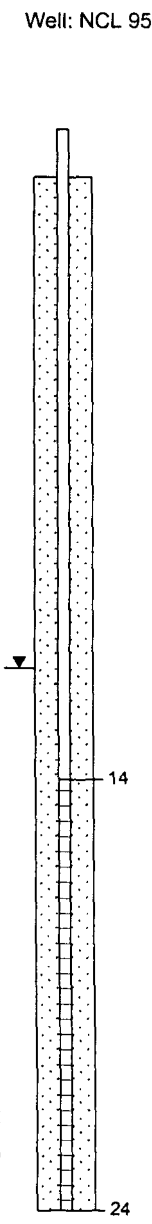
LOG OF BORING NCL 95-08

(Page 1 of 1)

RFI Phase II
North Colony Landfarm
Navajo Refining Company
Artesia, New Mexico

Date Started:	: 06/25/95	Drilling Method:	: Hydraulic push
Time Started	: 1330	Sampling Method:	: 2'x3/4"ID Splitspoon
Date Completed	: 06/25/95	Drilled By:	: Pool Environmental
Hole Diameter:	: 2"	Logged By:	: D.G. Boyer

Depth in Feet	Samples	Recovery (ft)	GRAPHIC	USCS	DESCRIPTION	PID Interval (ft)	PID (ppm)
0					No information		
	1	1.5			Clay, brown, firm, crumbly	3 - 5	15
5							
	2	1.4			Same as above	8 - 10	16
10	3	2			Same as above. 10.4-12 ft., clay, light gray, hydrocarbon (H/C) odor	10 - 12	1092
	4	2		CL	Clay, gray, H/C odor. H/C product and water squeezed out of core at approx. 13.5 ft.	12 - 14	1064
15	5	2			Silt Clay, gray, saturated, strong H/C odor, clay forms cohesive ribbons when rolled in fingers	14 - 16	933
	6	2			Clay, gray, firm, slightly crumbly, H/C odor, lighter color at 18 ft.	16 - 18	1011
	7	2			Clay, gray, H/C odor. Core surface moist at 19.5 ft., dry below. Surface color green, interior is brown.	18 - 20	310
20				GC	Thin gravel zone at 20.2 ft.		
	8	2			Clay, gray grading to brown below.	20 - 22	465
	9	2		CL	Clay, brown, firm, uniform. 23.7 - 24 ft., silty clay, light brown, no H/C odor.	22 - 24	52
25							
30							



Notes:
Water depth 12.4 ft. BLS @1535 6/25.
Photoionization Detector (PID) readings are from jar headspace analysis of grab samples taken from the splitspoon at the designated intervals.
On 8/1/95, cored 24 ft. and installed 15 ft. of 2 in. PVC temporary casing with 10 ft. of screen. At 1200 on 8/2 measured DTW of 11.4 ft. with 1/16 to 1/8 in. H/C product.
Plugged back holes with medium bentonite chips, hydrated with 5 gallons fresh water.

LOG OF BORING NCL 95-08A

(Page 1 of 1)

RFI Phase II
North Colony Landfarm
Navajo Refining Company
Artesia, New Mexico

Date Started:	: 08/03/95	Drilling Method:	: Solid Stem Auger
Time Started	:	Sampling Method:	: Cuttings
Date Completed	: 08/03/95	Drilled By:	: Pool Environmental
Hole Diameter:	: 3.5 "	Logged By:	: D.G. Boyer

Depth in Feet	Samples	GRAPHIC	USCS	DESCRIPTION	PID Interval (ft)	PID (ppm)
0	1	▨	CL	Clay, blue gray from 3-5 ft., possible H/C odor.	3 - 5	0
5	2	▨		Clay, light brown, no odor	8 - 10	0
10	3	▨		Clay, light brown, no odor. Water at approx. 12 ft.		
15						
20						
25						
30						

Notes:

Hole located 109 ft. west of NCL 95-08. Plugged back hole with medium bentonite chips, hydrated with 5 gallons fresh water.

Photoionization Detector (PID) readings are from jar headspace analysis of grab samples taken from the splitspoon at the designated intervals.

LOG OF BORING NCL 95-08B

(Page 1 of 1)

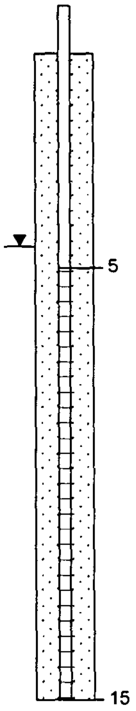
RFI Phase II
North Colony Landfarm
Navajo Refining Company
Artesia, New Mexico

Date Started: : 08/03/95
Time Started: :
Date Completed : 08/03/95
Hole Diameter: : 3.5 "

Drilling Method: : Solid Stem Auger
Sampling Method: : Cuttings
Drilled By: : Pool Environmental
Logged By: : D.G. Boyer

Depth in Feet	Samples	GRAPHIC	USCS	DESCRIPTION	PID Interval (ft)	PID (ppm)
0	1	▨	CL	Clay, blue gray from 3-5 ft.		
5	2	▨	CL	Clay, darker color, strong H/C odor	6 - 7 8 - 9	6 94
10	3	▨	CL	Clay, dark gray, water and product. Sandy at bottom.	10 - 12	51
14			SC			
15						
20						
25						
30						

Well: NCL 95-08B



Notes:

NCL 95-08B located approximately 60 ft. west of NCL 95-08. Installed 10 ft. of temporary PVC screen for H/C product search. On 8/4 DTW 4.5 ft. BLS with product skim seen on bailer.

Plugged back hole with medium bentonite chips, hydrated with 5 gallons fresh water. Photoionization Detector (PID) readings are from jar headspace analysis of grab samples taken from the splitspoon at the designated intervals.

LOG OF BORING NCL 95-08C

(Page 1 of 1)

RFI Phase II
North Colony Landfarm
Navajo Refining Company
Artesia, New Mexico

Date Started:	: 08/03/95	Drilling Method:	: Solid Stem Auger
Time Started	:	Sampling Method:	: Cuttings
Date Completed	: 08/03/95	Drilled By:	: Pool Environmental
Hole Diameter:	: 3.5 "	Logged By:	: D.G. Boyer

Depth in Feet	Samples	GRAPHIC	USCS	DESCRIPTION	PID Interval (ft)	PID (ppm)
0	1			Clay, brown		
5	2			Clay, brown		
10	3		CL	Clay, brown		
15	4			Clay, brown. 18 to 20 ft., clay, blue gray	16 - 18	78
					18 - 20	77
20				Clay, blue gray.		
	5		GC	Cobble zone beginning at 21 ft.		
25						
30						

Notes:
NCL 95-08C located approximately 80 ft. east of NCL 95-08. Installed 10 ft. of temporary PVC screen for H/C product search. Casing base set at 21 ft. due to gravels, 8/3 DTW 12.8 ft. with H/C product. 8/4 DTW 12.3 ft. BLS with 1/8 in. H/C product.
Plugged back hole with medium bentonite chips, hydrated with 5 gallons fresh water. Photoionization Detector (PID) readings are from jar headspace analysis of grab samples taken from the splitspoon at the designated intervals.

Navajo

LOG OF BORING NCL 95-08D

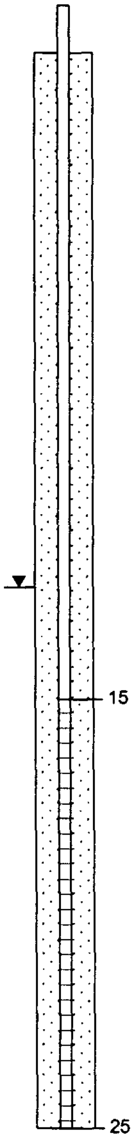
(Page 1 of 1)

RFI Phase II
North Colony Landfarm
Navajo Refining Company
Artesia, New Mexico

Date Started:	: 08/03/95	Drilling Method:	: Solid Stem Auger
Time Started	:	Sampling Method:	: Cuttings
Date Completed	: 08/03/95	Drilled By:	: Pool Environmental
Hole Diameter:	: 3.5 "	Logged By:	: D.G. Boyer

Depth in Feet	Samples	USCS	DESCRIPTION	PID Interval (ft)	PID (ppm)
0	1		Clay, brown		
5	2		Clay, brown		
10	3	CL	Clay, brown		
15	4		Clay, blue gray. 17 - 20 ft., Clay, brown, saturated 19 - 20 ft	15 - 17	70
20	5		Clay, brown, no cobble zone.		
25					
30					

Well: NCL 95-08D



Notes:
NCL 95-08D located approximately 140 ft. east of NCL 95-08, and approximately 60 ft. west of NCL 95-09.
Installed 10 ft. of temporary PVC screen for H/C product search. 8/4 DTW 12.4 ft. BLS with skim H/C product.
Plugged back hole with medium bentonite chips, hydrated with 5 gallons fresh water. Photoionization Detector (PID) readings are from jar headspace analysis of grab samples taken from the splitspoon at the designated intervals.

LOG OF BORING NCL 95-09

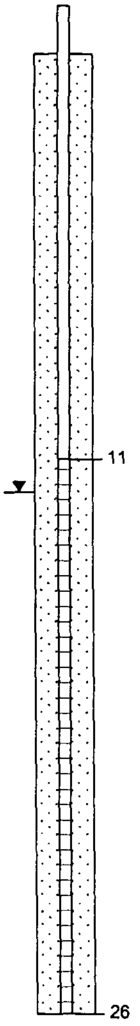
(Page 1 of 1)

RFI Phase II
North Colony Landfarm
Navajo Refining Company
Artesia, New Mexico

Date Started:	: 07/31/95	Drilling Method:	: Hydraulic push
Time Started	: 1530	Sampling Method:	: 2'x3/4"ID Splitspoon
Date Completed	: 07/31/95	Drilled By:	: Pool Environmental
Hole Diameter:	: 2"	Logged By:	: D.G. Boyer

Depth in Feet	Samples	Recovery (ft)	GRAPHIC	USCS	DESCRIPTION	PID Interval (ft)	PID (ppm)
0					No information		
5	1	0.2	▨	CL	Clay, dark brown, slightly moist, plastic (sample from cuttings, no recovery in splitspoon)		
	2	1.4			Silty clay, light gray and brown, grading to caliche clay at bottom, no odor	8 - 10	0
10	3	1.5			Caliche clay, brown and gray mottling, grading to chalk color at bottom, no odor	10 - 12	0
	4	2			Caliche clay, chalk to light brown color, moist at 12 ft., crystals (calcite?) in matrix, no odor	12 - 14	0
15	5	2			Caliche clay, chalk to light brown color, dry, crumbly, orange brown staining from 14-14.5 ft., becoming gray to dark gray with depth. 15.2 - 15.4 ft., black streaks, H/C odor.	14 - 16	40
	6	1.7			Clay, dark gray. 16.4 - 17.7 ft., clay, light gray, dry, very hard (used rig hammer to drive), H/C odor.	16 - 18	264
	7	2			Same as above. 18.5 - 19.4 ft., clay, gray, firm, H/C odor. 19.4 - 20 ft., clay, gray and brown, becoming softer at 20 ft., very stong H/C odor.	18 - 20	103
20	8	1.2			Same as above. 20.5 - 21.2 ft., clay, becoming light gray to light brown and soft at bottom.	20 - 22	92
	9	2			Clay, light brown, moist, soft, plastic, wet at 22 ft., no odor.	22 - 24	16
25	10	2			Clay, brown, slightly plastic. 25.1 - 26 ft., clay with silt, slightly moist, no odor.	24 - 26	5
30							
35							

Well: NCL 95-09



Notes:
Location is 200 ft. SE of NCL 95-08 along north side of Truck Bypass road.

Placed 15 ft. 3/4 in. screen in hole for water/product test. Water depth 11.9 ft. BLS @1130 8/2/95, no product or odor noted from pipe.

Plugged back hole with medium bentonite chips, hydrated with 5 gallons fresh water. Photoionization Detector (PID) readings are from jar headspace analysis of grab samples taken from the splitspoon at the designated intervals.

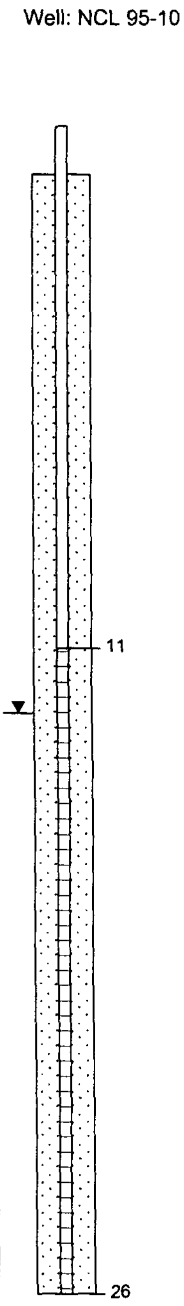
LOG OF BORING NCL 95-10

(Page 1 of 1)

RFI Phase II
North Colony Landfarm
Navajo Refining Company
Artesia, New Mexico

Date Started:	: 08/01/95	Drilling Method:	: Hydraulic push
Time Started	: 0730	Sampling Method:	: 2'x3/4"ID Splitspoon
Date Completed	: 08/01/95	Drilled By:	: Pool Environmental
Hole Diameter:	: 2"	Logged By:	: D.G. Boyer

Depth in Feet	Samples	Recovery (ft)	GRAPHIC	USCS	DESCRIPTION	PID Interval (ft)	PID (ppm)
0					No information		
5	1	1.4	▨		Silty clay, dark brown, plastic with occassional white flakes	3 - 5	0
	2	1.2	▨		Caliche clay, white, no odor	8 - 10	2
10	3	2	▨		Caliche clay, chalk color, dry, crumbly, no odor	10 - 12	2
	4	0.9	▨	CL	Same as above. 12.4 - 12.9 ft., caliche clay, becoming soft, cohesive, slightly moist.	12 - 14	4
15	5	1.5	▨		Caliche clay, soft, becoming dark brown at 15.4 ft. Possible slight H/C odor.	14 - 16	6
	6	1.5	▨		Clay, light brown with caliche inclusion zones from 16.5 - 16.7 ft. then brown again, soft, strong H/C odor. Moist at top.	16 - 18	115
	7	2	▨		Clay, brown with gray zones, strong H/C odor. 18.7 - 20 ft., Clay and caliche clay, mottled, some gray staining, slight H/C odor.	18 - 20	80
20	8	2	▨		Clay, silty, brown with some gray. 20.3 - 20.8 ft., clay, light brown. 20.8 - 22 ft., clay, brown to light brown.	20 - 22	4
	9	1.9	▨		Silty clay, light brown, mottled, soft. 23.8 - 23.9 ft., clayey gravel, wet, no odor.	22 - 24	1
			○	GC	23.8 - 24.2 ft. Clayey gravel, wet.		
25	10	1.7	▨	CL	24.2 - 25.7 ft., clay, soft to 25.1 ft., then harder.	24 - 26	2
30							



Notes:
Located 200 ft. SE of NCL 95-09.
Placed 15 ft. 3/4 in. screen in hole for water/product test.
Water depth 12.5 ft. BLS 8/2/95, no product or odor.
Plugged back hole with medium bentonite chips, hydrated with 5 gallons fresh water. Photoionization Detector (PID) readings are from jar headspace analysis of grab samples taken from the splitspoon at the designated intervals.

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LOG OF BORING NCL 95-11

(Page 1 of 1)

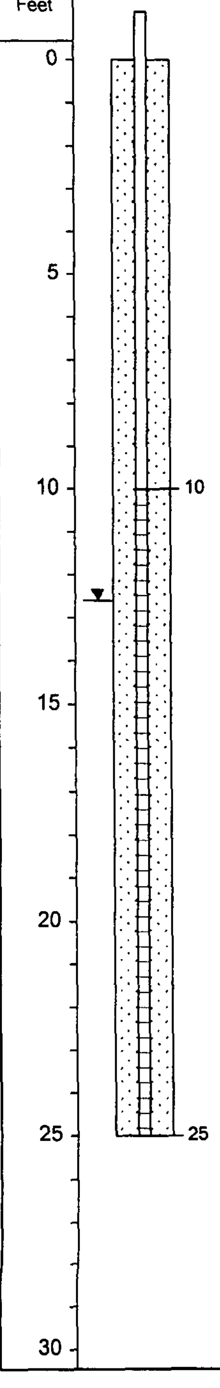
RFI Phase II
North Colony Landfarm
Navajo Refining Company

Artesia, New Mexico

Date Started:	: 08/01/95	Drilling Method:	: Solid Stem Auger
Time Started	: 0930	Sampling Method:	: None
Date Completed	: 08/01/95	Drilled By:	: Pool Environmental
Hole Diameter:	: 3.5 "	Logged By:	: D.G. Boyer

Depth in Feet

Well: NCL 95-11



DESCRIPTION

NCL 95-11 located 200 ft. southeast of NCL 95-06. Cored to 25 ft. Hole was not logged but cuttings observed. Discolored clay soil about 15 - 18 ft. Clay with H/C odor but no fluid at 20 ft. Clean, damp clay at total depth. Installed 15 ft. of screen and 10 ft. of temporary PVC casing for H/C product search.

Depth to water 12.6 ft. BLS on 8/2/95; no product but H/C odor on water level probe.

Plugged back hole with medium bentonite chips, hydrated with 5 gallons fresh water.

LOG OF BORING NCL 95-12

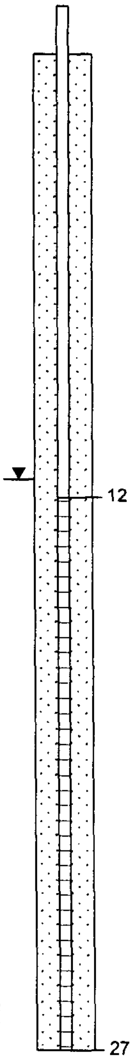
(Page 1 of 1)

RFI Phase II
North Colony Landfarm
Navajo Refining Company
Artesia, New Mexico

Date Started:	: 08/01/95	Drilling Method:	: Hydraulic push
Time Started	: 1100	Sampling Method:	: 2'x3/4"ID Splitspoon
Date Completed	: 08/01/95	Drilled By:	: Pool Environmental
Hole Diameter:	: 2"	Logged By:	: D.G. Boyer

Depth in Feet	Samples	Recovery (ft)	GRAPHIC	USCS	DESCRIPTION	PID Interval (ft)	PID (ppm)
0					No sample information first 3 ft.		
	1	2			Silty clay, dark brown, hard, white flakes in matrix.	3 - 5	0
5	2	0			No recovery.		
	3	2			Silty clay, light brown with caliche streaks and inclusions, hard, no odor.	8 - 10	0
10	4	2			Clay, gray, very strong H/C odor throughout.	10 - 12	97
	5	2		CL	Same as above with gray and brown discoloration, H/C odor throughout.	12 - 14	132
15	6	2			Same as above, clay very hard with caliche.	14 - 16	100
	7	2			Same as above, clay very hard with caliche.	16 - 18	119
	8	2			Same as above, clay very hard with caliche.	18 - 20	125
20	9	2			Clay, gray and brown with less H/C odor.	20 - 22	15
				ML	Clayey silt, gray-brown.		
	10	2		CL	22.5 -23.1 ft., silty clay, gray-brown. 23.1 - 23.8 ft., clay, dark gray with gravel, saturated.	22 - 24	No PID
				GC	23.8 - 24 ft. clayey gravel, gravels small (<1/4 in.), H/C odor.		
25	11	0			No recovery.		
	12	1.5		CL	Sandy clay, gray H/C odor. 25.2 -26.1 ft., clay, light brown, medium soft. 26.1 - 26.5 ft., sandy clay, light brown, dry.	25 - 27	5

Well: NCL 95-12



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35

Notes:
Samples from 3 to 24 ft. taken with splitspoon using pickup truck-mounted sampler. Samples from 24 to 27 ft. taken using CME-75 truck mounted drill.

Placed 15 ft. 3/4 in. screen in hole for water/product test. Water depth 11.5 ft. BLS @ 1130 8/2/95, strong odor of product on bailer, but none seen.

Plugged back hole with medium bentonite chips, hydrated with 5 gallons fresh water. Photoionization Detector (PID) readings are from jar headspace analysis of grab samples taken from the splitspoon at the designated intervals.

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LOG OF BORING NCL 95-13

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RFI Phase II
North Colony Landfarm
Navajo Refining Company
Artesia, New Mexico

Date Started: : 07/31/95
Time Started : 1630
Date Completed : 07/31/95
Hole Diameter: : 2"
Drilling Method: : Hydraulic push
Sampling Method: : 2'x3/4"ID Splitspoon
Drilled By: : Pool Environmental
Logged By: : D.G. Boyer

Depth in Feet	Samples	Recovery (ft)	GRAPHIC	USCS	DESCRIPTION	PID Interval (ft)	PID (ppm)
0					No information.		
5	1	1.3	▨	CL	Silty clay, dark brown, white flakes, no odor.	3 - 5	1
	2	1.8	▨		Clay, light brown with hard caliche streaks, no odor	8 - 10	0
10	3	2	▨		Same as above	10 - 12	0
	4	2	▨		Same as above	12 - 14	1
15	5	2	▨		Same as above, becoming softer at 15 ft.	14 - 16	1
	6	1.5	▨		16 - 17.3 ft. Clay, light brown, soft. 17.3 - 17.5 ft., gravelly clay, white, saturated, septic odor, gravel size <1/2 in.	16 - 18	1
	7	1.1	░	GC	18 - 19.5 ft. Clayey gravel, light brown, saturated	18 - 20	2
					No recovery		
20	8	1.9	▨	CL	Silty clay, light brown becoming soft and moist at 20.8 ft. 21.5 - 21.9 ft., caliche clay, chalk white, soft, moist, septic odor.	20 - 22	2
25							
30							

Notes:
Hole located 200 ft. northeast of NCL 95-12, 7 ft. north of white wastewater pipeline marker, approximately 40 ft. east of 2 pipeline shutoff values.

Plugged back hole with medium bentonite chips, hydrated with 5 gallons fresh water. Photoionization Detector (PID) readings are from jar headspace analysis of grab samples taken from the splitspoon at the designated intervals.

Navajo

LOG OF BORING NCL 95-14

(Page 1 of 1)

RFI Phase II
North Colony Landfarm
Navajo Refining Company
Artesia, New Mexico

Date Started: : 08/02/95
Time Started : 0830
Date Completed : 08/02/95
Hole Diameter: : 2"

Drilling Method: : Hydraulic push
Sampling Method: : 2'x3/4"ID Splitspoon
Drilled By: : Pool Environmental
Logged By: : D.G. Boyer

Depth in Feet	Samples	Recovery (ft)	GRAPHIC	USCS	DESCRIPTION	PID Interval (ft)	PID (ppm)
0					No information.		
5	1	1.5	▨		Clay, dark brown with white flakes, soft, plastic, no odor.	3 - 5	0
	2	2	▨		Same as above. 9 - 10 ft., transition to caliche clay, stiffer, light brown, no odor	8 - 10	0
10	3	2	▨	CL	Caliche clay, light brown, no odor, caliche pebbles in clay at 12 ft.	10 - 12	0
	4	0.3, 2	▨		Caliche clay, frequent caliche inclusions, moist at 12 ft., no odor, no recovery for PID. No recovery for 14-16 or 16-18 ft., pulled out and moved over 3 ft. 12 - 14 ft., Caliche clay, chalk white, small pebbles at 12.5 ft., no odor	12 - 14	0
15	5	2	▨		Caliche clay, chalk white. 15.5 - 16 ft., clay, light brown, slight odor	14 - 16	12
	6	2	▨		Clay, light brown, medium stiff, some gray zones from 16.4 - 16.8 and 17.6 - 17.9 ft., moderate odor.	16 - 18	112
	7	1.8	▥	ML	Clayey silt, saturated. Used downhole hammer at 19 ft.	18 - 20	5
			▩	GC	19.1 - 19.2 ft. small gravel zone, size <1/2 in.		
20			▨	CL	19.2-20.2 ft.,caliche clay, inclusions, poss. slight odor		
	8	2	▩	GC	20.2 - 20.6 ft., clayey gravel, saturated, gravel to 3/4 in. in splitspoon.	20 - 22	2
			▨	CL	Caliche clay, becoming harder with depth. Slight odor on auger near water zone, none in clay on auger tip.		
25					Notes: Hole located approximately 1/2 distance between NCL 95-09 and NCL 95-13. Plugged back hole with med. bentonite chips, hydrated with 5 gallons fresh water. Photoionization Detector (PID) readings are from jar headspace analysis of grab samples taken from the splitspoon at the designated intervals. On 8/3 redrilled hole 4 ft. north for monitor well, encountered product and abandoned hole.		

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LOG OF BORING NCL 95-14A, 95-14B, 95-15A

(Page 1 of 1)

RFI Phase II
North Colony Landfarm
Navajo Refining Company
Artesia, New Mexico

Date Started: : 08/03/95
Time Started :
Date Completed : 08/03/95
Hole Diameter: : 3.5 "

Drilling Method: : Solid Stem Auger
Sampling Method: : Cuttings
Drilled By: : Pool Environmental
Logged By: : D.G. Boyer

Depth in Feet	GRAPHIC	USCS	DESCRIPTION
0			
5			Notes, NCL 95-14A: Cored to 25 ft., no log record made, hole clean of hydrocarbons. Plugged back hole with medium bentonite chips, hydrated with 5 gallons fresh water.
10			Notes, NCL 95-14B: Redrilled NCL 95-14 at a location 4 ft. north for monitor well installation; encountered free product. No log record made. Plugged back hole with medium bentonite chips, hydrated with 5 gallons fresh water.
15			Notes, NCL 95-15A: Cored to 20 ft. No log record made but observed blue gray clay at approximately 18 ft. PID 51 PPM at 18 - 20 ft. Lowered bailer, product on water, strong odor. Plugged back hole with medium bentonite chips, hydrated with 5 gallons fresh water.
20			Location Notes: NCL 95-14A located 93 ft. south of NCL 95-14. NCL 95-15 located 79 ft. south of NCL 95-13. NCL 95-15A located 48 ft. west of NCL 95-15. NCL 95-14 located 58 ft. southwest of NCL 95-15A. NCL 95-14A located 99 ft. south of NCL 95-14. NCL 95-14B located 4 ft. north of NCL 95-14. NCL 95-09 located 148 ft. south of NCL 95-14A. NCL 95-16 located 103 ft. southeast of NCL 95-13.
25			
30			

LOG OF BORING NCL 95-15

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RFI Phase II
North Colony Landfarm
Navajo Refining Company

Artesia, New Mexico

Date Started:	: 08/02/95	Drilling Method:	: Hollow Stem Auger
Time Started	:	Sampling Method:	: 5 ft. core barrel
Date Completed	: 08/02/95	Drilled By:	: Pool Environmental
Hole Diameter:	: 8 1/4 in.	Logged By:	: D.G. Boyer

Depth in Feet	Samples	Recovery (ft)	GRAPHIC	USCS	DESCRIPTION	PID Interval (ft)	PID (ppm)
0	1	N/A			Location was to be replacement site for well to be installed at NCL 95-14 Sample from cuttings. Saturated from 1 - 5 ft. with diesel (?) hydrocarbons.		
5	2	2	▨	CL	Silty clay, dark brown with white streaks, stained at top and bottom, no odor. 5.5 - 7 ft., clay, dark gray to black, hard, slight septic odor.	5 - 7	5
					No recovery		
10	3	5	▨	CL	Silty clay, gray, strong H/C odor, dry, crumbly. 12.2 - 13 ft., same as above with caliche. 13 - 15 ft., caliche clay, chalk white, no obvious odor.	12 - 14	32
15	4	5	▨		Caliche clay, chalk color, dry crumbly with brownish zones. 16.6 - 19.1 ft., caliche clay, light gray, soft, strong H/C odor. 19.1 - 20 ft., sandy clay, light brown and gray, strong H/C odor.	18 - 20	118
20					Notes: Plugged back hole with medium bentonite chips, hydrated with 5 gallons fresh water. Photoionization Detector (PID) readings are from jar headspace analysis of grab samples taken from the splitspoon at the designated intervals.		
25							

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LOG OF BORING NCL 95-16 (MW-56)

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RFI Phase II
North Colony Landfarm
Navajo Refining Company
Artesia, New Mexico

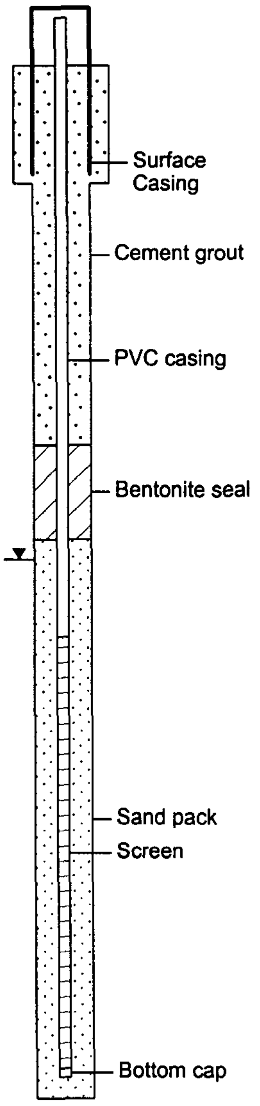
Date Started:	: 08/07/95	Drilling Method:	: Hollow Stem Auger
Time Started	: 1315	Sampling Method:	: 5 ft. core barrel
Date Completed	: 08/07/95	Drilled By:	: Pool Environmental
Hole Diameter:	: 8 1/4 in. OD	Logged By:	: D.G. Boyer

Depth in Feet	Samples	DESCRIPTION	GRAPHIC	USCS
0		No information - cored with solid stem auger, 0 - 4 ft.		
5	1	4-9 ft. Clay, dark brown with white flecks, stiff, plastic, no odor, 2 ft. recovery		CL
	2	9-10 ft. Same as above.		
10		10.1 - 11.2 ft., Clayey silt with caliche, chalk and light brown mottling, stiff, slightly damp, no odor. 11.2 - 11.8 ft., same as above, very stiff, no odor, 2.8 ft. recovery.		ML
15	3	14-16 ft. Clayey silt with caliche, brown, dry crumbly, no odor. 16.6 - 17.8 ft., Clayey silt, gravelly, 2 in. water in hole, 3.8 ft. recovery.		
20	4	19 - 20.6 ft. Clayey gravel to gravelly clay, light gray to white, caliche gravel to 1 in.		GC
		20.6 - 24 ft. Silty clay to clayey silt, light brown to chalk color with occassional gravel, 5 ft. recovery		CL
25				
30				

Notes:
NCL 95-16 located 10 ft. N. of Drum Storage Area wall, 103 ft. SE of 95-13, and 232 ft. SW of MW-45. Depth to water at 12.1 ft. BLS @1345 on 8/08. Photoionization Detector (PID) readings are from jar headspace analysis of grab samples taken from drill cuttings at designated intervals. On 8/08/95, hole was bailed by drillers to develop.

Well: MW-56

Elev.: 3362.05



Well Construction Information

DRILLING INFORMATION

Date completed	: 8/07/95
Hole diameter	: 8 1/4 in.
Depth Hole BLS	: 24 ft.
Drilling Method	: HSA
Drilled by	: Pool Environmental
Logged by	: D. G. Boyer

CASING, SCREEN & CAP

Material, joints	: PVC, threaded
Diameter	: 2 in. ID
Screen type	: Johnson Slotted
Screen length	: 10 ft.
Screen opening	: 0.010 slot
Scrn. placement	: 13.4 - 23.4 ft. BLS
Bottom Cap	: 0.2 ft PVC
Protector Casing	: Above-ground steel
Lock Key #	: P-493

SEALS & SAND PACK

Cement seal type	: Cement with 5 % : powered bentonite
Seal placement	: 0 - 8.8 ft. BLS
Annular seal type	: Med. bentonite : chips, ("Pure Gold")
Seal placement	: 8.8 - 11.0 ft. BLS
Sand pack type	: 10-20 CSSI silica
Sand placement	: 11.0 - 24 ft. BLS

ELEVATIONS

Ground elevation	: 3359.13 ft.
Inner casing, top	: 3362.05 ft.
Outer casing, top	: 3362.42 ft.

NOTES

PID Readings (ppm):

0-4 ft.	Not measured
7-9 ft.	0
12-13 ft.	0
15-16 ft.	2
17-18 ft.	2
20-21 ft.	2
23-24 ft.	4

COMPLETION NOTES:

Driller bailed 6.9 gallons 8/8
Developed with pump 8/9/95
Purged 30 gallons prior to sampling, pumped at 1.6 gpm with pump intake at 20 ft.
Purge info. @30 gal, 0940: 23 C, 4700 umhos, pH 7
Depth to water prior to sampling: 14.4 ft. below top inner casing.

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LOG OF BORING NCL 95-E

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RFI Phase II
North Colony Landfarm
Navajo Refining Company

Artesia, New Mexico

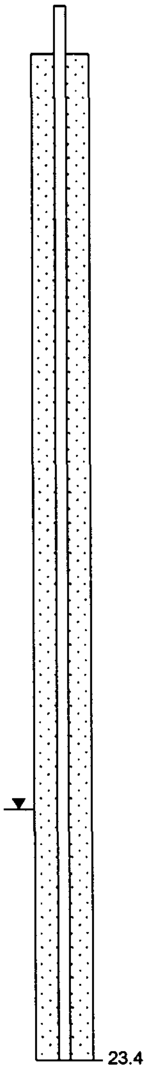
Date Started:	: Unknown	Drilling Method:	: Unknown
Time Started	: N/A	Sampling Method:	: N/A
Date Observed	: 06/24/95	Drilled By:	: Unknown
Hole Diameter:	: N/A	Information By:	: D.G. Boyer

Depth in Feet	GRAPHIC	USCS	DESCRIPTION
0			
5			Notes:
10			
15			
20			
25			
30			

Notes:

Hole "E" was located between well NCL-33 and boring NCL 95-03. Hole was cased with 4 in. PVC with a sick-up of 3 ft. above ground. On 06/24/95 depth to water was 20.5 ft. below TOC. Depth to product was 16.9 ft. Product thickness 3.6 ft. No drilling, completion, or other information about the hole is available.

In September 1997, hole was not located during attempt to obtain product sample. Area had been leveled and modified for installation of new crude oil unloading and transfer facilities.



LOG OF BORING NCL 92-01

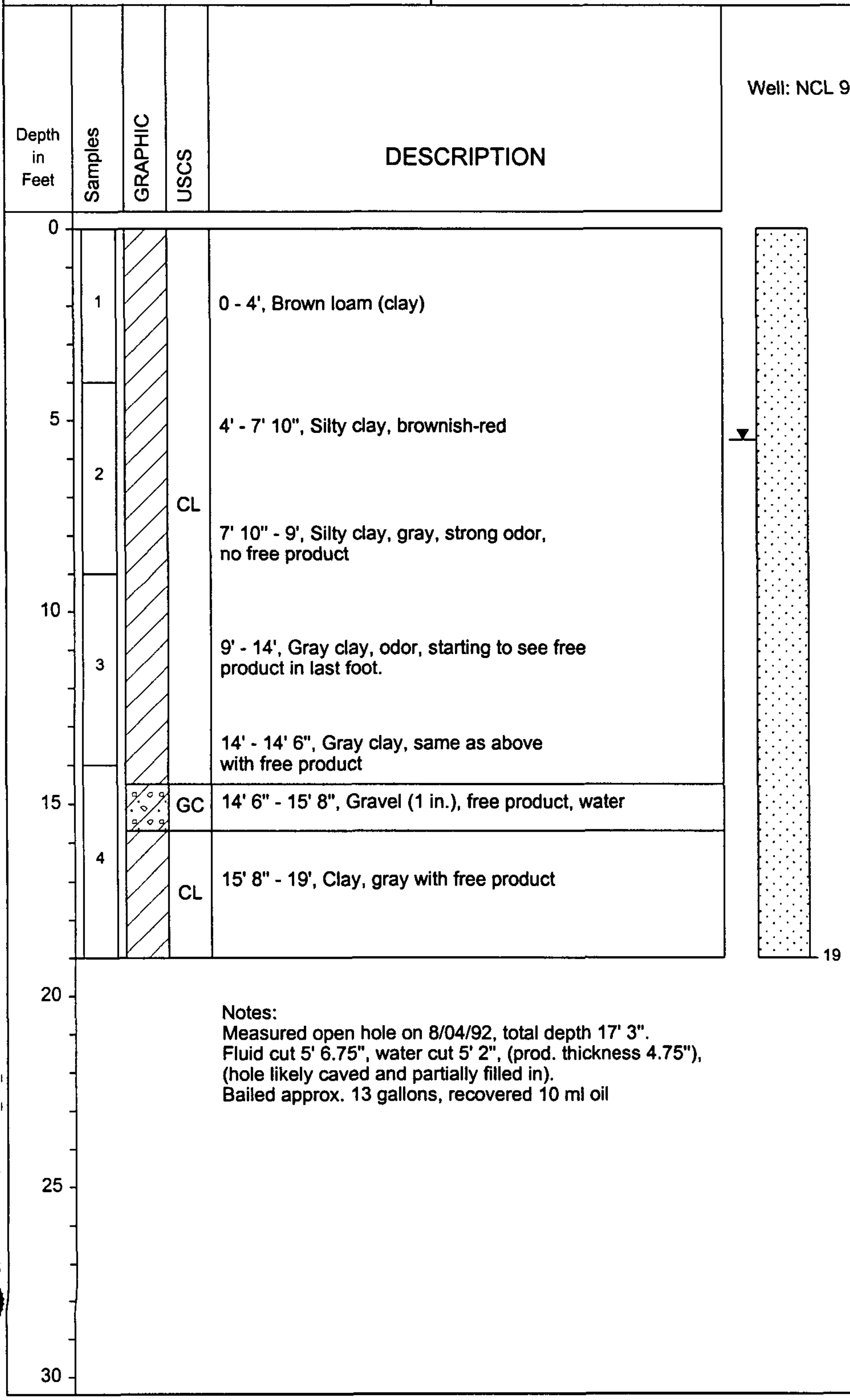
(Page 1 of 1)

RFI Phase II
North Colony Landfarm
Navajo Refining Company

Artesia, New Mexico

Date Started: : 08/03/92
Time Started :
Date Completed : 08/03/92
Hole Diameter: : 8 1/4 in.

Drilling Method: : Hollow Stem Auger
Sampling Method: : 5 ft. core barrel
Drilled By: : Pool Environmental
Logged By: : D. Moore



0 - 4', Brown loam (clay)

4' - 7' 10", Silty clay, brownish-red

7' 10" - 9', Silty clay, gray, strong odor, no free product

9' - 14', Gray clay, odor, starting to see free product in last foot.

14' - 14' 6", Gray clay, same as above with free product

14' 6" - 15' 8", Gravel (1 in.), free product, water

15' 8" - 19', Clay, gray with free product

Notes:
Measured open hole on 8/04/92, total depth 17' 3".
Fluid cut 5' 6.75", water cut 5' 2", (prod. thickness 4.75"),
(hole likely caved and partially filled in).
Bailed approx. 13 gallons, recovered 10 ml oil

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Navajo

LOG OF BORING NCL 92-02

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RFI Phase II
North Colony Landfarm
Navajo Refining Company
Artesia, New Mexico

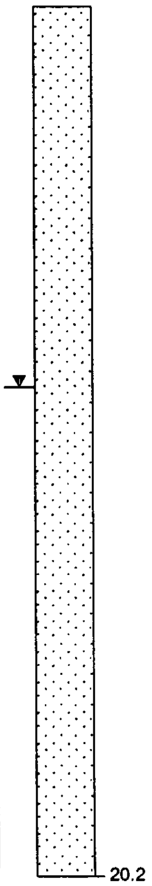
Date Started: : 08/03/92
Time Started :
Date Completed : 08/03/92
Hole Diameter: : 8 1/4 in.

Drilling Method: : Hollow Stem Auger
Sampling Method: : 5 ft. core barrel
Drilled By: : Pool Environmental
Logged By: : D. Moore

Depth in Feet	Samples	GRAPHIC	USCS	DESCRIPTION
0	1	▨	CL	0 - 4' 2", Dark brown loam
5		░		4' 2" - 5' 7", Caliche-like rock, off-white with nodules, chalky
	2	▨	CL	5' 7" - 9' 8", Brown loam
10	3	▨		9' 8" - 12' 6", Brown loam with gypsum nodules, grades into tan then white caliche, damp.
		░		12' 6" - 14', Caliche, white, damp, plastic
15	4	▨	CL	14' - 14' 1", Gray with odor and plastic 14' 1" - 15' 4", Clay, red, damp, slight odor 15' 4" - 20', Clay, gray with product
20				
25				
30				

Notes:
Measured open hole on 8/04/92, total depth 20' 2".
Fluid cut 9' 0.12", water cut 8' 10", (prod. thickness 2")
Bailed approx. 15 gallons, recovered 70 ml oil

Well: NCL 92-02



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LOG OF BORING NCL 92-03

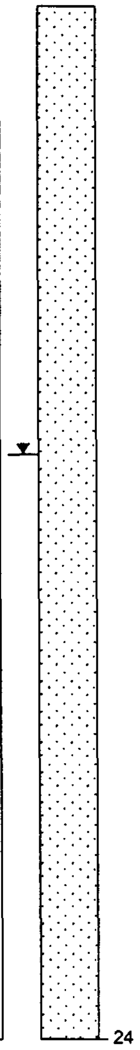
(Page 1 of 1)

RFI Phase II
North Colony Landfarm
Navajo Refining Company
Artesia, New Mexico

Date Started:	: 08/03/92	Drilling Method:	: Hollow Stem Auger
Time Started	:	Sampling Method:	: 5 ft. core barrel
Date Completed	: 08/03/92	Drilled By:	: Pool Environmental
Hole Diameter:	: 8 1/4 in.	Logged By:	: D. Moore

Depth in Feet	Samples	GRAPHIC	USCS	DESCRIPTION
0	1		CL	0 - 4', Brown loam with roots
5	2			4' - 6' 2", Brown loam, very few roots last foot
				6' 2" - 9', White to light gray, clayey, silty, with some gravel. No odor, some roots.
10	3			9' - 14', Same as above, gypsum crystals, increasing with depth.
15	4			14' - 19', Same as above, light gray grading to dark gray in bottom, very slight odor of hydrocarbon, no free product.
20				19' - 20.6', Dark gray, as above.
	5			20.6' - 24', Drilled extremely fast, no detection of free product, but some water; odor of hydrocarbon.
25				Notes: Measured open hole on 8/04/92, total depth 20' 10", (hole likely caved and partially filled in). Water cut 10' 5.75", bailed approx. 15 gallons, skim of oil.
30				

Well: NCL 92-03



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Navajo

LOG OF BORING NCL 92-04

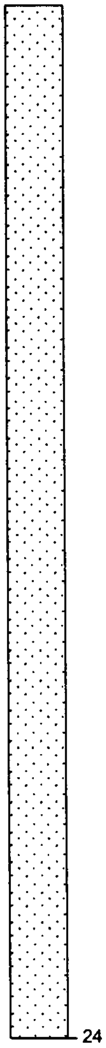
(Page 1 of 1)

RFI Phase II
North Colony Landfarm
Navajo Refining Company
Artesia, New Mexico

Date Started:	: 08/03/92	Drilling Method:	: Hollow Stem Auger
Time Started	:	Sampling Method:	: 5 ft. core barrel
Date Completed	: 08/03/92	Drilled By:	: Pool Environmental
Hole Diameter:	: 8 1/4 in.	Logged By:	: D. Moore

Well: NCL 92-04

Depth in Feet	Samples	GRAPHIC	USCS	DESCRIPTION
0	1			0 - 5', Brown loam, no roots
5	2			5' - 9', Loam, tan, clayey, caliche with nodules
10	3		CL	9' - 11' 2", Same as above.
				11' 2" - 14', Dark gray, strong H/C odor
15	4			14' - 19', Same as above, free product on last 1".
20	5			19' - 21' 4", Same as above, free product.
			GC	21' 4" - 22' 6", 2 " gravel, as above, with water.
			CL	22' 6" - 24', Dark gray, strong H/C odor.
25				
30				



Notes:
Measured open hole on 8/04/92, bailed 8 bailers, no oil.
(No water measurement recorded)

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LOG OF BORING NCL 92-05

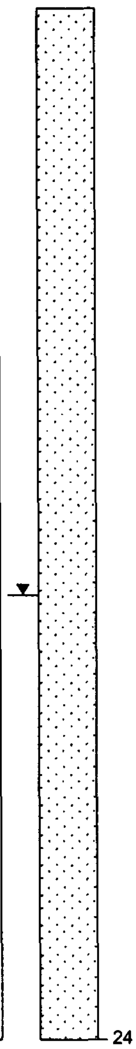
(Page 1 of 1)

RFI Phase II
North Colony Landfarm
Navajo Refining Company
Artesia, New Mexico

Date Started:	: 08/05/92	Drilling Method:	: Hollow Stem Auger
Time Started	:	Sampling Method:	: 5 ft. core barrel
Date Completed	: 08/05/92	Drilled By:	: Pool Environmental
Hole Diameter:	: 8 1/4 in.	Logged By:	: D. Moore

Depth in Feet	Samples	GRAPHIC	USCS	DESCRIPTION
0	1	▨	CL	0 - 2', Brown sandy loam
				2' - 3', Brown sandy loam with gravel
				3' - 4', Brown sandy loam with H/C odor and color
5	2			4' - 9', Sandy, silty clay with plasticity, strong odor and gray-dark gray color, no free product.
10	3			9' - 14', Sandy clay, gray-dark gray, strong odor, no free product.
15	4			14' - 16' 1", Same as above with 1/4" gravel (water zone?), no free product.
				16' 1" - 19', Sandy clay, light brown with caliche nodules
20	5			19' - 24', Same as above, nodules getting larger.
25				
30				

Well: NCL 92-05



Notes:
Cored in Eagle Draw
Measured open hole on 8/06/92, total depth 20 ft., (hole likely caved and partially filled in).
Fluid cut 13' 8", water cut 13' 9.25", (product thickness approx. 1.25"), skim of oil.

Navajo

LOG OF BORING NCL 92-06

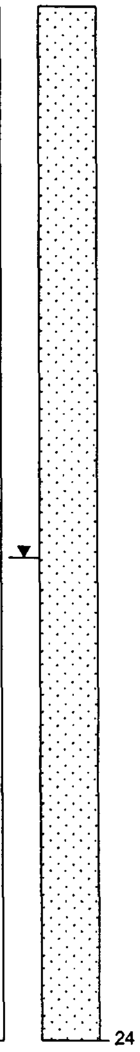
(Page 1 of 1)

RFI Phase II
North Colony Landfarm
Navajo Refining Company
Artesia, New Mexico

Date Started:	: 08/05/92	Drilling Method:	: Hollow Stem Auger
Time Started	:	Sampling Method:	: 5 ft. core barrel
Date Completed	: 08/05/92	Drilled By:	: Pool Environmental
Hole Diameter:	: 8 1/4 in.	Logged By:	: D. Moore

Depth in Feet	Samples	GRAPHIC	USCS	DESCRIPTION
0	1	▨		0 - 2', Dark brown sandy loam
		▨		2' - 5', Light brown sandy clay
5	2	▨		5' - 6', Light gray sandy clay,H/C odor
		▨		6' - 9', Same as above, getting sandier.
10	3	▨		9' - 12', Sandy gray clay, with H/C odor.
		▨	CL	12' - 13', As above with 1/8" gravel
		▨		13' - 14', Drilling break, no recovery.
15	4	▨		14' - 19', Sandy gray clay with H/C odor, water in last 1 ft.
20	5	▨		19' - 24', Sandy gray clay with water, H/C odor.
25				
30				

Well: NCL 92-06



Notes:
Cored in Eagle Draw
Measured open hole on 8/06/92, total depth 18' 11"
(hole likely caved and partially filled in),
fluid cut 12' 10.25", water cut 12' 10.13", skim of oil.

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Navajo

LOG OF BORING NCL 92-07

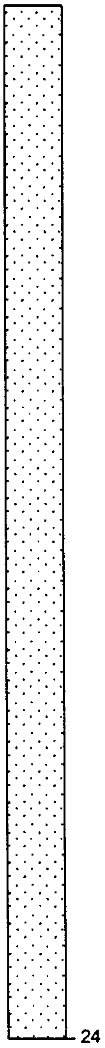
(Page 1 of 1)

RFI Phase II
North Colony Landfarm
Navajo Refining Company
Artesia, New Mexico

Date Started:	: 08/05/92	Drilling Method:	: Hollow Stem Auger
Time Started	:	Sampling Method:	: 5 ft. core barrel
Date Completed	: 08/05/92	Drilled By:	: Pool Environmental
Hole Diameter:	: 8 1/4 in.	Logged By:	: D. Moore

Depth in Feet	Samples	GRAPHIC	USCS	DESCRIPTION
0	1	▨		0 - 5', Brown loam
5	2	▨		5' - 15', Silty clay, tan to light yellow.
10	3	▨	CL	
15	4	▨		15' - 19', Tan clay, silty with slight H/C odor, wet.
20	5	▨		19' - 24', Same as above, water at 22 ft.
25				Notes: Measured open hole on 8/06/92, total depth 19' 10" (hole likely caved and partially filled in). (No water measurement recorded)
30				

Well: NCL 92-07



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APPENDIX B4

RFI SUPPLEMENTAL INVESTIGATION, LITHOLOGIC BORING LOGS

LOG OF BORING NCL 97-A1

(Page 1 of 1)

RFI Supplemental Investigation
North Colony Landfarm
July-September, 1997

Navajo Refining Company

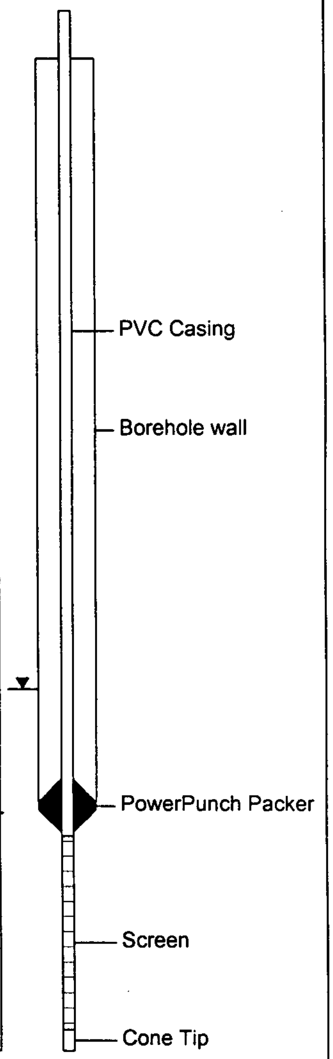
Artesia, New Mexico

Date Drilled	: 07/29/97	Drilling Method	: Hollow Stem Auger
Time Start, Finish	: 1415, 1530	Drill Equipment	: B-61 Direct Push
Coordinates	: 226' East, 128' South	Drilled By	: Layne Envir. Serv.
Hole Diameter	: 6 inch	Logged By	: D.G. Boyer

Sample Condition:	Sample From:
Remoulded	SS Split Spoon
Undisturbed	ST Shelby Tube
Lost	CT Auger Cuttings
Rock Core	CB 5 ft. Core Barrel

Depth in Feet	Samples	Sample From:	Blows per 2 ft.	Recovery (ft)	GRAPHIC	USCS	DESCRIPTION
0							
	1	CT					0-8 ft. Silty clay, light brown, with some sand and caliche fragments in cuttings. Some black H/C soil material
5							
						CL	
	2	CT					8-10 ft. Silty clay as above without H/C material
10							
	3	CT					10-13 ft. Silty clay
	4	CT					13-15 ft. Silty clay
15							15-15.9 ft. Sitly clay, light gray, slight H/C odor (diesel?)
	5	SS	8/21/21/22	1.6		CA	15.9-16.1 ft. Caliche clay, gray
						CL	16.6-17 ft. Clay, brown, stiff, no H/C odor
	6	SS	4/8				17-18 ft. Clay, mottled tan and chalk color, stiff, no H/C odor
							18 ft. Start push with "PowerPunch" direct push tool. Pushed to 23 ft.
20							
25							
30							

Well: NCL 97-A1



Notes:

Coordinate location measured from North Colony Landfarm northwest corner fence post. Completion with 5 ft. of 3/4 in. PVC screen and PVC riser in hole, drive rod removed. At 0745 on 7/30, DTW approximately 14.6 ft. BLS. Dry during purging. Let recover overnight. Sampled at 0953 on 7/31. EC 2,990 umhos @ 77.6 F. pH 7.0 (strip).
After sampling, removed PVC screen and riser, left bottom cone tip and seal in hole. Plugged bottom 8 ft. hole with cement/bentonite slurry; 5 to 8 ft. plugged with bentonite chips (hydrated); remainder of hole plugged with clean cuttings. H/C = Petroleum hydrocarbon

LOG OF BORING NCL 97-A2

(Page 1 of 1)

RFI Supplemental Investigation
North Colony Landfarm
July-September, 1997

Navajo Refining Company

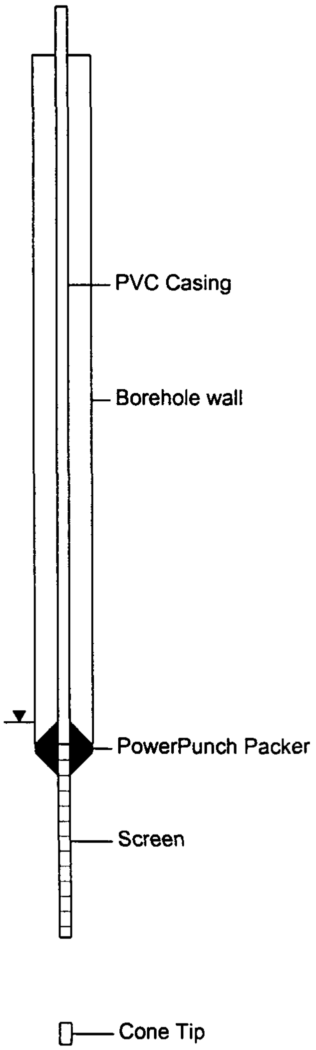
Artesia, New Mexico

Date Drilled	: 07/29/97	Drilling Method	: Hollow Stem Auger
Time Start, Finish	: 1330, 1400	Drill Equipment	: B-61 Direct Push
Coordinates	: 185' East, 86' South	Drilled By	: Layne Envir. Serv.
Hole Diameter	: 6 inch	Logged By	: D.G. Boyer

Sample Condition:	Sample From:
Remoulded	SS Split Spoon
Undisturbed	ST Shelby Tube
Lost	CT Auger Cuttings
Rock Core	CB 5 ft. Core Barrel

Depth in Feet	Samples	Sample From:	Blows per 2 ft.	Recovery (ft)	GRAPHIC	USCS	DESCRIPTION
0	1	CT				ML	0-1 ft. Surface material and dirt 1-3.5 ft. Sandy silt with mixed black hydrocarbon material
	2	CT				CL	3.5-5 ft. Silty clay, light brown, with small pebbles, H/C odor
5	3	CT					5-10 ft. Silty clay, same as above
10	4	CT					10-15 ft. Silty clay, same as above
15	5	SS	6/10/13	1.8			15-17 ft. Clay, light brown with gray mottling and caliche fragments. Clay slightly sandy and plastic. Very slight or no H/C odor
20							17 ft. Start push with "PowerPunch" direct push tool. Pushed to 23 ft. Final screen depth 20.5 feet due to screen refusal in hole.
25							
30							

Well: NCL 97-A2



Notes:
Coordinate location measured from North Colony Landfarm northwest corner fence post. Completion with 5 ft. of 3/4 in. PVC screen and PVC riser in hole, drive rod removed. At completion, purged approximately 1 gallon to dryness. At 1640 on 7/30, DTW approximately 15.5 ft. BLS. Purged additional 1/2 gallon prior to sampling. At sampling, EC 4,078 umhos @ 74 F, pH 7.5 (strip).
After sampling, removed PVC screen and riser, left bottom cone tip and seal in hole. Plugged bottom 8 ft. hole with cement/bentonite slurry; 5 to 8 ft. plugged with bentonite chips (hydrated); remainder of hole plugged with clean cuttings. H/C = Petroleum hydrocarbon

LOG OF BORING NCL 97-A3

(Page 1 of 1)

RFI Supplemental Investigation
North Colony Landfarm
July-September, 1997

Navajo Refining Company

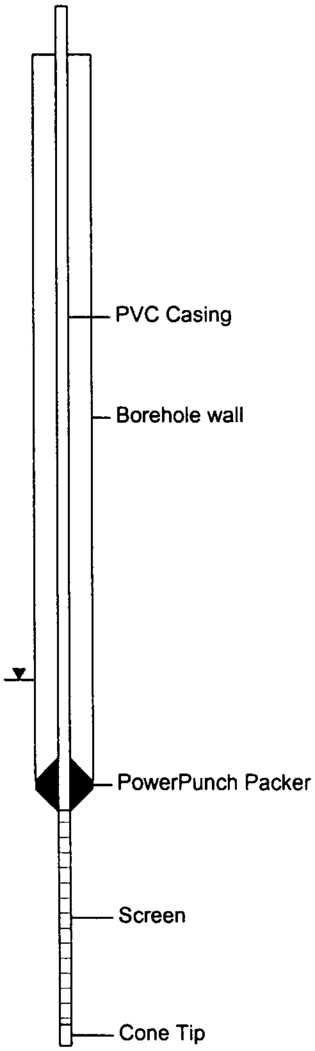
Artesia, New Mexico

Date Drilled	: 07/29/97	Drilling Method	: Hollow Stem Auger
Time Start, Finish	: 1015, 1315	Drill Equipment	: B-61 Direct Push
Coordinates	: 90' East, 50' South	Drilled By	: Layne Envir. Serv.
Hole Diameter	: 6 inch	Logged By	: D.G. Boyer

Sample Condition:	Sample From:
Remoulded	SS Split Spoon
Undisturbed	ST Shelby Tube
Lost	CT Auger Cuttings
Rock Core	CB 5 ft. Core Barrel

Well: NCL 97-A3

Depth in Feet	Samples	Sample From:	Blows per 2 ft.	Recovery (ft)	GRAPHIC	USCS	DESCRIPTION
0	1	CT				CL	1.5-4 ft. Black, H/C soil
5	2	CT					4-10 ft. Silty clay, light brown (tan) with pebbles, H/C odor
10	3	CT					10-15 ft. Silty clay, dark brown, slight H/C odor, moist
							14-15 ft. Very strong H/C odor, increasing with depth
15							15-17 ft. Clay, light brown, very plastic, no H/C odor, caliche piece in tip
	4	SS	7/10/16/19	1.8			
	5	CT					17-18 ft. Same as above
20							18 ft. Start push with "PowerPunch" direct push tool; lost tip, replaced and re-entered. Pushed to 23 ft. Set screen from 17.5 to 22.5 ft.
25							
30							



Notes:
Coordinate location measured from North Colony Landfarm northwest corner fence post. Completion with 5 ft. of 3/4 in. PVC screen and PVC riser in hole, drive rod removed. At 1600 on 7/29, DTW approx. 14.5 ft. BLS. Purged 1 gallon prior to sampling. No indicator parameters recorded. After sampling, removed PVC screen and riser, left bottom cone tip and seal in hole. Plugged bottom 8 ft. hole with cement/bentonite slurry; 5 to 8 ft. plugged with bentonite chips (hydrated); remainder of hole plugged with clean cuttings. Plugged back hole with medium bentonite chips, hydrated with 5 gallons fresh water. H/C = Petroleum hydrocarbon

LOG OF BORING NCL 97-A4

(Page 1 of 1)

RFI Supplemental Investigation
North Colony Landfarm
July-September, 1997

Navajo Refining Company

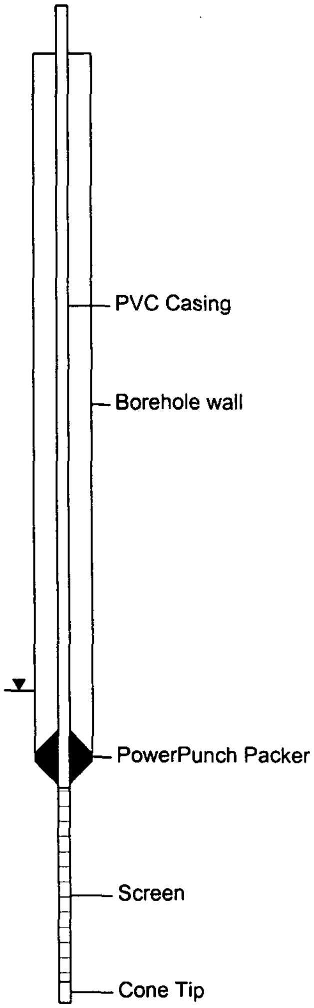
Artesia, New Mexico

Date Drilled	: 07/30/97	Drilling Method	: Hollow Stem Auger
Time Start, Finish	: 0630, 0730	Drill Equipment	: B-61 Direct Push
Coordinates	: 318' East, 80' South	Drilled By	: Layne Envir. Serv.
Hole Diameter	: 6 inch	Logged By	: D.G. Boyer

Sample Condition:	Sample From:
Remoulded	SS Split Spoon
Undisturbed	ST Shelby Tube
Lost	CT Auger Cuttings
Rock Core	CB 5 ft. Core Barrel

Well: NCL 97-A4

Depth in Feet	Samples	Sample From:	Blows per 2 ft.	Recovery (ft)	GRAPHIC	USCS	DESCRIPTION
0	1	CT					0-1.5 ft. Reworked hydocarbon waste soil material, brown
	2	CT					1.5-4 ft. Black landfarm material, H/C odor
5	3	CT				CL	4-10 ft. Clay, light brown, slight H/C odor
10	4	CT					10-15 ft. Silty clay, light brown, increasing H/C odor
15	5	SS	10/28/19/42	1.4		CA	15-17 ft. Clay and caliche clay, tan and white with gray mottling. Some very fine grained sand. Strong diesel odor.
20							17 ft. Start push with "PowerPunch" direct push tool. Pushed to 22 ft.



25

30

Notes:

Coordinate location measured from North Colony Landfarm northwest corner fence post. Completion with 5 ft. of 3/4 in. PVC screen and PVC riser in hole, drive rod removed. At 0756 on 7/31, DTW approximately 14.75 ft. BLS. Purged approx. 1/2 gallon prior to sampling. At sampling, EC 2,660 umhos @ 76 F. pH 7.3 (strip).
After sampling, removed PVC screen and riser, left bottom cone tip and seal in hole. Plugged bottom 8 ft. hole with cement/bentonite slurry; 5 to 8 ft. plugged with bentonite chips (hydrated); remainder of hole plugged with clean cuttings.

H/C = Petroleum hydrocarbon

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LOG OF BORING NCL 97-B1

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RFI Supplemental Investigation
North Colony Landfarm
July-September, 1997

Navajo Refining Company

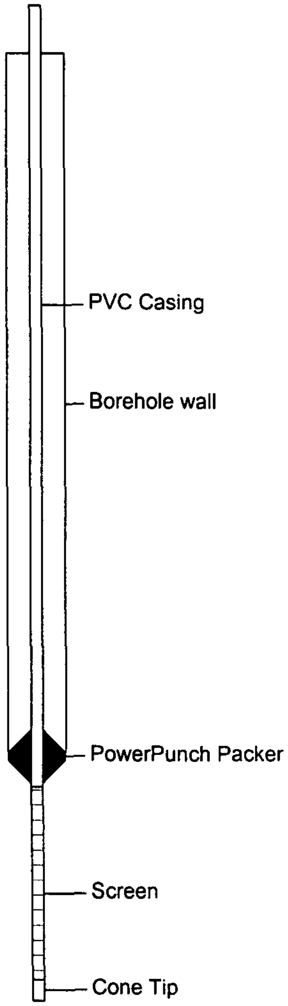
Artesia, New Mexico

Date Drilled	: 07/30/97	Drilling Method	: Hollow Stem Auger
Time Start, Finish	: 0900, 0930	Drill Equipment	: B-61 Direct Push
Coordinates	: 134' West, 122' South	Drilled By	: Layne Envir. Serv.
Hole Diameter	: 6 inch	Logged By	: D.G. Boyer

Sample Condition:	Sample From:
Remoulded	SS Split Spoon
Undisturbed	ST Shelby Tube
Lost	CT Auger Cuttings
Rock Core	CB 5 ft. Core Barrel

Well: NCL 97-B1

Depth in Feet	Samples	Sample From:	Blows per 2 ft.	Recovery (ft)	GRAPHIC	USCS	DESCRIPTION
0	1	CT			▨		0-1 ft. Reworked landfarm material, dark brown to black, refinery odor
	2	CT			▨		2-5 ft. Clay, dark gray, some odor
5	3	CT			▨	CL	5-8 ft. Clay, dark brown, some odor
	4	CT			▨		8-10 ft. Clay, brown, no odor
10	5	CT			▨		10-13 ft. Silty clay, tan, slight H/C odor
	6	CT			▥	ML	13-15 ft. Clayey silt, light gray, with caliche
15	7	SS	8/16/18/20	1.8	▥		15-16.2 ft. Clayey silt, light brown and chalk color, with caliche, strong H/C odor
					▨	CL	16.2-17 ft. Clay, brown, slight H/C odor
20							17 ft. Start push with "PowerPunch" direct push tool. Pushed to 22 ft. Photograph taken of cuttings
25							
30							



Notes:

Coordinate location measured from North Colony Landfarm northeast corner fence post. Completion with 5 ft. of 3/4 in. PVC screen and PVC riser in hole, drive rod removed. On 7/31 a.m., well is dry.

Removed PVC screen and riser, left bottom cone tip and seal in hole. Plugged bottom 8 ft. hole with cement/bentonite slurry; 5 to 8 ft. plugged with bentonite chips (hydrated); remainder of hole plugged with clean cuttings.

H/C = Petroleum hydrocarbon

LOG OF BORING NCL 97-B2

(Page 1 of 1)

RFI Supplemental Investigation
North Colony Landfarm
July-September, 1997

Navajo Refining Company

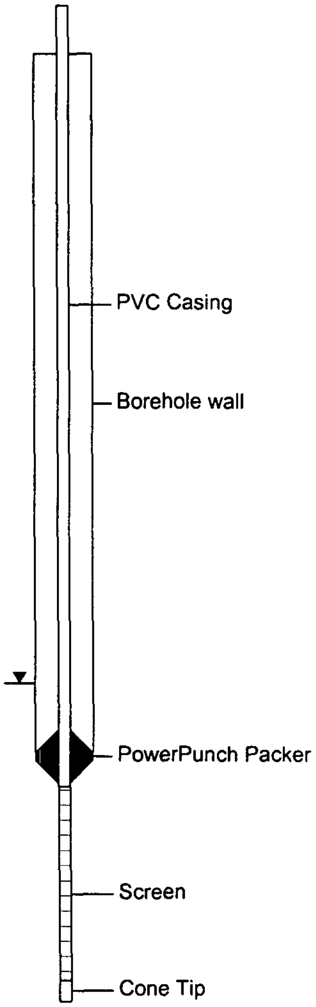
Artesia, New Mexico

Date Drilled : 07/30/97
Time Start, Finish : 0945, 1045
Coordinates : 47' West, 38' South
Hole Diameter : 6 inch
Drilling Method : Hollow Stem Auger
Drill Equipment : B-61 Direct Push
Drilled By : Layne Envir. Serv.
Logged By : D.G. Boyer

Sample Condition:	Sample From:
Remoulded	SS Split Spoon
Undisturbed	ST Shelby Tube
Lost	CT Auger Cuttings
Rock Core	CB 5 ft. Core Barrel

Depth in Feet	Samples	Sample From:	Blows per 2 ft.	Recovery (ft)	GRAPHIC	USCS	DESCRIPTION
0	1	CT			▨		0-3 ft. Reworked landfarm material, clayey, black
5	2	CT			▨	CL	3-5 ft. Landfarm material and clay, dark gray and black, slight odor
	3	CT			▨		5-8 ft. Silty clay, brown and light gray, plastic
10	4	CT			▥		8-10 ft. Clayey silt with caliche fragments, tan
	5	CT			▥	ML	10-13 ft. Clayey silt with caliche fragments, light brown
15	6	CT			▥		13-15 ft. Clayey silt, as above 15-16 ft. Clayey silt, light brown (tan)
	7	SS	6/8/8/10		▨	CL	16-17 ft. Clay, brown, stiff, dry
20							17 ft. Start push with "PowerPunch" direct push tool. Pushed to 22 ft. Photograph taken of cuttings and splitspoon core
25							
30							

Well: NCL 97-B2



Notes:

Coordinate location measured from North Colony Landfarm northeast corner fence post. Completion with 5 ft. of 3/4 in. PVC screen and PVC riser in hole, drive rod removed. At 0925 7/31, DTW is approximately 14.6 ft. BLS. Purged approximately 1/2 gallon prior to sampling. At sampling, EC 5,470 umhos @ 78.5 F. pH 7.5 (strip).

Removed PVC screen and riser, left bottom cone tip and seal in hole. Plugged bottom 8 ft. hole with cement/bentonite slurry; 5 to 8 ft. plugged with bentonite chips (hydrated); remainder of hole plugged with clean cuttings.

H/C = Petroleum hydrocarbon

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LOG OF BORING NCL 97-B3

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RFI Supplemental Investigation
North Colony Landfarm
July-September, 1997

Navajo Refining Company

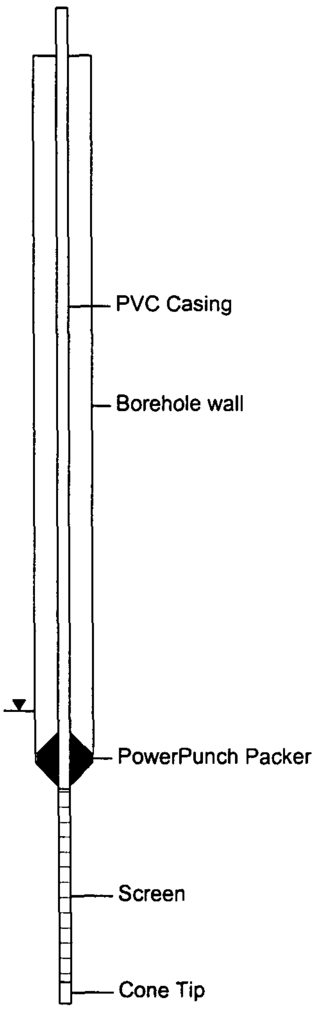
Artesia, New Mexico

Date Drilled	: 07/30/97	Drilling Method	: Hollow Stem Auger
Time Start, Finish	: 0745, 0845	Drill Equipment	: B-61 Direct Push
Coordinates	: 200' West, 70' South	Drilled By	: Layne Envir. Serv.
Hole Diameter	: 6 inch	Logged By	: D.G. Boyer

Sample Condition:	Sample From:
Remoulded	SS Split Spoon
Undisturbed	ST Shelby Tube
Lost	CT Auger Cuttings
Rock Core	CB 5 ft. Core Barrel

Well: NCL 97-B3

Depth in Feet	Samples	Sample From:	Blows per 2 ft.	Recovery (ft)	GRAPHIC	USCS	DESCRIPTION
0	1	CT				CL	0-3 ft. Surface material and landfarm hydrocarbons, black, amine-like odor
	2	CT					3-5 ft. Clay, brown and dark gray, less odor
5	3	CT					5-8 ft. Clay, brown and gray, some H/C odor
	4	CT					8-10 ft. Clay, brown, stiff, plastic
10	5	CT				ML	10-13 ft. Clayey silt, light brown, no odor
	6	CT					13-15 ft. Clayey silt with caliche and very fine grained sand, gray, strong H/C odor
15	7	SS	10/16/18/20	1.4			15-16 ft. Clayey silt, gray and brown mottled, with very fine grained sand, H/C odor 16-17 ft. Clayey silt, brown and chalk color
20							17 ft. Start push with "PowerPunch" direct push tool. Pushed to 22 ft. Photograph taken of cuttings
25							
30							



Notes:

Coordinate location measured from North Colony Landfarm northeast corner fence post. Completion with 5 ft. of 3/4 in. PVC screen and PVC riser in hole, drive rod removed. At 0830 7/31, DTW is approximately 15.2 ft. BLS. Purged approximately 1/2 gallon prior to sampling. At sampling, EC 4,050 umhos @ 79.7 F, pH 7.3 (strip).

Removed PVC screen and riser, left bottom cone tip and seal in hole. Plugged bottom 8 ft. hole with cement/bentonite slurry; 5 to 8 ft. plugged with bentonite chips (hydrated); remainder of hole plugged with clean cuttings.

H/C = Petroleum hydrocarbon

LOG OF BORING NCL 97-C1

(Page 1 of 1)

RFI Supplemental Investigation
North Colony Landfarm
July-September, 1997

Navajo Refining Company

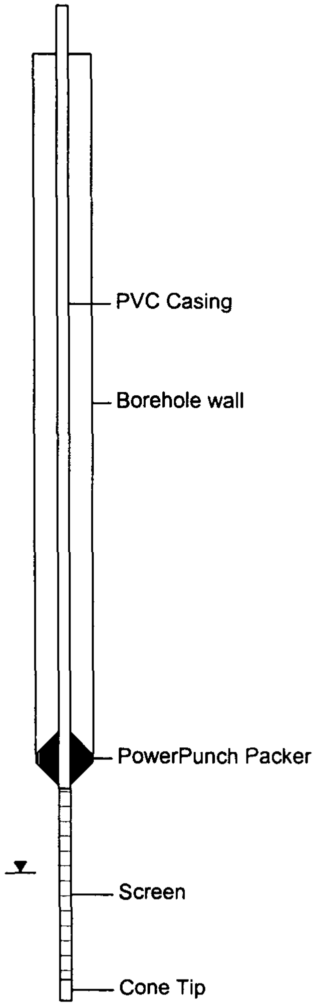
Artesia, New Mexico

Date Drilled	: 07/30/97	Drilling Method	: Hollow Stem Auger
Time Start, Finish	: 1110, 1145	Drill Equipment	: B-61 Direct Push
Coordinates	: 103' East, 26' North	Drilled By	: Layne Envir. Serv.
Hole Diameter	: 6 inch	Logged By	: D.G. Boyer

Sample Condition:	Sample From:
Remoulded	SS Split Spoon
Undisturbed	ST Shelby Tube
Lost	CT Auger Cuttings
Rock Core	CB 5 ft. Core Barrel

Depth in Feet	Samples	Sample From:	Blows per 2 ft.	Recovery (ft)	GRAPHIC	USCS	DESCRIPTION
0	1	CT			▨	CL	0-2 ft. Landfarm material and clay, black
	2	CT			▨		2-5 ft. Landfarm material and clay, dark brown
5	3	CT			▨		5-8 ft. Clay, brown, very plastic, slight odor
	4	CT			▥	ML	8-10 ft. Clayey silt, light gray and brown (tan), with caliche pebbles
10	5	CT			▩	CG	10-13 ft. Gravelly clay, blue gray, limestone gravels to 3/4 in., diesel odor. Max PID measurement of 100 ppm
	6	CT			▥	ML	13-15 ft. Clayey silt, light gray, slightly moist, plastic, slight H/C odor. Max PID measurement of 484 ppm
15	7	SS	8/20/31/46	1.4	▧	SC	15-17 ft. Clayey sand, sand very fine grained, light brown and tan, occassional gray zone, slight or no H/C odor
20							17 ft. Start push with "PowerPunch" direct push tool. Pushed to 22 ft. Photograph taken of cuttings

Well: NCL 97-C1



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Notes:

Coordinate location measured from North Colony Landfarm southwest corner fence post. Completion with 5 ft. of 3/4 in. PVC screen and PVC riser in hole, drive rod removed. At 1010 7/31, DTW is approximately 19.0 ft. BLS. Purged approximately 1/4 gallon prior to sampling. At sampling, EC 3,620 umhos @ 75.4 F, pH 7.3 (strip).

Removed PVC screen and riser, left bottom cone tip and seal in hole. Plugged bottom 8 ft. hole with cement/bentonite slurry; 5 to 8 ft. plugged with bentonite chips (hydrated); remainder of hole plugged with clean cuttings.

H/C = Petroleum hydrocarbon

LOG OF BORING NCL 97-C2

(Page 1 of 1)

RFI Supplemental Investigation
North Colony Landfarm
July-September, 1997

Navajo Refining Company

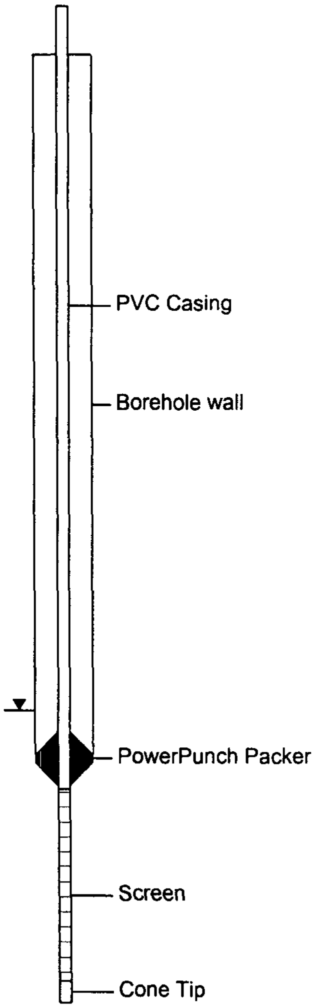
Artesia, New Mexico

Date Drilled	: 07/30/97	Drilling Method	: Hollow Stem Auger
Time Start, Finish	: 1400, 1450	Drill Equipment	: B-61 Direct Push
Coordinates	: 103' East, 26' North	Drilled By	: Layne Envir. Serv.
Hole Diameter	: 6 inch	Logged By	: D.G. Boyer

Sample Condition:	Sample From:
Remoulded	SS Split Spoon
Undisturbed	ST Shelby Tube
Lost	CT Auger Cuttings
Rock Core	CB 5 ft. Core Barrel

Well: NCL 97-C2

Depth in Feet	Samples	Sample From:	Blows per 2 ft.	Recovery (ft)	GRAPHIC	USCS	DESCRIPTION
0	1	CT				CL	0-2 ft. Landfarm material, black, clayey
	2	CT					2-5 ft. Clay, dark brown, very plastic, slight odor
5	3	CT					5-7 ft. Clay, brown, very plastic
	4	CT					7-9 ft. Silty clay, gray blue, some pebbles, very plastic
10	5	CT					9-13 ft. Clay, dark gray, some pebbles, very plastic, slightly moist, strong H/C odor
	6	CT					13-15 ft. Silty clay, light gray, strong H/C odor
15	7	SS	8/12/20/30	1.4		ML	15-17 ft. Clayey, sandy silt, sand very fine grained, light brown with mottled gray from 15-16 ft. H/C odor thru out
20							17 ft. Start push with "PowerPunch" direct push tool. Pushed to 22 ft. Photographs taken of cuttings
25							
30							



Notes:

Coordinate location measured from North Colony Landfarm southwest corner fence post. Completion with 5 ft. of 3/4 in. PVC screen and PVC riser in hole, drive rod removed. At 1044 7/31, DTW is approximately 15.2 ft. BLS. Purged approximately 0.5 gallon prior to sampling. At sampling, EC 2,060 umhos @ 79 F, pH 7.3 (strip).

Removed PVC screen and riser, left bottom cone tip and seal in hole. Plugged bottom 8 ft. hole with cement/bentonite slurry; 5 to 8 ft. plugged with bentonite chips (hydrated); remainder of hole plugged with clean cuttings.

H/C = Petroleum hydrocarbon

LOG OF BORING NCL 97-C3

(Page 1 of 1)

RFI Supplemental Investigation
North Colony Landfarm
July-September, 1997

Navajo Refining Company

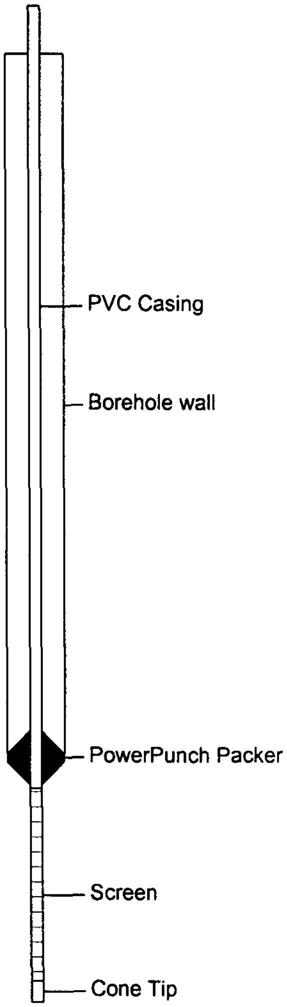
Artesia, New Mexico

Date Drilled	: 07/30/97	Drilling Method	: Hollow Stem Auger
Time Start, Finish	: 1155, 1220	Drill Equipment	: B-61 Direct Push
Coordinates	: 160' East, 100' North	Drilled By	: Layne Envir. Serv.
Hole Diameter	: 6 inch	Logged By	: D.G. Boyer

Sample Condition:	Sample From:
Remoulded	SS Split Spoon
Undisturbed	ST Shelby Tube
Lost	CT Auger Cuttings
Rock Core	CB 5 ft. Core Barrel

Depth in Feet	Samples	Sample From:	Blows per 2 ft.	Recovery (ft)	GRAPHIC	USCS	DESCRIPTION	PID (ppm)
0	1	CT			▨	CL	0-2 ft. Landfarm material, brown and black, refinery odor	81.5
	2	CT			▨		2-5 ft. Clay and landfarm material, brown and gray, odor	69
5	3	CT			▨		5-7 ft. Clay and caliche clay, tan, with pebbles, H/C odor	86
	4	CT			⁙	SC	7-9 ft. Clayey sand, light gray, with pebbles, strong H/C odor	214
10	5	CT			⁙		9-12 ft. Clayey sand as above, black and gray color, strong H/C odor	71
	6	CT			▥	ML	12-14 ft. Clayey silt, gray, some small pebbles	78
15	7	SS	5/12/20/30	1.4	▨	CL	15-17 ft. Clay, brown, stiff, some caliche zones (chalk color)	11
20							17 ft. Start push with "PowerPunch" direct push tool. Pushed to 22 ft.	
25								
30								

Well: NCL 97-C3



Notes:

Coordinate location measured from North Colony Landfarm southwest corner fence post. Completion with 5 ft. of 3/4 in. PVC screen and PVC riser in hole, drive rod removed. Dry hole at 1730 7/30 and at 0700 7/31.

Removed PVC screen and riser, left bottom cone tip and seal in hole. Plugged bottom 8 ft. hole with cement/bentonite slurry; 5 to 8 ft. plugged with bentonite chips (hydrated); remainder of hole plugged with clean cuttings.

H/C = Petroleum hydrocarbon

LOG OF BORING NCL 97-D1

(Page 1 of 1)

RFI Supplemental Investigation
North Colony Landfarm
July-September, 1997

Navajo Refining Company

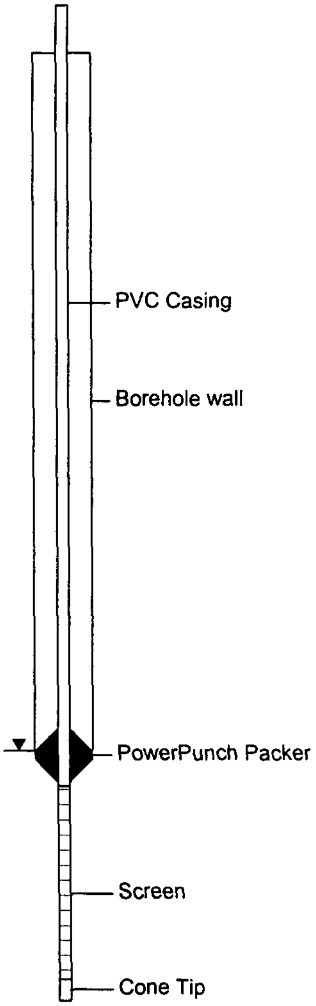
Artesia, New Mexico

Date Drilled	: 07/30/97	Drilling Method	: Hollow Stem Auger
Time Start, Finish	: 1520, 1600	Drill Equipment	: B-61 Direct Push
Coordinates	: 80' West, 73' North	Drilled By	: Layne Envir. Serv.
Hole Diameter	: 6 inch	Logged By	: D.G. Boyer

Sample Condition:	Sample From:
Remoulded	SS Split Spoon
Undisturbed	ST Shelby Tube
Lost	CT Auger Cuttings
Rock Core	CB 5 ft. Core Barrel

Depth in Feet	Samples	Sample From:	Blows per 2 ft.	Recovery (ft)	GRAPHIC	USCS	DESCRIPTION
0	1	CT				CL	0-2 ft. Landfarm material, black, strong refinery odor
	2	CT					2-5 ft. Clay, black and brown, some odor
5	3	CT					5-7 ft. Clay, black and brown, very plastic, odor
	4	CT					7-10 ft. Clay, brown and light brown, very plastic, slight odor
10	5	CT				ML	10-12 ft. Clayey silt, chalk white, with caliche fragments, no H/C odor
	6	CT					12-15 ft. Clayey silt, light brown, plastic, slightly moist, diesel odor
15	7	SS	7/13/17/24	1.6			15-17 ft. Clayey silt, light brown and chalk color, mottled, occassional light gray color, stong diesel odor
20							17 ft. Start push with "PowerPunch" direct push tool. Pushed to 22 ft. Photograph taken of cuttings and splitspoon core

Well: NCL 97-D1



Notes:

Coordinate location measured from North Colony Landfarm southeast corner fence post. Completion with 5 ft. of 3/4 in. PVC screen and PVC riser in hole, drive rod removed. At 1256 7/31, DTW is approximately 16.2 ft. BLS. Purged approximately 0.4 gallon prior to sampling. At sampling, EC 3,450 umhos @ 81 F, pH 7.0 (strip).

Removed PVC screen and riser, left bottom cone tip and seal in hole. Plugged bottom 8 ft. hole with cement/bentonite slurry; 5 to 8 ft. plugged with bentonite chips (hydrated); remainder of hole plugged with clean cuttings.

H/C = Petroleum hydrocarbon

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LOG OF BORING NCL 97-D2

(Page 1 of 1)

RFI Supplemental Investigation
North Colony Landfarm
July-September, 1997

Navajo Refining Company

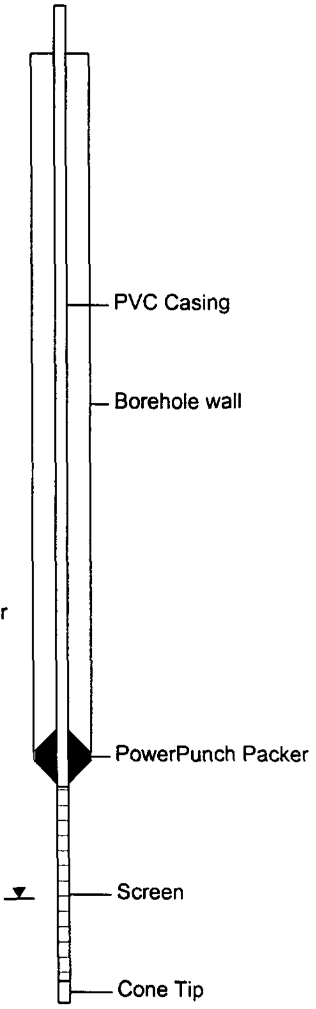
Artesia, New Mexico

Date Drilled	: 07/30/97	Drilling Method	: Hollow Stem Auger
Time Start, Finish	: 1455, 1515	Drill Equipment	: B-61 Direct Push
Coordinates	: 164' West, 64' North	Drilled By	: Layne Envir. Serv.
Hole Diameter	: 6 inch	Logged By	: D.G. Boyer

Sample Condition:	Sample From:
Remoulded	SS Split Spoon
Undisturbed	ST Shelby Tube
Lost	CT Auger Cuttings
Rock Core	CB 5 ft. Core Barrel

Well: NCL 97-D2

Depth in Feet	Samples	Sample From:	Blows per 2 ft.	Recovery (ft)	USCS	DESCRIPTION
0	1	CT			CL	0-2 ft. Landfarm material, black, refinery odor
	2	CT				2-5 ft. Clay, dark gray and black
5	3	CT				5-7 ft. Clay, brown, very plastic, slight odor
	4	CT				7-8 ft. Clay, brown, very plastic
	5	CT			ML	9-10 ft. Clayey silt, light brown, plastic, slight H/C odor
10	6	CT				10-12 ft. Clayey silt, light brown, plastic, no H/C odor
	7	CT				12-14 ft. Clayey silt, light brown (chalk) color, plastic, no odor
	8	CT			CH	14-15.5 ft. Clay, light brown, very plastic (fat clay)
15	9	SS	6/8/10/22	1.8	ML	15.5-17 ft. Silt with clay and very fine grained sand, light brown, chalk and light gray mottled, stong H/C odor
						17 ft. Start push with "PowerPunch" direct push tool. Pushed to 22 ft. Photographs taken of cuttings
20						
25						
30						



Notes:

Coordinate location measured from North Colony Landfarm southeast corner fence post. Completion with 5 ft. of 3/4 in. PVC screen and PVC riser in hole, drive rod removed. At 1235 7/31, DTW is approximately 19.6 ft. BLS. Purged approximately 1/5 gallon prior to sampling. At sampling, EC 3,940 umhos @ 79 F, pH 7.5 (strip).

Removed PVC screen and riser, left bottom cone tip and seal in hole. Plugged bottom 8 ft. hole with cement/bentonite slurry; 5 to 8 ft. plugged with bentonite chips (hydrated); remainder of hole plugged with clean cuttings.

H/C = Petroleum hydrocarbon

LOG OF BORING NCL BG 97-01

(Page 1 of 1)

RFI Supplemental Investigation
North Colony Landfarm
July-September, 1997

Navajo Refining Company

Artesia, New Mexico

Date Drilled	: 08/01/97	Drilling Method	: Hollow Stem Auger
Time Start, Finish	: 1005, 1030	Drill Equipment	: B-61 Split Spoon
Coordinates	: 82' East, 33' North	Drilled By	: Layne Envir. Serv.
Hole Diameter	: 6 inch	Logged By	: D.G. Boyer

Sample Condition:	Sample From:
Remoulded	SS Split Spoon
Undisturbed	ST Shelby Tube
Lost	CT Auger Cuttings
Rock Core	CB 5 ft. Core Barrel

Depth in Feet	Samples	Sample From:	Blows 1st ft.	Blows 2nd ft.	Recovery (ft)	GRAPHIC	USCS	DESCRIPTION
0	1	CT					ML	0-2 ft. Clayey silt, chalk white
	2	CT						2-5 ft. Clayey sandy silt, sand very fine grained
5	3	SS	8/9	14/16	1			5-7 ft. Clayey sandy silt with caliche, light brown (tan) and chalk color, mottled, sample collected for lead and chromium metals
	4	CT	12/16	18/22	1			7-9 ft. Clayey silt, light brown (tan) and chalk color, mottled, occassional caliche with crystals (calcite?) seen in caliche, sample collected for lead and chromium metals
10	5	SS	10/10	14/14	1.6			9-11 ft. Clayey silt, as above, sample collected for lead and chromium metals
15								

Notes:

Coordinate location measured from North Colony Landfarm northwest corner fence post. Plugged back hole with clean cuttings.

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LOG OF BORING NCL BG 97-02

(Page 1 of 1)

RFI Supplemental Investigation
North Colony Landfarm
July-September, 1997

Navajo Refining Company

Artesia, New Mexico

Date Drilled	: 08/01/97	Drilling Method	: Hollow Stem Auger
Time Start, Finish	: 0825, 0850	Drill Equipment	: B-61 Split Spoon
Coordinates	: 135' East, 12' North	Drilled By	: Layne Envir. Serv.
Hole Diameter	: 6 inch	Logged By	: D.G. Boyer

Sample Condition:	Sample From:
Remoulded	SS Split Spoon
Undisturbed	ST Shelby Tube
Lost	CT Auger Cuttings
Rock Core	CB 5 ft. Core Barrel

Depth in Feet	Samples	Sample From:	Blows 1st ft.	Blows 2nd ft.	Recovery (ft)	GRAPHIC	USCS	DESCRIPTION
0								
	1	CT						0-2 ft. Clayey sandy silt, light brown, with medium sand grains
	2	CT						2-5 ft. Clayey silt, light brown, dry
5								
	3	SS	17/15	17/21	1.7		ML	5-7 ft. Clayey silt with caliche inclusions, calcite crystals, sample collected for lead and chromium metals
	4	CT						7-9 ft. Clayey silt, as above
10	5	SS	16/24	28/19	1.6			9-11 ft. Clayey silt with caliche, tan and chalk color mottled, caliche rock 3/4 in. in spoon at 10.5 ft., sample collected for lead and chromium metals
15								

Notes:

Coordinate location measured from North Colony Landfarm northwest corner fence post. Plugged back hole with clean cuttings.

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LOG OF BORING NCL BG 97-03

(Page 1 of 1)

RFI Supplemental Investigation
North Colony Landfarm
July-September, 1997

Navajo Refining Company

Artesia, New Mexico

Date Drilled	: 08/01/97	Drilling Method	: Hollow Stem Auger
Time Start, Finish	: 0935, 0955	Drill Equipment	: B-61 Split Spoon
Coordinates	: 80' East, 65' North	Drilled By	: Layne Envir. Serv.
Hole Diameter	: 6 inch	Logged By	: D.G. Boyer

Sample Condition:	Sample From:
Remoulded	SS Split Spoon
Undisturbed	ST Shelby Tube
Lost	CT Auger Cuttings
Rock Core	CB 5 ft. Core Barrel

Depth in Feet	Samples	Sample From:	Blows 1st ft.	Blows 2nd ft.	Recovery (ft)	GRAPHIC	USCS	DESCRIPTION
0	1	CT				▥	ML	0-2 ft. Clayey silt, light brown and chalk color
	2	CT						2-5 ft. Clayey sandy silt, light brown, sand very fine grained
5	3	SS	9/14	18/19				5-7 ft. No record, sample collected for lead and chromium metals
	4	CT				▨	CL	7-9 ft. Clay, brown, plastic, some caliche, sample collected from cuttings for lead and chromium metals
10	5	SS	12/18	20/20	1.4			9-11 ft. Clay and caliche clay, light brown and chalk color, mottled, more caliche than at 7-9 ft., sample collected for lead and chromium metals
15								

Notes:

Coordinate location measured from North Colony Landfarm northwest corner fence post. Plugged back hole with clean cuttings.

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LOG OF BORING NCL BG 97-04

(Page 1 of 1)

RFI Supplemental Investigation
North Colony Landfarm
July-September, 1997

Navajo Refining Company

Artesia, New Mexico

Date Drilled	: 08/01/97	Drilling Method	: Hollow Stem Auger
Time Start, Finish	: 0855, 0930	Drill Equipment	: B-61 Split Spoon
Coordinates	: 110' East, 57' North	Drilled By	: Layne Envir. Serv.
Hole Diameter	: 6 inch	Logged By	: D.G. Boyer

Sample Condition:	Sample From:
Remoulded	SS Split Spoon
Undisturbed	ST Shelby Tube
Lost	CT Auger Cuttings
Rock Core	CB 5 ft. Core Barrel

Depth in Feet	Samples	Sample From:	Blows 1st ft.	Blows 2nd ft.	Recovery (ft)	GRAPHIC	USCS	DESCRIPTION
0	1	CT					ML	0-2 ft. Clayey silt, chalk color with caliche (possible pad material)
	2	CT						2-5 ft. Clayey silt, light brown, soft, moist
5	3	SS	8/9	11/12	1.5			5-7 ft. Clayey silt, light brown, occassional caliche gravel, sample collected for lead and chromium metals
	4	CT					CL	7-9 ft. Clay, brown, plastic, occassional sand grains, sample collected from cuttings for lead and chromium metals
10	5	SS	21/14	19/19	1.4			9-11 ft. Clay and caliche clay, light brown and chalk color, mottled, sample collected for lead and chromium metals
15								

Notes:

Coordinate location measured from North Colony Landfarm northwest corner fence post. Plugged back hole with clean cuttings.

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Navajo

LOG OF BORING NCL BG 97-05

(Page 1 of 1)

RFI Supplemental Investigation
North Colony Landfarm
July-September, 1997

Navajo Refining Company

Artesia, New Mexico

Date Drilled	: 08/01/97	Drilling Method	: Hollow Stem Auger
Time Start, Finish	: 1030, 1055	Drill Equipment	: B-61 Split Spoon
Coordinates	: 35' East, 75' North	Drilled By	: Layne Envir. Serv.
Hole Diameter	: 6 inch	Logged By	: D.G. Boyer

Sample Condition:	Sample From:
Remoulded	SS Split Spoon
Undisturbed	ST Shelby Tube
Lost	CT Auger Cuttings
Rock Core	CB 5 ft. Core Barrel

Depth in Feet	Samples	Sample From:	Blows 1st ft.	Blows 2nd ft.	Recovery (ft)	GRAPHIC	USCS	DESCRIPTION
0								0-5 ft. No record
5							ML	
	3	SS	7/6	6/10	1			5-7 ft. Clayey silt with caliche, mottled light brown and chalk color, sample collected for lead and chromium metals
	4	CT	7/12	16/20	1.4			7-9 ft. Clayey silt with caliche fragments, color mottled as above, sample collected for lead and chromium metals
10	5	SS	6/9	11/20	1.4			9-11 ft. Clayey silt, as above, sample collected for lead and chromium metals
15								

Notes:

Coordinate location measured from North Colony Landfarm northwest corner fence post. Plugged back hole with clean cuttings.

Photographs taken of splitspoon cores

APPENDIX B5

MONITOR WELL LITHOLOGIC LOGS

[illegible]l #1 (NCL-31) **Sample Log** Page 1 of

Project Navajo Refinery Location SW corner of Colony Landfarm

Drilling Contractor D. Anderson Driller Richard Helper Eddie

Rig Type Hollow stem Hole Diameter 8 inches Drilling Fluid N/A

Type of Sample split spoon & Shelby Date and Time Drilling Began 10/19/82 1:30pm Date and Time Drilling End 3:00pm

Geraghty and Miller Representative J. Dauchy and T. Bouvette

Blows per 6 inches	% Recovery	Sample Description	Depth Feet to Feet
		Fill - brown topsoil with gravel and concrete	0 - 2
		brittle brown silty clay, poorly sorted with white pebbles	2 - 3
		brittle brown silty clay, dense no pebbles	3 - 7
		tan silty clay, plastic, moist	7 - 8½
[illegible] - 11-16	split spoon 8½ - 10	gray silty clay w/gyp. & unweather anhydrite poorly sorted, organic smell	8½ - 14
6 - 6 - 8	split spoon 14 - 15½	dolmite gravel water bearing seams (2") interbed w/gray brown silty clay, saturated	14 - 16
4 - [illegible] - 5	split spoon 17½ - 19	brown brittle sandy silty clay w/red & white coarse grains	16 - 20
	Shelby tube 20 - 22	red clay, well sorted, unsaturated	20 - 22

Well #2 (NCL-32) **Sample Log** Page 2 of

Project Navajo Refinery Location [illegible] ~~SE corner of Telephone Storage~~

Drilling Contractor D. Anderson Driller Richard Helper Eddie

Rig Type Hollow stem Hole Diameter 8" inches Drilling Fluid N/A

Type of Sample split spoon & shelby Date and Time Drilling Began 10/20/82 7:20 am Date and Time Drilling End 9:00am

Geraghty and Miller Representative J. Dauchy T. Bouvette

Blows per 6 inches	% Recovery	Sample Description	Depth Feet to Feet
		dark brown topsoil	0 - 2½
		light brown silty clay w/unweather anhydrite, poorly sorted	2½ - 4
3 - 4 - 5	split spoon 5 - 6½	tan silty clay, brittle, poorly sorted	4 - 6
		red silty clay	6 - 6½
[illegible] - 6-10	split spoon 1- - 11½	light brown silty clay, mottled, poorly sorted	6½ - 10½
	organic smell	pebble seam wet, dolmite gravel, 2"	10½
		tan silty clay, same as above	10½ - 13
5 - 8 -12	split spoon 15 - 16½	gray silty clay, well sorted less dense organic smell	13 - 16
9 -16-17	split spoon 17½ - 19	anhydritic sand & pebble seams interbed with brownish red sandy silty clay	16 - 22
6 - 7- 9	split spoon 20 - 21½		
7 - 8-9	split spoon 22½ - 24	red clay, well sorted, dry & hard	22½ - 24

W[illegible] #3 NCL-33 **Sample Log** Page 3 of ____

Project Navajo Refinery Location NE of Colony @ Entrace Gate

Drilling Contractor D. Anderson Driller Richard Helper Eddie

Rig Type Hollow stem Hole Diameter 8" inches Drilling Fluid N/A

Type of Sample split spoon & Shelby Date and Time Drilling Began 10/20/82 10:00 am Date and Time Drilling End 11.30 am

Geraghty and Miller Representative J. Dauchy T. Bouvette

Blows per 6 inches	% Recovery	Sample Description	Depth Feet to Feet
		Brown topsoil	0 - 4
	Shelby tube 10 - 11	poorly sorted light brown silty clay w/unweathered anhydrite	4 - 13
	organic smell	gray brittle silty clay with white & red coarse grains	13 - 14½
3 - 7 - 8	split spoon 15 - 16½	anhydrite sand interbedded in white clay silty clay and red & tan silty clay	14½ - 17
5 - 7	split spoon 17 - 18½	red clay	17 - 19½

Geraghty & Miller, Inc.

W #4 NCL-34 **Sample Log** Page 4 of

Project Navajo Refinery Location East fence of Colony

Drilling Contractor D. Anderson Driller Richard Helper Eddie

Rig Type Hollow stem Hole Diameter 8" inches Drilling Fluid N/A

Type of Sample split spoon & shelby Date and Time Drilling Began 10/20/82 2:10 pm Date and Time Drilling End 3:30 pm

Geraghty and Miller Representative J. Dauchy T. Bouvette

Blows per 6 inches	% Recovery	Sample Description	Depth Feet to Feet
		brown topsoil & fill	0 - 6
	organic smell	gray brown mottled silty clay w/unweather anhydrite, poorly sorted	6 - 10
7 - 12 -16	split spoon 10 - 11½	very brittle gyp in silty clay w/unweathered anhydrite	10 - 16
	shelby tube 15 - 17	water bearing anhydritic sand inter lain in gray silty clay & gyp	16 - 20
		gray clay, well sorted	20 - 22

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ALBUQUERQUE, NEW MEXICO 87107
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page 1 of 5

LOG OF BORINGS

Date: 5/17/90

Project: NAVAJO REFINERY CO.

Boring no.: NCL-100-90 (NCL-49)

Drilling method: 8" AUGER (HOLLOW STEM).

LOG

from	to	Description CUTTINGS	MAY OVA rdng PPM	comments START @ 8:30
0	3.0	SILT w/carbonate, Buff, moderately moist,		
3.0	5.0	SILT w/ minor clay, BRN, Mod. moist		
5.0	6.5	SPLIT SPOON CORE	0.0	BLOWS PER 6" 14-20-23
5.0	8.0	SILT w/minor clay, Redish BRN, carbonates (small) (1/10"), mod. moist		
8.0	10.0	Same as above except larger carbonate noddules (1/4")		
10	11.5	SPLIT SPOON CORE	0.0	BLOWS PER 6" 13-28-22
10.0	15.0	CLAYEY SILT, carbonates (v. small), Redish BRN, MOIST		
15	16.5	SPLIT SPOON CORE	0.0	BLOW PER 6" 7-12-21
15	17.5	CLAYEY SILT, Redish BRN, V. MOIST		
17.5	19	SPLIT SPOON CORE	3.0	BLOWS PER 6" 9-10-14
17.5	20.0	CLAYEY SILT w/carbonates, Redish BRN, V. MOIST		Saturation?

notes: SPLIT SPOON LOGGED ON SEPARATE SHEET

JOHN W. SHOMAKER, INC.
GEOLOGY-HYDROGEOLOGY
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ALBUQUERQUE, NEW MEXICO 87107
(505) 345-3407

page 2 of 5

LOG OF BORINGS

Date: 5/17/90

Project: NAVAJO REFINERY CO.

Boring no.: NCL-100-90 (NCL-49)

Drilling method: 8" AUGER

LOG

from	to	Description	MAX OVA rdng PPM	comments
20.0	21.5	SPLIT SPOON CORE	27.0	BLOWS PER 6" 4-7-10
21.5	22.5	SAME AS 17.5 - 22.5		
22.5	24.0	SPLIT SPOON CORE DEFINATE SATURATION	22.0	BLOWS PER 6" 7-11-25
22.5		SAME AS ABOVE		
25.0	26.5	SPLIT SPOON CORE	0.0	BLOWS PER 6" 21-11-14
25	30	Same as above w/ a fraction of V. Fine sand		
30	31.5	SPLIT SPOON CORE	0.0	BLOWS PER 6" 10-17-50

notes:

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LOG OF BORINGS

Date: 5-17-90

(NCL-49)

Project: Navajo Refining Co.

Boring no.: NCL-100-90

Drilling method: Splitspoon

LOG

from	to	Description	OVA rdng	comments
5	6	silt, red brn, red buff; carbonate, mod. mstr.		08:30 5-6.5 ft 80% recovery
6	6.2	clayey silt, red brn; carb; mod. mstr		
6.2	6.5	silt, buff, minor red brn; carb., minor carb nodules; mod. mstr		
10	11.5	clayey silt, red brn; carb. & carb nodules; moist; 2-3" thk interbedded w/ caliche, buff, moist 2-3" thick		10-11.5' 100% recovery
15	15.5	As Above		15-16.5' 75% recovery
15.5	16.2	clay, red brn, minor blk mottling; v. moist		

notes:

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page 4 of 5

LOG OF BORINGS

Date: 5-17-96

Project: Navajo Refining Co.

Boring no.: NCL-100-96 (NCL-49)

Drilling method: Split Spoon

LOG

from	to	Description	OVA rdng	comments
16.2	17.5	silt, buff, minor clay; carb & carb nodules; V. moist; minor blk mottling		
17.5	19	clayey silt, red brn, carb., 2 - 1½" thick caliche zones interbedded @ 17.8' & 18.5'; blk mottling on caliche; V. moist, saturated?		17.5-19 ft 100% recovery
20	21.5	clayey silt, red brn; minor carb & carb nodules; V. moist		20-21.5 ft 100% recovery
22.5	23	silt, red brn; minor carb. & carb nodules; Saturated		22.5-24 ft 100% recovery
23	24	sandy silt, red brn interbedded w/ caliche 1"-2" thk, saturated		

notes:

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(505) 345-3407

LOG OF BORINGS

Date: 5-17-90

(NCL-49)

Project: Navajo Refining Co.

Boring no.: NCL-100-90

Drilling method: Hollow Stem Auger

Split Spoon

LOG

from	to	Description	OVA rdng	comments
25	25.3	silt, red brn; minor carb. & Carb nodules, saturated		25-26.5 100% recovery
25.3	25.5	caliche, sandy silt, red buff saturated		
25.5	26.5	sandy silt, red brn; minor Carb. & carb. nodules, saturated		
30	31.1	sandy silt, red brn; minor carb stringers, saturated		30-31.5 ft 90% recovery
31.1	31.5	sandy silt, red brn - reddish buff, high carbonate content saturated		

notes: 10:00 Bailed borehole w/ 5 5/8" steel bailer
Until water in borehole thinned ~ 35 gals

LOG OF BORING MW-53

(Page 1 of 1)

RFI Phase II
North Colony Landfarm
Navajo Refining Company
Artesia, New Mexico

Date Started:	: 06/25/95	Drilling Method:	: Hydraulic push
Time Started	: 0900	Sampling Method:	: 2'x3/4"ID Splitspoon
Date Completed	: 06/25/95	Drilled By:	: Pool Environmental
Hole Diameter:	: 2"	Logged By:	: D.G. Boyer

Depth in Feet	Samples	Recovery (ft)	GRAPHIC	USCS	DESCRIPTION	PID Interval (feet)	PID (ppm)
0					No information	0-3	None
	1	1.3		ML	Silt, light brown, grading to silty clay at 4 ft.		
5				CL	4 - 5 ft., clay, brown, white calcite (?) streaks, dry, crumbly, no odor	3-5	11
	2	1.5			Clay, light brown to chalk color, small calcite (?) crystals, no odor	8-10	16
10					Same as above with increasing caliche clay, no odor		
	3	1.5				10-12	9
	4	2			Clay, light brown, slightly plastic, becoming crumbly at 12.4 ft., pebbles (1/2 in.) at 14 ft., no odor	12-14	8
15	5	2			Caliche gravel and light brown clay, dry. At 15.2 ft., clay, brown, plastic Gravel and caliche to 16.4 ft., size to 3/4 in., no odor	14-16	93
				GC	At 16.4 ft., clay, light brown to gray, hard, slightly plastic.		
	6	2		CL	At 17.5 ft., silty clay, brown, moist, expansive in split spoon, no odor Clay, brown, slightly plastic.	16-18	96
	7	2		GC	18.7 - 19.1 ft., clayey gravel, dry	18-20	21
20				CL	19.1 - 20 ft., clay, brown, soft (no moisture), occasional gravel, no odor		
	8	2			Clay, light brown, slightly plastic, but generally hard, no odor Clay, light brown, occasional small gravel	20-22	21
	9	2		GC	Caliche zones (0.1 - 0.2 ft. thick) at 22.2, 22.7 and 23.8 - 24 ft., clay expanded in spoon, no odor	22-24	18
25	10	2		CL	Clay, light brown, occasional small gravel and caliche zones, no odor	24-26	15
30							

Notes: See monitor well conpletion log for additonal information. Completed hydraulic push at 1000, began auger drilling at 1015. Water on bit at 20 ft, none seen in hole. Auger hole drilled to 24 ft. PID readings are from jar headspace analysis of grab samples taken from drill cuttings at designated intervals. PID readings likely impacted by moisture or exhibited carry-over from previous samples. Depth to water at 14.24 ft. BLS @ 0915 6/29.

10-27-1 C:\MTECH46_nav-ncl_ncl_95\lgmw-53.bor

Navajo

LOG OF BORING MW-54A

(Page 1 of 1)

RFI Phase II
North Colony Landfarm
Navajo Refining Company
Artesia, New Mexico

Date Started:	: 12/14/95	Drilling Method:	: Hollow Stem Auger
Time Started	: 1300	Sampling Method:	: 5 ft. core barrel
Date Completed	: 12/14/95	Drilled By:	: Pool Environmental
Hole Diameter:	: 8 1/4 in. OD	Logged By:	: D.G. Boyer

Depth in Feet	Samples	Recovery (ft)	GRAPHIC	USCS	DESCRIPTION	PID Interval (feet)	PID (ppm)
0				ML	Cored with solid stem auger, 0-5 ft. 0-2.5 ft. Clayey silt, brown, some roots, dry. Log from cuttings.	0-5	3
				CL	2.5-5 ft. Silty clay, light brown, dry		
5	1	2.2			Clay and caliche. Silty clay, light brown, very dry. Caliche inclusions in clay, chalk color with very small crystals	5-10	1
10	2	4.7			Clay with caliche 11.9-12.7 ft. Clay, light brown to brown, slightly moist, soft 12.7-14.7 ft. Same as above with caliche gravel to 1 1/4 in.	10-15	5
15	3	3.8			15-16.4 ft. Silty clay, light brown, slightly damp. 16.4-18 ft. Same as above, color alternating brown and light brown, H/C odor, black streaks at 16.4 ft. 18-18.8 ft. Clay, light brown, no odor	15-20	908
20	4	5			20-20.4 ft. Clay, light brown, saturated, cohesive, plastic. 21.3-22 ft. Silty clay.		
				GC	22-23.4 ft. Clayey caliche gravels, generally small (<1/2") but some >3", saturated.		
				CL	23.4-25 ft. Clay with occassional gravel. 5 ft. recovery.		
25	5	5		CL	25-26.9 ft. Silty clay, moist with occassional gravel.		
				ML	26.9-27.3 ft. Clayey silt, wet, some small gravel.		
				CL	27.3-29 ft. Silty clay, brown, moist.		
30				ML	29-30.4 ft. Silty clay with some sand and very fine gravels.		
				GM	30.4-31 ft. Silty gravel		
	6	5		SM	31-33 ft. Silty sand, light brown, very fine grained with some clay and gravel, saturated 33-35 ft. Sand increasing with gravels. River gravels at 35 ft., flat, size to 3 in.		
35							

Notes:
See monitor well log for well completion information. 6 in. smear of product on auger when retreived. Backfilled hole to 27.5 ft. with medium bentonite chips. Depth to water at 14.1 ft. BLS @1130 12/15. Photoionization Detector (PID) readings are from jar headspace analysis of grab samples taken from drill cuttings at designated intervals. PID readings are from boring NCL 95-01.

40

LOG OF BORING MW-54B

(Page 1 of 1)

RFI Phase II
North Colony Landfarm
Navajo Refining Company
Artesia, New Mexico

Date Started:	: 12/19/95	Drilling Method:	: Hollow Stem Auger
Time Started	: P.M.	Sampling Method:	: 5 ft. core barrel
Date Completed	: 12/20/95	Drilled By:	: Pool Environmental
Hole Diameter:	: 8 1/4 in. OD	Logged By:	: D.G. Boyer

Depth in Feet	Samples	Recovery (ft)	GRAPHIC	USCS	DESCRIPTION
0					Drilled with 12 in. OD HSA to 30 ft. (See boring log record for MW-54A for lithology). Left auger in ground for temporary protection/surface casing. Followed in hole with 8 1/4 in. auger with 5 ft. core barrel (Size 12 in.OD, 9 1/2 in. ID).
30	1	4		CL	29-32.5 ft. Silty clay, light brown, slightly moist, plastic, occassional gravel (to 2") every 18 in., no odor, becoming slightly sandy,wet at 32.5 ft.
35	2	4		SC	32.5-34.6 ft. Clayey sand, light brown 34.6-36.8 ft. Sandy clay, very fine-grained sand.
				GC	36.8-37.8 ft. Gravels with clay. River gravel, smooth, rounded, gray, size to 3 in., saturated
				CL	37.8-38.5 ft. Sandy clay.
40	3	NA		GW	38.5-42 ft. Gravels, clean, pea-sized up to 3 in. (mainly 3/4-1 1/2 in.). Auger jammed with rock at 41.5 ft., pulled out core barrel, cleaned, reentered hole.
				GC	42-44 ft. Clayey gravel.
45	4	5		CH	44-48 ft. Clay, brown, stiff, dry.
50					
55					

Note:
See monitor well completion log for additional information. Boring located 12 ft. NE of MW-54A. Installed well with base at 44 ft. No PID readings taken. Depth to water prior to sampling at 17.44 ft. below top of inner casing.

LOG OF BORING MW-55 (NCL 95-07)

(Page 1 of 1)

RFI Phase II
North Colony Landfarm
Navajo Refining Company
Artesia, New Mexico

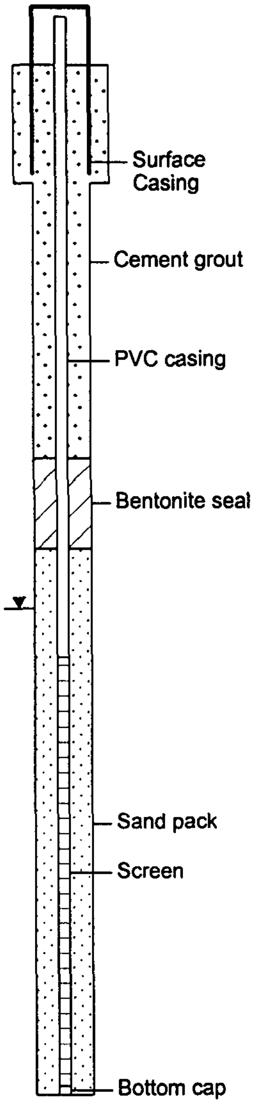
Date Started: : 06/25/95
Time Started : 1215
Date Completed : 06/25/95
Hole Diameter: : 2"

Drilling Method: : Hydraulic push
Sampling Method: : 2'x3/4"ID Splitspoon
Drilled By: : Pool Environmental
Logged By: : D.G. Boyer

Depth in Feet	Samples	DESCRIPTION	GRAPHIC	USCS
0		No information		
5	1	3-5 ft. Clay, brown with white streaks, lighter brown at 4.2 ft., no odor, 1.2 ft. recovery		CL
	2	8-10 ft. Silty clay to clayey silt, brown to chalk color, dry, crumbly, caliche clay at 8 ft., some brown staining on core surface, 1.7 ft. recovery		
10	3	10-12 ft. Silty clay to clayey silt, light brown with soft zones every few inches, extensive small crystals (calcite?) where soft, 2 ft. recovery		
	4	12-14 ft. Silty clay to clayey silt, light brown, fewer zones with crystals, 1 ft. recovery		
15	5	14-16 ft. Silty clay to clayey silt, light brown, no caliche zones, lighter color and softer at 16 ft., 2 ft. recovery		
	6	16-18 ft. Clay, very light brown, hard, 2 ft. recovery		
	7	18-20 ft. Silty clay, brown, some lighter color zones, no caliche, 2 ft. recovery		
20	8	20-22 ft. Same as above, 2 ft. recovery		
25				
30				

Notes:
No odor in any core sample
Depth to water at 17.3 ft. BLS @1600 6/25. Plugged back NCL 95-07 hole with medium bentonite chips, hydrated with 5 gallons fresh water.
Photoionization Detector (PID) readings are from jar headspace analysis of grab samples taken from drill cuttings at designated intervals.
On 8/08/95, hole was redrilled and completed as MW-55 with DTW of 12.3 ft. BLS.

Well: MW-55
Elev.: 3363.57



Well Construction Information

DRILLING INFORMATION
Date completed : 8/08/95
Hole diameter : 8 1/4 in.
Depth Hole BLS : 23.9 ft.
Drilling Method : HSA
Drilled by : Pool Environmental
Logged by : D. G. Boyer

CASING, SCREEN & CAP
Material, joints : PVC, threaded
Diameter : 2 in. ID
Screen type : Johnson Slotted
Screen length : 10 ft.
Screen opening : 0.010 slot
Scrn. placement : 13.7 - 23.7 ft. BLS
Bottom Cap : 0.2 ft PVC
Protector Casing : Above-ground steel
Lock Key # : P-493

SEALS & SAND PACK
Cement seal type : Cement with 5 % : powered bentonite
Seal placement : 0 - 9.1 ft. BLS
Annular seal type : Med. bentonite : chips, ("Pure Gold")
Seal placement : 9.1 - 11.2 ft. BLS
Sand pack type : 10-20 CSSI silica
Sand placement : 11.2 - 23.9 ft. BLS

ELEVATIONS
Ground elevation : 3360.75 ft.
Inner casing, top : 3363.57 ft.
Outer casing, top : 3363.97 ft.

NOTES
PID Readings (ppm):

0-3 ft.	Not measured
3-5 ft.	30
8-10 ft.	49
10-12 ft.	45
12-14 ft.	29
14-16 ft.	34
16-18 ft.	22
18-20 ft.	18
20-22 ft.	18

(Note: PID likely impacted by moisture or exhibited carry-over from previous sample)

COMPLETION NOTES:

Driller bailed 22 gallons 8/8
Developed with pump 8/9/95
Purged 30 gallons prior to sampling, pumped at 1.5 gpm with pump intake at 20 ft.
Purge info. @25gal, 0855: 22 C, 2800 umhos, pH 7
Depth to water prior to sampling: 15.36 ft. below top inner casing.

LOG OF BORING MW-56 (NCL 95-16)

(Page 1 of 1)

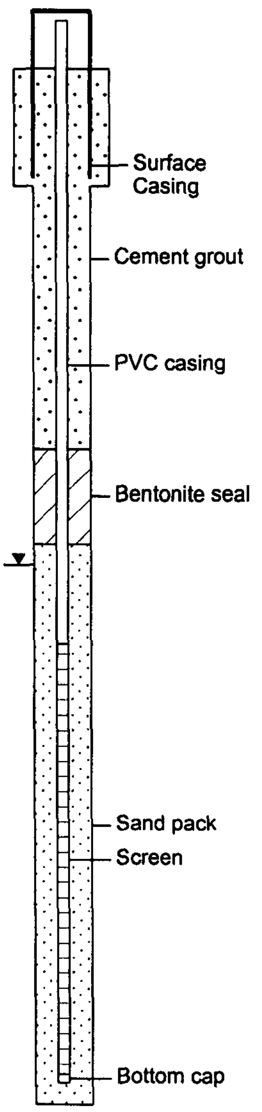
RFI Phase II
North Colony Landfarm
Navajo Refining Company
Artesia, New Mexico

Date Started:	: 08/07/95	Drilling Method:	: Hollow Stem Auger
Time Started	: 1315	Sampling Method:	: 5 ft. core barrel
Date Completed	: 08/07/95	Drilled By:	: Pool Environmental
Hole Diameter:	: 8 1/4 in. OD	Logged By:	: D.G. Boyer

Depth in Feet	Samples	DESCRIPTION	GRAPHIC	USCS
0		No information - cored with solid stem auger, 0 - 4 ft.		
5	1	4-9 ft. Clay, dark brown with white flecks, stiff, plastic, no odor, 2 ft. recovery		CL
		9-10 ft. Same as above.		
10	2	10.1 - 11.2 ft., Clayey silt with caliche, chalk and light brown mottling, stiff, slightly damp, no odor. 11.2 - 11.8 ft., same as above, very stiff, no odor, 2.8 ft. recovery.		
15	3	14-16 ft. Clayey silt with caliche, brown, dry crumbly, no odor. 16.6 - 17.8 ft., Clayey silt, gravelly, 2 in. water in hole, 3.8 ft. recovery.		ML
20	4	19 - 20.6 ft. Clayey gravel to gravelly clay, light gray to white, caliche gravel to 1 in.		GC
		20.6 - 24 ft. Silty clay to clayey silt, light brown to chalk color with occassional gravel, 5 ft. recovery		CL
25				
30				

Notes:
NCL 95-16 located 10 ft. N. of Drum Storage Area wall, 103 ft. SE of 95-13, and 232 ft. SW of MW-45. Depth to water at 12.1 ft. BLS @1345 on 8/08. Photoionization Detector (PID) readings are from jar headspace analysis of grab samples taken from drill cuttings at designated intervals. On 8/08/95, hole was bailed by drillers to develop.

Well: MW-56
Elev.: 3362.05



Well Construction Information

DRILLING INFORMATION
Date completed : 8/07/95
Hole diameter : 8 1/4 in.
Depth Hole BLS : 24 ft.
Drilling Method : HSA
Drilled by : Pool Environmental
Logged by : D. G. Boyer

CASING, SCREEN & CAP
Material, joints : PVC, threaded
Diameter : 2 in. ID
Screen type : Johnson Slotted
Screen length : 10 ft.
Screen opening : 0.010 slot
Scrn. placement : 13.4 - 23.4 ft. BLS
Bottom Cap : 0.2 ft PVC
Protector Casing : Above-ground steel
Lock Key # : P-493

SEALS & SAND PACK
Cement seal type : Cement with 5 % : powered bentonite
Seal placement : 0 - 8.8 ft. BLS
Annular seal type : Med. bentonite : chips, ("Pure Gold")
Seal placement : 8.8 - 11.0 ft. BLS
Sand pack type : 10-20 CSSI silica
Sand placement : 11.0 - 24 ft. BLS

ELEVATIONS
Ground elevation : 3359.13 ft.
Inner casing, top : 3362.05 ft.
Outer casing, top : 3362.42 ft.

NOTES
PID Readings (ppm):

0-4 ft.	Not measured
7-9 ft.	0
12-13 ft.	0
15-16 ft.	2
17-18 ft.	2
20-21 ft.	2
23-24 ft.	4

COMPLETION NOTES:

Driller bailed 6.9 gallons 8/8
Developed with pump 8/9/95
Purged 30 gallons prior to sampling, pumped at 1.6 gpm with pump intake at 20 ft.
Purge info. @30 gal, 0940: 23 C, 4700 umhos, pH 7
Depth to water prior to sampling: 14.4 ft. below top inner casing.

APPENDIX B6

MONITOR WELL CONSTRUCTION LOGS

Tops of 5' screens 12' to 11' below gl.

DETAILS OF WELL CONSTRUCTION

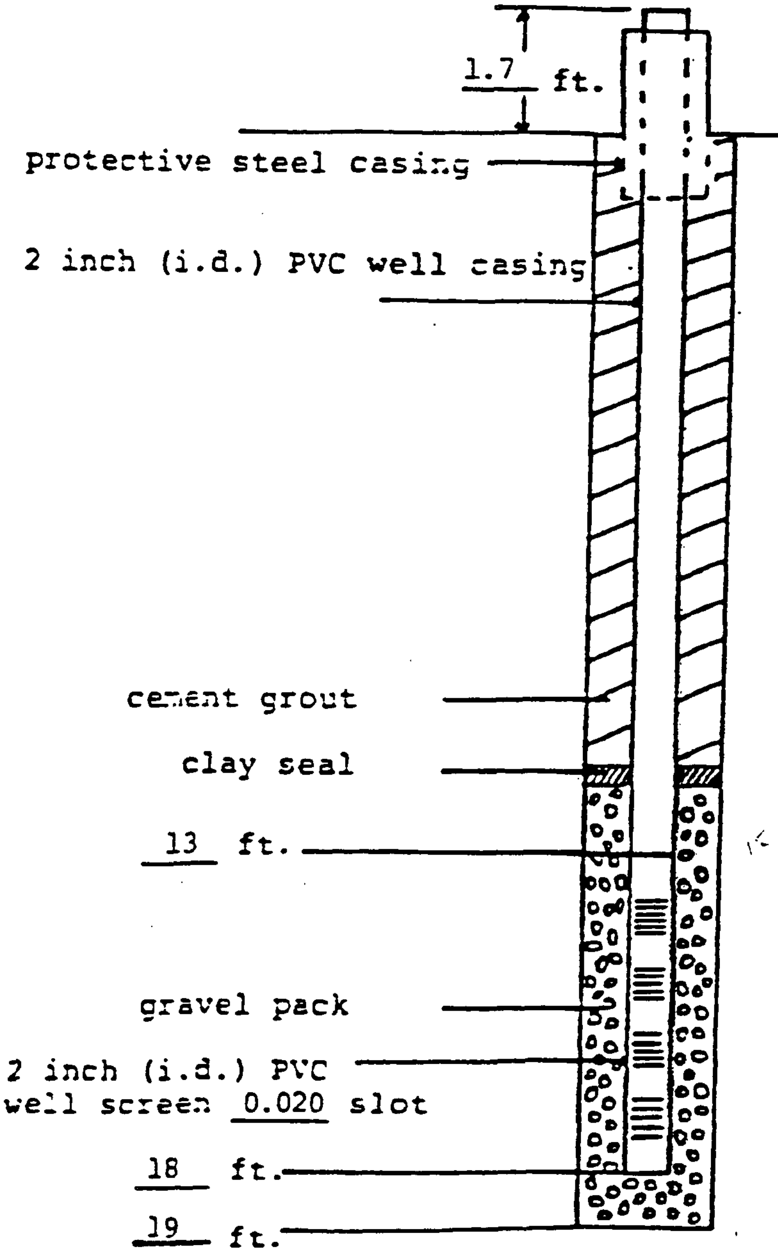
DATE 10/22/82

WELL #1 (NCL-31)

PROJECT Navajo Refinery

LOCATION

WATER LEVEL MEASUREMENT Held 10.5 Wet 0.34 DTW 10.16



GEOLOGIC

LOG

All measurements are referred to land surface except depth to water which is measured from top of casing

DETAILS OF WELL CONSTRUCTION

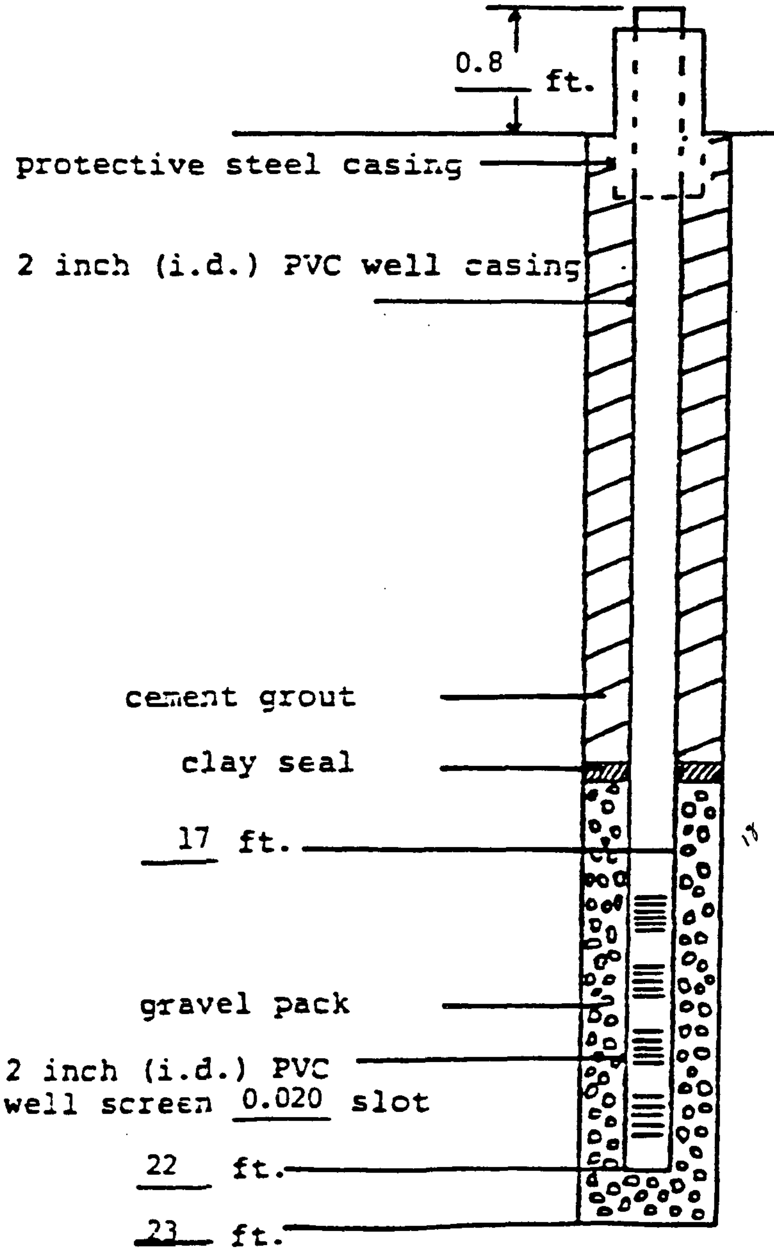
DATE 11/22/82

WELL #2 (NCL-32)

PROJECT Navajo Refinery

LOCATION

WATER LEVEL MEASUREMENT Held 10.0 Wet 0.30 DTW 9.7



GEOLOGIC

LOG

All measurements are referred to land surface except depth to water which is measured from top of casing

DETAILS OF WELL CONSTRUCTION

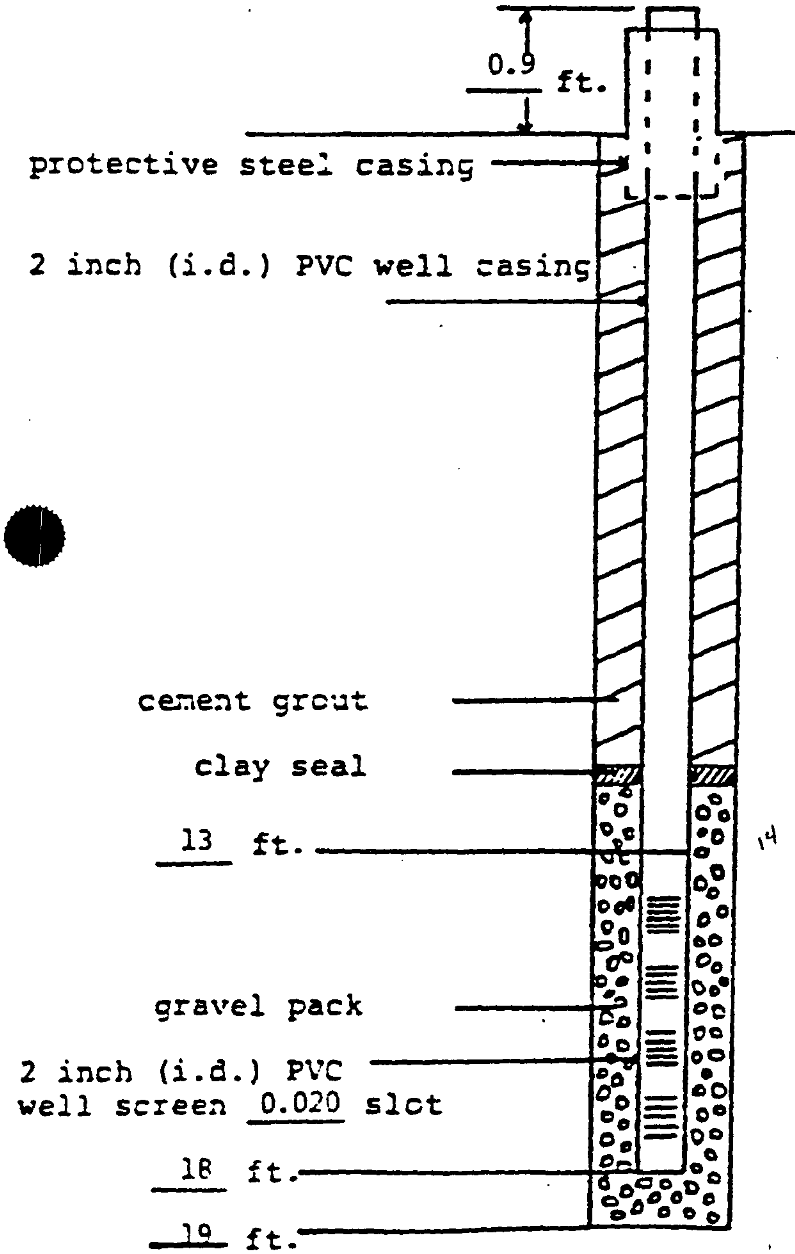
DATE 10/22/82

WELL #3 (NCL-33)

PROJECT Navajo Refinery

LOCATION

WATER LEVEL MEASUREMENT' Held 10.0 Wet 0.19 DTW 9.81



GEOLOGIC

LOG

All measurements are referred to land surface except depth to water which is measured from top of casing

DETAILS OF WELL CONSTRUCTION

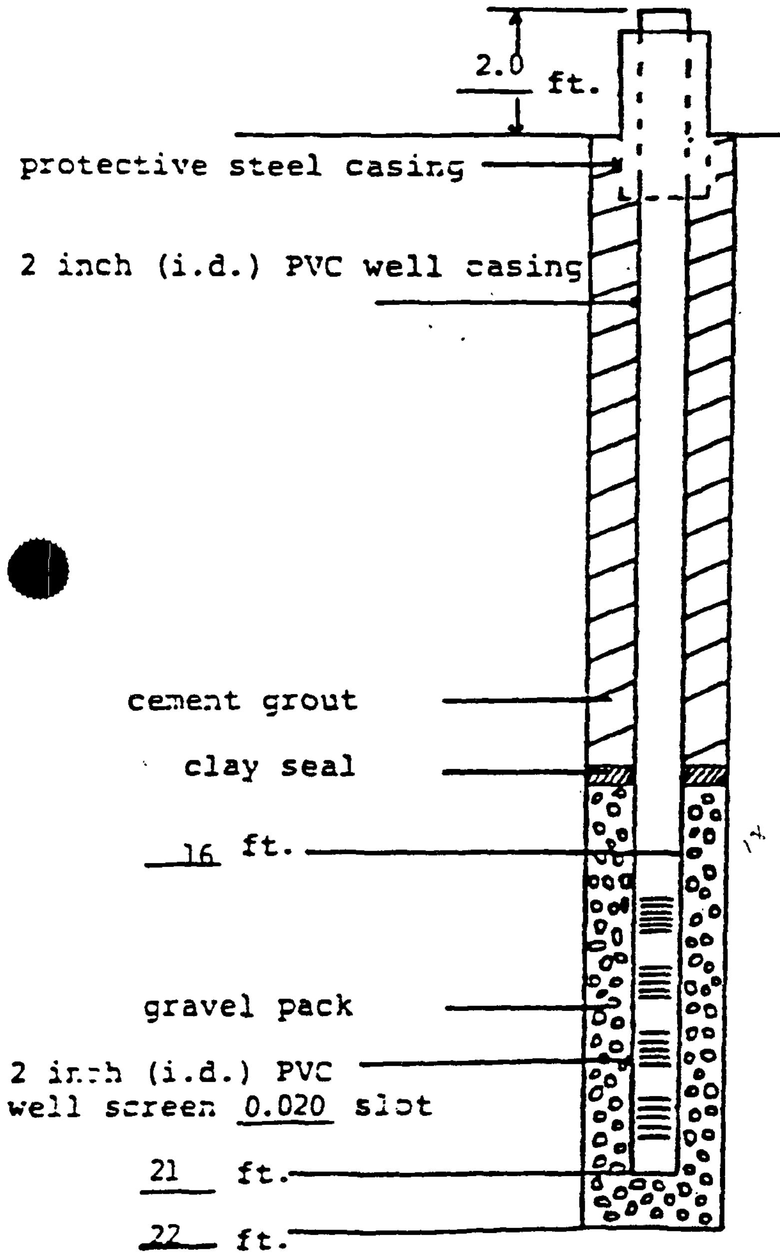
DATE 10/22/82

WELL #4 (NCL-34)

PROJECT Navajo Refinery

LOCATION ____________

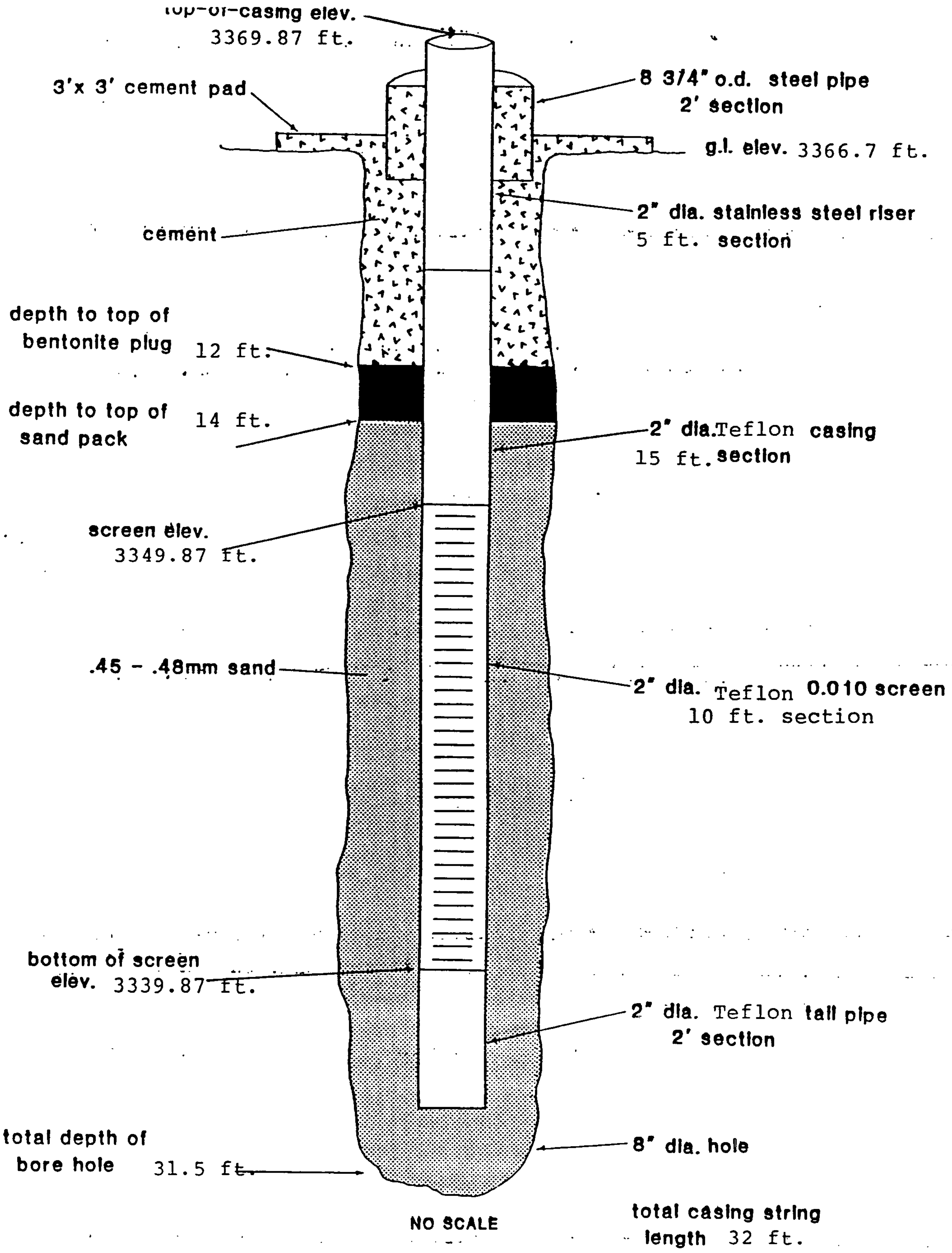
WATER LEVEL MEASUREMENT' Held 11.3 Wet 0.70 DTW 10.60



GEOLOGIC

LOG

All measurements are referred to land surface except depth to water which is measured from top of casing



NCL-100-90

NCL-49

JOHN W. SHOMAKER, INC.
May, 1990

Navajo

LOG OF WELL MW-53

(Page 1 of 1)

RFI Phase II
North Colony Landfarm
Navajo Refining Company
Artesia, New Mexico

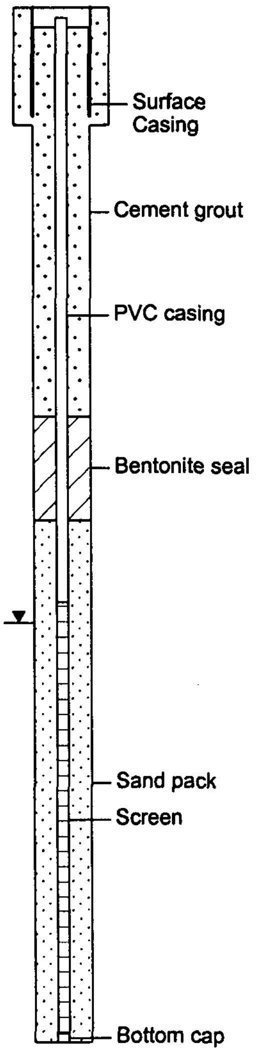
Date Started: : 06/25/95
Time Started: : 0900
Date Completed: : 06/25/95
Hole Diameter: : 2"

Drilling Method: : Hydraulic push
Sampling Method: : 2'x3/4"ID Splitspoon
Drilled By: : Pool Environmental
Logged By: : D.G. Boyer

Depth in Feet	Samples	GRAPHIC	USCS	DESCRIPTION
0				No information
	1		ML	Silt, light brown
5			CL	4 - 5 ft., clay, brown, white calcite (?) streaks, dry, crumbly, no odor,
	2			Clay, light brown to chalk color, small calcite (?) crystals, no odor
10	3			Same as above with increasing caliche clay, no odor
	4			Clay, light brown, slightly plastic, becoming crumbly at 12.4 ft., pebbles (1/2 in.) at 14 ft., no odor
15	5			Caliche gravel and light brown clay, dry. At 15.2 ft., clay, brown, plastic
			GC	Gravel & caliche, size to 3/4 in., no odor
	6		CL	Clay, light brown to gray, hard, slightly plastic. At 17.5 ft., silty clay, brown, moist, expansive in split spoon, no odor Clay, brown, slightly plastic.
	7		GC	18.7 - 19.1 ft., clayey gravel, dry
20	8		CL	19.1 - 20 ft., clay, brown, soft (no moisture), occasional gravel, no odor Clay, light brown, slightly plastic, but generally hard, no odor Clay, light brown, occ. small gravel
	9		GC	Caliche zones (0.1 - 0.2 ft. thick) at 22.2, 22.7 and 23.8 - 24 ft., clay expanded in spoon, no odor
25	10		CL	Clay, light brown, occasional small gravel and caliche zones, no odor
30				

Notes:
See lithologic log MW-53 for PID and additonal drilling information. Completed hydraulic push at 1000, began auger drilling at 1015. Water on bit at 20 ft, none seen in hole. Auger hole drilled to 24 ft. Depth to water at 14.24 ft. BLS @ 0915 6/29.

Well: MW-53
Elev.: 3367.53



Well Construction Information

DRILLING INFORMATION
Date completed : 6/25/95
Hole diameter : 8 1/4 in.
Depth Hole BLS : 24
Drilling Method : HSA
Drilled by : Pool Environmental
Logged by : D. G. Boyer

CASING, SCREEN & CAP
Material, joints : PVC, threaded
Diameter : 2 in. ID
Screen type : Johnson Slotted
Screen length : 10 ft.
Screen opening : 0.010 slot
Scrn. placement : 13.8 - 23.8 ft. BLS
Bottom Cap : 0.2 ft PVC
Protector Casing : Flush-mount steel
Lock Key # : P-493

SEALS & SAND PACK
Cement seal type : Cement with 5 % : powered bentonite
Seal placement : 0 - 9.5 ft. BLS
Annular seal type : Med. bentonite : chips, ("Pure Gold")
Seal placement : 9.5 - 11.9 ft. BLS
Sand pack type : 10-20 CSSI silica
Sand placement : 11.9 - 24 ft. BLS

ELEVATIONS
Ground elevation : 3367.71 ft.
Inner casing, top : 3367.67 ft.
Outer casing, top : 3367.87 ft.

NOTES
COMPLETION:

Driller bailed well 6/25/95 to develop. Developed with pump 6/29/95. Purged 30 gallons prior to sampling, pumped approx. 0.5 gpm.
Purge info. @30 gal, 1030: 24 C, 2600 umhos, pH 7
Depth to water prior to sampling: 14.24 ft. below top inner casing.

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LOG OF WELL MW-54A

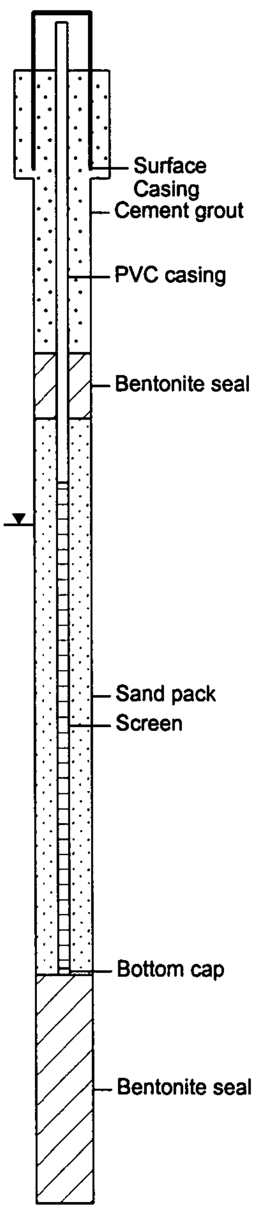
(Page 1 of 1)

RFI Phase II
North Colony Landfarm
Navajo Refining Company
Artesia, New Mexico

Date Started:	: 12/14/95	Drilling Method:	: Hollow Stem Auger
Time Started	: 1300	Sampling Method:	: 5 ft. core barrel
Date Completed	: 12/14/95	Drilled By:	: Pool Environmental
Hole Diameter:	: 8 1/4 in. OD	Logged By:	: D.G. Boyer

Depth in Feet	Samples	DESCRIPTION	GRAPHIC	USCS
0		Cored with solid stem auger, 0-5 ft. 0-2.5 ft. Clayey silt, brown, some roots, dry. Log from cuttings.		ML
5 10 15 20	1 2 3 4	2.5-5 ft. Silty clay, light brown, dry Clay and caliche. Silty clay, light brown, very dry. Caliche inclusions in clay, chalk color with very small crystals. Clay with caliche 11.9-12.7 ft. Clay, light brown to brown, slightly moist, soft 12.7-14.7 ft. Same as above with caliche gravel to 1 1/4 in. 15-16.4 ft. Silty clay, light brown, slightly damp. 16.4-18 ft. Same as above, color alternating brn and lt. brn, H/C odor, black streaks at 16.4 ft. 18-18.8 ft. Clay, light brown, no odor 20-20.4 ft. Clay, light brown, saturated, cohesive, plastic. 21.3-22 ft. Silty clay.		CL
		22-23.4 ft. Clayey caliche gravels, generally small (<1/2") but some >3", saturated.		GC
25	5	23.4-25 ft. Clay with occ. gravel 25-26.9 ft. Silty clay, moist with occassional gravel.		CL
		26.9-27.3 ft. Clayey silt, wet, some small gravel.		ML
		27.3-29 ft. Silty clay, brown, moist.		CL
30		29-30.4 ft. Clayey silt w/some sand and v. fine gravels		ML
		30.4-31 ft. Silty gravel		GM
35	6	31-33 ft. Silty sand, light brown, v fn. grained, some clay & gravel, saturated. 33-35 ft. Sand increasing with gravels. River gravels at 35 ft., flat, size to 3 in.		SM
40		Notes: See lithologic log MW-54A for PID and addtional drilling information. 6 in. smear of product on auger when retreived. Backfilled hole to 27.5 ft. with medium bentonite chips. Depth to water at 14.1 ft. BLS @1130 12/15.		

Well: MW-54A
Elev.: 3365.38



Well Construction Information

DRILLING INFORMATION

Date completed	: 12/14/95
Hole diameter	: 8 1/4 in.
Depth Hole BLS	: 35
Drilling Method	: HSA
Drilled by	: Pool Environmental
Logged by	: D. G. Boyer

CASING, SCREEN & CAP

Material, joints	: PVC, threaded
Diameter	: 2 in. ID
Screen type	: Johnson Slotted
Screen length	: 15 ft.
Screen opening	: 0.010 slot
Scrn. placement	: 12.7 - 27.7 ft. BLS
Bottom Cap	: 0.2 ft PVC
Protector Casing	: Above-ground steel
Lock Key #	: P-493

SEALS & SAND PACK

Cement seal type	: Cement with 5 % : powered bentonite
Seal placement	: 0 - 8.7 ft. BLS
Annular seal type	: Med. bentonite : chips, ("Pure Gold")
Seal placement	: 8.7 - 10.7 ft. BLS
Sand pack type	: 10-20 CSSI silica
Sand placement	: 10.7 - 27.7 ft. BLS

ELEVATIONS

Ground elevation	: 3361.96 ft.
Inner casing, top	: 3365.38 ft.
Outer casing, top	: 3365.66 ft.

NOTES

COMPLETION:

12/15/95
Developed with pump, purged approx. 120 gallon to clean, test @ 1.3 gpm with 4' drawdown.

12/22/95
Purged 6 gallons prior to sampling, @ 1310:
2500 umhos, pH 7
Depth to water prior to sampling: 17.47 ft. below top inner casing.

LOG OF WELL MW-54B

(Page 1 of 1)

RFI Phase II
North Colony Landfarm
Navajo Refining Company
Artesia, New Mexico

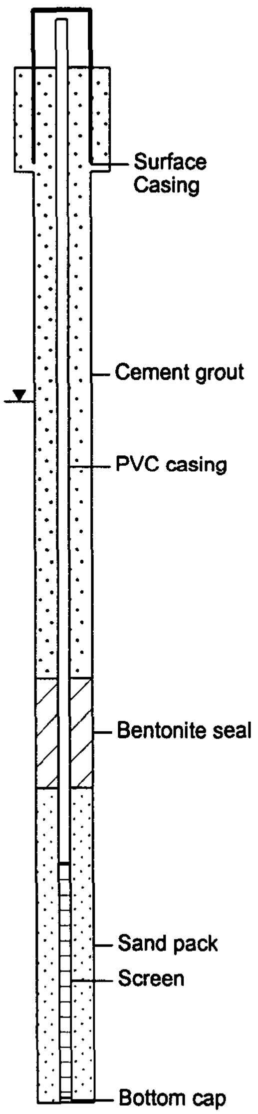
Date Started:	: 12/19/95	Drilling Method:	: Hollow Stem Auger
Time Started	: P.M.	Sampling Method:	: 5 ft. core barrel
Date Completed	: 12/20/95	Drilled By:	: Pool Environmental
Hole Diameter:	: 8 1/4 in. OD	Logged By:	: D.G. Boyer

Depth in Feet	Samples	DESCRIPTION	GRAPHIC	USCS
		Drilled with 12 in. OD HSA to 30 ft. (See boring log record for MW-54A for lithology). Left auger in ground for temporary protection/surface casing. Followed in hole with 8 1/4 in. auger with 5 ft. core barrel (Size 12 in.OD, 9 1/2 in.ID).		
	1	29-32.5 ft. Silty clay, light brown, slightly moist, plastic, occ. gravel (to 2") every 18 in., no odor, becoming slightly sandy,wet @32.5 ft.		CL
	2	32.5-34.6 ft. Clayey sand, light brn. 34.6-36.8 ft. Sandy clay, very fine-grained sand.		SC
		36.8-37.8 ft. Gravels with clay. River gravel, smooth, rounded, gray, size to 3 in., saturated.		GC
	3	37.8-38.5 ft. Sandy clay.		CL
		38.5-42 ft. Gravels, clean, pea-sized up to 3 in.(mainly 3/4-1 1/2 in.)		GW
	4	42-44 ft. Clayey gravel.		GC
		44-48 ft. Clay, brown, stiff, dry.		CH

Depth in Feet: 0, 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55

Note:
See lithologic log MW-54B for additional information. Located 12 ft. NE of MW-54A. Auger jammed w/rock at 41.5 ft., pulled out core barrel, cleaned, reentered hole. Installed well with base at 44 ft.

Well: MW-54B
Elev.: 3365.36



Well Construction Information

DRILLING INFORMATION
Date completed : 12/20/95
Hole diameter : 8 1/4 in.
Depth Hole BLS : 48
Drilling Method : HSA
Drilled by : Pool Environmental
Logged by : D. G. Boyer

CASING, SCREEN & CAP
Material, joints : PVC, threaded
Diameter : 2 in. ID
Screen type : Johnson Slotted
Screen length : 10 ft.
Screen opening : 0.010 slot
Scrn. placement : 33.8 - 43.8 ft. BLS
Bottom Cap : 0.2 ft PVC
Protector Casing : Above-ground steel
Lock Key # : P-493

SEALS & SAND PACK
Cement seal type : Cement with 5 % : bentonite, tremied
Seal placement : 0 - 26 ft. BLS
Annular seal type : Liquid bentonite : grout
Seal placement : 26 - 30.6 ft. BLS
Sand pack type : 10-20 CSSI silica
Sand placement : 30.6 - 44 ft. BLS

ELEVATIONS
Ground elevation : 3362.05 ft.
Inner casing, top : 3365.36 ft.
Outer casing, top : 3365.59ft.

NOTES

No PID Readings taken.

COMPLETION NOTES:

Installed well with base at 44 ft. Upon completion, used 17 bags sand to 32 ft. When pulled outer auger, bridged sand rises to 30.6 ft. Added 5 ft. liquid bentonite grout. Cemented to surface with cement grout, mixed in grout tank at ratio of 3 bags cement with 1 cup bentonite powder.

12/21/95
Developed with pump.

12/22/95
Purged 15 gallons prior to sampling, @ 1219: 2400 umhos, pH 7
Depth to water prior to sampling: 17.44 ft. below top inner casing.

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LOG OF WELL MW-55 (NCL 95-07)

(Page 1 of 1)

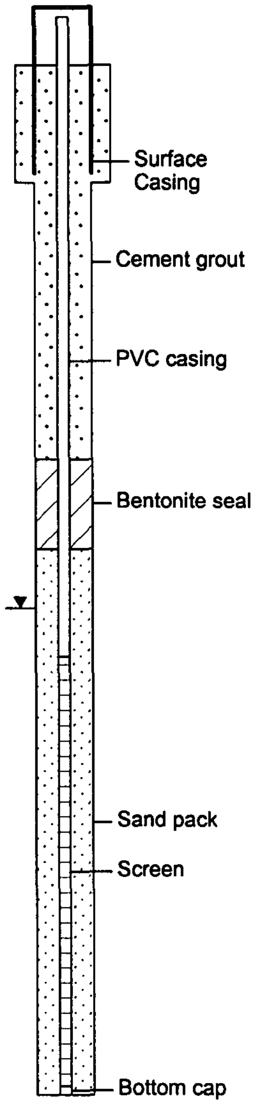
RFI Phase II
North Colony Landfarm
Navajo Refining Company
Artesia, New Mexico

Date Started:	: 06/25/95	Drilling Method:	: Hydraulic push
Time Started	: 1215	Sampling Method:	: 2'x3/4"ID Splitspoon
Date Completed	: 06/25/95	Drilled By:	: Pool Environmental
Hole Diameter:	: 2"	Logged By:	: D.G. Boyer

Depth in Feet	Samples	DESCRIPTION	GRAPHIC	USCS
0		No information		
5	1	3-5 ft. Clay, brown with white streaks, lighter brown at 4.2 ft., no odor, 1.2 ft. recovery	▨	
	2	8-10 ft. Silty clay to clayey silt, brown to chalk color, dry, crumbly, caliche clay at 8 ft., some brown staining on core surface, 1.7 ft. recovery	▨	
10	3	10-12 ft. Silty clay to clayey silt, light brown with soft zones every few inches, extensive small crystals (calcite?) where soft, 2 ft. recovery	▨	
	4	12-14 ft. Silty clay to clayey silt, light brown, fewer zones with crystals, 1 ft. recovery	▨	CL
15	5	14-16 ft. Silty clay to clayey silt, light brown, no caliche zones, lighter color and softer at 16 ft., 2 ft. recovery	▨	
	6	16-18 ft. Clay, very light brown, hard, 2 ft. recovery	▨	
	7	18-20 ft. Silty clay, brown, some lighter color zones, no caliche, 2 ft. recovery	▨	
20	8	20-22 ft. Same as above, 2 ft. recovery	▨	
25 30		Notes: No odor in any core sample Depth to water at 17.3 ft. BLS @1600 6/25. Plugged back NCL 95-07 hole with medium bentonite chips, hydrated with 5 gallons fresh water. Photoionization Detector (PID) readings are from jar headspace analysis of grab samples taken from drill cuttings at designated intervals. On 8/08/95, hole was redrilled and completed as MW-55 with DTW of 12.3 ft. BLS.		

Well: MW-55

Elev.: 3363.57



Well Construction Information

DRILLING INFORMATION

Date completed	: 8/08/95
Hole diameter	: 8 1/4 in.
Depth Hole BLS	: 23.9 ft.
Drilling Method	: HSA
Drilled by	: Pool Environmental
Logged by	: D. G. Boyer

CASING, SCREEN & CAP

Material, joints	: PVC, threaded
Diameter	: 2 in. ID
Screen type	: Johnson Slotted
Screen length	: 10 ft.
Screen opening	: 0.010 slot
Scrn. placement	: 13.7 - 23.7 ft. BLS
Bottom Cap	: 0.2 ft PVC
Protector Casing	: Above-ground steel
Lock Key #	: P-493

SEALS & SAND PACK

Cement seal type	: Cement with 5 % : powered bentonite
Seal placement	: 0 - 9.1 ft. BLS
Annular seal type	: Med. bentonite : chips, ("Pure Gold")
Seal placement	: 9.1 - 11.2 ft. BLS
Sand pack type	: 10-20 CSSI silica
Sand placement	: 11.2 - 23.9 ft. BLS

ELEVATIONS

Ground elevation	: 3360.75 ft.
Inner casing, top	: 3363.57 ft.
Outer casing, top	: 3363.97 ft.

NOTES

PID Readings (ppm):

0-3 ft.	Not measured
3-5 ft.	30
8-10 ft.	49
10-12 ft.	45
12-14 ft.	29
14-16 ft.	34
16-18 ft.	22
18-20 ft.	18
20-22 ft.	18

(Note: PID likely impacted by moisture or exhibited carry-over from previous sample)

COMPLETION NOTES:

Driller bailed 22 gallons 8/8
Developed with pump 8/9/95
Purged 30 gallons prior to sampling, pumped at 1.5 gpm with pump intake at 20 ft.
Purge info. @25gal, 0855:
22 C, 2800 umhos, pH 7
Depth to water prior to sampling: 15.36 ft. below top inner casing.

LOG OF WELL MW-56 (NCL 95-16)

(Page 1 of 1)

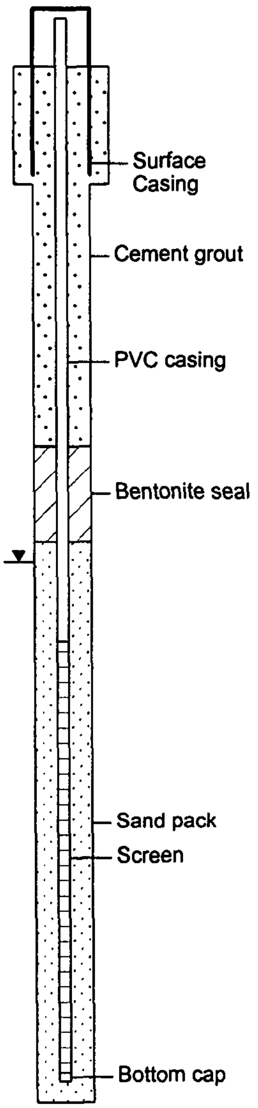
RFI Phase II
North Colony Landfarm
Navajo Refining Company
Artesia, New Mexico

Date Started:	: 08/07/95	Drilling Method:	: Hollow Stem Auger
Time Started	: 1315	Sampling Method:	: 5 ft. core barrel
Date Completed	: 08/07/95	Drilled By:	: Pool Environmental
Hole Diameter:	: 8 1/4 in. OD	Logged By:	: D.G. Boyer

Depth in Feet	Samples	DESCRIPTION	GRAPHIC	USCS
0		No information - cored with solid stem auger, 0 - 4 ft.		
5	1	4-9 ft. Clay, dark brown with white flecks, stiff, plastic, no odor, 2 ft. recovery		CL
10	2	9-10 ft. Same as above.		
		10.1 - 11.2 ft., Clayey silt with caliche, chalk and light brown mottling, stiff, slightly damp, no odor.		ML
		11.2 - 11.8 ft., same as above, very stiff, no odor, 2.8 ft. recovery.		
15	3	14-16 ft. Clayey silt with caliche, brown, dry crumbly, no odor.		
		16.6 - 17.8 ft., Clayey silt, gravelly, 2 in. water in hole, 3.8 ft. recovery.		
20	4	19 - 20.6 ft. Clayey gravel to gravelly clay, light gray to white, caliche gravel to 1 in.		GC
		20.6 - 24 ft. Silty clay to clayey silt, light brown to chalk color with occassional gravel, 5 ft. recovery		CL
25		Notes: NCL 95-16 located 10 ft. N. of Drum Storage Area wall, 103 ft. SE of 95-13, and 232 ft. SW of MW-45. Depth to water at 12.1 ft. BLS @1345 on 8/08. Photoionization Detector (PID) readings are from jar headspace analysis of grab samples taken from drill cuttings at designated intervals. On 8/08/95, hole was bailed by drillers to develop.		
30				

Well: MW-56

Elev.: 3362.05



Well Construction Information

DRILLING INFORMATION

Date completed : 8/07/95
Hole diameter : 8 1/4 in.
Depth Hole BLS : 24 ft.
Drilling Method : HSA
Drilled by : Pool Environmental
Logged by : D. G. Boyer

CASING, SCREEN & CAP

Material, joints : PVC, threaded
Diameter : 2 in. ID
Screen type : Johnson Slotted
Screen length : 10 ft.
Screen opening : 0.010 slot
Scrn. placement : 13.4 - 23.4 ft. BLS
Bottom Cap : 0.2 ft PVC
Protector Casing : Above-ground steel
Lock Key # : P-493

SEALS & SAND PACK

Cement seal type : Cement with 5 % powered bentonite
Seal placement : 0 - 8.8 ft. BLS
Annular seal type : Med. bentonite chips, ("Pure Gold")
Seal placement : 8.8 - 11.0 ft. BLS
Sand pack type : 10-20 CSSI silica
Sand placement : 11.0 - 24 ft. BLS

ELEVATIONS

Ground elevation : 3359.13 ft.
Inner casing, top : 3362.05 ft.
Outer casing, top : 3362.42 ft.

NOTES

PID Readings (ppm):

0-4 ft.	Not measured
7-9 ft.	0
12-13 ft.	0
15-16 ft.	2
17-18 ft.	2
20-21 ft.	2
23-24 ft.	4

COMPLETION NOTES:

Driller bailed 6.9 gallons 8/8
Developed with pump 8/9/95
Purged 30 gallons prior to sampling, pumped at 1.6 gpm with pump intake at 20 ft.
Purge info. @30 gal, 0940: 23 C, 4700 umhos, pH 7
Depth to water prior to sampling: 14.4 ft. below top inner casing.

GW-28

Appendix C

Appendix C

APPENDIX C

CORE LABORATORIES ANALYSES REPORT

CORELAB

PETROLEUM TESTING SERVICES

October 6, 1997

Navajo Refining Company
501 East Main Street
Artesia, NM 88210
ATTN: Charlie Ebarb

Dear Mr. Ebarb:

Enclosed are the results of our analysis on your sample labeled NCL-34. As a result of our chromatographic analysis, it appears that your sample is a biologically degraded crude with approximately 48% of this sample occurring in the diesel range.

If you have any additional questions, please contact us at 1-800-734-2673.

Sincerely,

CORE LABORATORIES

MJWaits

M. Jean Waits
Supervising Chemist

Enclosures:
Analytical Report 974143-1

/MJW

Core Laboratories, Inc.
8210 Mosley Road, Houston, Texas 77075-1110, P.O. Box 34766, Houston, Texas 77234-4766, (713) 943-9776, Fax (713) 943 3846

CORELAB

CORE LABORATORIES

LABORATORY TESTS RESULTS

09/24/97

JOB NUMBER: 974143 CUSTOMER: NAVAJO REFINING COMPANY ATTN: CHARLIE EBARB

CLIENT I.D.........:
DATE SAMPLED.......: 09/04/97
TIME SAMPLED.......: 14:00
WORK DESCRIPTION...: NCL-34 9-4-97 1400

LABORATORY I.D...: 974143-0001
DATE RECEIVED....: 09/09/97
TIME RECEIVED....: 11:16
REMARKS..........:

TEST DESCRIPTION	FINAL RESULT	LIMITS/*DILUTION	UNITS OF MEASURE	TEST METHOD	DATE	TECHN
Capillary Gas Chromatography	Attached		See Attached	Capillary GC	09/12/97	MJW
Ethylene Dichloride	<10	10	ppm	GCMS	09/16/97	BT
Lead in Gasoline by X-Ray Spec.	0.06		g Pb/ US Gal.	ASTM D-5059 Meth. A	09/16/97	JT
Simulated Distillation of Crude		*1		ASTM D-5307	09/18/97	JJB
% OFF	Deg. F.	0				
IBP	219	0				
5	306	0				
10	347	0				
15	382	0				
20	409	0				
25	434	0				
30	461	0				
35	491	0				
40	527	0				
45	565	0				
50	605	0				
55	656	0				
60	700	0				
65	747	0				
70	794	0				
75	844	0				
80	897	0				
85	957	0				
90	ND	0				
95	ND	0				
% Recovered	87.8	0	@ 1000 deg. F			
% Residue	12.2	0	@ 1000 deg. F			

CORE LAB

CORE LABORATORIES

P.O. Box 34766
Houston, TX 77234
(713) 943-9776

Navajo Refining
Job No: 974143-1
Sample ID: NCL-34 9/4/97 1400

CAPILLARY ANALYSIS

	Wt. %	L.V. %	Mole %
2-Methylpentane	0.01	0.01	0.02
3-Methylpentane	0.01	0.02	0.03
n-Hexane	0.01	0.01	0.03
Methylcyclopentane	0.04	0.05	0.10
Cyclohexane	0.11	0.12	0.27
2-Methylhexane	0.02	0.03	0.05
2,3-Dimethylpentane	0.03	0.03	0.06
1,1-Dimethylcyclopentane	0.01	0.02	0.03
3-Methylhexane	0.07	0.08	0.14
cis-1,3-Dimethylcyclopentane	0.05	0.05	0.10
trans-1,3-Dimethylcyclopentane	0.04	0.05	0.09
trans-1,2-Dimethylcyclopentane	0.09	0.09	0.17
n-Heptane	0.07	0.09	0.14
Methylcyclohexane	0.54	0.56	1.10
2,2-Dimethylhexane	0.06	0.07	0.10
Ethylcyclopentane	0.04	0.05	0.09
2,5-Dimethylhexane	0.03	0.03	0.05
2,4-Dimethylhexane	0.03	0.04	0.06
trans,cis-1,2,4-Trimethylcyclopentane	0.09	0.09	0.16
3,3-Dimethylhexane	0.01	0.01	0.01
trans,cis-1,2,3-Trimethylcyclopentane	0.12	0.13	0.22
2,3-Dimethylhexane	0.08	0.09	0.14
2-Methyl-3-Ethylpentane	0.03	0.04	0.06
2-Methylheptane	0.13	0.15	0.22
4-Methylheptane	0.03	0.04	0.06
cis-1,3-Dimethylcyclohexane	0.47	0.49	0.84
trans-1,4-Dimethylcyclohexane	0.11	0.12	0.19
2,2,4,4-Tetramethylpentane	0.05	0.05	0.07
trans-1-Ethyl-3-Methylcyclopentane	0.06	0.06	0.10
cis-1-Ethyl-3-Methylcyclopentane	0.05	0.05	0.09
trans-1-Ethyl-2-Methylcyclopentane	0.12	0.12	0.22
1-Ethyl-1-Methylcyclopentane	0.01	0.01	0.02

CORELAB

CORE LABORATORIES

P.O. Box 34766
Houston, TX 77234
(713) 943-9776

Navajo Refining
Job No: 974143-1
Sample ID: NCL-34 9/4/97 1400

Page 2

CAPILLARY ANALYSIS

	Wt. %	L.V. %	Mole %
trans-1,2-Dimethylcyclohexane	0.19	0.20	0.34
n-Octane	0.34	0.39	0.59
Isopropylcyclopentane	0.03	0.03	0.05
2-Methyl-4-Ethylhexane	0.02	0.02	0.03
2,3,5-Trimethylhexane	0.01	0.01	0.02
cis-1-Ethyl-2-Methylcyclopentane	0.02	0.02	0.03
2,2-Dimethylheptane	0.01	0.01	0.01
cis-1,2-Dimethylcyclohexane	0.10	0.10	0.18
n-Propylcyclopentane	0.70	0.73	1.25
2,6-Dimethylheptane	0.27	0.29	0.43
1,1,3-Trimethylcyclohexane	0.36	0.39	0.57
3,5-Dimethylheptane	0.16	0.17	0.24
2,3,3-Trimethylhexane	0.02	0.03	0.04
3,3-Dimethylheptane	0.04	0.04	0.06
3-Methyl-3-Ethylhexane	0.04	0.04	0.06
Ethylbenzene	0.74	0.69	1.40
trans,trans-1,2,4-Trimethylcyclohexane	0.18	0.18	0.28
cis,trans-1,3,5-Trimethylhexane	0.01	0.01	0.01
m+p-Xylene	0.35	0.33	0.67
para-Xylene	0.38	0.35	0.71
2,3-Dimethylheptane	0.03	0.04	0.05
3,4-Dimethylheptane	0.08	0.09	0.13
4-Ethylheptane	0.06	0.07	0.09
2,3-Dimethyl-3-Ethylpentane	0.02	0.02	0.03
4-Methyloctane	0.10	0.11	0.15
2-Methyloctane	0.12	0.14	0.19
3-Ethylheptane	0.12	0.13	0.19
3-Methyloctane	0.23	0.26	0.36
3,3-Diethylpentane	0.03	0.03	0.04
ortho-Xylene	0.04	0.03	0.07
1,1,2-Trimethylcyclohexane	0.10	0.10	0.16
1-Methyl-2-Propylcyclopentane	0.18	0.19	0.29

CORE LABORATORIES

P.O. Box 34766
Houston, TX 77234
(713) 943-9776

Navajo Refining
Job No: 974143-1
Sample ID: NCL-34 9/4/97 1400

Page 3

CAPILLARY ANALYSIS

	Wt. %	L.V. %	Mole %
cis-1-Ethyl-3-Methylcyclohexane	0.34	0.35	0.54
trans-1-Ethyl-4-Methylcyclohexane	0.18	0.18	0.29
iso-Butylcyclopentane	0.07	0.07	0.10
2,2,6-Trimethylheptane	0.02	0.02	0.03
n-Nonane	0.46	0.51	0.71
Unidentified C-9 Compounds	0.18	0.20	0.28
trans-1-Ethyl-3-Methylcyclohexane	0.22	0.23	0.35
1-Methyl-1-Ethylcyclohexane	0.06	0.06	0.09
iso-Propylbenzene	0.19	0.18	0.32
sec-Butylcyclopentane	0.26	0.27	0.42
iso-Propylcyclohexane	0.16	0.16	0.26
2,2-Dimethyloctane	0.09	0.10	0.12
4,4-Dimethyloctane	0.06	0.06	0.08
3,5-Dimethyloctane	0.07	0.08	0.10
Propylcyclohexane	0.46	0.47	0.73
n-Butylcyclopentane	0.16	0.16	0.25
2,6-Dimethyloctane	0.65	0.73	0.92
n-Propylbenzene	0.50	0.46	0.82
1,3-Dimethyl-2-Ethylcyclohexane	0.32	0.33	0.46
meta-Ethyltoluene	0.43	0.40	0.72
para-Ethyltoluene	0.39	0.36	0.64
1,3,5-Trimethylbenzene	0.26	0.24	0.43
4-Ethyloctane	0.11	0.12	0.15
5-Methylnonane	0.13	0.14	0.18
4-Methylnonane	0.24	0.27	0.34
ortho-Ethyltoluene	0.28	0.25	0.46
3-Ethyloctane	0.12	0.13	0.17
3-Methylnonane	0.39	0.43	0.55
trans-1-Methyl-4-isopropylcyclohexane	0.12	0.12	0.17
1,2,4-Trimethylbenzene	0.64	0.59	1.06
ter-Butylcyclohexane	0.09	0.09	0.13
cis-1-Methyl-4-isopropylcyclohexane	0.11	0.11	0.15

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CORE LABORATORIES

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Navajo Refining
Job No: 974143-1
Sample ID: NCL-34 9/4/97 1400

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CAPILLARY ANALYSIS

	Wt. %	L.V. %	Mole %
1-Ethyl-2,3-Dimethylcyclohexane	0.09	0.09	0.13
iso-Butylbenzene	0.08	0.07	0.12
n-Decane	0.13	0.15	0.18
Unidentified C-10 Compounds	0.91	1.01	1.28
1,2,3-Trimethylbenzene	0.37	0.35	0.62
Indane	0.15	0.12	0.25
1-Methyl-4-isopropylbenzene	0.14	0.13	0.20
sec-Butylcyclohexane	0.90	0.89	1.28
1-Methyl-2-isopropylbenzene	0.05	0.05	0.07
1,3-Diethylbenzene	0.19	0.18	0.28
1-Methyl-3-Propylbenzene	0.66	0.62	0.98
n-Butylbenzene	0.21	0.20	0.31
1,3-Dimethyl-5-Ethylbenzene	0.31	0.29	0.47
1,2-Diethylbenzene	0.10	0.09	0.15
1-Methyl-2-Propylbenzene	0.38	0.35	0.56
4-Methyldecane	0.18	0.20	0.23
1,4-Dimethyl-2-Ethylbenzene	0.22	0.21	0.33
1,3-Dimethyl-4-Ethylbenzene	0.37	0.34	0.56
3-Methyldecane	0.21	0.23	0.27
1,2-Dimethyl-4-Ethylbenzene	0.33	0.30	0.49
1-Methyl-3-ter-Butylbenzene	0.08	0.08	0.11
1,3-Dimethyl-2-Ethylbenzene	0.20	0.18	0.30
1-Methyl-4-ter-Butylbenzene	0.07	0.06	0.09
1,2-Dimethyl-3-Ethylbenzene	0.32	0.29	0.48
n-Undecane	1.01	1.10	1.29
Unidentified C-11 Compounds	3.38	3.68	4.33
1,2,4,5-Tetramethylbenzene	0.12	0.11	0.18
(2-Methylbutyl)Benzene	0.19	0.18	0.25
1,2,3,5-Tetramethylbenzene	0.38	0.34	0.56
1,2,3,4-Tetramethylbenzene	0.32	0.29	0.48
Pentylbenzene	0.28	0.26	0.38
trans-1-Methyl(4-Methylpentane)cyclopentane	0.20	0.20	0.26

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CAPILLARY ANALYSIS

	Wt. %	L.V. %	Mole %
n-Dodecane	1.02	1.09	1.19
Naphthalene	0.06	0.04	0.10
2-Methyl Naphthalene	0.58	0.46	0.81
1-Methyl Naphthalene	0.56	0.44	0.78
Unidentified C12 Compounds	5.33	5.01	6.56
Tridecane	0.84	0.68	0.91
Unidentified C13 Compounds	7.27	5.89	8.06
Tetradecane	0.78	0.63	0.78
Unidentified C14 Compounds	4.81	3.89	4.84
Pentadecane	0.28	0.29	0.26
Unidentified C15 Compounds	3.26	3.40	3.07
Hexadecane	0.27	0.28	0.24
Unidentified C16 Compounds	2.84	2.98	2.51
Heptadecane	0.07	0.07	0.06
Pristane	1.09	1.13	0.82
Unidentified C17 Compounds	2.39	2.49	1.99
Octadecane	0.21	0.22	0.17
Phytane	0.91	0.96	0.65
Unidentified C18 Compounds	1.01	1.05	0.79
Nonadecane	0.31	0.32	0.23
Unidentified C19 Compounds	0.53	0.55	0.40
Eicosane	0.02	0.02	0.01
Unidentified C20 Compounds	0.53	0.54	0.37
Heneicosane	0.03	0.03	0.02
Unidentified C21 Compounds	0.55	0.57	0.37
Docosane	0.07	0.07	0.04
Unidentified C22 Compounds	0.44	0.45	0.28
Tricosane	0.04	0.04	0.03
Unidentified C23 Compounds	0.24	0.25	0.15
Tetracosane	0.02	0.02	0.01
Unidentified C24 Compounds	0.10	0.10	0.06
Pentacosane	0.01	0.01	0.01
C25 Plus Compounds	35.54	37.43	20.19
	100.00	100.00	100.00

Post-it® Fax Note 7671

To Dave Boyer		Date 10-9-97	# of pages ▶
Co./Dept.		From Charlie Ebarb	
Phone #		Co. Navajo Refining	
Fax # 505-281-1335		Phone #	
		Fax #	

INTEROFFICE COMMUNICATION

October 9, 1997

TO: Dave Boyer

FROM: Charlie Ebarb

SUBJECT: NCL-34

API Gravity = 27.9
Specific Gravity = 0.8877
Distillation °F
IBP = 280
10% = 366
20% = 414
30% = 460
40% = 522
50% = 598
60% = 668
70% = 698
80% = 719
90% = 740
Started cracking at 92% recovery (~745°F)
Sulfur=1.0475 wt%

GW-28

Appendix D

Appendix D

APPENDIX D

STATISTICAL DATA SHEETS

BACKGROUND DATA					NON-BACKGROUND DATA				
					A THRU D				
Location	Cr Bkgd	Pb Bkgd	z-score, Cr	z-score, pb	Location	Cr (mg/Kg)	Pb (mg/Kg)	z-zcore Cr	z-score Pb
BG 97-01	6.51	4.11	-0.7381	-0.7156	A-1	7.5	7	-0.7610	0.1847
BG 97-02	6.51	3.97	-0.7381	-0.7820	A-2	8.2	6	-0.6095	-0.2702
BG 97-03	4.19	1.92	-1.4286	-1.7536	A-3	5.9	7	-1.1074	0.1847
BG 97-04	10.8	4.45	0.5387	-0.5545	A-4	14.0	4	0.6459	-1.1802
BG 97-05	12.4	5.38	1.0149	-0.1137	A-5	4.9	5	-1.3238	-0.7252
Dup #1	14.6	6.82	1.6696	0.5687	A-5(dup)	4.5	6	-1.4104	-0.2702
BG-01	6.8	7	-0.6518	0.6540	A-6	6.5	6	-0.9775	-0.2702
BG-02	6.7	5	-0.6815	-0.2938	A-7	5.7	4	-1.1506	-1.1802
BG-03	8.1	7	-0.2649	0.6540	A-8	8.0	7	-0.6528	0.1847
BG-04	5.8	7	-0.9494	0.6540	A-9	13.8	8	0.6026	0.6397
BG-05	5.9	4	-0.9196	-0.7678	A-10	3.2	2	-1.6918	-2.0901
BG-06	12.1	8	0.9256	1.1280	A-11	8	4	-0.6528	-1.1802
BG-07	13	10	1.1935	2.0758	A-12	13	4	0.4294	-1.1802
BG 94-06	8	4	-0.2946	-0.7678	A-13	12	6	0.2130	-0.2702
BG-08	13.4	*42	1.3125	17.2417	A-14	10	8	-0.2199	0.6397
					A-15	8	6	-0.6528	-0.2702
		*outlier			A-16	9	4	-0.4364	-1.1802
Sum	134.81	78.65			A-17	10	3	-0.2199	-1.6351
max	14.6	10			B-1	9.5	8	-0.3281	0.6397
mean	8.9873	5.6179			B-2	14.0	6	0.6459	-0.2702
Stdev	3.3642	2.1078			B-3	8.6	6	-0.5229	-0.2702
var	11.3181	4.4426			B-4	9.2	8	-0.3931	0.6397
no. observ.	15	14			B-5	9.6	8	-0.3065	0.6397
					B-5(dup)	13.9	9	0.6242	1.0946
					B-6	5.8	6	-1.1290	-0.2702
t-Test: Two-Sample Assuming Equal Variances					B-7	18.7	7	1.6632	0.1847
					B-8	9.1	7	-0.4147	0.1847
	Cr (mg/Kg)	*Cr Bkgd*			B-9	11.5	16	0.1048	4.2793
Mean	11.01594203	8.98733333			B-10	9.1	7	-0.4147	0.1847
Variance	21.37047741	11.3181352			B-11	13	6	0.4294	-0.2702
Observations	69	15			B-12	13	8	0.4294	0.6397
Pooled Variance	19.65422387				B-13	13	5	0.4294	-0.7252
Hypothesized Mean Dif	0				B-14	14	5	0.6459	-0.7252
df	82				C-1	16.6	9	1.2087	1.0946
t Stat	1.6062046				C-2	13.3	8	0.4944	0.6397
P(T<=t) one-tail	0.056036653				C-3	7.2	4	-0.8260	-1.1802
t Critical one-tail	1.663647708				C-4	8.9	9	-0.4580	1.0946
P(T<=t) two-tail	0.112073305				C-5	8.9	4	-0.4580	-1.1802
t Critical two-tail	1.989319571				C-6	11.6	9	0.1264	1.0946
					C-7	10.3	9	-0.1550	1.0946
t-Test: Two-Sample Assuming Unequal Variances					C-8	9.6	6	-0.3065	-0.2702
					C-9	6.8	6	-0.9126	-0.2702
	Cr (mg/Kg)	*Cr Bkgd*			C-10	8.7	5	-0.5013	-0.7252
Mean	11.01594203	8.98733333			C-10(dup)	6.3	6	-1.0208	-0.2702
Variance	21.37047741	11.3181352			C-11	11	5	-0.0035	-0.7252
Observations	69	15			C-11(dup)	12	5	0.2130	-0.7252
Hypothesized Mean Dif	0				C-12	23	11	2.5939	2.0045
df	27				C-13	18	8	1.5117	0.6397
t Stat	1.966412076				C-14	12	4	0.2130	-1.1802
P(T<=t) one-tail	0.029804495				C-15	15	8	0.8623	0.6397
t Critical one-tail	1.703288035				C-16	11	6	-0.0035	-0.2702
P(T<=t) two-tail	0.05960899				C-17	24	10	2.8104	1.5496
t Critical two-tail	2.051829142				C-18	10	4	-0.2199	-1.1802
					D-1	6.4	5	-0.9991	-0.7252
					D-2	12.3	8	0.2779	0.6397
					D-3	8.3	6	-0.5879	-0.2702

					D-4	7.3	3	-0.8043	-1.6351
					D-5	9.4	6	-0.3498	-0.2702
					D-6	7.3	5	-0.8043	-0.7252
					D-7	8.0	6	-0.6528	-0.2702
					D-8	7.5	6	-0.7610	-0.2702
					D-9	7.7	8	-0.7177	0.6397
					D-10	8.5	7	-0.5446	0.1847
					D-10(dup)	9.0	7	-0.4364	0.1847
					D-11	22	10	2.3775	1.5496
					D-12	18	8	1.5117	0.6397
					D-12(dup)	18	8	1.5117	0.6397
					D-14	19	8	1.7281	0.6397
					D-15	23	9	2.5939	1.0946
	Mean Cr	**Stdev Cr**	**Mean Pb**	**STdev Pb**	**max**	24	16		
A1-A17	8.4556	3.1905	5.3889	1.7197	**mean**	11.0159	6.5942		
B1-B14	11.4667	3.1865	7.4667	2.6421	**Stdev**	4.6228	2.1984		
C1-C18	12.2100	4.9175	6.8000	2.2384	**var**	21.3705	4.8329		
D1-D15	11.9813	5.8541	6.8750	1.7464	**no. obs.**	69	69		

BACKGROUND DATA					NON-BACKGROUND DATA				
					A THRU D				
Location	Cr Bkgd	Pb Bkgd	z-score, Cr	z-score, pb	Location	Cr (mg/Kg)	Pb (mg/Kg)	z-zcore Cr	z-score Pb
BG 97-01	6.51	4.11	-0.7381	-0.7156	A-1	7.5	7	-0.7610	0.1847
BG 97-02	6.51	3.97	-0.7381	-0.7820	A-2	8.2	6	-0.6095	-0.2702
BG 97-03	4.19	1.92	-1.4286	-1.7536	A-3	5.9	7	-1.1074	0.1847
BG 97-04	10.8	4.45	0.5387	-0.5545	A-4	14.0	4	0.6459	-1.1802
BG 97-05	12.4	5.38	1.0149	-0.1137	A-5	4.9	5	-1.3238	-0.7252
Dup #1	14.6	6.82	1.6696	0.5687	A-5(dup)	4.5	6	-1.4104	-0.2702
BG-01	6.8	7	-0.6518	0.6540	A-6	6.5	6	-0.9775	-0.2702
BG-02	6.7	5	-0.6815	-0.2938	A-7	5.7	4	-1.1506	-1.1802
BG-03	8.1	7	-0.2649	0.6540	A-8	8.0	7	-0.6528	0.1847
BG-04	5.8	7	-0.9494	0.6540	A-9	13.8	8	0.6026	0.6397
BG-05	5.9	4	-0.9196	-0.7678	A-10	3.2	2	-1.6918	-2.0901
BG-06	12.1	8	0.9256	1.1280	A-11	8	4	-0.6528	-1.1802
BG-07	13	10	1.1935	2.0758	A-12	13	4	0.4294	-1.1802
BG 94-06	8	4	-0.2946	-0.7678	A-13	12	6	0.2130	-0.2702
BG-08	13.4	*42	1.3125	17.2417	A-14	10	8	-0.2199	0.6397
					A-15	8	6	-0.6528	-0.2702
		*outlier			A-16	9	4	-0.4364	-1.1802
Sum	134.81	78.65			A-17	10	3	-0.2199	-1.6351
max	14.6	10			B-1	9.5	8	-0.3281	0.6397
mean	8.9873	5.6179			B-2	14.0	6	0.6459	-0.2702
Stdev	3.3642	2.1078			B-3	8.6	6	-0.5229	-0.2702
var	11.3181	4.4426			B-4	9.2	8	-0.3931	0.6397
no. observ.	15	14			B-5	9.6	8	-0.3065	0.6397
					B-5(dup)	13.9	9	0.6242	1.0946
					B-6	5.8	6	-1.1290	-0.2702
t-Test: Two-Sample Assuming Equal Variances					B-7	18.7	7	1.6632	0.1847
					B-8	9.1	7	-0.4147	0.1847
	Pb (mg/Kg)	*Pb Bkgd*			B-9	11.5	16	0.1048	4.2793
Mean	6.594202899	5.61785714			B-10	9.1	7	-0.4147	0.1847
Variance	4.832907076	4.44263352			B-11	13	6	0.4294	-0.2702
Observations	69	14			B-12	13	8	0.4294	0.6397
Pooled Variance	4.770270579				B-13	13	5	0.4294	-0.7252
Hypothesized Mean Diff	0				B-14	14	5	0.6459	-0.7252
df	81				C-1	16.6	9	1.2087	1.0946
t Stat	1.525041468				C-2	13.3	8	0.4944	0.6397
P(T<=t) one-tail	0.06557198				C-3	7.2	4	-0.8260	-1.1802
t Critical one-tail	1.663884177				C-4	8.9	9	-0.4580	1.0946
P(T<=t) two-tail	0.131143959				C-5	8.9	4	-0.4580	-1.1802
t Critical two-tail	1.989687917				C-6	11.6	9	0.1264	1.0946
					C-7	10.3	9	-0.1550	1.0946
t-Test: Two-Sample Assuming Unequal Variances					C-8	9.6	6	-0.3065	-0.2702
					C-9	6.8	6	-0.9126	-0.2702
	Pb (mg/Kg)	*Pb Bkgd*			C-10	8.7	5	-0.5013	-0.7252
Mean	6.594202899	5.61785714			C-10(dup)	6.3	6	-1.0208	-0.2702
Variance	4.832907076	4.44263352			C-11	11	5	-0.0035	-0.7252
Observations	69	14			C-11(dup)	12	5	0.2130	-0.7252
Hypothesized Mean Diff	0				C-12	23	11	2.5939	2.0045
df	19				C-13	18	8	1.5117	0.6397
t Stat	1.568696454				C-14	12	4	0.2130	-1.1802
P(T<=t) one-tail	0.066611388				C-15	15	8	0.8623	0.6397
t Critical one-tail	1.729131327				C-16	11	6	-0.0035	-0.2702
P(T<=t) two-tail	0.133222776				C-17	24	10	2.8104	1.5496
t Critical two-tail	2.093024705				C-18	10	4	-0.2199	-1.1802
					D-1	6.4	5	-0.9991	-0.7252
					D-2	12.3	8	0.2779	0.6397

					D-3	8.3	6	-0.5879	-0.2702
					D-4	7.3	3	-0.8043	-1.6351
					D-5	9.4	6	-0.3498	-0.2702
					D-6	7.3	5	-0.8043	-0.7252
					D-7	8.0	6	-0.6528	-0.2702
					D-8	7.5	6	-0.7610	-0.2702
					D-9	7.7	8	-0.7177	0.6397
					D-10	8.5	7	-0.5446	0.1847
					D-10(dup)	9.0	7	-0.4364	0.1847
					D-11	22	10	2.3775	1.5496
					D-12	18	8	1.5117	0.6397
					D-12(dup)	18	8	1.5117	0.6397
					D-14	19	8	1.7281	0.6397
					D-15	23	9	2.5939	1.0946
	Mean Cr	**Stdev Cr**	**Mean Pb**	**STdev Pb**	**max**	24	16		
A1-A17	8.4556	3.1905	5.3889	1.7197	**mean**	11.0159	6.5942		
B1-B14	11.4667	3.1865	7.4667	2.6421	**Stdev**	4.6228	2.1984		
C1-C18	12.2100	4.9175	6.8000	2.2384	**var**	21.3705	4.8329		
D1-D15	11.9813	5.8541	6.8750	1.7464	**no. obs.**	69	69		

GW-28

Appendix E

Appendix E

APPENDIX E

VADOSE ZONE MODELING
SAMPLE DATA OUTPUT SHEETS

GW-28

Appendix F

Appendix F

APPENDIX F

GROUNDWATER TESTING AND MODELING

APPENDIX F1

AQUIFER TEST DATA AND GRAPHS

APPENDIX C

1. Slug Test Data Set Configuration for Hydraulic Conductivity Determination

NRC Monitor Well	MW-54A Slug In	MW-54A Slug Out	MW-54A Slug In	MW-54B Slug In	MW-54B Slug Out
Test Date:	12/22/95	12/22/95	12/22/95	12/22/95	12/22/95
Test Identification	Test-2	Test-3	Test-4	Test-0	Test-1
Initial rise/drawdown in well, s_o (ft.)	1.76	2.32	2.26	2.49	2.66
Radius of well casing, r_c (ft.)	0.08333	0.08333	0.08333	0.08333	0.08333
Radius of well borehole, r_w (ft.)	0.3438	0.3438	0.3438	0.3438	0.3438
Saturated aquifer thickness, b (ft.)	13.53	13.53	13.53	28.6	28.6
Screen length, L (ft.)	9.5	9.5	9.5	9.5	9.5
Height of water in well, H (ft.)	13.53	13.53	13.53	28.6	28.6
Hydraulic Conductivity, K (ft/min)	0.00078	0.001094	0.000782	0.008135	0.008136
Transmissivity, T (ft^2/min)	N/A	N/A	N/A	0.15	0.13

2. Hydraulic Conductivity Determined using the Bouwer and Rice Method

The method uses a graphical approach to calculation of hydraulic conductivity whereby the straight line portion of the time-drawdown graph is fitted and the line extended to the logarithmic y-axis. For any value of time, a displacement (drawdown) can be determined and used, together with the "shape factor," to calculate the hydraulic conductivity.

$$\ln s_o - \ln s_t = (2\,K\,L\,t) / (r_c^2 \ln(r_e/r_w))$$

where:

s_o = initial drawdown in well due to instantaneous removal of water from well (ft.)
s_t = drawdown in well at time t (ft.)
K = hydraulic conductivity (ft/min)
L = length of well screen (ft.)
r_c = radius of well casing (ft.)
$\ln(r_e/r_w)$ = empirical "shape factor" determined from tables provided by Bouwer and Rice
r_e = equivalent radius over which head loss occurs (ft.)
r_w = radius of well, including sand pack (ft.)
b = saturated thickness of aquifer (ft.)

3. Transmissivity Determined using Cooper, et al., Method

This method utilizes a curve-matching technique to determine transmissivity. Time is plotted logarithmically on the x-axis, and the ratio of displacement (drawdown) at time **t** to displacement at time **t** = 0 is plotted on the Y-axis. The plotted curve is overlain and compared against a series of type-curves and the best match selected. For the best match, coordinate points are selected and entered into standard equations to determine transmissivity. The equations are generated using complex Bessel functions and are not shown here.

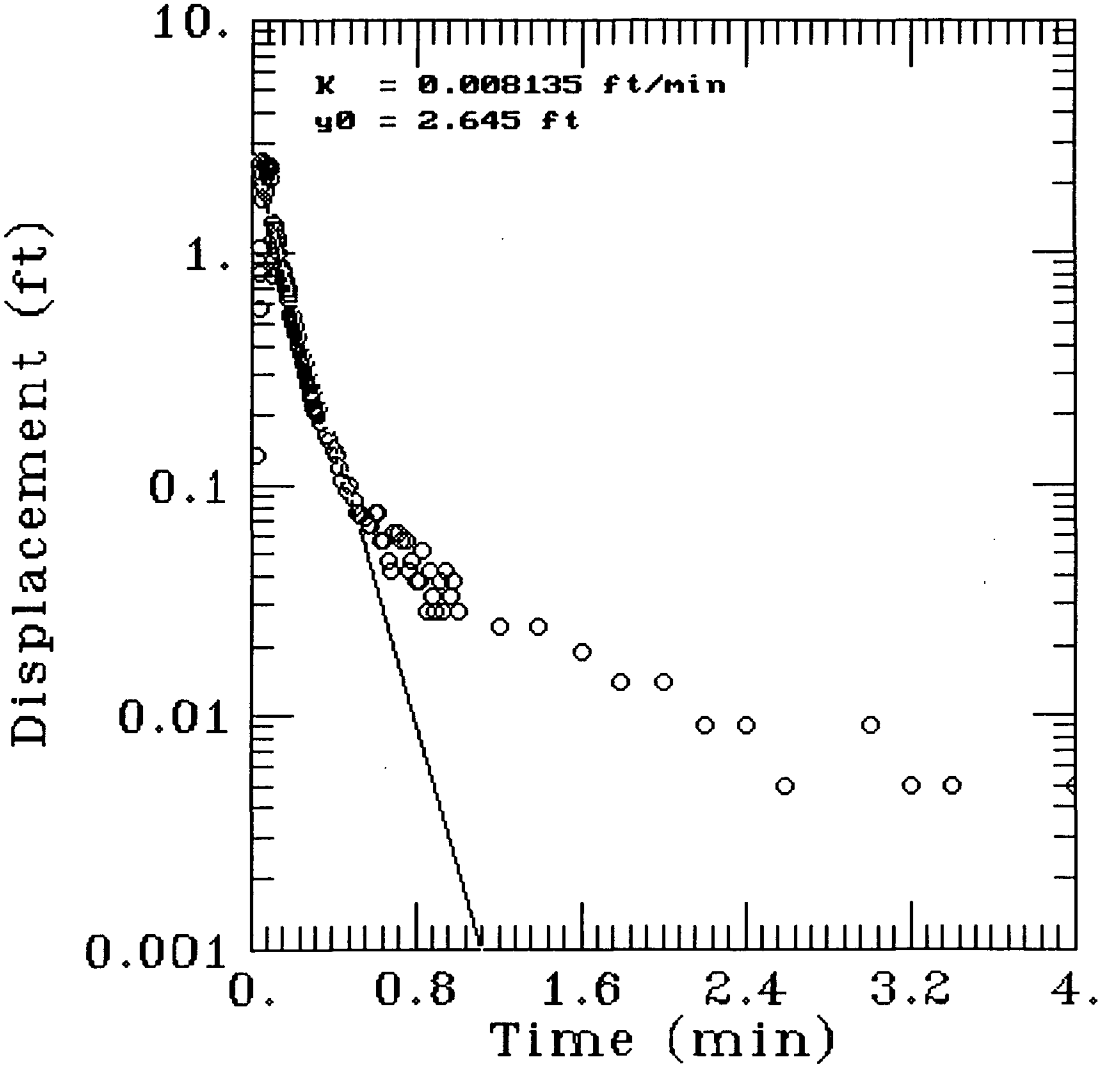
4. References

Computer programs utilizing both the Bouwer and Rice method, and the Cooper method to determine solutions to slug-test data are available from a number of public domain or commercial sources, together with extensive documentation of the applicability and limitations of the methods. The basic references which first described the test methods are listed below:

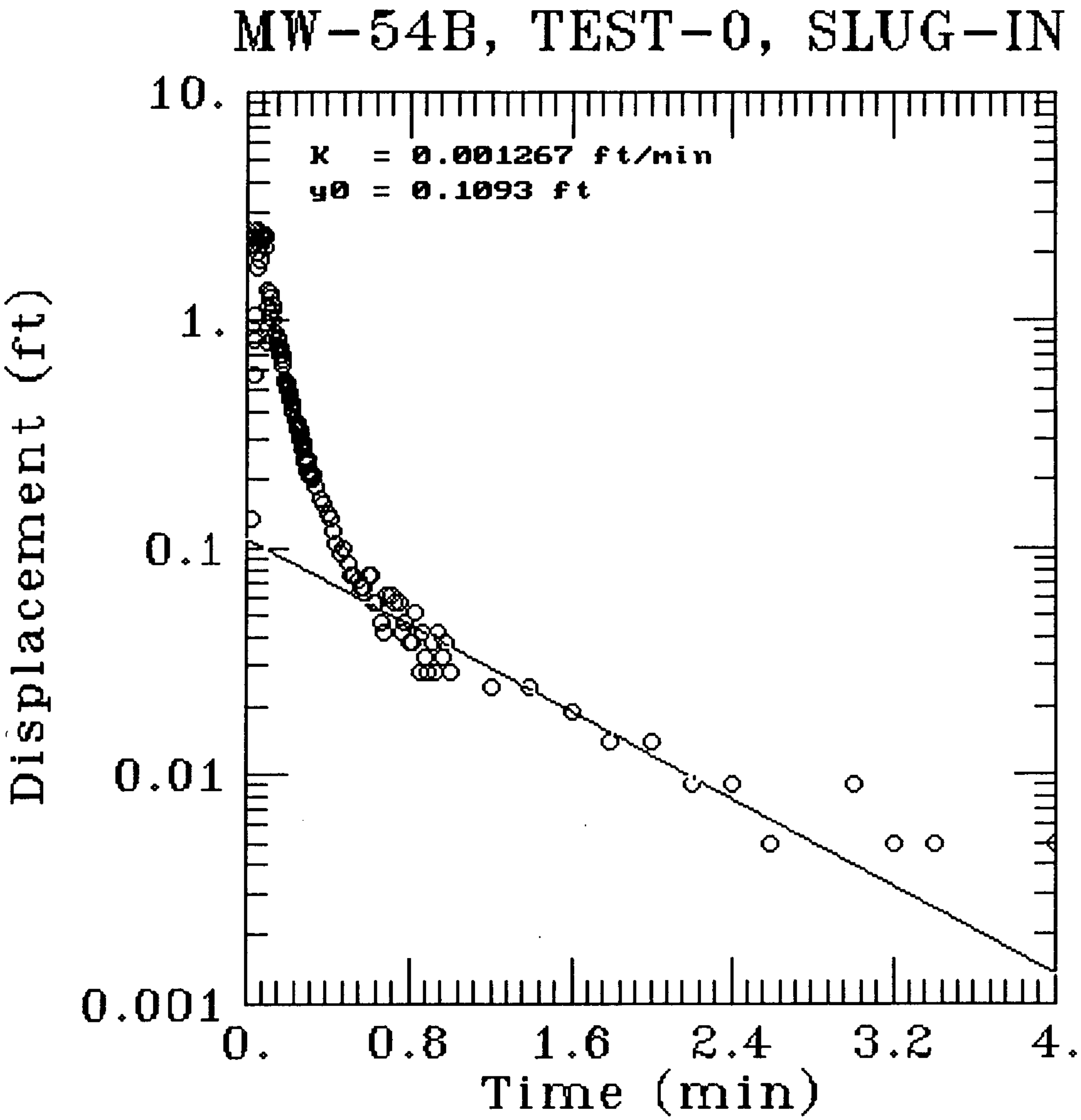
Bouwer, H., 1989. "The Bouwer and Rice Slug Test -- an Update." *Ground Water*, vol. 27, no. 3, pp. 304-309.

Bouwer, H. and R.C. Rice, *1976*. "A Slug Test Method for Determining Hydraulic Conductivity of Unconfined Aquifers with Completely or Partially Penetrating Wells." *Water Resources Research*, vol. 12, no. 3, pp. 423-428.

Cooper, H.H., Jr., J.D. Bredehoeft, and I.S. Papadopulos, 1967. "Response of a Finite Diameter Well to an Instantaneous Charge of Water." *Water Resources Research*, vol. 3, pp. 263-269.

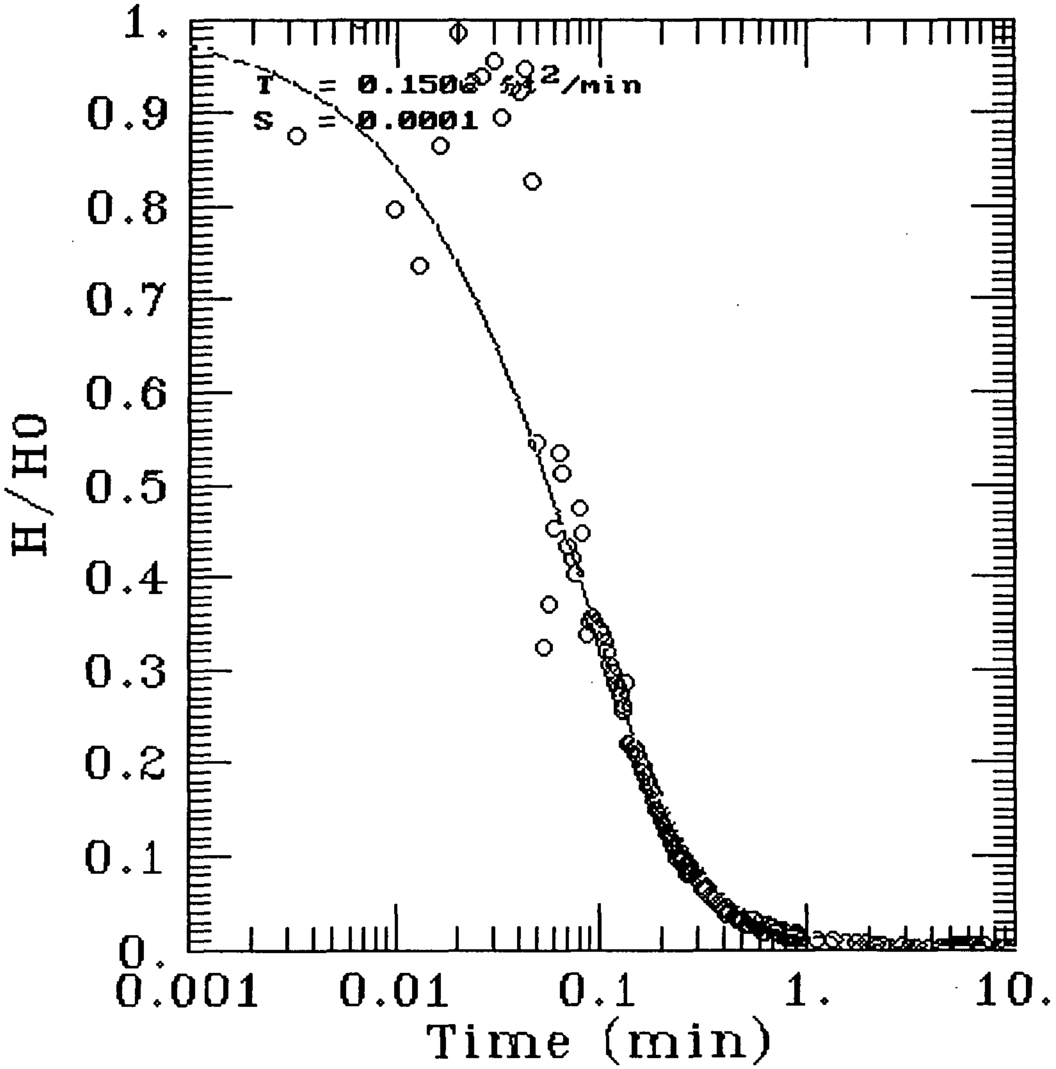


MW-54B, TEST-0, SLUG-IN

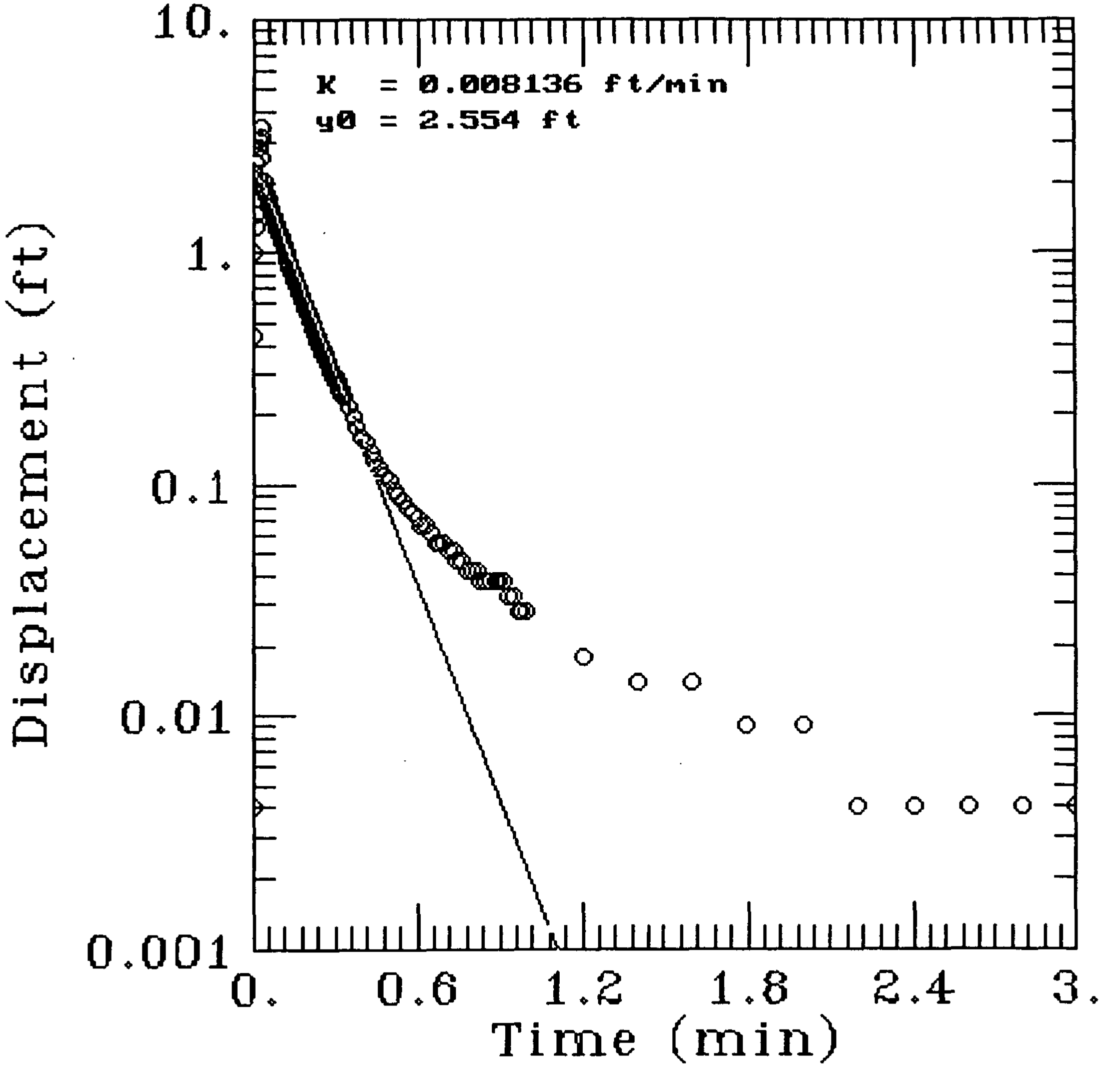


MW-54B, TEST-0, SLUG-IN

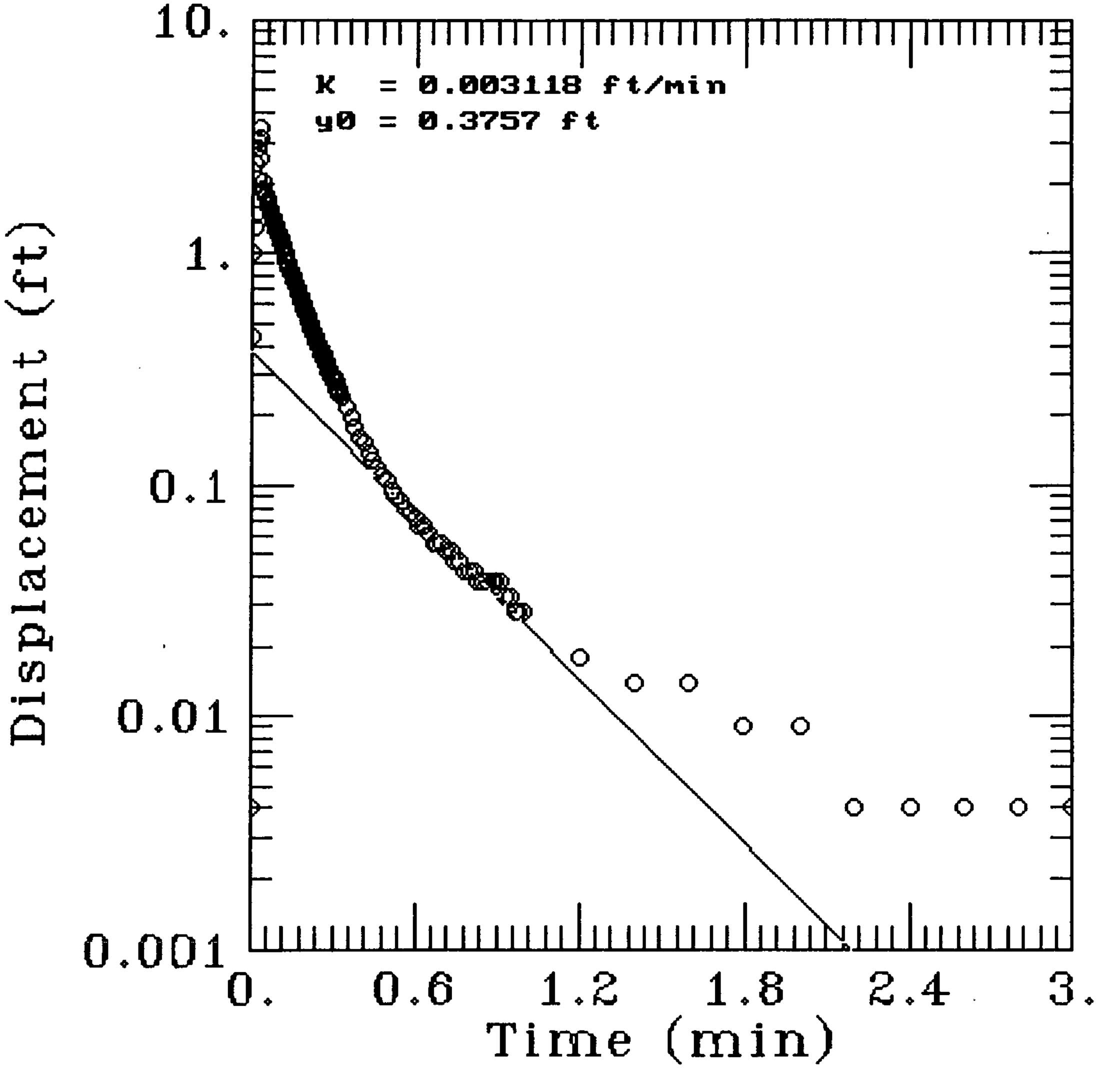
MW-54B, TEST-0, SLUG-IN

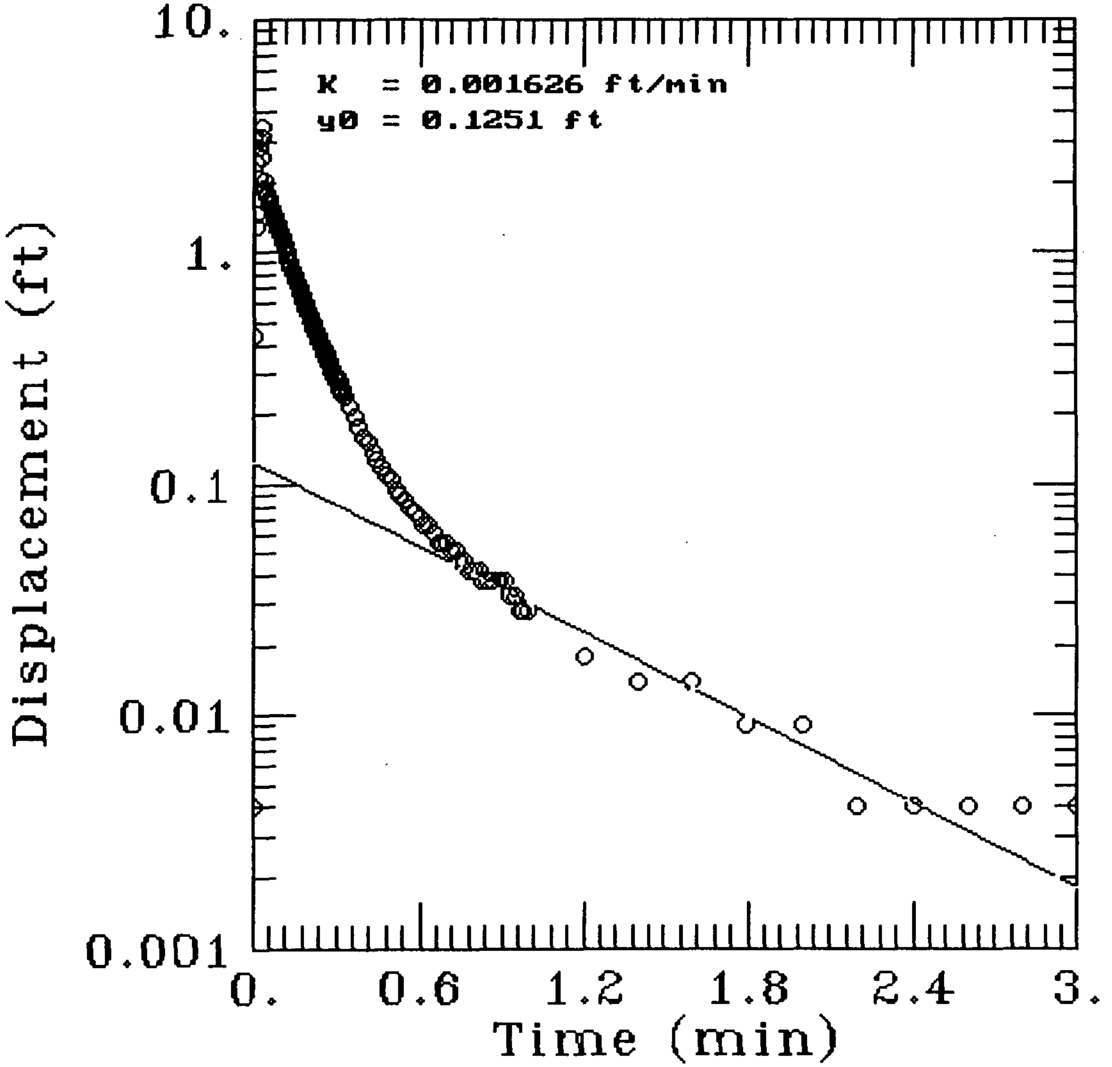


MW-54B TEST-1, SLUG-OUT

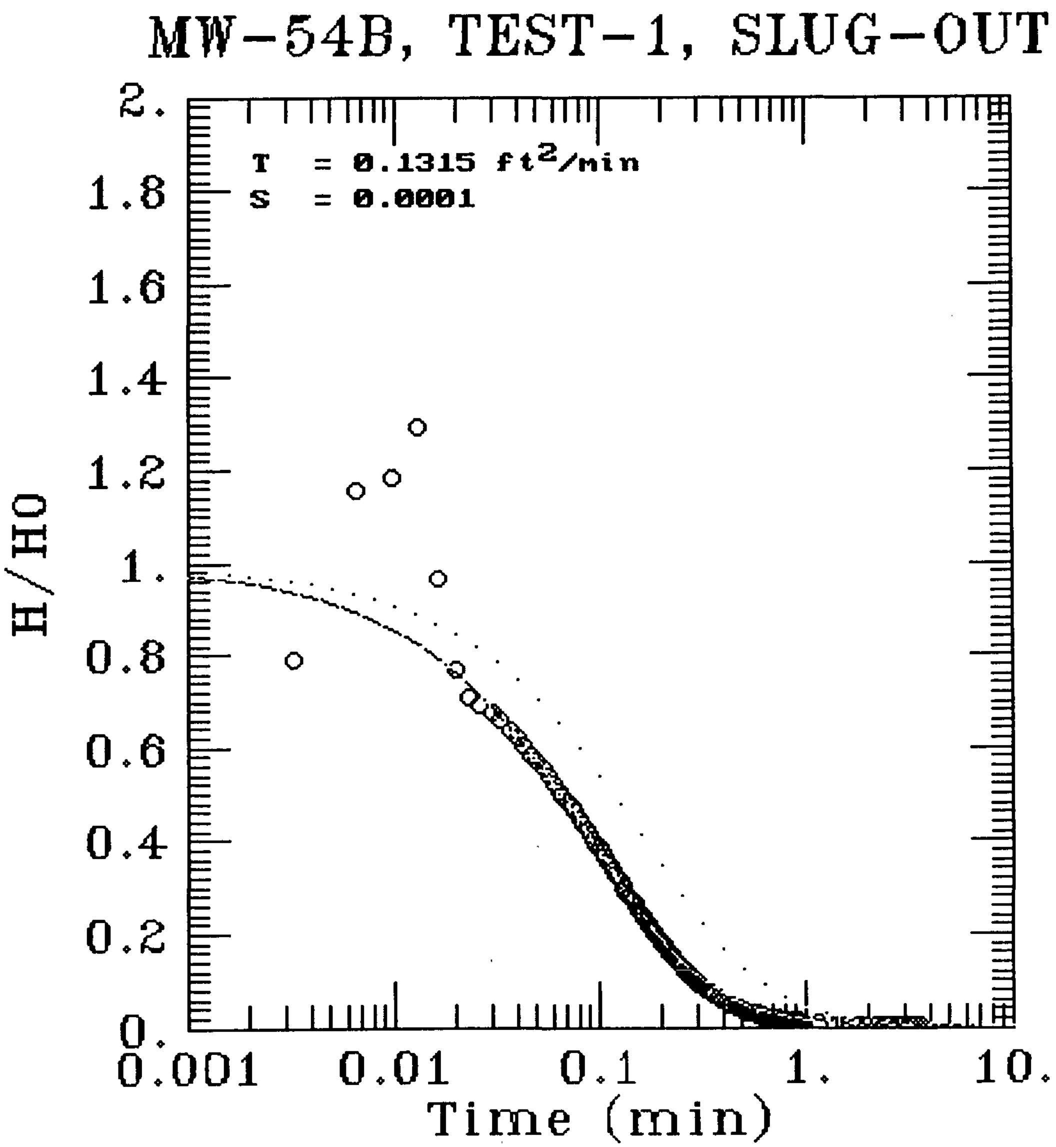


MW-54B TEST-1, SLUG-OUT

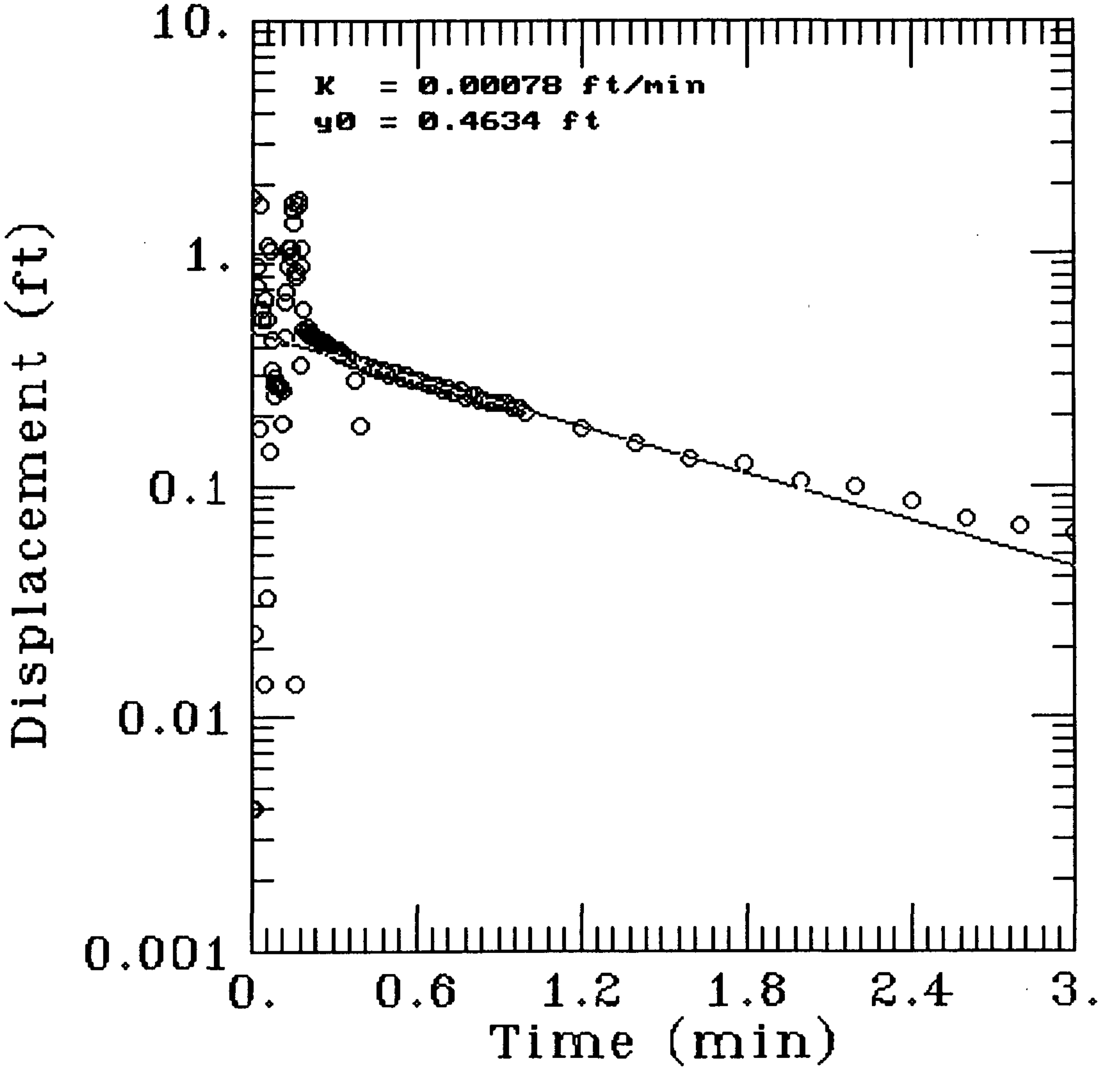


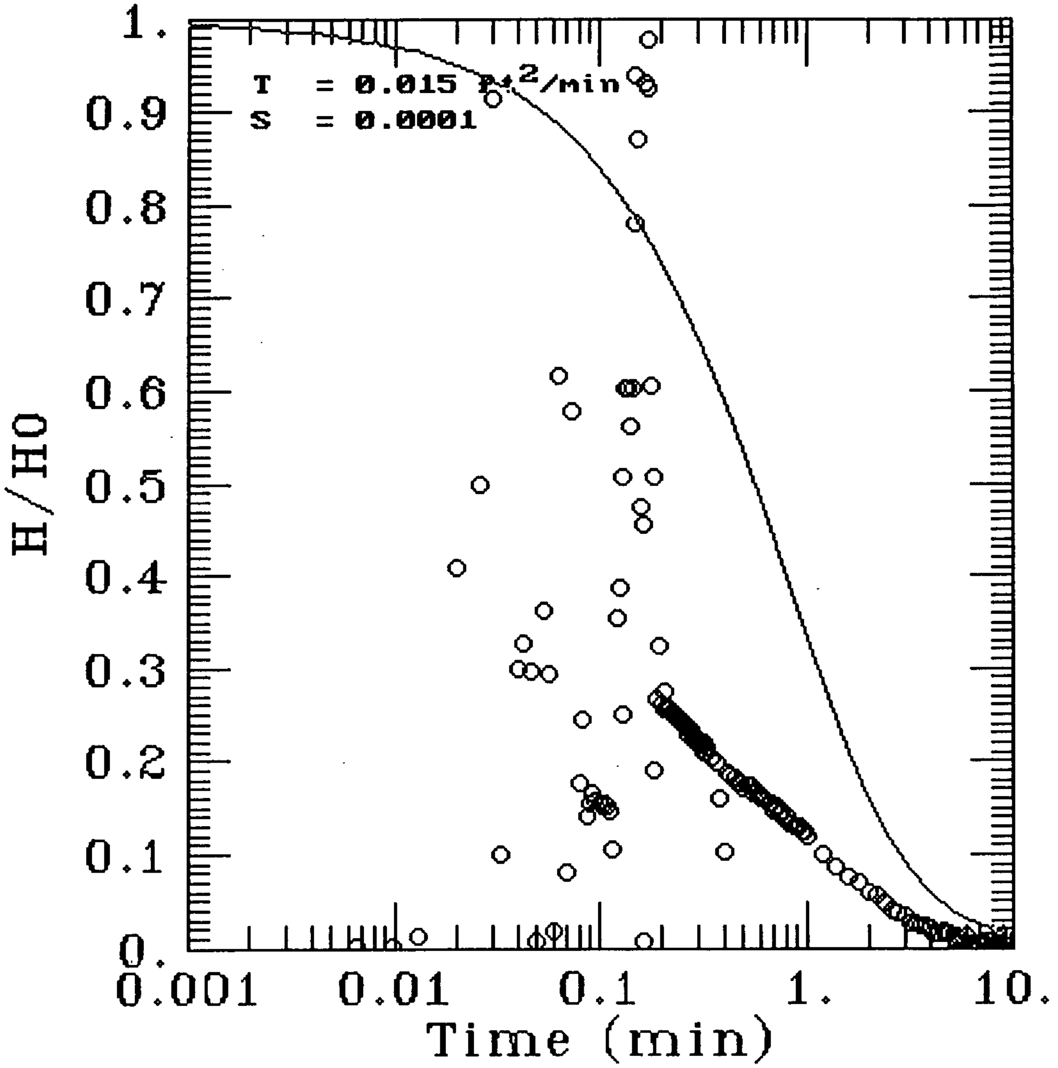


MW-54B, TEST-1, SLUG-OUT


MW-54B, TEST-1, SLUG-OUT
T = 0.1315 ft²/min
S = 0.0001
H/H0
2.
1.8
1.6
1.4
1.2
1.
0.8
0.6
0.4
0.2
0.
0.001
0.01
0.1
1.
10.
Time (min)

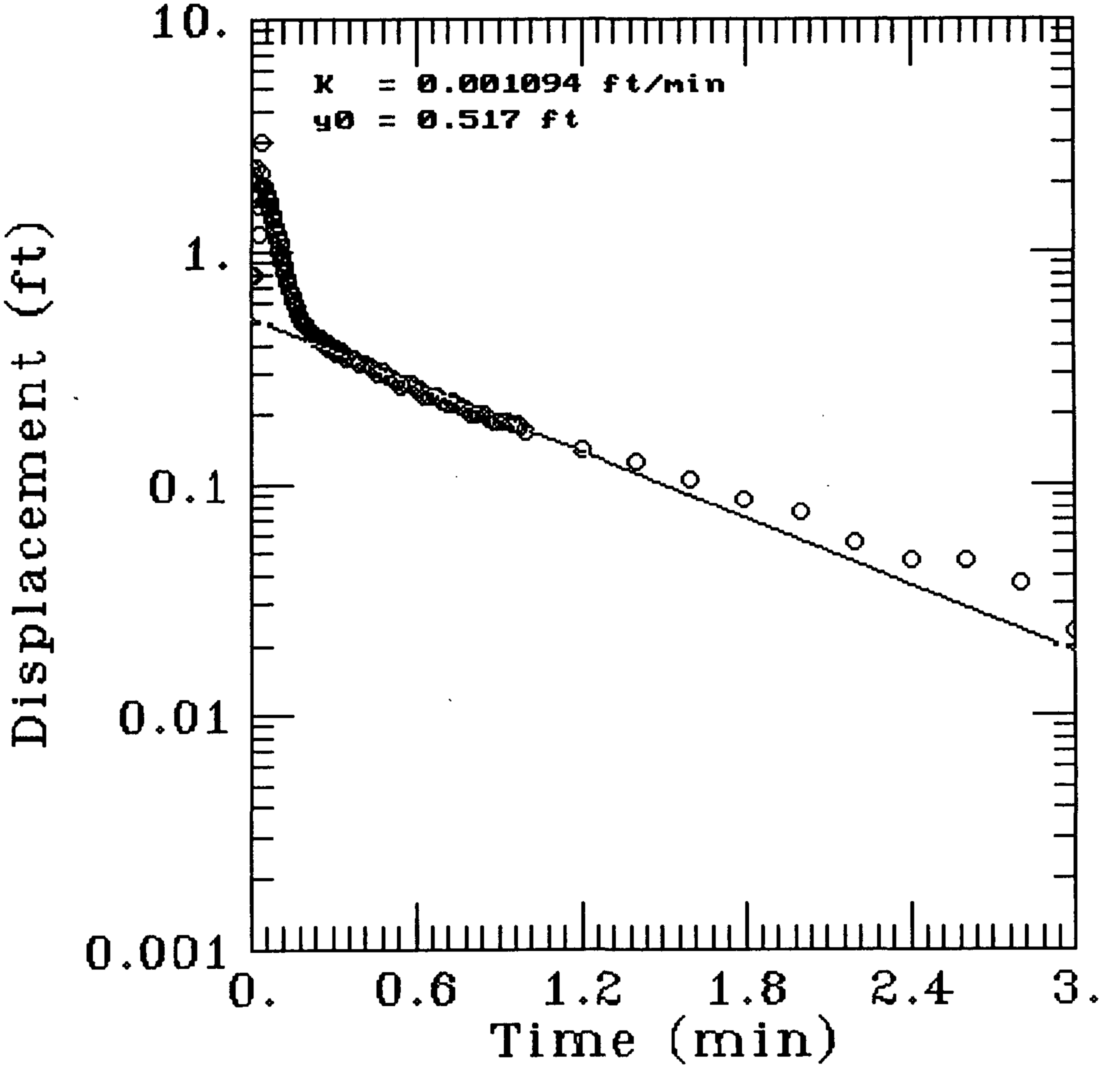
MW-54A, TEST-2, SLUG-IN



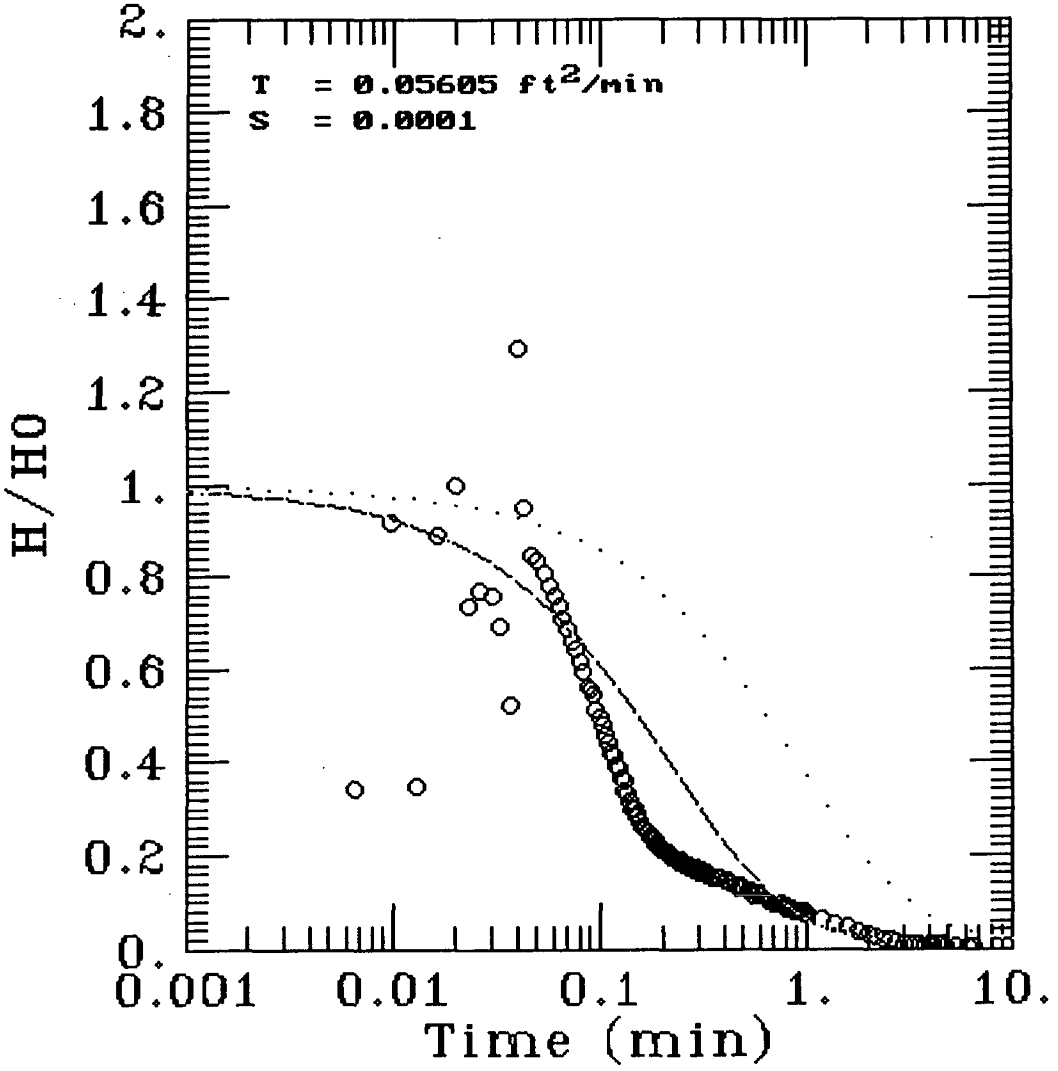


MW-54A, TEST-2, SLUG-IN

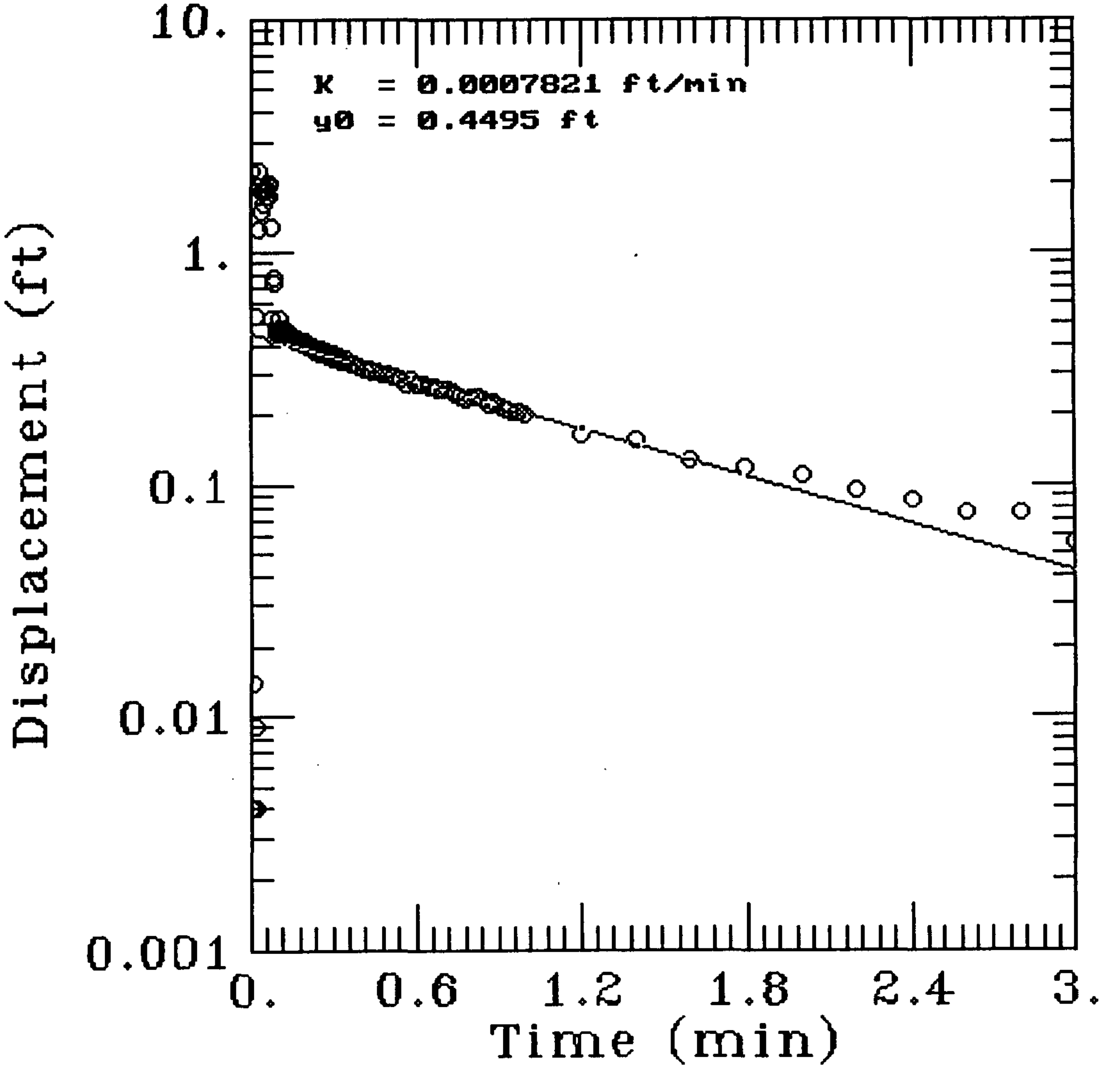
MW-54A, TEST-3, SLUG-OUT

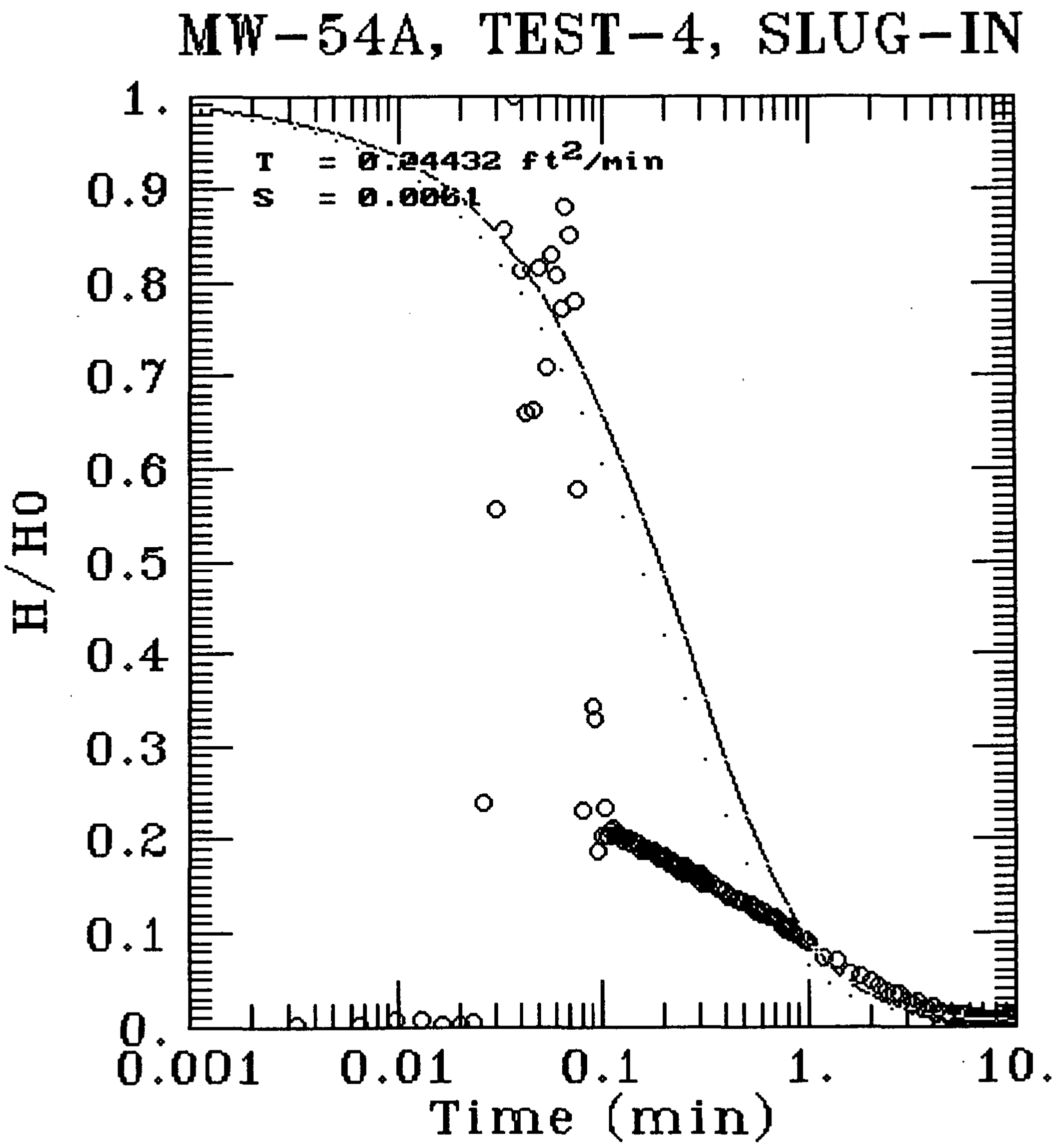


MW-54A, TEST-3, SLUG-OUT



MW-54A, TEST-4, SLUG-IN




MW-54A, TEST-4, SLUG-IN
T = 0.24432 ft^2/min
S = 0.0061
H/H0
1.
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.
0.001
0.01
0.1
1.
10.
Time (min)

APPENDIX F2

GROUNDWATER MODELING
SAMPLE DATA OUTPUT SHEETS

GW-28

Appendix G

Appendix G

APPENDIX G

SOIL AND WATER QUALITY LABORATORY DATA SHEETS

APPENDIX G1

NCL MONITOR WELL DATA TABULATION, 1990-1997

NCL-31

NCL-31, Quarter/Year:	1st 90	2nd 90	3rd 90	4th 90	1st 91	2nd 91	3rd 91	4th 91
SampleDate:	13-Apr-90	NR	03-Oct-90	19-Dec-90	11-Apr-91	16-Jul-91	12-Nov-91	08-Jan-92
Laboratory:	CORE		PSI	ENSECO	BETZ	BETZ	BETZ	BETZ
Volatiles (ug/L):								
benzene	ND		ND	ND	17	26	8	<50
ethylbenzene	ND		ND	ND	29	66	28	30
toluene	ND		ND	ND	<5	<5	<5	<50
total xylenes	ND		ND	ND	<5	6	<5	<50
acetone (a)	NR		NR	NR	NR	NR	NR	NR
2-Butanone (MEK)	ND		ND	ND	<100	<100	<100	<1,000
1,2-Dichloroethane	ND		ND	ND	<5	<5	<5	<50
methylene chloride (a)	NR		NR	NR	NR	NR	NR	NR
Semi-Volatiles (ug/L):								
anthracene	ND		ND	ND	<10	<10	<100	<100
chrysene	ND		ND	ND	<10	<10	<100	<100
dibenzofuran	ND		ND	ND	<10	<10	<100	<100
fluorene	3.2		ND	ND	<10	<10	<100	<100
1-methylnaphthalene	2.8		ND	ND	<10	<10	<100	<100
2-methylnaphthalene	2.6		NR	NR	NR	NR	NR	NR
naphthalene	ND		ND	ND	<10	<10	<100	<100
phenanthrene	1.5		ND	ND	<10	<10	<100	<100
Metals (ug/L):								
aluminum	NR		NR	NR	NR	NR	NR	NR
arsenic	17		30	94	46	11	9	13
barium	284		60	ND	140	250	1,090	987
beryllium	NR		NR	NR	NR	NR	NR	NR
boron	NR		NR	NR	NR	NR	NR	NR
cadmium	ND		ND	ND	<5	<5	<5	<5
chromium	ND		ND	25	<10	21	21	23
cobalt	NR		NR	NR	NR	NR	NR	NR
copper	NR		NR	NR	NR	NR	NR	NR
iron	NR		NR	NR	NR	NR	NR	NR
lead	ND		ND	120	27	6	<3	6
manganese	NR		NR	NR	NR	NR	NR	NR
mercury	ND		ND	ND	<0.2	<0.2	<0.2	<0.2
molybdenum	NR		NR	NR	NR	NR	NR	NR
nickel	NR		NR	NR	NR	NR	NR	NR
selenium	NR		NR	NR	NR	NR	NR	NR
silver	NR		NR	NR	NR	NR	NR	NR
uranium (total)	NR		NR	NR	NR	NR	NR	NR
vanadium	NR		NR	NR	NR	NR	NR	NR
zinc	NR		10	NR	NR	NR	NR	NR
Indicators:								
pH (S.U.)	6.2		6.5	6.2	6.8	6.7	6.5	6.7
spec. cond. (umhos)	2,860		2,130	2,147	1,830	2,010	2,200	19,800
sulfide (mg/L)	2.88		0.05	ND	<0.2	0.3	<0.1	0.3
total phenols (mg/L)	ND		ND	ND	0.05	<0.05	0.08	0.04
Notes:								
(a) This analyte is a common laboratory solvent which may be an artifact from sample collection or analysis.								
(b) ND -- Not detected, detection limits not specified in 1990 reports; NR -- Not reported; NS -- Not Sampled								

NCL-31

NCL-31, Quarter/Year:	1st 92	2nd 92	3rd 92	4th 92	1st 93	2nd 93	3rd 93	4th 93
SampleDate:	19-Mar-92	29-Jun-92	22-Oct-92	09-Dec-92	10-Feb-93	29-Apr-93	28-Sep-93	16-Dec-93
Laboratory:	BETZ	BETZ	BETZ	BETZ	BETZ	BETZ	IML	TRACE
Volatiles (ug/L):								
benzene	6	4J	6.9	7	4J	<5	<25	3.1
ethylbenzene	33	28	38	49	<5	<5	<25	2.4
toluene	<5	<5	1.1 J	2 J	<5	<5	<25	<0.5
total xylenes	<10	<5	5.4	12	<5	<5	<25	<1
acetone (a)	NR	NR	NR	NR	NR	NR	NR	<10
2-Butanone (MEK)	<100	<100	<10	<100	<100	<100	<50	<20
1,2-Dichloroethane	<5	<5	<5	<5	<5	<5	<25	<2
methylene chloride (a)	NR	NR	NR	NR	NR	NR	NR	<1
Semi-Volatiles (ug/L):								
anthracene	<100	NR	NR	NR	NR	<20	<10	<1
chrysene	<100	<100	<10	<10	<20	<20	<10	<1
dibenzofuran	<100	<100	6 J	9 J	16J	<20	<10	<5
fluorene	<100	<100	<10	<10	<20	<20	<10	<1
1-methylnaphthalene	40 J	<100	15	<10	<20	<20	<10	NR
2-methylnaphthalene	NR	NR	NR	NR	NR	NR	<10	1
naphthalene	<100	<100	5 J	7 J	<20	<20	<10	1
phenanthrene	<100	<100	<10	<10	<20	<20	<10	<1
Metals (ug/L):								
aluminum	NR	NR	NR	NR	NR	NR	NR	<500
arsenic	12	<5	26	10	24	13	33	<100
barium	2,640	345	910	161	1,550	1,000	100	<100
beryllium	NR	NR	NR	NR	NR	NR	NR	<50
boron	NR	NR	NR	NR	NR	NR	NR	<400
cadmium	<5	<5	<5	<5	NR	<5	<2	<50
chromium	24	14	16	<10	17	20	<20	<50
cobalt	NR	NR	NR	NR	NR	NR	NR	<50
copper	NR	NR	NR	NR	NR	NR	NR	<50
iron	NR	NR	NR	NR	NR	NR	NR	1,370
lead	11	5	9	7	10	18	20	<50
manganese	NR	NR	NR	NR	NR	NR	NR	2,400
mercury	<0.2	<0.2	<0.2	<0.2	NR	<0.2	<0.2	<1
molybdenum	NR	NR	NR	NR	NR	NR	NR	<50
nickel	NR	NR	NR	NR	NR	NR	NR	<50
selenium	NR	NR	NR	NR	NR	NR	NR	<100
silver	NR	NR	NR	NR	NR	NR	NR	<10
uranium (total)	NR	NR	NR	NR	NR	NR	NR	<500
vanadium	NR	NR	NR	NR	NR	NR	NR	<100
zinc	NR	NR	NR	NR	NR	NR	NR	<50
Indicators:								
pH (S.U.)	6.8	6.59	6.75	6.83	7.0	6.7	6.9	7.5
spec. cond. (umhos)	2,040	2,260	2,010	2,270	2,230	2,050	855	1,046
sulfide (mg/L)	<0.10	0.8	<0.100	<0.100	<0.1	<0.1	<1	35
total phenols (mg/L)	0.05	0.03	0.01	0.02	0.02	0.01	<0.01	0.04

Notes:

(a) This analyte is a common laboratory solvent which may be an artifact from sample collection or analysis.

(b) ND -- Not detected, NR -- Not reported, NS -- Not Sampled

(c) J -- Estimated concentration, meets identification but below calibration range

NCL-31

NCL-31, Quarter/Year:	1st 94	2nd 94	3rd 94	4th 94	1st 95	2nd 95	3rd 95	4th 95
SampleDate:	04-Mar-94	17-Jun-94	19-Sep-94	27-Dec-94	23-Mar-95	08-Jun-95	13-Sep-95	NS (c)
Laboratory:	TRACE	TRACE	TRACE	TRACE	TRACE	TRACE	TRACE	
Volatiles (ug/L):								
benzene	<0.2	9	<2	<1	<2	<10	<20	
ethylbenzene	<0.5	<5	<5	<1	<2	<10	<20	
toluene	<0.5	<5	<5	<1	<2	<10	<20	
total xylenes	<1	<10	26	<2	<4	<20	<40	
acetone (a)	<10	<100	<100	NR	NR	NR	NR	
2-Butanone (MEK)	<20	<200	<200	<20	<100	<500	<1,000	
1,2-Dichloroethane	<2	<20	<20	<2	<2	<10	<20	
methylene chloride (a)	<1	<10	<10	<1	<10	<50	<100	
Semi-Volatiles (ug/L):								
anthracene	<1	<1	<1	<1	<1	<1	<10	
chrysene	<1	<1	<1	<1	<1	<1	<10	
dibenzofuran	<5	<5	NR	NR	NR	NR	NR	
fluorene	<1	<1	<1	<1	<1	<1	<10	
1-methylnaphthalene	NR	NR	NR	NR	NR	NR	NR	
2-methylnaphthalene	<1	1	NR	NR	NR	NR	NR	
naphthalene	<1	<1	<1	<1	<1	<1	<10	
phenanthrene	<1	<1	<1	<1	<1	<1	<10	
Metals (ug/L):								
aluminum	<100	200	400	130	330	252,000	7,600	
arsenic	<100	<100	<100	<100	<100	<100	<200	
barium	<100	<50	80	<500	<500	4,780	<30	
beryllium	<10	<10	<10	<10	<50	<50	<10	
boron	<50	390	470	490	420	850	410	
cadmium	<10	<10	<10	<10	<10	80	<20	
chromium	<10	<10	<10	<10	<10	210	<50	
cobalt	<10	<50	<50	<50	<50	<50	<30	
copper	<10	<50	<50	<50	<50	<50	<20	
iron	1,060	1,140	1,180	980	720	206,000	5,660	
lead	<50	3	<1	<1	<1	3	<1	
manganese	3,170	2,400	2,120	2,100	2,250	4,880	1,980	
mercury	<1	<1	<1	<1	<1	<1	<1	
molybdenum	<50	<50	<50	<50	<50	120	<100	
nickel	<10	<50	<50	<50	<50	<50	<200	
selenium	<100	<1	<1	<1	<1	2	2	
silver	<10	2	2	<1	<1	<1	0.3	
uranium (total)	<500	<500	<500	<500	<500	<500	<500	
vanadium	<50	<50	<50	<50	<50	280	<50	
zinc	<10	10	20	30	10	510	30	
Indicators:								
pH (S.U.)	7.1	7.4	7.9	6.53	7.5	7.3	7.1	
spec. cond. (umhos)	1,816	1,110	1,230	2,180	1,910	1,850	1,990	
sulfide (mg/L)	<0.03	<0.1	<0.05	38	4	2	<2	
total phenols (mg/L)	<0.1	0.017	0.09	0.004	0.09	<0.01	0.043	
Notes:								
(a) This analyte is a common laboratory solvent which may be an artifact from sample collection or analysis.								
(b) ND -- Not detected, NR -- Not reported, NS -- Not Sampled								
(c) NCL-31 replaced as background well by MW-53, no longer routinely sampled								

NCL-32

NCL-32, Quarter/Year:	1st 90	2nd 90	3rd 90	4th 90	1st 91	2nd 91	3rd 91	4th 91
	13-Apr-90	NR	03-Oct-90	19-Dec-90	11-Apr-91	16-Jul-91	12-Nov-91	08-Jan-92
Laboratory:	CORE		PSI	ENSECO	BETZ	BETZ	BETZ	BETZ
Volatiles (ug/L):								
benzene	ND		ND	ND	<5	<5	<5	<5
ethylbenzene	ND		ND	ND	<5	<5	<5	<5
toluene	ND		ND	ND	<5	<5	<5	<5
total xylenes	ND		ND	ND	<5	<5	<5	<5
acetone (a)	NR		NR	NR	NR	NR	NR	NR
2-Butanone (MEK)	ND		ND	ND	<100	<100	<100	<100
1,2-Dichloroethane	ND		ND	ND	<5	<5	<5	<5
methylene chloride (a)	NR		NR	NR	NR	NR	NR	NR
Semi-Volatiles (ug/L):								
anthracene	ND		ND	ND	<10	<10	<10	<10
chrysene	ND		ND	ND	<10	<10	<10	<10
dibenzofuran	ND		ND	ND	<10	<10	<10	<10
fluorene	ND		ND	ND	<10	<10	<10	<10
1-methylnaphthalene	ND		ND	ND	<10	<10	<10	<10
2-methylnaphthalene	NR		NR	NR	NR	NR	NR	NR
naphthalene	ND		ND	ND	<10	<10	<10	<10
phenanthrene	ND		ND	ND	<10	<10	<10	<10
Metals (ug/L):								
aluminum	NR		NR	NR	NR	NR	NR	NR
arsenic	ND		ND	ND	ND	<5	<5	<5
barium	30		19	ND	30	230	17	21
beryllium	NR		NR	NR	NR	NR	NR	NR
boron	NR		NR	NR	NR	NR	NR	NR
cadmium	ND		ND	ND	<5	<5	<5	<5
chromium	ND		ND	1.5	<10	15	21	21
cobalt	NR		NR	NR	NR	NR	NR	NR
copper	NR		NR	NR	NR	NR	NR	NR
iron	NR		NR	NR	NR	NR	NR	NR
lead	ND		ND	ND	7	<3	<3	<3
manganese	NR		NR	NR	NR	NR	NR	NR
mercury	ND		ND	ND	<0.2	<0.2	<0.2	<0.2
molybdenum	NR		NR	NR	NR	NR	NR	NR
nickel	NR		NR	NR	NR	NR	NR	NR
selenium	NR		NR	NR	NR	NR	NR	NR
silver	NR		NR	NR	NR	NR	NR	NR
uranium (total)	NR		NR	NR	NR	NR	NR	NR
vanadium	NR		NR	NR	NR	NR	NR	NR
zinc	30		NR	NR	NR	NR	NR	NR
Indicators:								
pH (S.U.)	6.2		6.2	6.5	6.5	6.7	6.5	6.6
spec. cond. (umhos)	2,860		3,030	3,270	2,260	2,960	3,230	3,020
sulfide (mg/L)	ND		2.4	ND	<0.2	<0.10	<0.10	<0.1
total phenols (mg/L)	ND		ND	ND	<0.05	<0.05	<0.05	<0.05
Notes:								
(a) This analyte is a common laboratory solvent which may be an artifact from sample collection or analysis.								
(b) ND -- Not detected, detection limits not specified in 1990 reports; NR -- Not reported; NS -- Not Sampled								

NCL-32

NCL-32, Quarter/Year:	1st 92	2nd 92	3rd 92	4th 92	1st 93	2nd 93	3rd 93	4th 93
SampleDate:	19-Mar-92	30-Jun-92	21-Oct-92	09-Nov-92	10-Feb-93	29-Apr-93	29-Sep-93	16-Dec-93
Laboratory:	BETZ	BETZ	BETZ	BETZ	BETZ	BETZ	IML	TRACE
Volatiles (ug/L):								
benzene	<5	<5	<5	<5	<5	<5	<5	<0.2
ethylbenzene	<5	<5	<10	<5	<5	<5	<5	<0.5
toluene	<5	<5	<10	<5	<5	<5	<5	<0.5
total xylenes	<5	<5	<10	<5	<5	<5	<5	<1
acetone (a)	NR	NR	NR	NR	NR	NR	NR	<10
2-Butanone (MEK)	<100	<100	<10	<100	<100	<100	<10	<20
1,2-Dichloroethane	<5	<5	<5	<5	<5	<5	<5	<2
methylene chloride (a)	NR	NR	NR	NR	NR	NR	NR	<1
Semi-Volatiles (ug/L):								
anthracene	<100	NR	NR	NR	NR	<10	<10	<1
chrysene	<100	<10	<10	<10	<10	<10	<10	<1
dibenzofuran	<100	<10	<10	<10	<10	<10	<10	<5
fluorene	<100	<0	<10	<10	<10	<10	<10	<1
1-methylnaphthalene	<100	<10	<10	<10	<10	<10	<10	NR
2-methylnaphthalene	NR	<10	NR	NR	NR	NR	<10	<1
naphthalene	<100	<10	<10	<10	<10	<10	<10	<1
phenanthrene	<100	<10	<10	<10	8J	<10	<10	<1
Metals (ug/L):								
aluminum	NR	NR	NR	NR	NR	NR	NR	<500
arsenic	<5	<5	<5	<5	<5	<5	<5	<100
barium	20	16	19	18	24	30	<100	<100
beryllium	NR	NR	NR	NR	NR	NR	NR	<50
boron	NR	NR	NR	NR	NR	NR	NR	<100
cadmium	<5	<5	<5	<5	<5	<5	<2	<50
chromium	16	15	11	13	18	30	<20	<50
cobalt	NR	NR	NR	NR	NR	NR	NR	<50
copper	NR	NR	NR	NR	NR	NR	NR	<50
iron	NR	NR	NR	NR	NR	NR	NR	180
lead	9	<3	<0.3	<3	<3	12	<10	<50
manganese	NR	NR	NR	NR	NR	NR	NR	670
mercury	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<2	<1
molybdenum	NR	NR	NR	NR	NR	NR	NR	<50
nickel	NR	NR	NR	NR	NR	NR	NR	<50
selenium	NR	NR	NR	NR	NR	NR	NR	<100
silver	NR	NR	NR	NR	NR	NR	NR	<10
uranium (total)	NR	NR	NR	NR	NR	NR	NR	<500
vanadium	NR	NR	NR	NR	NR	NR	NR	<100
zinc	NR	NR	NR	NR	NR	NR	NR	<50
Indicators:								
pH (S.U.)	6.7	6.47	6.74	6.93	6.8	6.5	6.7	7.0
spec. cond. (umhos)	3,030	3,160	2,970	3,120	1,910	2,820	1,308	982
sulfide (mg/L)	<0.10	<0.10	<0.10	<0.10	<0.1	<0.1	<1.0	5.6
total phenols (mg/L)	0.9	0.02	<0.010	0.02	<0.1	<0.1	<0.1	0.04
Notes:								
(a) This analyte is a common laboratory solvent which may be an artifact from sample collection or analysis.								
(b) NR -- Not reported								

NCL-32

NCL-32, Quarter/Year:	1st 94	2nd 94	3rd 94	4th 94	1st 95	2nd 95	3rd 95	4th 95
SampleDate:	04-Mar-94	17-Jun-94	19-Sep-94	18-Dec-94	23-Mar-95	08-Jun-95	13-Sep-95	01-Dec-95
Laboratory:	TRACE	TRACE	TRACE	TRACE	TRACE	TRACE	TRACE	NET
Volatiles (ug/L):								
benzene	<0.2	1	<2	<1	<1	<1	<2	<5
ethylbenzene	<0.5	<0.5	<5	<1	<1	<1	<2	<5
toluene	<0.5	<0.5	<5	<1	<1	<1	<2	<5
total xylenes	<1	<1	<10	<2	<2	<3	<4	<5
acetone (a)	<10	<10	<100	NR	NR	NR	NR	<10
2-Butanone (MEK)	<20	<20	<200	<20	<50	<50	<100	<20
1,2-Dichloroethane	<2	<2	<20	<2	<1	<1	<2	<5
methylene chloride (a)	<1	<1	<10	<1	<5	<5	<10	<5
Semi-Volatiles (ug/L):								
anthracene	<1	<1	<1	<1	<1	<1	<10	<6
chrysene	<1	<1	<1	<1	<1	<1	<10	<6
dibenzofuran	<5	<5	NR	NR	NR	NR	NR	<6
fluorene	<1	<1	<1	<1	<1	<1	<10	<6
1-methylnaphthalene	NR	NR	NR	NR	NR	NR	NR	NR
2-methylnaphthalene	<1	<1	NR	NR	NR	NR	NR	<6
naphthalene	<1	<1	<1	<1	<1	<1	<10	<6
phenanthrene	<1	<1	<1	<1	<1	<1	<10	<6
Metals (ug/L):								
aluminum	<100	130	200	260	380	47,800	2,400	170
arsenic	<100	<100	<100	<100	<100	<100	<200	<30
barium	<100	<50	<50	<500	<500	170	70	20
beryllium	<10	<10	<10	<10	<50	<50	<10	<10
boron	<50	170	250	300	230	340	150	<100
cadmium	<10	<10	<10	<10	<10	<10	100	<10
chromium	<10	<10	<10	<10	<10	<10	<50	<10
cobalt	<10	<50	<50	<50	<50	<50	<30	<10
copper	<10	<50	<50	<50	<50	<50	<20	<10
iron	180	110	240	100	750	16,900	840	430
lead	<50	<1	<1	<1	<1	<1	<1	<30
manganese	1,170	920	900	400	990	1,080	1,150	840
mercury	<1	<1	<1	<1	<1	<1	<1	<0.20
molybdenum	<50	<50	<50	<50	<50	<50	<100	<10
nickel	30	<50	<50	<50	<50	<50	<200	<30
selenium	100	<1	<1	<1	<1	2	<1	<40
silver	<10	<1	<1	<1	<1	<1	<0.1	<10
uranium (total)	<500	<500	<500	<500	<500	<500	<500	NR
vanadium	<50	<50	<50	<50	<50	<50	<50	<10
zinc	20	<10	<10	<10	100	80	<20	<30
Indicators:								
pH (S.U.)	6.9	7.1	7.5	6.56	7.3	7.2	7.3	7.4
spec. cond. (umhos)	1,678	1,018	1,001	3,270	2,550	2,420	2,280	2,730
sulfide (mg/L)	<0.03	<0.1	<0.05	<0.05	6	<2	6	<0.01
total phenols (mg/L)	<0.1	0.027	<0.002	<0.0002	<0.02	<0.01	<0.005	<0.01
Notes:								
(a) This analyte is a common laboratory solvent which may be an artifact from sample collection or analysis.								
(b) NR -- Not reported								

NCL-32

NCL-32, Quarter/Year:	1st 96	2nd 96	3rd 96	4th 96	1st 97	2nd 97	3rd 97	4th 97
SampleDate:	18-Mar-96	12-Jul-96	09-Sep-96	11-Dec-96	25-Mar-97	18-Jun-97	02-Sep-97	
Laboratory:	NET	NET	PACE	PACE	PACE	PACE	PACE	
Volatiles (ug/L):								
benzene	<1.0	<5	<5	<5	<5	<5	<5	
ethylbenzene	<1.0	<5	<5	<5	<5	<5	<5	
toluene	<1.0	<5	<5	<5	<5	<5	<5	
total xylenes	<1.0	<5	<5	8.9	<5	<5	<5	
acetone (a)	<20	<100	<10	<10	15.4	<10	<10	
2-Butanone (MEK)	<10	<100	<10	<10	<10	<10	<10	
1,2-Dichloroethane	<1.0	<5	<5	<5	<5	<5	<5	
methylene chloride (a)	<10	<5	<5	<5	<5	<5	<5	
Semi-Volatiles (ug/L):								
anthracene	NR	<10	<10	<11.5	<10	<10	<10	
chrysene	NR	<10	<10	<11.5	<10	<10	<10	
dibenzofuran	NR	<10	<10	<11.5	<10	<10	<10	
fluorene	NR	<10	<10	<11.5	<10	<10	<10	
1-methylnaphthalene	NR	NR	NR	NR	NR	NR	NR	
2-methylnaphthalene	NR	<10	<10	<11.5	<10	<10	<10	
naphthalene	<5	<10	<10	<11.5	<10	<10	<10	
phenanthrene	NR	<10	<10	<11.5	<10	<10	<10	
Metals (ug/L):								
aluminum	403	93	<200	<200	<200	<200	763	
arsenic	5	<5	<10	<10	<10	<10	10.2	
barium	25	18	<200	<200	<200	<200	<200	
beryllium	<1	<1	<5	<5	<5	<5	<5	
boron	255	228	<500	<500	170	136	148	
cadmium	<1	<1	<5	<5	<5	<5	<5	
chromium	3	<5	<10	<10	<10	<10	<10	
cobalt	3	<5	<50	<50	<50	<50	<50	
copper	7	10	<25	<25	<25	<25	<25	
iron	399	204	<100	114	149	428	838	
lead	<5	<5	<3	<3	<3	<3	6	
manganese	793	843	914	929	862	924	882	
mercury	<0.20	<0.20	<0.20	<0.200	<0.2	<0.2	<0.2	
molybdenum	7	12	<10	<10	<10	<10	<10	
nickel	<8	<5	<40	<40	<40	<40	<40	
selenium	<5	8	<5	<5	<5	<5	<5	
silver	<2	<2	<10	<10	<10	<10	<10	
uranium (total)	NR	NR	NR	4	6	28	31	
vanadium	<10	<5	<50	<50	<50	<50	<50	
zinc	26	<10	<20	<20	<20	89.3	61.9	
Indicators:								
pH (S.U.)	7.5	7.2	7.1	7.4	7.6	7.3	NR	
spec. cond. (umhos)	2,790	1,950	1,930	2,830	3,290	3,550	NR	
sulfide (mg/L)	<0.50	<0.05	<0.02	<0.02	<0.02	<0.02	<0.02	
total phenols (mg/L)	0.01	<0.01	<0.005	<0.005	0.01	<0.01	<0.01	

Notes:

(a) This analyte is a common laboratory solvent which may be an artifact from sample collection or analysis.

(b) NR -- Not reported

(c) Sample extract could not be concentrated to the method specified volume - so report limit is elevated

NCL-33

NCL-33, Quarter/Year:	1st 90	2nd 90	3rd 90	4th 90	1st 91	2nd 91	3rd 91	4th 91
SampleDate:	13-Apr-90	NR	03-Oct-90	19-Dec-90	11-Apr-91	16-Jul-91	12-Nov-91	08-Jan-92
Laboratory:	CORE		PSI	ENSECO	BETZ	BETZ	BETZ	BETZ
Volatiles (ug/L):								
benzene	ND		ND	ND	<5	<5	410	190
ethylbenzene	ND		ND	ND	<5	<5	910	440
toluene	ND		ND	ND	<5	<5	14	30
total xylenes	ND		ND	ND	<5	<5	260	100
acetone (a)	NR		NR	NR	NR	NR	NR	NR
2-Butanone (MEK)	ND		ND	ND	<100	<100	<100	<100
1,2-Dichloroethane	ND		ND	ND	<5	<5	<5	<25
methylene chloride (a)	NR		NR	NR	NR	NR	NR	NR
Semi-Volatiles (ug/L):								
anthracene	ND		ND	ND	<10	<10	<100	<100
chrysene	ND		ND	ND	<10	<10	<100	<100
dibenzofuran	ND		ND	ND	<10	<10	<100	<100
fluorene	ND		ND	ND	<10	<10	<100	<100
1-methylnaphthalene	ND		ND	ND	<10	<10	<100	NR
2-methylnaphthalene	NR		NR	NR	NR	NR	NR	860
naphthalene	ND		ND	ND	<10	<10	100	430
phenanthrene	ND		ND	ND	<10	<10	<100	<100
Metals (ug/L):								
aluminum	NR		NR	NR	NR	NR	NR	NR
arsenic	ND		ND	ND	<5	<5	11	10
barium	110		33	ND	68	29	35	43
beryllium	NR		NR	NR	NR	NR	NR	NR
boron	NR		NR	NR	NR	NR	NR	NR
cadmium	ND		ND	ND	<5	<5	<5	<5
chromium	ND		ND	1	<10	17	28	23
cobalt	NR		NR	NR	NR	NR	NR	NR
copper	NR		NR	NR	NR	NR	NR	NR
iron	NR		NR	NR	NR	NR	NR	NR
lead	ND		11	ND	6	<3	<3	4
manganese	NR		NR	NR	NR	NR	NR	NR
mercury	ND		ND	ND	<0.2	<0.2	<0.2	<0.2
molybdenum	NR		NR	NR	NR	NR	NR	NR
nickel	NR		NR	NR	NR	NR	NR	NR
selenium	NR		NR	NR	NR	NR	NR	NR
silver	NR		NR	NR	NR	NR	NR	NR
uranium (total)	NR		NR	NR	NR	NR	NR	NR
vanadium	50		NR	NR	NR	NR	NR	NR
zinc	50		NR	NR	NR	NR	NR	NR
Indicators:								
pH (S.U.)	6.2		7.0	6.2	7.0	6.7	6.5	6.3
spec. cond. (umhos)	3,250		2,890	3,120	2,370	2,200	3,490	3,060
sulfide (mg/L)	ND		3.2	ND	<0.2	<0.1	0.6	0.4
total phenols (mg/L)	ND		ND	ND	<0.05	<0.05	0.07	0.12
Notes:								
(a) This analyte is a common laboratory solvent which may be an artifact from sample collection or analysis.								
(b) ND -- Not detected. Detection limits not specified in 1990 reports. NR -- Not reported								

NCL-33

NCL-33, Quarter/Year:	1st 92	2nd 92	3rd 92	4th 92	1st 93	2nd 93	3rd 93	4th 93
SampleDate:	19-Mar-92	29-Jun-92	21-Oct-92	09-Nov-92	10-Feb-93	29-Apr-93	28-Sep-93	16-Dec-93
Laboratory:	BETZ	BETZ	BETZ	BETZ	BETZ	BETZ	IML	TRACE
Volatiles (ug/L):							(e)	
benzene	150	65	14	12	2J	<5	<5	<0.2
ethylbenzene	910	340	82	52	13	5	<5	3.1
toluene	20 J	10 J	2.6 J	<5	<5	<5	<5	1.1
total xylenes	140	65	22	13	8	<5	<5	1.5
acetone (a)	NR	NR	NR	NR	NR	NR	NR	<10
2-Butanone (MEK)	<1,000	<500	<10	<100	<100	<100	<10	<20
1,2-Dichloroethane	<50	<25	<5	<5	<5	<5	<5	<2
methylene chloride (a)	NR	NR	NR	NR	NR	NR	NR	<1
Semi-Volatiles (ug/L):							(e)	
anthracene	<100	NR	NR	NR	NR	<50	<40	<1
chrysene	<100	<100	<10	<10	<100	<50	<40	<1
dibenzofuran	<100	<100	<10	<10	<100	<50	<40	<5
fluorene	<100	<100	<10	<10	<100	<50	<40	<1
1-methylnaphthalene	200	24	4 J	<10	30 J	<50	<40	NR
2-methylnaphthalene	NR	NR	NR	NR	NR	NR	<40	<1
naphthalene	80 J	70	<10	<10	<100	<50	<40	<1
phenanthrene	<100	<100	<10	<10	<100	<50	<40	<1
Metals (ug/L):								
aluminum	NR	NR	NR	NR	NR	NR	NR	<500
arsenic	10	7	5	8	<5	<5	<5	<100
barium	61	82	86	52	45	20	<100	<100
beryllium	NR	NR	NR	NR	NR	NR	NR	<50
boron	NR	NR	NR	NR	NR	NR	NR	<100
cadmium	<5	<5	<5	<5	<5	<5	<2	<50
chromium	16	18	19	14	16	10	<20	<50
cobalt	NR	NR	NR	NR	NR	NR	NR	<50
copper	NR	NR	NR	NR	NR	NR	NR	<50
iron	NR	NR	NR	NR	NR	NR	NR	960
lead	4	35	4	3	<3	<3	<10	<50
manganese	NR	NR	NR	NR	NR	NR	NR	190
mercury	<0.2	<0.2	<0.2	<.20	<0.2	<0.2	<2	<1
molybdenum	NR	NR	NR	NR	NR	NR	NR	<50
nickel	NR	NR	NR	NR	NR	NR	NR	<50
selenium	NR	NR	NR	NR	NR	NR	NR	<100
silver	NR	NR	NR	NR	NR	NR	NR	<10
uranium (total)	NR	NR	NR	NR	NR	NR	NR	<500
vanadium	NR	NR	NR	NR	NR	NR	NR	100
zinc	NR	NR	NR	NR	NR	NR	NR	<50
Indicators:								
pH (S.U.)	6.7	6.27	6.75	6.6	6.8	6.6	6.7	7.0
spec. cond. (umhos)	2,890	2,820	2,780	2,890	2,180	2,500	1,023	848
sulfide (mg/L)	0.4	1	0.2	0.3	0.13	<0.1	<1.0	1.2
total phenols (mg/L)	0.31	0.7	0.03	0.3	0.05	0.02	<0.05	0.07
Notes:								
(a) This analyte is a common laboratory solvent which may be an artifact from sample collection or analysis.								
(b) NR - Not reported								

NCL-33

NCL-33, Quarter/Year:	1st 94	2nd 94	3rd 94	4th 94	1st 95	2nd 95	3rd 95	4th 95
SampleDate:	04-Mar-94	17-Jun-94	19-Sep-94	28-Dec-94	23-Mar-95	08-Jun-95	13-Sep-95	01-Dec-95
Laboratory:	TRACE	TRACE	TRACE	TRACE	TRACE	TRACE	TRACE	NET
Volatiles (ug/L):								
benzene	<0.2	13	<2	<1	<2	<100	<100	<5
ethylbenzene	<0.5	<5	<5	<1	<2	<100	<100	<5
toluene	<0.5	<5	<5	<1	<2	<100	<100	<5
total xylenes	<1	<10	<10	<2	<4	<200	<200	<5
acetone (a)	<10	<100	<100	NR	NR	NR	NR	<10
2-Butanone (MEK)	<20	<200	<200	<20	<100	<5,000	<5,000	<20
1,2-Dichloroethane	<2	<20	<20	<2	<2	<100	<100	<5
methylene chloride (a)	<1	<10	<10	<1	<10	<500	<500	<5
Semi-Volatiles (ug/L):								
anthracene	<1	<1	<1	<1	<1	<1	<100	<6
chrysene	<1	<1	<1	<1	<1	<1	<100	<6
dibenzofuran	<5	<5	NR	NR	NR	NR	NR	<6
fluorene	<1	<1	<1	<1	<1	<1	<100	<6
1-methylnaphthalene	NR	NR	NR	NR	NR	NR	NR	NR
2-methylnaphthalene	2	<1	NR	NR	NR	NR	NR	<6
naphthalene	<1	<1	<1	<1	<1	<1	<100	<6
phenanthrene	<1	<1	<1	<1	<1	<1	<100	<6
Metals (ug/L):								
aluminum	<100	120	100	220	2,950	95,700	3,500	11,800
arsenic	<100	<100	<100	<100	<100	<100	<200	40
barium	<100	<50	50	<500	<500	1,930	<30	620
beryllium	<10	<10	<10	<10	<50	<50	<10	<10
boron	170	640	400	480	480	580	560	220
cadmium	<10	<10	<10	<10	<10	60	<20	10
chromium	<10	30	<10	<10	<10	90	<50	20
cobalt	<10	<50	<50	<50	<50	<50	<30	10
copper	<10	<50	<50	<50	<50	<50	<20	20
iron	510	540	460	170	6,390	134,000	2,350	40,900
lead	120	22	<1	<1	19	16	<1	50
manganese	80	90	90	<100	250	630	420	290
mercury	<1	<1	<1	<1	<1	<1	<1	0.2
molybdenum	<50	<50	<50	<50	<50	<50	<100	10
nickel	20	80	<50	<50	<50	<50	<200	<30
selenium	<100	<1	<1	<1	1	2	<1	<40
silver	<10	<1	<1	<1	<1	<1	<0.10	<10
uranium (total)	<500	<500	<500	<500	<500	<500	<500	NR
vanadium	<50	<50	<50	<50	80	240	<50	70
zinc	<10	20	<10	<10	120	180	<20	70
Indicators:								
pH (S.U.)	6.8	6.9	7.1	7.35	7.3	6.8	7.1	7.3
spec. cond. (umhos)	1,265	1,364	901	2,490	1,920	1,800	1,860	2,090
sulfide (mg/L)	<0.03	<0.1	<0.05	0.4	20	<2	4	0.05
total phenols (mg/L)	<0.1	0.051	0.08	<0.002	0.06	<0.01	0.007	0.02
Notes:								
(a) This analyte is a common laboratory solvent which may be an artifact from sample collection or analysis.								
(b) NR -- Not reported								

NCL-33

NCL-33, Quarter/Year:	1st 96	2nd 96	3rd 96	4th 96	1st 97	2nd 97	3rd 97	4th 97
SampleDate:	03-Mar-96	11-Jul-96	10-Sep-96	19-Dec-96	26-Mar-97	19-Jun-97	02-Sep-97	
Laboratory:	NET	NET	PACE	PACE	PACE	PACE	PACE	
Volatiles (ug/L):								
benzene	<5	<5	<5	<5	<5	<5	<5	
ethylbenzene	<5	<5	<5	<5	<5	<5	<5	
toluene	<5	<5	<5	<5	<5	<5	<5	
total xylenes	<5	<5	<5	12	<5	<5	<5	
acetone (a)	22	<100	<10	<10	<10	<10	<10	
2-Butanone (MEK)	<20	<100	<10	<10	<10	<10	<10	
1,2-Dichloroethane	<5	<5	<5	<5	<5	<5	<5	
methylene chloride (a)	<5	<5	<5	<5	<5	<5	<5	
Semi-Volatiles (ug/L):								
anthracene	NR	<10	<10	<10	<10	<10	<10	
chrysene	NR	<10	<10	<10	<10	<10	<10	
dibenzofuran	NR	<10	<10	<10	<10	<10	<10	
fluorene	NR	<10	<10	<10	<10	<10	<10	
1-methylnaphthalene	NR	NR	NR	NR	NR	NR	NR	
2-methylnaphthalene	NR	<10	<10	<10	<10	<10	<10	
naphthalene	NR	<10	<10	<10	<10	<10	<10	
phenanthrene	NR	<10	<10	<10	<10	<10	<10	
Metals (ug/L):								
aluminum	2,020	11,200	256	1,320	911	1,110	15,500	
arsenic	6	12	<10	<10	<10	<10	26.3	
barium	101	281	<200	<200	<200	<200	324	
beryllium	<1	<1	<5	<5	<5	<5	<5	
boron	310	255	<500	1,700	394	348	283	
cadmium	<1	1	<5	<5	<5	<5	<5	
chromium	4	19	<10	<10	17.1	14.4	31.9	
cobalt	<5	7	<50	<50	<50	<50	<50	
copper	9	28	<25	<25	<25	<25	<25	
iron	2,260	19,100	804	5,390	2,960	4,070	30,800	
lead	<5	28	<3	<3	<3	16.3	20.1	
manganese	110	427	89.7	122	89.2	183	188	
mercury	<0.20	<0.20	<0.20	<0.20	<0.2	<0.2	<0.2	
molybdenum	6	9	<10	<10	<10	<10	11.7	
nickel	6	12	<40	<40	<40	<40	<40	
selenium	<5	<5	<5	<5	<5	<5	<5	
silver	<2	<2	<10	<10	<10	<10	<10	
uranium (total)	NR	NR	NR	40	23	19.7	32	
vanadium	12	38	<50	<50	<50	<50	52.5	
zinc	19	87	<20	<20	<20	124	95	
Indicators:								
pH (S.U.)	7.3	7.0	6.8	7.1	7.1	7.6	NR	
spec. cond. (umhos)	2,010	1,600	1,550	2,550	2,550	2,320	NR	
sulfide (mg/L)	<.50	<0.10	<0.02	0.038	0.029	<0.02	<0.02	
total phenols (mg/L)	<0.01	<0.01	0.18	0.007	<0.010	0.0294	<0.01	
Notes:								
(a) This analyte is a common laboratory solvent which may be an artifact from sample collection or analysis.								
(b) NR -- Not reported								

NCL-34

NCL-34, Quarter/Year:	1st 90	2nd 90	3rd 90	4th 90	1st 91	2nd 91	3rd 91	4th 91
SampleDate:	13-Apr-90	NR	03-Oct-90					09-Jan-92
Laboratory:	CORE		PSI	NS	NS	NS	NS	BETZ
Volatiles (ug/L):								
benzene	320		78					20,000
ethylbenzene	520		150					3,900
toluene	ND		ND					19,000
total xylenes	170		38					4,700
acetone (a)	NR		NR					NR
2-Butanone (MEK)	ND		ND					<100
1,2-Dichloroethane	ND		10					<100
methylene chloride (a)	NR		NR					NR
Semi-Volatiles (ug/L):								
anthracene	83		ND					<100
chrysene	ND		ND					<100
dibenzofuran	ND		ND					<100
fluorene	63		28					<100
1-methylnaphthalene	650		270					<100
2-methylnaphthalene	460		180					NR
naphthalene	300		148					330
phenanthrene	84		ND					<100
Metals (ug/L):								
aluminum	NR		NR					NR
arsenic	20		ND					<5
barium	1,240		824					5,660
beryllium	NR		NR					NR
boron	NR		NR					NR
cadmium	ND		ND					<5
chromium	10		ND					18
cobalt	NR		NR					NR
copper	10		NR					NR
iron	NR		NR					NR
lead	40		ND					6
manganese	NR		NR					NR
mercury	ND		ND					<0.2
molybdenum	NR		NR					NR
nickel	NR		NR					NR
selenium	NR		NR					NR
silver	NR		NR					NR
uranium (total)	NR		NR					NR
vanadium	50		NR					NR
zinc	10		NR					NR
Indicators:								
pH (S.U.)	NR		NR					NR
spec. cond. (umhos)	NR		NR					NR
sulfide (mg/L)	1.04		ND					20
total phenols (mg/L)	0.1		ND					0.81
Notes:								
(a) This analyte is a common laboratory solvent which may be an artifact from sample collection or analysis.								
(b) ND -- Not detected. Detection limits not specified in 1990 reports. NR -- Not reported. NS -- Not sampled								

NCL-34

NCL-34, Quarter/Year:	1st 92	2nd 92	3rd 92	4th 92	1st 93	2nd 93	3rd 93	4th 93
SampleDate:	19-Mar-92	29-Jun-92	21-Oct-92	09-Nov-92	10-Feb-93	29-Apr-93	28-Sep-93	16-Dec-93
Laboratory:	BETZ	BETZ	BETZ	BETZ	BETZ	BETZ	IML	TRACE
Volatiles (ug/L):							(c)	
benzene	6,900	9,100	7,500	7,100	9,400	7,600	9,360	2,772
ethylbenzene	2,900	3,600	3,400	3,000	3,800	2,900	3,410	1,450
toluene	2,400	3,900	4,400	3,500	3,200	1,600	1,570	444
total xylenes	2,900	3,900	4,300	2,800	3,500	2,800	4,000	1,455
acetone (a)	NR	NR	NR	NR	NR	NR	NR	<10
2-Butanone (MEK)	<10,000	<2,000	<500	<100	<10,000	<10,000	<50	<20
1,2-Dichloroethane	<50	160	<250	<500	<500	<500	<25	<2
methylene chloride (a)	NR	NR	NR	NR	NR	NR	NR	<1
Semi-Volatiles (ug/L):							(c)	
anthracene	<100	NR	NR	NR	NR	<200	<10	<1
chrysene	<100	<100	<100	<10	<1000	<200	<10	<1
dibenzofuran	<100	<100	<100	<10	<1000	100 J	<10	<5
fluorene	<100	<100	34 J	<10	<1000	80 J	<10	<1
1-methylnaphthalene	400	510	1,260	<10	3,400	3,800	<10	NR
2-methylnaphthalene	NR	NR	NR	NR	NR	NR	<10	<1
naphthalene	290	250	699	420	2,300	900	<10	155
phenanthrene	<100	<100	60 J	<10	420J	<200	<10	<1
Metals (ug/L):								
aluminum	NR	NR	NR	NR	NR	NR	NR	<500
arsenic	<5	<5	<5	6	<5	<5	<5	<100
barium	2,420	2,810	2,540	1,390	2,480	1,700	1,300	1,300
beryllium	NR	NR	NR	NR	NR	NR	NR	<50
boron	NR	NR	NR	NR	NR	NR	NR	300
cadmium	<5	<5	<5	<5	<5	<5	<2	<50
chromium	16	17	18	13	23	20	<20	<50
cobalt	NR	NR	NR	NR	NR	NR	NR	<50
copper	NR	NR	NR	NR	NR	NR	NR	<50
iron	NR	NR	NR	NR	NR	NR	NR	460
lead	3	27	11	10	17	10	20	<50
manganese	NR	NR	NR	NR	NR	NR	NR	210
mercury	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<2	<1
molybdenum	NR	NR	NR	NR	NR	NR	NR	<50
nickel	NR	NR	NR	NR	NR	NR	NR	<50
selenium	NR	NR	NR	NR	NR	NR	NR	<100
silver	NR	NR	NR	NR	NR	NR	NR	<10
uranium (total)	NR	NR	NR	NR	NR	NR	NR	<500
vanadium	NR	NR	NR	NR	NR	NR	NR	100
zinc	NR	NR	NR	NR	NR	NR	NR	<50
Indicators:								
pH (S.U.)	6.8	6.2	6.5	6.61	6.5	6.4	6.8	7.1
spec. cond. (umhos)	1,950	2,090	2,080	2,220	2,030	1,800	729	943
sulfide (mg/L)	22	9.3	3.9	17.3	13.6	10	14	2
total phenols (mg/L)	0.65	0.52	0.34	0.46	0.74	0.42	<0.05	0.05
Notes:								
(a) This analyte is a common laboratory solvent which may be an artifact from sample collection or analysis.								
(b) NR -- Not reported								
(c) Unknown hydrocarbons in analyses								
(d) J - Estimated concentration, meets identification but below calibration range								

NCL-34

NCL-34, Quarter/Year:	1st 94	2nd 94	3rd 94	4th 94	1st 95	2nd 95	3rd 95	4th 95
SampleDate:	04-Mar-94	17-Jun-94	19-Sep-94	28-Dec-94	24-Mar-95	08-Jun-95	13-Sep-95	01-Dec-95
Laboratory:	TRACE	TRACE	TRACE	TRACE	TRACE	TRACE	TRACE	NET
Volatiles (ug/L):								
benzene	5,375	6,995	1,309	4,278	4,490	10,075	12,700	8,900
ethylbenzene	2,026	2,340	1,745	3,805	4,120	3,170	2,880	3,300
toluene	488	<250	83	114	<100	<1000	533	490
total xylenes	1,858	2,045	1,455	2,805	3,142	2,230	2,439	2,100
acetone (a)	<10	<5,000	<500	NR	NR	NR	NR	<500
2-Butanone (MEK)	<20	<10,000	<1,000	<2,000	<5,000	<50,000	<10,000	<1,000
1,2-Dichloroethane	<2	<1,000	<100	<200	<100	<1,000	<200	<200
methylene chloride (a)	<1	<500	<50	<100	<500	<5,000	<1,000	<200
Semi-Volatiles (ug/L):								
anthracene	<1	<1	<1	13	<1	29	<100	<700
chrysene	<1	<1	<1	<1	<1	<1	<100	<700
dibenzofuran	<5	<5	NR	NR	NR	NR	NR	<700
fluorene	<1	<1	<1	7	13	<1	<100	<700
1-methylnaphthalene	NR	NR	NR	NR	NR	NR	NR	NR
2-methylnaphthalene	<1	48	NR	NR	NR	NR	NR	4,800
naphthalene	<1	93	50	164	<1	<1	212	3,200
phenanthrene	<1	<1	<1	<1	<1	<1	<100	<700
Metals (ug/L):								
aluminum	<100	300	100	<80	340	174,000	3,500	1,150
arsenic	<100	<100	<100	100	<100	<100	<200	<30
barium	1,000	950	1,380	1,100	1,800	2,340	<30	1,960
beryllium	<10	<10	<10	<10	<50	<50	<10	<10
boron	110	1,040	320	260	300	470	230	160
cadmium	<10	<10	<10	10	<10	20	<20	<10
chromium	<10	10	<10	20	<10	20	<50	<10
cobalt	<10	<50	<50	<50	<50	<50	<30	<10
copper	<10	<50	<50	<50	<50	<50	<20	<10
iron	740	490	260	250	210	90,300	550	1,140
lead	<50	2	4	<1	<1	31	<1	<30
manganese	220	140	140	100	60	580	20	160
mercury	<1	<1	<1	<1	<1	<1	<1	<0.20
molybdenum	<50	<50	<50	<50	<50	<50	<100	<10
nickel	10	<50	<50	<50	<50	<50	<200	<30
selenium	<100	<1	<1	<1	<1	2	7	<40
silver	<10	<1	<1	<1	<1	4	<0.10	<10
uranium (total)	<500	<500	<500	<500	<500	<500	<500	NR
vanadium	<50	<50	<50	<50	<50	<50	<50	<10
zinc	<10	10	<10	20	<10	240	90	600
Indicators:								
pH (S.U.)	7.0	6.8	7.0	7.0	7.25	6.9	7.0	7.2
spec. cond. (umhos)	1,097	1,693	937	2,250	2,250	1,560	2,360	2,450
sulfide (mg/L)	18.4	<0.1	<0.05	<0.05	38	16	8	1.4
total phenols (mg/L)	0.2	0.066	0.08	0.072	0.25	0.27	0.326	0.12
Notes:								
(a) This analyte is a common laboratory solvent which may be an artifact from sample collection or analysis.								
(b) NR -- Not reported								

NCL-34

NCL-34, Quarter/Year:	1st 96	2nd 96	3rd 96	4th 96	1st 97	2nd 97	3rd 97	4th 97
SampleDate:	24-Mar-96	NS	11-Sep-96	23-Dec-96	27-Mar-97	19-Jun-97	03-Sep-97	
Laboratory:	NET		PACE	PACE	PACE	PACE	PACE	
Volatiles (ug/L):								
benzene	9,700		17,500 d	13,500d	6,380 d	7,020 d	7,750 d	
ethylbenzene	5,700		3,420 d	4,030 d	1,540 d	2,250 d	2,470 d	
toluene	390		<500 d	<500 d	<250 d	<250 d	<250 d	
total xylenes	5,300		2,910 d	3,380 d	661 d	1,150 d	2,080 d	
acetone (a)	2,700		<1,000 d	<1,000 d	<500 d	<500 d	<500 d	
2-Butanone (MEK)	2,300		<1,000 d	<1,000 d	<500 d	<500 d	<500 d	
1,2-Dichloroethane	200		<500 d	<500 d	<250 d	<250 d	<250 d	
methylene chloride (a)	<500		<500 d	<500 d	<250 d	<250 d	<250 d	
Semi-Volatiles (ug/L):								
anthracene	NR		<200 d	<400 c,d	<500 d	<100 d	<200 c,d	
chrysene	NR		<200 d	<400 c,d	<500 d	<100 d	<200 c,d	
dibenzofuran	NR		<200 d	<400 c,d	<500 d	<100 d	<200 c,d	
fluorene	NR		<200 d	<400 c,d	<500 d	<100 d	<200 c,d	
1-methylnaphthalene	NR		NR	NR	NR	NR	NR	
2-methylnaphthalene	NR		369 d	1490 c,d	2,200 d	391 d	908 c,d	
naphthalene	<600		290 d	908 c,d	1,400 d	283 d	506 c,d	
phenanthrene	NR		<200 d	<400 c,d	<500 d	<100 d	<200 c,d	
Metals (ug/L):								
aluminum	7,430		452	56,400	68,700	2,440	23,800	
arsenic	17		<10	13.3	14.9	<10	<10	
barium	2,190		2,300	3,910	3,920	2,180	2,830	
beryllium	1		<5	<5	<5	<5	<5	
boron	260		<500	1,390	118	193	279	
cadmium	<1		<5	<5	<5	<5	<5	
chromium	15		<10	51	113	12	25.6	
cobalt	<5		<50	<50	<50	<50	<50	
copper	18		<25	38.4	54.5	<25	<25	
iron	11,800		337	49,000	55,400	1,470	18,300	
lead	39		<3	108	122	10.7	41	
manganese	244		93	736	751	117	343	
mercury	<0.20		<0.20	<0.20	<0.20	<0.2	<0.2	
molybdenum	8		<10	<10	<10	<10	<10	
nickel	11		<40	<40	<40	<40	<40	
selenium	<5		<5	<5	<5	<5	<5	
silver	<2		<10	<10	<10	<10	<10	
uranium (total)	NR		NR	10	8	9	7	
vanadium	16		<50	87.4	109	<50	<50	
zinc	75		20.3	173	449	138	162	
Indicators:								
pH (S.U.)	7.6		7.4	7.3	7.3	7.4	NR	
spec. cond. (umhos)	2,080		2,530	2,300	2,300	2,450	NR	
sulfide (mg/L)	1.8		0.044	2.42 d	39.5 d	9.78 d	35.4 d	
total phenols (mg/L)	0.17		0.550 d	0.521 d	0.361 d	0.376 d	<0.10	
Notes:								
(a) This analyte is a common laboratory solvent which may be an artifact from sample collection or analysis.								
(b) NR -- Not Reported								
(c) Sample extract could not be concentrated to the method specified volume--so report is elevated								
(d) Sample was analyzed at a dilution								

NCL-44

NCL-44, Quarter/Year:	1st 90	2nd 90	3rd 90	4th 90	1st 91	2nd 91	3rd 91	4th 91
SampleDate:	13-Apr-90	NR	03-Oct-90					09-Jan-92
Laboratory:	CORE		PSI	NS	NS	NS	NS	BETZ
Volatiles (ug/L):								
benzene	26		32					100
ethylbenzene	170		140					160
toluene	ND		ND					20
total xylenes	150		140					120
acetone (a)	NR		NR					NR
2-Butanone (MEK)	ND		ND					<100
1,2-Dichloroethane	ND		ND					<25
methylene chloride (a)	NR		NR					NR
Semi-Volatiles (ug/L):								
anthracene	160		ND					285
chrysene	ND		ND					<150
dibenzofuran	140		ND					525
fluorene	110		114					555
1-methylnaphthalene	1,060		590					NR
2-methylnaphthalene	830		650					3,900
naphthalene	160		160					735
phenanthrene	ND		15					1,155
Metals (ug/L):								
aluminum	NR		NR					NR
arsenic	20		34					21
barium	120		389					36
beryllium	NR		NR					NR
boron	NR		NR					NR
cadmium	ND		ND					<5
chromium	ND		14					14
cobalt	NR		NR					NR
copper	NR		NR					NR
iron	NR		NR					NR
lead	40		13					19
manganese	NR		NR					NR
mercury	ND		ND					<0.2
molybdenum	NR		NR					NR
nickel	NR		NR					NR
selenium	NR		NR					NR
silver	NR		NR					NR
uranium (total)	NR		NR					NR
vanadium	NR		NR					NR
zinc	30		NR					NR
Indicators:								
pH (S.U.)	NR		NR					NR
spec. cond. (umhos)	NR		NR					NR
sulfide (mg/L)	ND		ND					0.5
total phenols (mg/L)	0.37		ND					0.26
Notes:								
(a) This analyte is a common laboratory solvent which may be an artifact from sample collection or analysis.								
(b) ND -- Not detected. Detection limits not specified in 1990 reports. NR -- Not reported, NS -- Not sampled								

NCL-44

NCL-44, Quarter/Year:	1st 92	2nd 92	3rd 92	4th 92	1st 93	2nd 93	3rd 93	4th 93
SampleDate:	19-Mar-92	29-Jun-92	21-Oct-92	09-Nov-92	10-Feb-93	29-Apr-93	28-Sep-93	16-Dec-93
Laboratory:	BETZ	BETZ	BETZ	BETZ	BETZ	BETZ	IML	TRACE
Volatiles (ug/L):							(c)	
benzene	17	15	18	23	64	15	13	31
ethylbenzene	15	13	17	24	200	51	103	141
toluene	<5	<5	<5	<5	3J	<5	<5	3.9
total xylenes	7	4 J	6.8	6	56	13	28	40
acetone (a)	NR	NR	NR	NR	NR	NR	NR	<10
2-Butanone (MEK)	<100	<100	<10	<100	<100	<100	<10	<20
1,2-Dichloroethane	<5	<5	<5	<5	<5	<5	<5	<2
methylene chloride (a)	NR	NR	NR	NR	NR	NR	NR	<1
Semi-Volatiles (ug/L):					(f)		(c)	
anthracene	<100	NR	NR	NR	NR	<50	<40	<1
chrysene	<100	<100	<10	<10	<250	<50	<40	<1
dibenzofuran	<100	<100	28	21	800	35 J	30 J	7
fluorene	<100	<100	29	21	850	<50	27 J	5
1-methylnaphthalene	140	<100	86	<10	2,430	400	83	NR
2-methylnaphthalene	NR	NR	NR	NR	NR	NR	107	21
naphthalene	<100	<100	11	11	525	25J	21J	7
phenanthrene	40	<100	31	22	1,230	<50	43	4
Metals (ug/L):								
aluminum	NR	NR	NR	NR	NR	NR	NR	<500
arsenic	12	15	17	16	22	14	21	<100
barium	202	151	272	317	946	180	200	200
beryllium	NR	NR	NR	NR	NR	NR	NR	<50
boron	NR	NR	NR	NR	NR	NR	NR	<100
cadmium	<5	<5	<5	<5	<5	<5	<2	<50
chromium	19	14	19	14	40	10	20	<50
cobalt	NR	NR	NR	NR	NR	NR	NR	<50
copper	NR	NR	NR	NR	NR	NR	NR	<50
iron	NR	NR	NR	NR	NR	NR	NR	1,070
lead	6	15	8	9	22	13	10	<50
manganese	NR	NR	NR	NR	NR	NR	NR	870
mercury	<0.2	<0.2	<0.2	<0.2	NR	<0.2	<2	<1
molybdenum	NR	NR	NR	NR	NR	NR	NR	<50
nickel	NR	NR	NR	NR	NR	NR	NR	<50
selenium	NR	NR	NR	NR	NR	NR	NR	<100
silver	NR	NR	NR	NR	NR	NR	NR	<10
uranium (total)	NR	NR	NR	NR	NR	NR	NR	<500
vanadium	NR	NR	NR	NR	NR	NR	NR	100
zinc	NR	NR	NR	NR	NR	NR	NR	<50
Indicators:								
pH (S.U.)	6.8	6.71	6.58	6.7	6.6	6.4	6.6	6.9
spec. cond. (umhos)	2,220	3,030	2,020	2,150	1,580	1,900	1,050	370
sulfide (mg/L)	0.2	0.2	0.4	0.4	0.6	0.3	<1	1.6
total phenols (mg/L)	0.02	0.4	0.02	0.02	0.12	0.05	<0.01	0.02
Notes:								
(a) This analyte is a common laboratory solvent which may be an artifact from sample collection or analysis.								
(b) NR -- Not reported								
(c) Unknown hydrocarbons in analyses								
(d) Acenapthene - 480 ug/L - 1st Quarter 1993								
(d) J - Estimated concentration, meets identification but below calibration range								

NCL-44

NCL-44, Quarter/Year:	1st 94	2nd 94	3rd 94	4th 94	1st 95	2nd 95	3rd 95	4th 95
SampleDate:	04-Mar-94	17-Jun-94	19-Sep-94	28-Dec-94	23-Mar-95	08-Jun-95	13-Sep-95	01-Dec-95
Laboratory:	TRACE	TRACE	TRACE	TRACE	TRACE	TRACE	TRACE	NET
Volatiles (ug/L):								
benzene	15	12	<2	5	<2	<10	<20	<5
ethylbenzene	49	<5	91	8	<2	5	<20	<5
toluene	1	<5	<5	<1	2	<10	<20	<5
total xylenes	14	<10	<10	<3	<4	<20	<40	<5
acetone (a)	<10	<100	<100	NR	NR	NR	NR	<10
2-Butanone (MEK)	<20	<200	<200	<20	<100	<500	<1,000	<20
1,2-Dichloroethane	<2	<20	<20	<2	<2	<10	<20	<5
methylene chloride (a)	<1	<10	<10	<1	<10	<50	<100	<5
Semi-Volatiles (ug/L):					(c)	(d)		
anthracene	<1	<1	5	<1	2	4	<10	<6
chrysene	<1	<1	<1	<1	<1	<1	<10	<6
dibenzofuran	5	5	NR	NR	NR	NR	NR	21.3
fluorene	4	5	5	2	<1	<1	<10	19.2
1-methylnaphthalene	NR	NR	NR	NR	NR	NR	NR	NR
2-methylnaphthalene	27	9	NR	NR	NR	NR	NR	61.8
naphthalene	10	2	<1	<1	<1	<1	<10	<6
phenanthrene	5	4	<1	<1	<1	<1	<10	14.8
Metals (ug/L):								
aluminum	300	90	400	360	440	69,900	900	1,530
arsenic	<100	<100	<100	<100	<100	<100	<200	<30
barium	400	<50	110	<500	<500	1,490	70	220
beryllium	<10	<10	<10	<10	<50	<50	<10	<10
boron	80	200	290	350	250	330	180	<100
cadmium	<10	<10	<10	<10	<10	<10	<20	<10
chromium	<10	<10	<10	<10	<10	50	<50	<10
cobalt	<50	<50	<50	<50	<50	<50	<30	<10
copper	<10	<50	<50	<50	<50	<50	<20	<10
iron	510	300	560	210	160	40,700	2,670	1,680
lead	<50	5	<1	<1	<1	<1	<1	<30
manganese	960	680	740	300	890	1,200	1,150	580
mercury	<1	<1	<1	<1	<1	<1	<1	<0.20
molybdenum	<50	<50	<50	<50	<50	<50	<100	10
nickel	10	<50	<50	<50	<50	<50	<200	<10
selenium	<100	<1	<1	<1	<1	1	<1	<30
silver	<10	10	<1	<1	<1	<1	<1	<40
uranium (total)	<500	<500	<500	<500	<500	<500	<500	NR
vanadium	<50	<50	<50	<50	<50	<50	<50	<10
zinc	<10	<10	<10	<10	<10	110	600	30
Indicators:								
pH (S.U.)	6.9	7.0	7.4	6.89	7.2	6.9	7.0	7.3
spec. cond. (umhos)	1,770	1,228	922	2,340	1,760	1,650	1,350	1,930
sulfide (mg/L)	<0.03	<0.1	<0.05	28.4	20	2	6	1.5
total phenols (mg/L)	<0.1	0.028	0.117	0.019	0.14	<0.01	0.007	0.02
Notes:								
(a) This analyte is a common laboratory solvent which may be an artifact from sample collection or analysis.								
(b) NR -- Not reported								
(c) Acenaphthene - 4 ug/L								
(d) Acenaphthene - 5 ug/L								

NCL-44

NCL-44, Quarter/Year:	1st 96	2nd 96	3rd 96	4th 96	1st 97	2nd 97	3rd 97	4th 97
SampleDate:	22-Mar-96	35,251.0	10-Sep-96	19-Dec-96	27-Mar-97	19-Jun-97	02-Sep-97	
Laboratory:	NET	NET	PACE	PACE	PACE	PACE	PACE	
Volatiles (ug/L):								
benzene	<5	<10	<5	<5	<5	<5	<5	
ethylbenzene	11	12	<5	<5	6.19	<5	<5	
toluene	<5	<5	<5	<5	<5	<5	<5	
total xylenes	<5	<5	<5	12.7	<5	<5	<5	
acetone (a)	12	<100	<10	<10	11.6 a	<10	<10	
2-Butanone (MEK)	<20	<100	<10	<10	<10	<10	<10	
1,2-Dichloroethane	<5	<5	<5	<5	<5	<5	<5	
methylene chloride (a)	<5	<5	<5	<5	<5	<5	<5	
Semi-Volatiles (ug/L):								
anthracene	NR	<10	<10	<10	<10	<10	<10	
chrysene	NR	<10	<10	<10	<10	<10	<10	
dibenzofuran	NR	<10	<10	<10	<10	<10	<10	
fluorene	NR	<10	<10	<10	<10	<10	<10	
1-methylnaphthalene	NR	NR	NR	NR	NR	NR	NR	
2-methylnaphthalene	NR	<10	<10	<10	<10	<10	11	
naphthalene	<10	<10	<10	<10	<10	<10	<10	
phenanthrene	NR	<10	<10	<10	<10	<10	<10	
Metals (ug/L):								
aluminum	6,020	1200	<200	251	<200	3,260	11,800	
arsenic	71	29	38.5	31.5	31.4	34.2	71.9	
barium	905	152	<200	<200	<200	<200	564	
beryllium	<1	<1	<5	<5	<5	<5	<5	
boron	258	222	<500	1,410	226	130	193	
cadmium	2	<1	<5	<5	<5	<5	<5	
chromium	17	6	<10	<10	<10	10.5	15.6	
cobalt	27	<5	<50	<50	<50	<50	<50	
copper	32	24	<25	<25	<25	<25	<25	
iron	12,300	890	666	670	743	3,000	15,200	
lead	26	<5	<3	<3	<3	4.98	9.12	
manganese	820	642	699	665	62	631	814	
mercury	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	
molybdenum	21	17	<10	<10	17.4	11.5	22.6	
nickel	25	<5	<40	<40	<40	<40	<40	
selenium	<5	<5	<5	<5	<5	<5	<5	
silver	<2	<2	<10	<10	<10	<10	<10	
uranium (total)	NR	NR	NR	10	11	9.8	9	
vanadium	29	<5	<50	<50	<50	<50	<50	
zinc	55	165	<20	<20	<20	133	5,030	
Indicators:								
pH (S.U.)	7.7	7.3	6.9	7.6	7.5	7.3	NR	
spec. cond. (umhos)	1,660	1960	1,320	2,670	2,800	2,250	NR	
sulfide (mg/L)	<0.50	0.1	<0.020	0.55	0.327	0.06	1.65 D1	
total phenols (mg/L)	<0.01	<0.01	0.01	0.02	0.014	0.0154	0.0103	
Notes:								
(a) This analyte is a common laboratory solvent which may be an artifact from sample collection or analysis.								
(b) NR -- Not reported								

NCL-49

NCL-49, Quarter/Year:	1st 90	2nd 90	3rd 90	4th 90	1st 91	2nd 91	3rd 91	4th 91
SampleDate:			03-Oct-90	19-Dec-90	11-Apr-91	16-Jul-91	12-Nov-91	08-Jan-92
Laboratory:	NR	NR	PSI	ENSECO	BETZ	BETZ	BETZ	BETZ
Volatiles (ug/L):								
benzene			ND	ND	<5	<5	<5	<5
ethylbenzene			ND	ND	<5	<5	<5	<5
toluene			ND	ND	<5	<5	<5	<5
total xylenes			ND	ND	<5	<5	<5	<5
acetone (a)			NR	NR	NR	NR	NR	NR
2-Butanone (MEK)			ND	ND	<100	<100	<100	<100
1,2-Dichloroethane			ND	ND	<5	<5	<5	<5
methylene chloride (a)			NR	NR	NR	NR	NR	NR
Semi-Volatiles (ug/L):								
anthracene			ND	ND	<10	<10	<10	<10
chrysene			ND	ND	<10	<10	<10	<10
dibenzofuran			ND	ND	<10	<10	<10	<10
fluorene			ND	ND	<10	<10	<10	<10
1-methylnaphthalene			ND	ND	<10	<10	<10	<10
2-methylnaphthalene			NR	NR	NR	NR	NR	NR
naphthalene			ND	ND	<10	<10	<10	<10
phenanthrene			ND	ND	<10	<10	<10	<10
Metals (ug/L):								
aluminum			NR	NR	NR	NR	NR	NR
arsenic			ND	ND	<5	<5	<5	<5
barium			110	ND	18	26	112	170
beryllium			NR	NR	NR	NR	NR	NR
boron			NR	NR	NR	NR	NR	NR
cadmium			ND	ND	<5	<5	<5	<5
chromium			10	2.7	<10	29	34	38
cobalt			NR	NR	NR	NR	NR	NR
copper			NR	NR	NR	NR	NR	NR
iron			NR	NR	NR	NR	NR	NR
lead			ND	ND	<3	<3	<3	5
manganese			NR	NR	NR	NR	NR	NR
mercury			ND	ND	<0.2	<0.2	<0.2	<0.2
molybdenum			NR	NR	NR	NR	NR	NR
nickel			NR	NR	NR	NR	NR	NR
selenium			NR	NR	NR	NR	NR	NR
silver			NR	NR	NR	NR	NR	NR
uranium (total)			NR	NR	NR	NR	NR	NR
vanadium			NR	NR	NR	NR	NR	NR
zinc			50	NR	NR	NR	NR	NR
Indicators:								
pH (S.U.)			6.2	6.5	6.5	6.7	6.5	6.6
spec. cond. (umhos)			2,820	2,950	2,580	2,190	2,930	2,810
sulfide (mg/L)			ND	ND	<0.2	<0.1	<0.1	<0.1
total phenols (mg/L)			ND	ND	<0.05	<0.05	<0.05	<0.02

Notes:

(a) This analyte is a common laboratory solvent which may be an artifact from sample collection or analysis.

(b) ND -- Not detected. Detection limits not specified in 1990 reports. NR -- Not reported. NS -- Not sampled.

NCL-49

NCL-49, Quarter/Year:	1st 92	2nd 92	3rd 92	4th 92	1st 93	2nd 93	3rd 93	4th 93
SampleDate:	19-Mar-92	30-Jun-92	21-Oct-92	09-Nov-92	10-Feb-93	29-Apr-93	28-Sep-93	16-Dec-93
Laboratory:	BETZ	BETZ	BETZ	BETZ	BETZ	BETZ	IML	TRACE
Volatiles (ug/L):							(g)	
benzene	<5	<5	<5	<5	<5	<5	<5	<0.2
ethylbenzene	<5	<5	<5	<5	<5	<5	<5	0.6
toluene	<5	<5	<5	<5	<5	<5	<5	<0.5
total xylenes	<5	<5	<5	<5	<5	<5	<5	<1.4
acetone (a)	NR	NR	NR	NR	NR	NR	NR	<10
2-Butanone (MEK)	<100	<100	<10	<100	<100	<100	<10	<20
1,2-Dichloroethane	<5	<5	<5	<5	<5	<5	<5	<2
methylene chloride (a)	NR	NR	NR	NR	NR	NR	NR	<1
Semi-Volatiles (ug/L):								
anthracene	<10	NR	NR	NR	NR	<10	<10	<1
chrysene	<10	<10	<10	<10	<10	<10	<10	<1
dibenzofuran	<10	<10	<10	<10	<10	<10	<10	<5
fluorene	<10	<10	<10	<10	<10	<10	<10	<1
1-methylnaphthalene	<10	<10	<10	<10	<10	<10	<10	NR
2-methylnaphthalene	NR	NR	NR	NR	NR	NR	<10	<1
naphthalene	<10	<10	<10	<10	<10	<10	<10	1
phenanthrene	<10	<10	<10	<10	<10	<10	<10	<1
Metals (ug/L):								
aluminum	NR	NR	NR	NR	NR	NR	NR	<500
arsenic	<5	<5	<5	<5	<5	<5	<5	<100
barium	146	104	120	55	122	40	<100	<100
beryllium	NR	NR	NR	NR	NR	NR	NR	<50
boron	NR	NR	NR	NR	NR	NR	NR	200
cadmium	<5	<5	<5	<5	<5	<5	<2	<50
chromium	37	27	28	14	34	30	<20	<50
cobalt	NR	NR	NR	NR	NR	NR	NR	<50
copper	NR	NR	NR	NR	NR	NR	NR	<50
iron	NR	NR	NR	NR	NR	NR	NR	180
lead	<3	5	<3	<3	<3	NR	<10	<50
manganese	NR	NR	NR	NR	NR	NR	NR	<50
mercury	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<2	<1
molybdenum	NR	NR	NR	NR	NR	NR	NR	<50
nickel	NR	NR	NR	NR	NR	NR	NR	<50
selenium	NR	NR	NR	NR	NR	NR	NR	<100
silver	NR	NR	NR	NR	NR	NR	NR	<10
uranium (total)	NR	NR	NR	NR	NR	NR	NR	<500
vanadium	NR	NR	NR	NR	NR	NR	NR	<100
zinc	NR	NR	NR	NR	NR	NR	NR	<50
Indicators:								
pH (S.U.)	7.1	6.72	7.1	7.44	7.1	7.4	7.0	7.4
spec. cond. (umhos)	2,790	2,870	3,240	3,560	1,850	2,600	1,866	581
sulfide (mg/L)	<0.100	<0.100	<0.100	<0.100	<0.1	<0.1	<1.0	3.2
total phenols (mg/L)	0.03	0.02	<0.010	0.03	0.02	0.01	<0.01	<0.01
Notes:								
(a) This analyte is a common laboratory solvent which may be an artifact from sample collection or analysis.								
(b) NR -- Not reported								
(c) Methyl-t-butylether 8 mg/L								

NCL-49

NCL-49, Quarter/Year:	1st 94	2nd 94	3rd 94	4th 94	1st 95	2nd 95	3rd 95	4th 95
SampleDate:	04-Mar-94	17-Jun-94	19-Sep-94	27-Dec-94	23-Mar-95	08-Jun-95	13-Sep-95	01-Dec-95
Laboratory:	TRACE	TRACE	TRACE	TRACE	TRACE	TRACE	TRACE	NET
Volatiles (ug/L):								
benzene	<0.2	1	<2	<1	<1	<1	2	<5
ethylbenzene	<0.5	<0.5	<5	<1	<1	<1	<1	<5
toluene	<0.5	1	<5	<1	<1	<1	<1	<5
total xylenes	<1	<1	<10	<2	<2	<2	<2	<5
acetone (a)	<10	<10	<100	NR	NR	NR	NR	<10
2-Butanone (MEK)	<20	<20	<200	<20	<50	<50	<50	<20
1,2-Dichloroethane	<2	<2	<20	<2	<1	<1	<1	<5
methylene chloride (a)	<1	<1	<10	<1	<5	<5	<5	<5
Semi-Volatiles (ug/L):								
anthracene	<1	<1	<1	<1	<1	<1	<1	<7
chrysene	<1	<1	<1	<1	<1	<1	<1	<7
dibenzofuran	<5	<5	NR	NR	NR	NR	NR	<7
fluorene	<1	<1	<1	<1	<1	<1	<1	<7
1-methylnaphthalene	NR	NR	NR	NR	NR	NR	NR	NR
2-methylnaphthalene	3	1	NR	NR	NR	NR	NR	<7
naphthalene	2	<1	<1	<1	<1	<1	<1	<7
phenanthrene	<1	2	<1	<1	<1	<1	<1	<7
Metals (ug/L):								
aluminum	<100	<80	400	1,200	2,760	28,100	1,500	5,120
arsenic	<100	<100	<100	200	<100	<100	200	<30
barium	<100	<50	<50	<500	<500	340	70	180
beryllium	<10	<10	<10	<10	<50	<50	<10	<10
boron	250	240	320	390	280	330	200	160
cadmium	<10	<10	<10	<10	<10	<10	100	<10
chromium	<10	20	<10	<10	<10	20	80	10
cobalt	<10	<50	<50	<50	<50	<50	<30	<10
copper	<10	<50	<50	<50	<50	<50	,20	<10
iron	<50	60	100	540	840	16,300	<30	3,190
lead	<50	<1	<1	<1	2	2	<1	<30
manganese	<10	<50	<50	<100	150	230	<10	60
mercury	<1	<1	<1	<1	<1	<1	<1	0.2
molybdenum	<50	<50	<50	<50	<50	<50	<100	<10
nickel	<10	<50	<50	<50	<50	<50	<200	<30
selenium	<100	<1	<1	<1	<1	2	<1	<40
silver	<10	<1	2	<1	<1	<1	0.2	<10
uranium (total)	<500	<500	<500	<500	<500	<500	<500	NR
vanadium	<50	<50	<50	70	<50	<50	<50	20
zinc	30	20	10	50	20	100	<20	30
Indicators:								
pH (S.U.)	7.0	7.4	7.9	6.71	7.9	7.5	7.4	7.4
spec. cond. (umhos)	1,681	1,246	1,124	2,830	2,540	2,370	2,430	2,690
sulfide (mg/L)	<0.03	<0.1	<0.05	72	2	<2	<2	<0.01
total phenols (mg/L)	<0.1	0.013	<0.002	0.019	<0.02	<0.01	<0.005	<0.01
Notes:								
(a) This analyte is a common laboratory solvent which may be an artifact from sample collection or analysis.								
(b) NR -- Not reported								

NCL-49

NCL-49, Quarter/Year:	1st 96	2nd 96	3rd 96	4th 96	1st 97	2nd 97	3rd 97	4th 97
SampleDate:	18-Mar-96	03-Jul-96	09-Sep-96	11-Dec-96	25-Mar-97	18-Jun-97	02-Sep-97	
Laboratory:	NET	NET	PACE	PACE	PACE	PACE	PACE	
Volatiles (ug/L):								
benzene	<1.0	<5	<5	<5	<5	<5	<5	
ethylbenzene	<1.0	<5	<5	<5	<5	<5	<5	
toluene	<1.0	<5	<5	<5	<5	<5	<5	
total xylenes	<1.0	<5	<5	6.54	<5	<5	<5	
acetone (a)	<20	<100	<10	<10	12.7 (a)	<10	<10	
2-Butanone (MEK)	<10	<100	<10	<10	<10	<10	<10	
1,2-Dichloroethane	<1.0	<5	<5	<5	<5	<5	<5	
methylene chloride (a)	<10	<5	<5	<5	5.07 (a)	<5	<5	
Semi-Volatiles (ug/L):								
anthracene	NR	<10	<10	<11.1 (c)	<10	<10	<10	
chrysene	NR	<10	<10	<11.1 (c)	<10	<10	<10	
dibenzofuran	NR	<10	<10	<11.1 (c)	<10	<10	<10	
fluorene	NR	<10	<10	<11.1 (c)	<10	<10	<10	
1-methylnaphthalene	NR	NR	NR	NR	NR	NR	NR	
2-methylnaphthalene	NR	<10	<10	<11.1 (c)	<10	<10	<10	
naphthalene	<5	<10	<10	<11.1 (c)	<10	<10	<10	
phenanthrene	NR	<10	<10	<11.1 (c)	<10	<10	<10	
Metals (ug/L):								
aluminum	643	347	<200	<200	<200	387	8,400	
arsenic	<5	<5	<10	<10	<10	<10	<10	
barium	32	20	<200	<200	<200	<200	<200	
beryllium	<1	<1	<5	<5	<5	<5	<5	
boron	333	267	<500	<500	212	183	176	
cadmium	<1	<1	<5	<5	<5	<5	<5	
chromium	<2	<5	<10	<10	<10	<10	32.3	
cobalt	<5	<5	<50	<50	<50	<50	<50	
copper	5	24	<25	<25	<25	<25	<25	
iron	206	146	<100	<100	<100	249	5,640	
lead	<5	<5	3.6	<3	<3	<3	3.56	
manganese	16	52	<15	<15	<15	21.7	62.4	
mercury	<0.20	<0.20	<0.20	<0.20	1.33	<0.20	<0.20	
molybdenum	<5	<5	<10	<10	<10	<10	<10	
nickel	2	<5	<40	<40	<40	<40	<40	
selenium	11	6	<5	<5	5.06	<5	6.61	
silver	<2	<2	<10	<10	<10	<10	<10	
uranium (total)	NR	NR	NR	30	25	40.2	11	
vanadium	<10	9	<50	<50	<50	<50	<50	
zinc	22	17	<20	<20	<20	131	120	
Indicators:								
pH (S.U.)	8.1	7.8	7.8	7.1	7.3	7	NR	
spec. cond. (umhos)	2,690	2,750	2,480	2,800	3,350	4,950	NR	
sulfide (mg/L)	<0.50	<0.10	<0.20	<0.02	<0.02	<0.02	0.033	
total phenols (mg/L)	<0.01	<0.01	<0.0050	<0.005	<0.01	<0.01	<0.01	

Notes:

(a) This analyte is a common laboratory solvent which may be an artifact from sample collection or analysis.

(b) NR --Not reported

(c) A reduced sample aliquot was extracted. The reporting limit is elevated accordingly.

MW-53

MW-53, Quarter/Year:	1st 94	2nd 94	3rd 94	4th 94	1st 95	2nd 95	3rd 95	4th 95
SampleDate:						29-Jun-95	NS	02-Dec-95
Laboratory:						IML		NET
Volatiles (ug/L):								
benzene						<5		<5
ethylbenzene						<5		<5
toluene						<5		<5
total xylenes						<5		<5
acetone (a)						<25		<10
2-Butanone (MEK)						<20		<20
1,2-Dichloroethane						<5		<5
methylene chloride (a)						<5		<5
Semi-Volatiles (ug/L):								
anthracene						<10		<6
chrysene						<10		<6
dibenzofuran						NR		<6
fluorene						<10		<6
1-methylnaphthalene						<10		NR
2-methylnaphthalene						NR		<6
naphthalene						<10		<6
phenanthrene						<10		<6
Metals (ug/L):								
aluminum						1,000		7,700
arsenic						<5		<30
barium						70		150
beryllium						<5		<10
boron						390		240
cadmium						<1		<10
chromium						7		10
cobalt						<20		10
copper						<10		<10
iron						730		5,300
lead						<10		<30
manganese						2,170		2,200
mercury						<1		0
molybdenum						<50		10
nickel						<50		30
selenium						<5		<40
silver						<10		<10
uranium (total)						<300		NR
vanadium						<20		20
zinc						<20		30
Indicators:								
pH (S.U.)						7.4		NR
spec. cond. (umhos)						2,750		NR
sulfide (mg/L)						NR		<0.01
total phenols (mg/L)						NR		<0.01
Notes:								
(a) This analyte is a common laboratory solvent which may be an artifact from sample collection or analysis.								
(b) NR -- Not reported, NS -- Not sampled								
(c) New well 6/29/95								

MW-53

MW-53, Quarter/Year:	1st 96	2nd 96	3rd 96	4th 96	1st 97	2nd 97	3rd 97	4th 97
SampleDate:	18-Mar-96	02-Jul-96	09-Sep-96	11-Dec-96	25-Mar-97	18-Jun-97	02-Sep-97	
Laboratory:	NET	NET	PACE	PACE	PACE	PACE	PACE	
Volatiles (ug/L):								
benzene	<1.0	<5	<5	<5	<5	<5	<5	
ethylbenzene	<1.0	<5	<5	<5	<5	<5	<5	
toluene	<1.0	<5	<5	<5	<5	<5	<5	
total xylenes	<1.0	<5	<5	8.9	<5	<5	<5	
acetone (a)	<20	<100	<10	<10	10.5 a	<10	<10	
2-Butanone (MEK)	<10	<100	<10	<10	<10	<10	<10	
1,2-Dichloroethane	<1.0	<5	<5	<5	<5	<5	<5	
methylene chloride (a)	<10	<5	<5	<5	<5	<5	<5	
Semi-Volatiles (ug/L):								
anthracene	NR	<10	<10	<11.1 c	<10	<10	<10	
chrysene	NR	<10	<10	<11.1 c	<10	<10	<10	
dibenzofuran	NR	<10	<10	<11.1 c	<10	<10	<10	
fluorene	NR	<10	<10	<11.1 c	<10	<10	<10	
1-methylnaphthalene	NR	NR	NR	NR	NR	NR	NR	
2-methylnaphthalene	NR	<10	<10	<11.1 c	<10	<10	<10	
naphthalene	<5	<10	<10	<11.1 c	<10	<10	<10	
phenanthrene	NR	<10	<10	<11.1 c	<10	<10	<10	
Metals (ug/L):								
aluminum	1,910	347	<200	1,810	<200	15,500	229	
arsenic	<5	<5	<10	<10	<10	<10	11.2	
barium	79	20	<200	<200	<200	<200	<200	
beryllium	<1	<1	<5	<5	<5	<5	<5	
boron	429	NR	<500	<500	401	212	370	
cadmium	<1	NR	<5	<5	<5	<5	<5	
chromium	2	NR	<10	<10	<10	15.5	<10	
cobalt	7	NR	<50	<50	<50	<50	<50	
copper	9	NR	<25	<25	<25	<25	<25	
iron	968	NR	<100	946	136	10,700	122	
lead	8	NR	<3	<3	<3	10.2	4.12	
manganese	2,010	NR	2,170	2,300	2,000	5,860	2,210	
mercury	<0.2	NR	<0.20	<0.20	<0.20	<0.20	<0.20	
molybdenum	12	NR	<10	<10	15.4	20.7	16.9	
nickel	10	NR	<40	<40	<40	<40	<40	
selenium	<5	NR	<5	<5	<5	<5	11.4	
silver	<2	NR	<10	<10	<10	<10	<10	
uranium (total)	NR	NR	NR	NR	19	18.1	30	
vanadium	<10	NR	<50	<50	<50	<50	<50	
zinc	114	NR	<20	<20	<20	109	32.4	
Indicators:								
pH (S.U.)	7.8	7.1	7.4	7.5	7.4	7.2	NR	
spec. cond. (umhos)	2,250	1,730	2,370	2,370	3,200	5,000	NR	
sulfide (mg/L)	<0.50	NR	<0.020	0.025	<0.02	<0.02	<0.02	
total phenols (mg/L)	0.02	NR	<0.0050	<0.005	<0.01	<0.01	<0.01	
Notes:								
(a) This analyte is a common laboratory solvent which may be an artifact from sample collection or analysis.								
(b) NR -- Not reported								
(c) Sample extract could not be concentrated to method volume; report limit higher								

MW-54A

MW-54A, Quarter/Year:	1st 94	2nd 94	3rd 94	4th 94	1st 95	2nd 95	3rd 95	4th 95
SampleDate:								22-Dec-95
Laboratory:								IML
Volatiles (ug/L):								
benzene								<5
ethylbenzene								6
toluene								<5
total xylenes								<5
acetone (a)								<30
2-Butanone (MEK)								<40
1,2-Dichloroethane								<5
methylene chloride (a)								<5
Semi-Volatiles (ug/L):								
anthracene								<50
chrysene								<50
dibenzofuran								NR
fluorene								<50
1-methylnaphthalene								NR
2-methylnaphthalene								<50
naphthalene								<50
phenanthrene								<50
Metals (ug/L):								
aluminum								400
arsenic								8
barium								30
beryllium								<5
boron								28
cadmium								<1
chromium								<5
cobalt								<20
copper								<10
iron								400
lead								<10
manganese								350
mercury								<1
molybdenum								<50
nickel								<50
selenium								<5
silver								<10
uranium (total)								NR
vanadium								<20
zinc								<20
Indicators:								
pH (S.U.)								8.1
spec. cond. (umhos)								2,380
sulfide (mg/L)								NR
total phenols (mg/L)								NR
Notes:								
(a) This analyte is a common laboratory solvent which may be an artifact from sample collection or analysis.								
(b) NS -- Not sampled								
(c) New well, 12/22/95								

MW-54A

MW-54A, Quarter/Year:	1st 96	2nd 96	3rd 96	4th 96	1st 97	2nd 97	3rd 97	4th 97
SampleDate:	23-Mar-96	05-Jul-96	11-Sep-96	19-Dec-96	25-Mar-97	18-Jun-97	02-Sep-97	
Laboratory:	NET	NET	PACE	PACE	PACE	PACE	PACE	
Volatiles (ug/L):								
benzene	<5	<5	<5	<5	<5	<5	<5	
ethylbenzene	6.5	<5	<5	<5	<5	<5	<5	
toluene	<5	<5	<5	<5	<5	<5	<5	
total xylenes	<5	<5	<5	7.2	<5	<5	<5	
acetone (a)	<10	<100	<10	<10	16.3	<10	<10	
2-Butanone (MEK)	<20	<100	<10	<10	<10	<10	<10	
1,2-Dichloroethane	<5	<5	<5	<5	<5	<5	<5	
methylene chloride (a)	<5	<5	<5	<5	<5	<5	<5	
Semi-Volatiles (ug/L):								
anthracene	NR	<10	<10	<10	<10	<10	<10	
chrysene	NR	<10	<10	<10	<10	<10	<10	
dibenzofuran	NR	<10	<10	<10	<10	<10	<10	
fluorene	NR	<10	<10	<10	<10	<10	<10	
1-methylnaphthalene	NR	NR	NR	NR	NR	NR	NR	
2-methylnaphthalene	NR	<10	13.3	11.5	<10	<10	<10	
naphthalene	<10	<10	<10	<10	<10	<10	<10	
phenanthrene	NR	<10	<10	<10	<10	<10	<10	
Metals (ug/L):								
aluminum	7,560	487	150	<200	<2000	2,980	17,200	
arsenic	14	9	<10	<10	<10	19.7	12.1	
barium	392	22	<200	<200	<200	<200	<200	
beryllium	2	<1	<5	<5	<5	<5	<5	
boron	248	217	<500	1,250	299	184	142	
cadmium	<1	<1	<5	<5	<5	<5	<5	
chromium	9	10	<10	<10	<10	<10	16.8	
cobalt	6	<5	<50	<50	<50	<50	<50	
copper	12	17	<25	<25	<25	<25	<25	
iron	5,070	675	1,140	532	473	3,820	12,500	
lead	7	7	<3	<3	<3	3.22	7.54	
manganese	444	306	417	351	320	497	487	
mercury	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	
molybdenum	<5	6	<10	<10	<10	<10	<10	
nickel	12	<5	<40	<40	<40	<40	<40	
selenium	<5	6	<5	<5	<5	<5	<5	
silver	<2	<2	<10	<10	<10	<10	<10	
uranium (total)	NR	NR	NR	40	25	23.5	23	
vanadium	17	<5	<50	<50	<50	<50	<50	
zinc	31	302	<20	<20	29	180	134	
Indicators:								
pH (S.U.)	7.4	7.1	7.7	7.3	7.2	7.2	NR	
spec. cond. (umhos)	2,060	2,020	1,810	2,650	2,830	6,000	NR	
sulfide (mg/L)	<0.50	0.06	<0.020	<0.020	<0.02	<0.02	<0.02	
total phenols (mg/L)	<0.01	<0.01	0.014	<0.0050	<0.01	<0.01	<0.01	
Notes:								
(a) This analyte is a common laboratory solvent which may be an artifact from sample collection or anlysis.								
(b) NR -- Not reported								

MW-54B

MW-54B, Quarter/Year:	**1st 94**	**2nd 94**	**3rd 94**	**4th 94**	**1st 95**	**2nd 95**	**3rd 95**	**4th 95**
SampleDate:								22-Dec-95
Laboratory:								IML
Volatiles (ug/L):								
benzene								<5
ethylbenzene								<5
toluene								<5
total xylenes								<5
acetone (a)								<30
2-Butanone (MEK)								<40
1,2-Dichloroethane								<5
methylene chloride (a)								<5
Semi-Volatiles (ug/L):								
anthracene								<10
chrysene								<10
dibenzofuran								NR
fluorene								<10
1-methylnaphthalene								NR
2-methylnaphthalene								<10
naphthalene								<10
phenanthrene								<10
Metals (ug/L):								
aluminum								<100
arsenic								<5
barium								20
beryllium								<5
boron								160
cadmium								<1
chromium								<5
cobalt								<20
copper								<10
iron								90
lead								<10
manganese								140
mercury								3
molybdenum								<50
nickel								<50
selenium								<5
silver								<10
uranium (total)								NR
vanadium								<20
zinc								<20
Indicators:								
pH (S.U.)								8.1
spec. cond. (umhos)								2,380
sulfide (mg/L)								NR
total phenols (mg/L)								NR
Notes:								
(a) This analyte is a common laboratory solvent which may be an artifact from sample collection or analysis.								
(b) NS -- Not sampled								
(c) New well, 12/22/95								

MW-54B

MW-54B, Quarter/Year:	**1st 96**	**2nd 96**	**3rd 96**	**4th 96**	**1st 97**	**2nd 97**	**3rd 97**	**4th 97**
SampleDate:	NS	NS	NS	NS	NS	NS	18-Sep-97	
Laboratory:							PACE	
Volatiles (ug/L):								
benzene							<5	
ethylbenzene							<5	
toluene							<5	
total xylenes							<5	
acetone (a)							<10	
2-Butanone (MEK)							<10	
1,2-Dichloroethane							<5	
methylene chloride (a)							<10	
Semi-Volatiles (ug/L):								
anthracene							<10.1 (c)	
chrysene							<10.1 (c)	
dibenzofuran							<10.1 (c)	
fluorene							<10.1 (c)	
1-methylnaphthalene							NR	
2-methylnaphthalene							<10.1 (c)	
naphthalene							<10.1 (c)	
phenanthrene							<10.1 (c)	
Metals (ug/L):								
aluminum							344	
arsenic							<10	
barium							<200	
beryllium							<5	
boron							130	
cadmium							<5	
chromium							<10	
cobalt							<50	
copper							<25	
iron							148	
lead							<3	
manganese							72.9	
mercury							1.57	
molybdenum							<10	
nickel							<40	
selenium							<5	
silver							<10	
uranium (total)							27	
vanadium							<50	
zinc							33.9	
Indicators:								
pH (S.U.)							6.82	
spec. cond. (umhos)							2,390	
sulfide (mg/L)							<0.02	
total phenols (mg/L)							<0.01	
Notes:								
(a) This analyte is a common laboratory solvent which may be an artifact from sample collection or analysis.								
(b) NR -- Not reported								
(c) A reduced sample aliquot was extracted. The reporting limit is elevated accordingly.								

MW-55

MW-55, Quarter/Year:	1st 94	2nd 94	3rd 94	4th 94	1st 95	2nd 95	3rd 95	4th 95
SampleDate:							09-Aug-95	NS
Laboratory:							IML	
Volatiles (ug/L):								
benzene							<5	
ethylbenzene							<5	
toluene							<5	
total xylenes							<5	
acetone (a)							<10	
2-Butanone (MEK)							<10	
1,2-Dichloroethane							<5	
methylene chloride (a)							<5	
Semi-Volatiles (ug/L):								
anthracene							<10	
chrysene							<10	
dibenzofuran							NR	
fluorene							<10	
1-methylnaphthalene							NR	
2-methylnaphthalene							<10	
naphthalene							<10	
phenanthrene							<10	
Metals (ug/L):								
aluminum							6,800	
arsenic							<5	
barium							190	
beryllium							<5	
boron							480	
cadmium							<1	
chromium							14	
cobalt							<20	
copper							20	
iron							4,240	
lead							<10	
manganese							220	
mercury							<1	
molybdenum							<50	
nickel							<50	
selenium							<5	
silver							<10	
uranium (total)							<300	
vanadium							20	
zinc							30	
Indicators:								
pH (S.U.)							7.1	
spec. cond. (umhos)							2,940	
sulfide (mg/L)							NR	
total phenols (mg/L)							NR	
Notes:								
(a) This analyte is a common laboratory solvent which may be an artifact from sample collection or analysis.								
(b) NS -- Not samnpled								
(c) New Well 8/09/95								

MW-55

MW-55, Quarter/Year:	**1st 96**	**2nd 96**	**3rd 96**	**4th 96**	**1st 97**	**2nd 97**	**3rd 97**	**4th 97**
SampleDate:	22-Mar-96	22-Jul-96	09-Sep-96	11-Dec-96	25-Mar-97	19-Jun-97	02-Sep-97	
Laboratory:	NET	NET	PACE	PACE	PACE	PACE	PACE	
Volatiles (ug/L):								
benzene	<5	<5	<5	<5	<5	<5	<5	
ethylbenzene	<5	<5	<5	<5	<5	<5	<5	
toluene	<5	<5	<5	<5	<5	<5	<5	
total xylenes	<5	<5	<5	6.3	<5	<5	<5	
acetone (a)	<10	<100	<10	<10	<10	<10	<10	
2-Butanone (MEK)	<20	<100	<10	<10	<10	<10	<10	
1,2-Dichloroethane	<5	<5	<5	<5	<5	<5	<5	
methylene chloride (a)	<5	<5	<5	<5	6.08 a	<5	<5	
Semi-Volatiles (ug/L):								
anthracene	NR	<10	<10	<11.6 c	<10	<10	<10	
chrysene	NR	<10	<10	<11.6 c	<10	<10	<10	
dibenzofuran	NR	<10	<10	<11.6 c	<10	<10	<10	
fluorene	NR	<10	<10	<11.6 c	<10	<10	<10	
1-methylnaphthalene	NR	NR	NR	NR	NR	NR	NR	
2-methylnaphthalene	NR	<10	<10	<11.6 c	<10	<10	<10	
naphthalene	<10	<10	<10	<11.6 c	<10	<10	<10	
phenanthrene	NR	<10	<10	<11.6 c	<10	<10	<10	
Metals (ug/L):								
aluminum	7,060	478	<200	304	<200	1,050	6,260	
arsenic	9	8	<10	<10	<10	<10	15	
barium	575	29	<200	<200	<200	<200	<200	
beryllium	2	<1	<5	<5	<5	<5	<5	
boron	465	430	578	1,050	508	352	328	
cadmium	<1	<1	<5	<5	<5	<5	<5	
chromium	10	<5	<10	<10	<10	<10	<10	
cobalt	4	<5	<50	<50	<50	<50	<50	
copper	11	12	<25	<25	<25	<25	<25	
iron	4,880	365	<100	125	<100	704	4,480	
lead	5	<5	<3	<3	<3	<3	<3	
manganese	239	185	172	192	190	213	259	
mercury	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	
molybdenum	21	21	<10	<10	18.2	17.5	16.1	
nickel	11	<5	<40	<40	<40	<40	<40	
selenium	6	<5	<5	<5	<5	<5	<5	
silver	<2	<2	<10	<10	<10	<10	<10	
uranium (total)	NR	NR	NR	NR	36	50.8	35	
vanadium	83	14	<50	<50	<50	<50	<50	
zinc	24	165	<20	<20	<20	99.8	77.6	
Indicators:								
pH (S.U.)	7.8	7.2	7.2	7.4	7.1	7.0	NR	
spec. cond. (umhos)	2,270	2,120	1,850	2,400	2,450	2,280	NR	
sulfide (mg/L)	0.05	<0.10	<0.020	<0.020	<0.02	<0.02	<0.02	
total phenols (mg/L)	<0.01	<0.01	<0.0050	<0.0050	<0.01	<0.01	<0.01	
Notes:								
(a) This analyte is a common laboratory solvent which may be an artifact from sample collection or analysis.								
(b) NR -- Not reported								
(c) A reduced sample aliquot was extracted. The reporting limit is elevated accordingly.								

MW-56

MW-56, Quarter/Year:	1st 94	2nd 94	3rd 94	4th 94	1st 95	2nd 95	3rd 95	4th 95
SampleDate:							09-Aug-95	NS
Laboratory:							IML	
Volatiles (ug/L):								
benzene							<5	
ethylbenzene							<5	
toluene							<5	
total xylenes							<5	
acetone (a)							<10	
2-Butanone (MEK)							<10	
1,2-Dichloroethane							<5	
methylene chloride (a)							<5	
Semi-Volatiles (ug/L):								
anthracene							<10	
chrysene							<10	
dibenzofuran							NR	
fluorene							<10	
1-methylnaphthalene							NR	
2-methylnaphthalene							<10	
naphthalene							<10	
phenanthrene							<10	
Metals (ug/L):								
aluminum							14,100	
arsenic							<7	
barium							130	
beryllium							<5	
boron							480	
cadmium							<1	
chromium							13	
cobalt							<20	
copper							20	
iron							5,850	
lead							<10	
manganese							310	
mercury							<1	
molybdenum							<50	
nickel							<50	
selenium							<5	
silver							<10	
uranium (total)							<300	
vanadium							30	
zinc							30	
Indicators:								
pH (S.U.)							6.9	
spec. cond. (umhos)							5,850	
sulfide (mg/L)							NR	
total phenols (mg/L)							NR	
Notes:								

(a) This analyte is a common laboratory solvent which may be an artifact from sample collection or analysis.

(b) NS -- Not sampled

(c) New well 8/09/95

MW-56

MW-56, Quarter/Year:	1st 96	2nd 96	3rd 96	4th 96	1st 97	2nd 97	3rd 97	4th 97
SampleDate:	23-Mar-96	05-Jul-96	09-Sep-96	11-Dec-96	25-Mar-97	19-Jun-97	03-Sep-97	
Laboratory:	NET	NET	PACE	PACE	PACE	PACE	PACE	
Volatiles (ug/L):								
benzene	<5	<5	<5	<5	<5	<5	<5	
ethylbenzene	<5	<5	<5	<5	<5	<5	<5	
toluene	<5	<5	<5	<5	<5	<5	<5	
total xylenes	<5	<5	<5	9.7	<5	<5	<5	
acetone (a)	<10	<100	<10	<10	<10	<10	<10	
2-Butanone (MEK)	<20	<100	<10	<10	<10	<10	<10	
1,2-Dichloroethane	<5	<5	<5	<5	<5	<5	<5	
methylene chloride (a)	<5	<5	<5	<5	<5	<5	<5	
Semi-Volatiles (ug/L):								
anthracene	NR	<10	<10	<11.4 c	<10	<10	<10	
chrysene	NR	<10	<10	<11.4 c	<10	<10	<10	
dibenzofuran	NR	<10	<10	<11.4 c	<10	<10	<10	
fluorene	NR	<10	<10	<11.4 c	<10	<10	<10	
1-methylnaphthalene	NR	NR	NR	NR	NR	NR	NR	
2-methylnaphthalene	NR	<10	<10	<11.4 c	<10	<10	<10	
naphthalene	<10	<10	<10	<11.4 c	<10	<10	<10	
phenanthrene	NR	<10	<10	<11.4 c	<10	<10	<10	
Metals (ug/L):								
aluminum	37,400	3,140	<200	525	<200	1,780	39,000	
arsenic	29	20	26	27.3	25	23.5	27.2	
barium	992	45	<200	<200	<200	<200	256	
beryllium	11	<1	<5	<5	<5	<5	<5	
boron	438	430	590	795	598	467	545	
cadmium	2	<1	<5	<5	<5	<5	<5	
chromium	29	<5	<10	<10	<10	<10	24.2	
cobalt	30	12	<50	<50	<50	<50	<50	
copper	39	14	<25	<25	<25	<25	<25	
iron	13,700	1,270	<100	<100	116	517	18,700	
lead	65	<5	<3	<3	<3	9.18	16.2	
manganese	471	257	229	240	206	254	373	
mercury	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	
molybdenum	6	12	<10	<10	16.6	11.8	15.9	
nickel	52	32	<40	<40	<40	<40	<40	
selenium	<5	<5	<5	<5	<5	<5	5.1	
silver	<2	<2	<10	<10	<10	<10	<10	
uranium (total)	NR	NR	NR	NR	56	4	44	
vanadium	75	20	<50	<50	<50	<50	57.6	
zinc	86	43	<20	<20	<20	159	229	
Indicators:								
pH (S.U.)	7.8	7.1	7.1	7.5	7.5	7.4	NR	
spec. cond. (umhos)	4,380	4,360	3,150	4,280	4,180	5,750	NR	
sulfide (mg/L)	<0.50	<0.10	<0.020	<0.020	<0.02	<0.02	<0.02	
total phenols (mg/L)	<0.01	0.02	0.017	0.029	<0.010	<0.01	0.0121	
Notes:								
(a) This analyte is a common laboratory solvent which may be an artifact from sample collection or analysis.								
(b) NR -- Not reported								
(c) Sample extract could not be concentrated to the method specified volume.								

APPENDIX G2

SOIL AND WATER LABORATORY DATA SHEETS, RFI PHASE I, 1994

APPENDIX G3

SOIL AND WATER LABORATORY DATA SHEETS, RFI PHASE II, 1995

APPENDIX G4

SOIL AND WATER LABORATORY DATA SHEETS, RFI SUPPLEMENTAL INVESTIGATION, 1997

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Appendix H

Appendix H

APPENDIX H

COPIES OF PRE-1994 REPORTS TECHNICAL CORRESPONDENCE

APPENDIX H1

COPIES OF PRE-1994 REPORTS AND TECHNICAL CORRESPONDENCE

APPENDIX H2

SOIL LABORATORY DATA SHEETS,
NCL SOIL SAMPLING, 1990