Final Technical Report

Site Investigation and Evaluation of Remediation Alternatives for the Post Oak Site, Lee County, Texas

(RRC Site No. 03-50217)

Volume I—Technical Report

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1.0 EXECUTIVE SUMMARY

The Bureau of Economic Geology (BEG) investigated the Post Oak site (RRC Site Code 03-50217) in Lee County, Texas, between June 1996 and August 1997. The site is a former sandstone quarry that was used for nonpermitted disposal of oil-field waste—specifically, spent drilling fluid. Disposal of wastes at the pit onsite occurred sometime before 1995, at which time the property owner reported the dumping to the Railroad Commission (RRC).

The scope of the BEG study was to determine the extent and composition of the waste materials, identify related impacted areas, determine the effects on ground-water quality, and evaluate risk-based options for site remediation. Constituents identified by BEG in waste materials at the site include petroleum hydrocarbons, chloride, and metals. This report presents (1) results of the site work and (2) remediation options for RRC to review before taking action at the site.

The waste materials, confined within the quarry walls and berms at the site, are underlain by sandstone, sands, and clays of the Wellborn Formation. There is no reported use of shallow or deep ground water in the immediate area, which is served by a rural water-supply company. In general, the waste materials were found to be nonhazardous, with low levels of TPH that are below guidance levels and moderate concentrations of chloride that are below levels that might limit biodegradation. The wastes exhibited negligible TCLP leaching potentials for organic compounds and metals. Petroleum hydrocarbon concentration in the wastes averaged 0.096 percent below cleanup standards set by either RRC or TNRCC. Chloride concentrations averaged 2,500 mg/kg below the limit set for nonpermitted landfarming or burial. Metals detected in the waste materials did not exceed the regulatory limit for disposal of nonhazardous waste. Naphthalene was detected in pit waters and waste materials just at or below action levels, respectively.

Judging from one round of sampling results, shallow ground water may have been impacted, specifically with respect to metals and chloride concentrations. The constituents detected above regulatory guidelines in onsite ground water were cadmium, chromium, lead and chloride. Naphthalene was the only petroleum hydrocarbon detected above regulatory guidelines in the ground water. Background concentrations of these constituents in shallow ground water in the area need to be determined both to confirm this apparent impact and to set appropriate cleanup goals. Electromagnetic (EM) surveys and information from borehole samples at the site indicated that impact from brackish-to-saline ground water outside of the immediate pit area is unlikely.

No justification for ground-water remediation was found on the basis of existing data. As a conservative approach, a plan B risk analysis was performed on constituents of concern at the site. The plan B analysis allows for modeling of offsite ground-water impacts. At this time, there are no identifiably complete ground-water pathways because of the presence of alternate potable-water sources. No calculated carcinogenic risks for any constituent stemmed from the ground-water pathway. There was an exceedance of the hazard index, mostly owing to the presence of cadmium. Both ground-water pathways (on- and offsite) exceeded recommended limits for future use, although they are unlikely to become complete exposure pathways.

Additional ground-water monitoring is needed to define background concentrations of constituents of concern and to verify the results of this study's sampling event. Should additional monitoring data verify the need to remediate the waste materials to control any ground-water impact, their removal from the pit and land spreading onsite probably would be the most cost-effective option. This would, however, require approval of the landowner and, with regard to wetland issues, the Army Corps of Engineers. As an interim measure, fencing of the pit is needed to keep out livestock and people and thereby reduce risk of exposure to an entrapment hazard posed by the waste materials, which have a very low load-bearing strength.

2.0 INTRODUCTION

The Railroad Commission of Texas (RRC) has statutory responsibility under S.B. 1103 (72nd Legislature, 1991) for oversight of cleanup of abandoned oil-field sites throughout Texas. Since 1991, RRC personnel have identified and inventoried abandoned oil-field sites as candidates for cleanup. The RRC ranked sites by giving priority to contaminated sites that (1) have had observable releases, (2) occur in ground-water recharge zones with high soil permeability, (3) lie near surface-water bodies or water-supply wells, or both, (4) have a high public profile and have received complaints, and (5) are near population centers. Straightforward solutions for cleanup are readily apparent for many of the sites.

At some oil-field sites, however, outlining cost-effective approaches to cleanup requires more information on the surface and subsurface extent of the contamination. For these priority sites, the Bureau of Economic Geology (BEG) is providing extensive site investigations for the RRC under interagency contract 94-0050. The purpose of these investigations is to provide the required information for planning and executing the appropriate level of remediation.

The Post Oak site in Lee County (RRC Site Code 03-50217) was used as a nonpermitted disposal pit for oil-field wastes such as salt water, drilling fluids, and oil-contaminated drilling materials or oil. Potential site contaminants include petroleum hydrocarbons, salts, and metals (such as barium), which are associated with drilling. Another concern at the start of this investigation was the possibility of other unknown contaminants that might have been illegally disposed of at the site, such as solvents, metals, PCB's, or pesticides. This report describes the investigation performed at the Post Oak site and recommendations for remediation of the site made on the basis of current information.

The principal tasks performed for this investigation were: (1) determination of the extent and composition of the solid waste materials present at each site; (2) identification of other potentially impacted areas, such as surface soils or surface water, via sampling and geophysical survey methods; (3) installation of ground-water monitoring wells to determine the effects on ground-water quality as influenced by the site; (4) search for local domestic wells to access data on water quality; and (5) evaluation of risk-based options for site remediation and closure. A thorough review of the RRC case files for each site was performed between June 1996 and March 1997. A site-reconnaissance visit was made to the three sites by BEG personnel in March 1997. Site-investigation work was performed from April through August 1997.

An assessment of potential risks to human health as posed by the site (section 5.0) is one aspect considered in recommending remedial measures. Although wastes from oil and gas production are exempt from most hazardous-material assessment requirements, this section has been included to address possible concerns about local impacts from the site. Generally this assessment follows risk-based corrective action (RBCA) guidance from ASTM E-1739 and the proposed Texas Risk Reduction Program (TNRCC, 1998). Although the ASTME-1739 guidance was developed for petroleum-release sites, such as leaking underground petroleum storage tanks (PST's) or pipelines, it was found to be relevant to these abandoned oil-field sites. The site was evaluated as a Plan B assessment (TNRCC, 1998), which includes evaluation of exposure to offsite ground-water receptors in the site-evaluation process and allows for adjustment of onsite-worker exposures. This level of assessment is conservative and protective of human health and is intended to be used as guidance only for recommendations for site remediation and not for detailed assessment of actual risks that may arise at this site. Importantly, this abandoned oil-field cleanup site is not subject to regulation by the TNRCC, and this well-documented methodology is being used solely for guidance purposes in the remediation-evaluation process.

Work was performed specifically to address the presence of oil and gas wastes at the Post Oak site. Other wastes that may exist, including trash piles or scrap metal, were considered to be beyond the scope of this investigation and were not evaluated. This site investigation is intended to provide information pertinent only to recommendations for remediation of the site from any impacts of oil and gas wastes.

2.1 Site Description

The Post Oak site is located approximately 8 mi east of the town of Giddings in Lee County, Texas, on Farm Road (FM) 180. It is shown on the Ledbetter USGS 7.5-minute quadrangle (USGS, 1988), where it is located about 6 mi north of the intersection of FM 180 and State Route 290, adjacent to Sunnyside Church and the intersection of FM 180 and County Road 119 (fig. 2.1). The site is a former rock quarry and includes the quarry pit, which contains tarlike material, drill-mud waste, and water. A berm surrounds part of the pit. No other structures exist within the fence line, which surrounds the immediate site area; a barn sits on the west side of the pit outside this fence. The property boundary is shown in figure 2.2.

Topography within 1 mi of the site slopes gently to moderately, steeper slopes lying adjacent to stream channels. At the site, the land surface slopes to the east and south-east. The site is located close to a ridge top and on a drainage divide, most likely a result of the resistant sandstone underlying the quarry area. Approximate elevation of the site is 360 ft above mean sea level (msl).

The predominant land use in the area is agriculture (cropland or cattle ranching) and oil/gas production. Some residences are located along FM 180 to the northeast and southwest, within .5 mi of the site. Most of the residences some 3,000 ft to the northeast are weekend-use cottages, although those to the south are mostly for permanent residents. To the north is a producing oil well and grazing land and to the west is the barn and a tank battery. To the south is woodland and grazing land. Approximately 100 ft to the northeast is the Sunnyside (Post Oak) Church, and across FM 180 to the east is a trailer residence and grazing land.

BEG personnel visited the site on March 6, 1997, to assess the condition of the pit. Although the site is partly surrounded by a fence, it is not gated and remains open to public access. The south and west sides of the pit are rock exposed from previous quarrying activities. The berm surrounding the north and east sides of the pit is intact, with no major erosional features. The pit, which is approximately 250 × 500 ft in size, contained clear fluid at a level about 5 ft below the top of the exposed rock face, zones of sediment, zones of sediment coated by a thick, weathered crust of tarlike material, and several vegetated areas. Debris, including trash such as aluminum cans, glass bottles, 5-gallon plastic buckets, a cow skeleton, and a dump of soil fill material was observed in the pit. The dried material was firm enough to support walking around the edges of the pit but was softer and wetter about 20 ft away from the berm. The tarlike material had an asphaltlike odor downwind of the pit. There was no obvious evidence of tar spills or barren areas that might indicate disposal sites outside of the pit area.

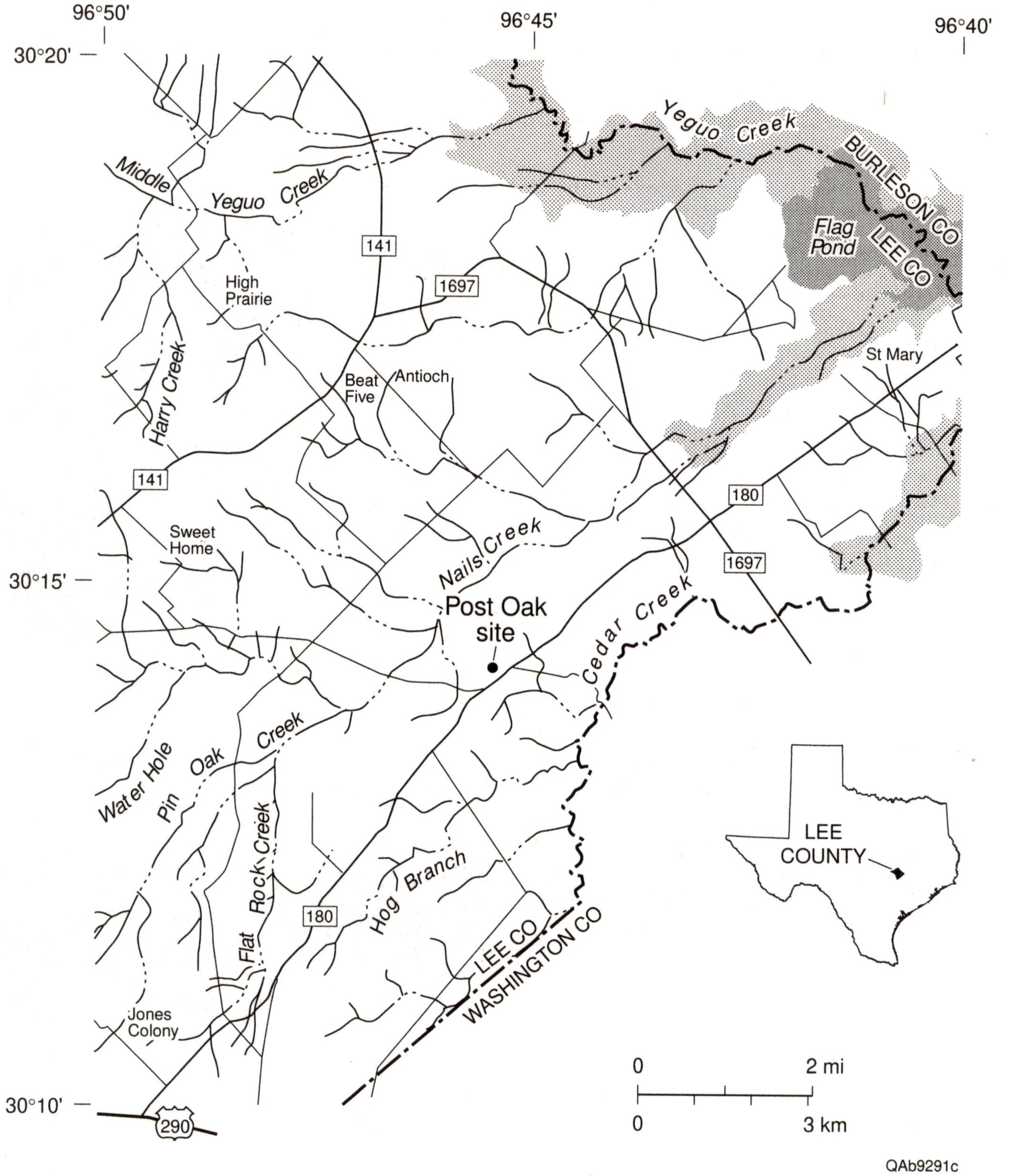


Figure 2.1. Location of the Post Oak site, Lee County, Texas.

The quarry-fill material was inspected by BEG personnel and drill-mud-type material was noted below about 2 inches. Zones of tarlike material were also observed. There was no evidence of oil seepage anywhere outside the quarry. The pit walls were heavily vegetated by grasses and shrubs, and grasses and cattails were noted in the pit. Approximately two-thirds of the pit contained water of an unknown depth. The edges of the pit had a variable area of black, tarlike material, which formed a crust over the drill mud.

2.2 Site Geology

The disposal operations at the Post Oak site involved an abandoned rock quarry in the Eocene Wellborn Formation of the Jackson Group. The well-cemented sandstone of the Wellborn Formation was used historically as local building stone. Rock from Wellborn quarries was used in construction of the Galveston seawall shortly after 1900 (Harris, 1941). Regionally the Wellborn, 95 to 150 ft thick, dips east-southeast at about 90 ft/mi (Harris, 1941; Shelby, 1965; Thompson, 1966; Proctor and others, 1974). The upper Carlos sandstone member is composed of medium-grained, locally silica-cemented quartz sandstone. Clay containing gray sandstone lenses and lignitic chocolate-colored sandstone beds are the other lithologies in the Wellborn Formation. Harris (1941) documented a section of alternating quartzitic sandstone and friable sand having bentonitic clay at lower intervals. Measured sections along strike from the Post Oak site show complex changes in sandstone thickness and facies relationships and cementation (Shelby, 1965). The Post Oak quarry was excavated in a north-east-trending (strike-oriented) cuesta that defines the outcrop of well-cemented sandstone. Nails Creek flows on the north side of the cuesta. A down-to-coast normal fault probably associated with the Mexia–Talco Fault system that juxtaposes Manning Formation clay and sandstone with the Wellborn Formation is mapped near the site (Proctor and others, 1974). The fault's position with respect to the quarry has not been determined.

Soils in the area are mapped as the Singleton–Burlwash–Shiro assemblage (TNRCC, 1997). These soils are shallow (20 inches thick) and consist of well-drained, loamy fine sand and fine sandy loam.

Oil and gas production in the area is from Giddings field in the Austin–Buda Fractured Chalk trend. Field discovery was in 1960, and production is from depths of 7,500 ft (Galloway and others, 1983).

2.3 Site Hydrology

2.3.1 Surface Water

There is no naturally occurring surface water body on the property; the nearest flowing surface water is a tributary of Nails Creek, which lies approximately .5 mi to the northwest and flows to the northeast toward Lake Somerville (fig. 2.1). The site is on a ridge top that runs southwest to northeast and functions as a drainage divide. This ridge decreases in elevation to the south. A small stream and stock tank are southwest of the site. The site is listed as an upland (nonwetland) on the wetland inventory map (U.S. Department of the Interior, 1992).

The onsite quarry contains variable quantities of water, depending on the season, most likely from rainfall and run-on from the land northwest of the pit. Seepage of water is most likely slowed by the disposed drill mud in the pit, which plugs drainage fractures in the sandstone. Another adjacent quarry pit containing no disposed wastes also contains no water.

2.3.3 Ground Water

The Wellborn Formation, part of the Jackson Group in Lee County, is considered an aquifer unit capable of yielding small to moderate amounts of water for domestic and stock use. The units above and below, stratigraphically, are not known to be aquifers (Thompson, 1966). The water rapidly becomes more mineralized downdip in the Wellborn. Depth to ground water is about 30 ft at the site and, thus, there is a significant unsaturated thickness beneath the quarry base. Some amount of seepage of rainfall and runoff in the pit probably reaches the water table beneath the site.

Regional (large-scale) ground-water flow is downdip, toward the southeast, in the aquifer units in the area (Thompson, 1966). Intermediate-scale flow will be influenced by the nearby creeks, to which ground water is discharged, and Lake Somerville, imparting a northeasterly component to flow (Toth, 1963; Freeze and Witherspoon, 1967). On a smaller scale immediately adjacent to the site, however, the flow direction can be both to the northwest, toward Nails Creek, and toward Yegua Creek to the southeast because the site is located at the top of a drainage divide. Because the site is situated on the outcrop of the Wellborn sandstone, the primary source of flow is percolation of recharging precipitation downward to the water table (Thompson, 1966). Flow patterns near the site are thus complex and variable with depth and horizontal distance from the site.

Historically wells near the site have produced from the Jackson and underlying Yegua Groups (Thompson, 1966). The major underlying aquifer unit used for municipal water supply, the Sparta sand, is found at depths greater than 1,200 ft below surface in the site area. A number of wells drilled for oil-field water supply in the area are screened from about 400 to 460 ft below land surface. Many wells in this part of the county are drilled to several hundred feet below ground surface (Thompson, 1966). Excess iron and sulfate concentrations in the water are a problem for local drinking-water quality. According to Mr. Robert Placke, a board member of the Ledbetter Water Supply Company, the residences to the north and south of the site, and the church, are supplied by the Ledbetter company and do not use well water for drinking (personal communication, July 15, 1997). The Ledbetter supply wells are located about 6 mi south of the site, south of State Route 290. Those wells are about 90 ft deep.

2.4 Site History

A complaint regarding unauthorized dumping of oil-field wastes at the site was sent to the RRC by Wickliff and Hall on behalf of their client, the property owner, Mr. Lewis Smith III on October 24, 1995. Mr. Smith III had also complained to the County Sheriff on January 13, 1994, about unauthorized dumping at the site. Mr. Smith's father acquired the property in 1972, and Mr. Smith III acquired the property from him in 1988. The property is subject to an oil and gas lease held by the Exxon Company, USA. No one resides on the property, and the property was never permitted for disposal activities by the RRC. Some dumping of salt water may have occurred at the site during the 1970's and 1980's (Wickliff and Hall, 1995). Unauthorized dumping of drilling mud and oily materials occurred on the property at an unknown time after Mr. Smith III acquired the property (Wickliff and Hall, 1995). Reports by the RRC dated August 31, 1993, indicate that the pit was "heavily oil saturated" on its banks. RRC staff sampled pit fluid samples and reported the results to Guy Grossman, RRC District 3 Director, on May 26, 1994. Chloride values of 342 and 537 mg/L were reported. Four pit sludge samples were also analyzed and reported on December 19, 1994. TPH values in the sludge varied from less than 1 percent to 49 percent. Chloride levels varied from 20 to 765 mg/L in the sludge extracts (1:1). TCLP metals results were generally below detection limits, with the exception of barium, which was detected in the extract between 0.99 and 1.4 mg/L. According to RRC files, Exxon reported to the RRC on March 11, 1994, that the site was indeed adjacent to an Exxon lease, but that Exxon had never used the site for dumping. Exxon also noted recent dumping activities evidenced by oily material on the pit sides, according to an RRC file document.

A letter report of a Phase II investigation at the site was made by Malcolm Pirnie Inc. to Mr. Lewis Smith III on August 25, 1994. Four soil samples and a composite "crust" sample were analyzed. These data were provided to the RRC by Wickliff and Hall on January 30, 1996. Four of the five waste/sediment samples yielded measurable values of total petroleum hydrocarbons (TPH, method 418.1: 180-10,000 mg/kg), and one yielded measurable chlorides (880 mg/kg). A composite sample of the oil waste yielded TPH of 390,000 mg/kg, chloride of 130 mg/kg, acetone of 360 mg/kg, and xylenes of 33 mg/kg. RCRA metals barium, chromium, and lead (1,770, 10, and 110 mg/kg, respectively). No volatile (VOC) or semivolatile organic carbon compounds (SVOC) or chlorinated pesticides/PCB's were reported above detection limits in the composite waste sample.

3.0 METHODOLOGY

3.1 Geophysics

3.1.1 Surface Geophysics

Electromagnetic induction (EM) line surveys were used to delineate areas of potential salt contamination in soils surrounding the waste-disposal area and to determine lateral and vertical trends in conductivity related to salt water in subsurface soils and ground water. We ran survey lines at coil separations of 10, 20, and 40 m (32.8, 65.6, and 131.2 ft) between the transmitter and receiver coils and two coil orientations (horizontal and vertical dipole) using the Geonics EM 34-3 meter. The effective penetration depth was 6 to 25 m (19.7 to 82 ft) for the horizontal dipole orientation and 12 to 50 m (39.4 to 164 ft) for the vertical dipole orientation. Station spacing was 10 m (32.8 ft) for each of the coil separations.

Conductivity values represent "bulk" conductivities, or an average conductivity of the soil volume beneath the transmitter and receiver coils, and are plotted on profiles and on maps at the midpoint between the transmitter and receiver coils. Values obtained from the horizontal dipole orientation are weighted by the conductivity of the uppermost third of the exploration depth. The vertical dipole orientation has a greater exploration depth, and the values are weighted by the conductivity of the middle third of the exploration depth. Inferences about potential leakage from the waste-disposal area and transport in ground water can be made from any detected plume geometry and hydraulic gradient and are discussed later (section 4.1). Soil and ground-water sampling data (sections 4.3 and 4.4), as well as borehole geophysical data (section 3.1.2), were used to confirm results of the survey.

3.1.2 Borehole Geophysics

The Geonics EM 39 borehole logging tool was used to measure apparent ground conductivity surrounding the monitoring-well boreholes and a single borehole placed on the berm near the center of the site area. This instrument detects changes in apparent ground conductivity related to lithology changes (for example, clay versus sand), as well as changes due to salt contamination. It functions similarly to the EM 34-3, except that the transmitter and receiver are contained in a single probe for down-hole use. Measurements are insensitive to the presence of PVC borehole casings, sand pack, and grout. The monitoring wells were located so that the EM 39 logs could be closely correlated with the surface EM 34 readings. Results are shown and discussed in section 4.1.

3.2 Global Positioning System and Location Survey

Global positioning survey (GPS) data, compass bearing and distance, and aerial photography data were combined to generate preliminary maps for the Post Oak site. Positional data were organized, evaluated for accuracy, and then transferred to ArcView Geographic Information System (GIS) software. A GIS data base was then developed for the site. Computer-scanned vertical aerial photography of each site was georeferenced and mathematically corrected for distortion. These images were then imported into a layer in the GIS. The photographs, serving as a backdrop to the site maps, also allowed the on-screen digitizing of features not measured in the field, such as roads and buildings. The property boundaries from the plat map were added electronically to the GIS files. These plat data were not field checked and are provided for information only.

A total survey station was used to survey in the locations of the soil borings during sampling. The total station produces complete x, y, and z coordinates for each surveyed sample point relative to a base station. The base station was then included in the GIS and the surveyed locations subsequently added to the GIS.

3.3 Sampling Methods

3.3.1 Probing/Hand Coring

The surface of the waste-disposal area within the quarry walls was divided into 15 100- by 100-ft grid spaces, and samples were extracted from each grid point. Sample locations are shown in figure 3.1. A graduated steel probe was used to measure the penetrable thickness of the waste materials and the thickness of any water at each sampling point. We extracted continuous cores from the surface to the base of the waste material using a clear PVC piston (suction) corer. Each sample was extruded onto plastic sheeting, logged, and photographed. Each core was scanned by a NORM scintillator for radiation above the background level of 9 μR/hr. Cores were composited across the full core length of 7 ft or less. No natural soil materials were obtained from beneath the waste-disposal area. Each sample was composited in a stainless steel bowl, placed in precleaned glass containers, and shipped on ice at 4°C. All samples were analyzed for TPH, chloride, electrical conductance (EC), and moisture. Selected samples were analyzed for RCRA 8 metals. One sample from the center of the waste-disposal area was selected for analysis of total organic halogens (TOX), semivolatile polynuclear aromatic hydrocarbons (PAH's), volatile organic compounds (VOC's), pesticides/PCB's, and toxicity characteristic leaching procedure analytes (TCLP) including VOC's, semivolatile organic compounds (SVOC's), RCRA 8 metals, and reactivity, corrosivity, and ignitability (RCI). TCLP methods are used as an approximation of the leaching effect that might be found in a landfill environment. Another sample was analyzed for landfarm parameters, including potassium, zinc, copper, nickel, total nitrogen, nitrate, ammonia nitrogen, and phosphorous. The sample for VOC's was not composited but was extruded directly into the sample container from the bottom of the sampler (sample interval 4 to 5 ft below surface).

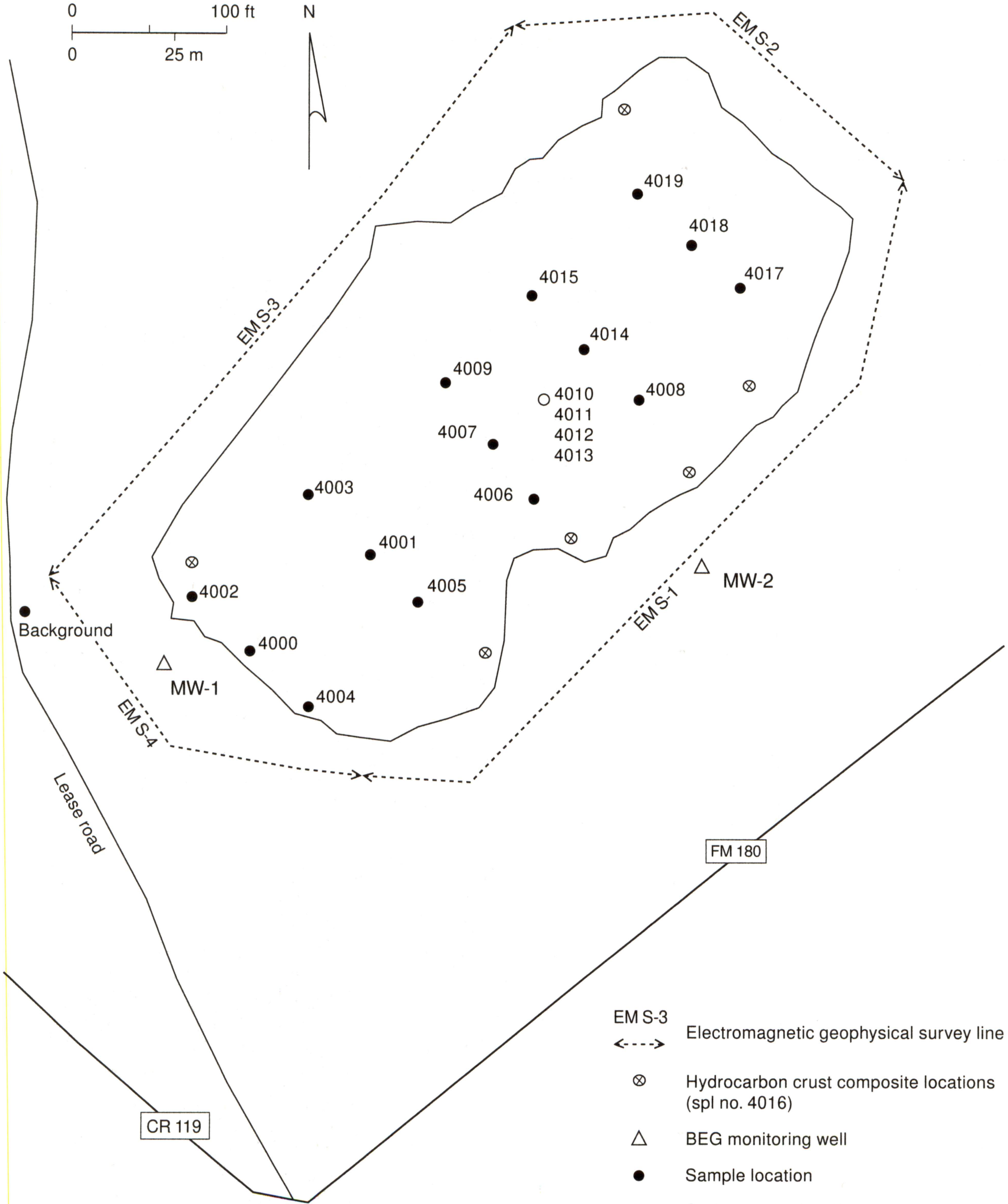


Figure 3.1. Sampling locations and EM 34 survey lines, Post Oak site.

One surface background soil sample was taken on the southwest side of the site. A decontaminated shovel was used to excavate a soil column from 0 to 2 ft in depth. Soil from this column then was composited in a stainless steel bowl, placed in a precleaned glass container, and shipped on ice for analysis of TPH, chloride, EC, and moisture. Samples were analyzed either by Chemsolve or the RRC Surface Mining and Reclamation Laboratory (organic analyses were performed by Chemsolve, and inorganic constituents were analyzed by the RRC lab). All samples were shipped within maximum holding times.

3.3.2 Surface Impoundment Sampling

One sample of the pit water was taken during the waste sampling event. Because the water was approximately 6 inches deep, a bailer was used to extract several sequential water columns from a central location in the pit. Containers were filled in the following order: VOC, TPH, RCRA 8 metals, cations/anions, and field parameters (pH, specific conductance). The sample location is shown in figure 3.1.

3.3.3 Monitoring-Well Installation

Two onsite monitoring wells were installed at the Post Oak site between June 25 and July 1, 1997. MW-1 was located in the most likely upgradient position. MW-2 was placed to intercept a "worst-case" sample of ground water, which might be impacted by pit wastes, and also to give source data for modeling potential impacts to the nearest possible domestic user location. Although a third well was planned for the northwest corner of the site, the drill rig could not access the area because of a fence and rough terrain. The wells were not sited to provide changes along flow paths because of the difficulty in locating this third well and because of the anticipated complex (radial) flow patterns that can occur in surface- and ground-water divide areas. Well locations are shown in figure 3.1. Well-construction details are illustrated in figure 3.2.

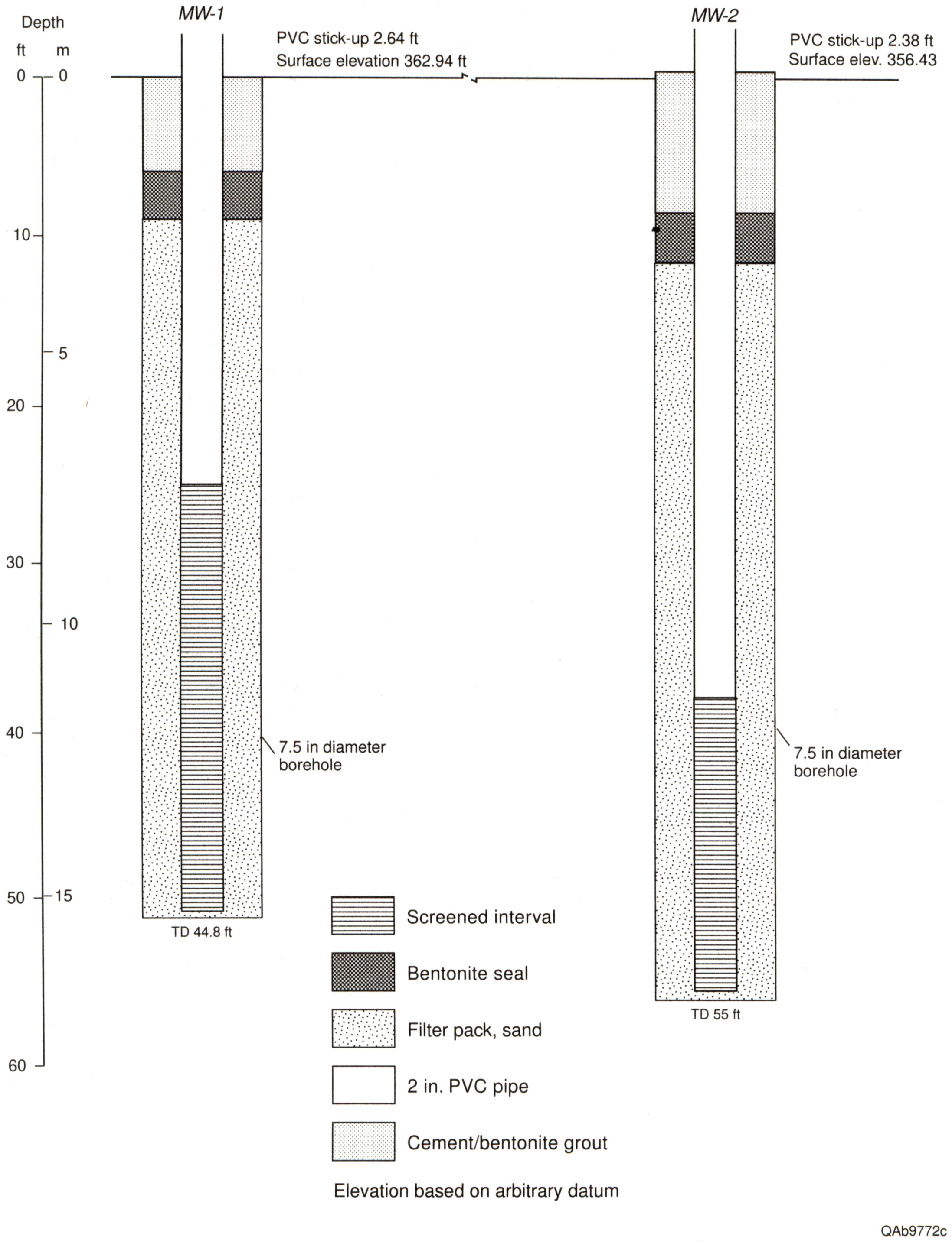


Figure 3.2. Monitoring-well construction data.

We installed the wells using the Bureau's Mobile B-57 drill rig according to mud rotary methods. The drilling mud was a pure bentonite/water slurry; no additional drilling-mud additives were used. Continuous cores were taken having a 2-inch-diameter, 5-ft-long core barrel. The hole was then reamed with a 5 7/8-inch tricone bit. The drill rig and all drilling equipment were decontaminated before drilling and between boreholes by a high-pressure steam cleaner. The sources of water for drilling were drinking water obtained from a Texas Department of Transportation facility and water from Lake Somerville. An EM 39 down-hole log was completed for each well before completion. We constructed monitoring wells of 2-inch I.D. PVC casing that had a 0.010-inch slotted screen, sand-packed them using clean, 20/40 silica sand, and then sealed them with Hole-Plug brand 100-percent bentonite pellets and 2-percent bentonite-cement grout. We completed monitoring wells 1 and 2 using a 4- × 4-inch steel protector casing that had a minimum 2-ft stick-up and a 2- × 2-ft-wide × 4-inch-thick concrete pad. All wells were equipped with a sealing internal cap and a protective padlock. We developed the wells using a centrifugal pump; MW-1 yield was less than 1 gpm, and MW-2 yielded approximately 3 gpm during development. We measured total dissolved solids and specific conductance during development using a calibrated Corning Checkmate modular field instrument. Details of well-completion data are shown in table 3.1. Boring logs and well-completion diagrams are provided in appendix A. The boring logs and monitoring-well sampling results are discussed in sections 4.2 and 4.3.

3.3.4 Domestic-Well Inventory

State well records from the TNRCC and the Texas Water Development Board (TWDB) were searched for wells within a 0.5-mi radius of the site. Because State well records are commonly incomplete or inaccurate, a door-to-door domestic-well inventory for the area surrounding the site was performed with the assistance of Mark Osterman of the RRC District No. 3 Office on June 12, 1997. Each dwelling within a 0.5-mi radius of the site was identified from maps and visual identification. Residents were contacted on June 12, 1997. A request-for-information letter was left

Table 3.1. Ground-water monitoring-well data. All data in feet from ground surface.

Well number	Total depth	Screened interval	Sand-pack interval	Seal interval	Depth to water[2] (7/9/97)	Relative ground surface elevation[1]
MW-1	46.95	24.8–46.95	9.8–46.95	0–6 (grout) 6–9.8 (bentonite)	31.8	362.94
MW-2	52.75	35–52.75	10.5–52.75	0–7.5 (grout) 7.5–10.5 (bentonite)	25.2	356.43

[1] All elevations relative to arbitrary 50-ft datum. Not surveyed into offsite grid.
[2] From top of casing.

for those residents not at home. No domestic wells were identified at any of the residences along FM 180. Residents contacted informed BEG that all residents in the area receive their water supply from the Ledbetter Water Company (Geneva Burns, personal communication, June 12, 1997), which was verified by the Ledbetter management board (section 2.3).

3.3.5 Ground-Water Sampling

Ground water was sampled at the two onsite monitoring wells on August 1, 1997. A Grundfos submersible pump was used to purge the wells further and to conduct hydrologic tests. Ground-water samples were collected at the end of the drawdown periods of the hydrologic tests. At MW-1, well-bore storage was approximately 2.6 gal. We produced about 9 gal (~3 well-bore volumes) in the series of slug withdrawals. At MW-2, more than 10 well-bore volumes of water were removed during the drawdown test prior to collection of water samples. Samples for analysis of ionic constituents and dissolved metals were filtered through an 0.45 μm Geotech high-flow filter attached at a tee to the discharge line. We acidified samples for cations and RCRA 8 metals using 1 mL of 6N HNO_3 in 125-mL polyallomer containers. Sample containers for PAH's and VOC's were filled from a disposable bailer after pumping had ceased to prevent excess volatilization from the pump action. Temperature was measured from the pump outlet stream; pH and alkalinity were measured at the wellhead in an unfiltered sample. Alkalinity was measured by titration of unfiltered samples with a standard dilute (approximately 0.16 N) H_2SO_4 solution by means of a Hach digital titrator. All water samples were shipped on ice at 4°C to the Chemsolve laboratory and were received and analyzed within maximum holding times. Results are shown and discussed in section 4.4.

3.4 Hydrologic Property Testing

Tests to determine transmissivity were conducted at the two monitoring wells in conjunction with collection of water samples for chemical analysis. Results are presented in section 4.4.1.

Because yield was low at MW-1, tests were repeatedly performed as slug tests in which much of the water was instantaneously purged from the well and then water-level recovery was monitored. The recovery periods in the MW-1 slug tests lasted from 23 to 29 min. At MW-2, which had higher yield, the hydrologic test consisted of an unsteady-state test, with water-level changes measured in the pumping well. We measured discharge rate for the 54-min drawdown period using a 5-gal (18.93 L) bucket and stopwatch; discharge was changed early in the test to provide more lift to move produced water over the berm and into the pit. The recovery stage of the test at MW-2 was aborted owing to impending severe weather. We recorded water levels during tests at both wells using a pressure transducer and programmable data logger attached to a laptop computer. Graphical inspection of the test data and information about subsurface stratigraphy indicated that the drawdown and recovery data should be analyzed by type-curve matching following the so-called delayed-yield (Boulton) method for unconfined and semiunconfined aquifers (Kruseman and De Ridder, 1983).

Graphical inspection of the test data at MW-1 showed that the recovery rate was less than predicted by the Theis equation. Information about subsurface stratigraphy and hydrologic setting at the Post Oak site suggests that the delayed water-table response is more likely the result of delayed gravity drainage than leakage into a confined aquifer. Accordingly, we analyzed recovery data by comparing water-level changes to the Boulton delayed-yield-type curves (Kruseman and De Ridder, 1983). Transmissivity was estimated from specific capacity because the pumping rate was not constant for the test at MW-2.

4.0 RESULTS

4.1 Geophysical Survey

Four surface geophysical survey lines were used to collect data at the site. Figure 3.1 shows the locations of these lines. Data for the 20- and 40-m coil spacings of the horizontal and vertical dipoles are shown in figures 4.1 and 4.2. Results from the surface geophysics were used to help

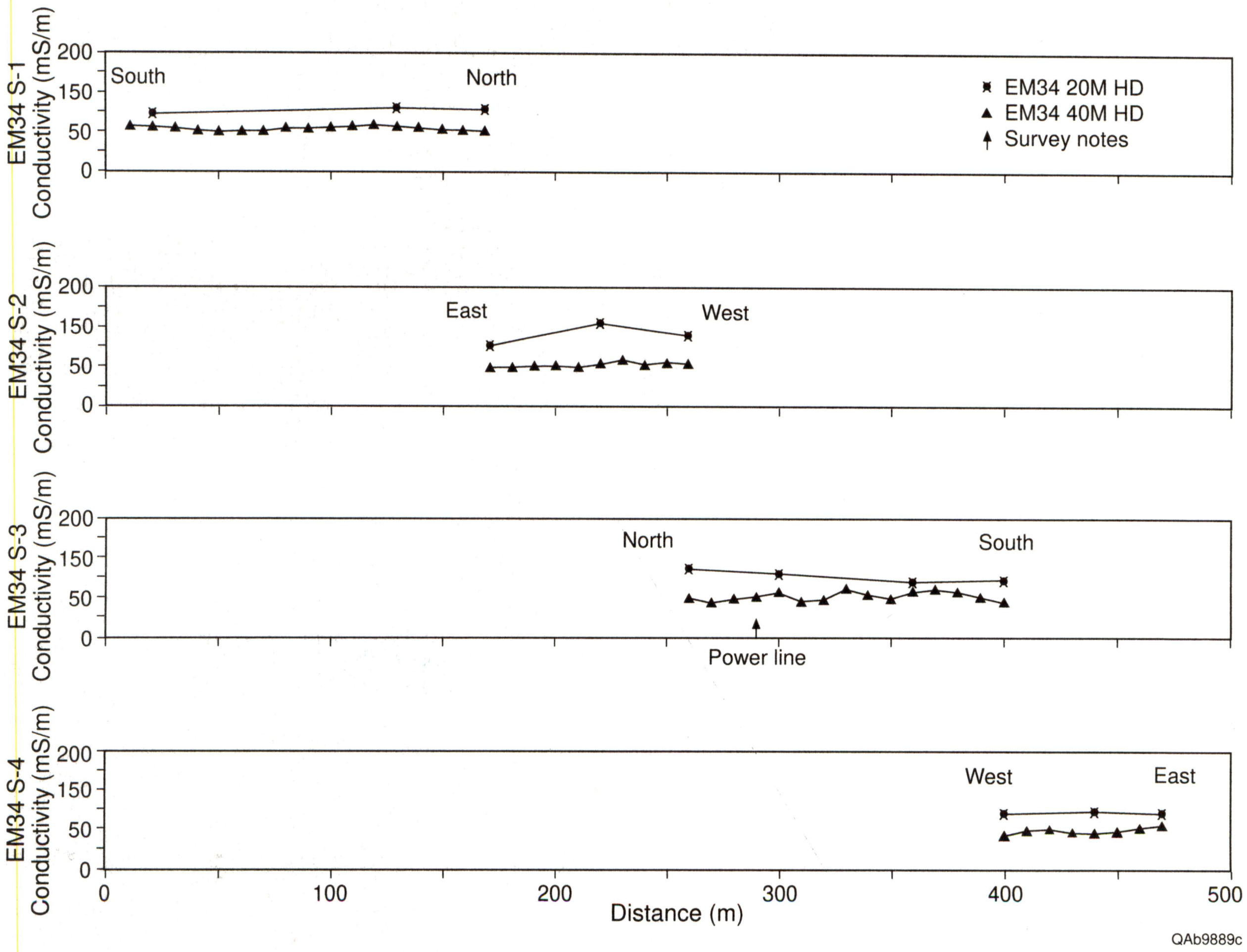


Figure 4.1. EM 34-3 electromagnetic geophysical survey data, horizontal dipole.

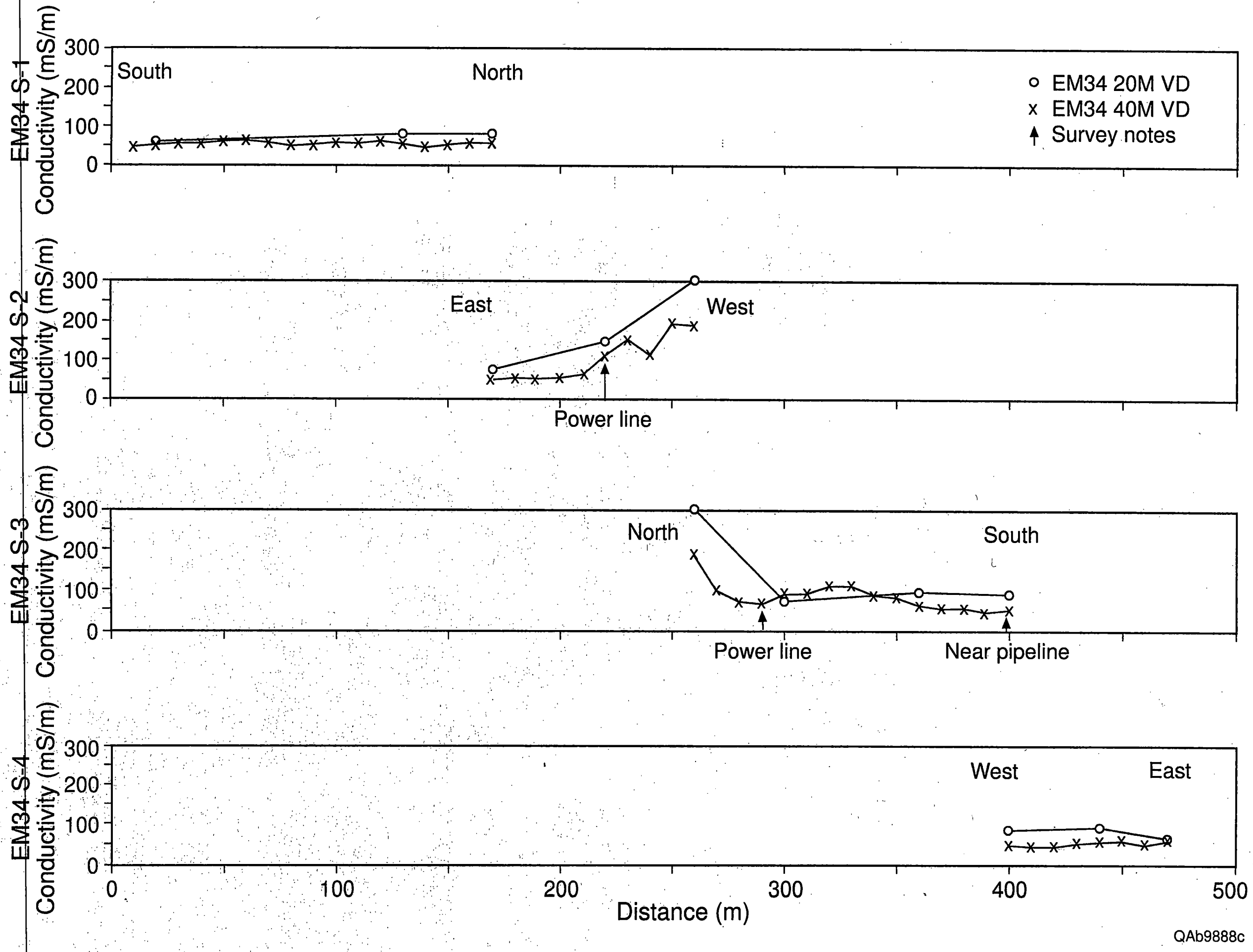


Figure 4.2. EM 34-3 electromagnetic geophysical survey data, vertical dipole.

locate monitoring well locations and to determine whether chloride impacts had spread outside of the pit area. Downhole geophysical logs from these locations (fig. 4.3) were then compared with chloride analyses to verify the surface data.

Because the horizontal dipole data tend to be weighted toward the surface, they were most indicative of the characteristics of the shallow subsurface to a depth of about 80 ft. All of the geophysical lines indicated low conductivities at all depths (<100 mS/m). Conductivities were slightly higher at depth, as shown by the comparison between the 20- and 40-m spacing lines. This comparison indicates the effects of lower conductivity water or lower water content in the unsaturated zone versus higher conductivities and wetter conditions in the saturated zone. Lithologies in the saturated zone are more clay-rich, which can produce higher conductivity values as well. All values for both lines are within normal ranges for soil conductivities. Two slightly elevated zones were noted on the east- to north-edge transect (fig. 4.1). This elevation is likely due to the presence of a power line and a fence near that transect. The power line will affect the 40-m vertical dipole data most strongly.

Vertical EM-39 borehole logs are shown in figure 4.3. The log from MW-2 shows four zones of increased conductivity. The first zone is at 0 to 1 m depth (elevation 356.4 to 352.9 ft) and corresponds to clayey surface soils. The second zone is at 7.0 to 9.2 m depth (elevation 333.4 to 326.3 ft) and corresponds to a claystone or clay-rich zone in the boring log. The third zone is at 9.5 to 12.0 m (elevation 326.3 to 317.1 ft) and corresponds to a lignitic and possibly clay-rich zone. The fourth zone is at 12.3 to 14.3 m (elevation 318 to 310 ft) and corresponds to a zone containing lignite and clay. The log from MW-1 is similar but shows only the upper three of these zones because it is a shallower well. All of these zones are expected to have somewhat increased natural conductivities, and the maximum values from MW-1 are within normal ranges for these materials (up to 160 mS/m) and consistent with the EM 34 data for that area. The lower two zones in MW-2 showed conductivities that were higher than expected and somewhat inconsistent with the EM-34 results.

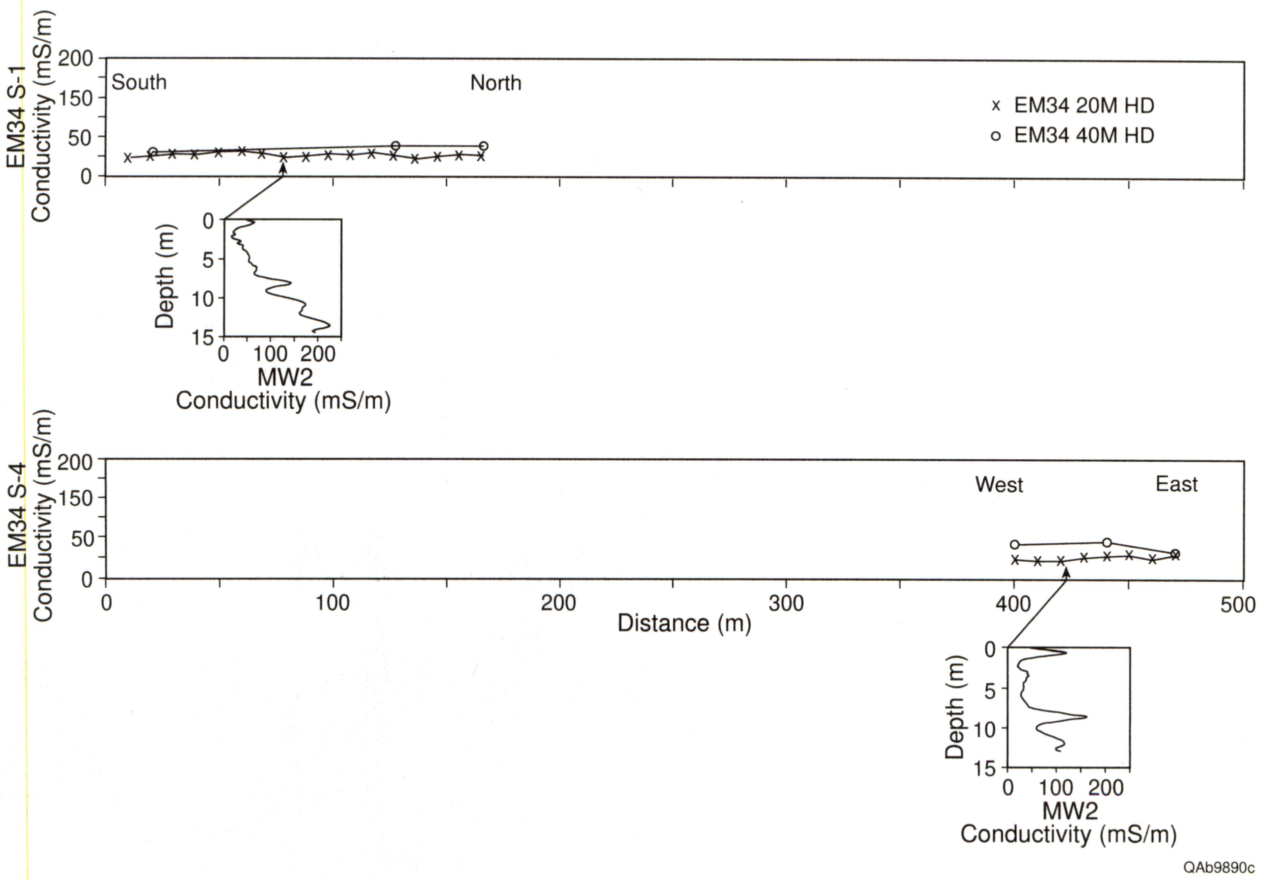


Figure 4.3. EM 34-3 and EM 39 combined electromagnetic geophysical survey data.

To further investigate the elevated EM 39 readings at MW-2, we constructed a graph of specific conductance versus cumulative volume pumped during development for each well (fig. 4.4). Values for water removed during early development, which was intended to remove fluids introduced by drilling, are not shown on this graph. The values for MW-2 initially were low but then increased substantially with continued pumping. A petroleumlike odor was also noted during the pumping at MW-2. The values for MW-1 tended to remain stable and similar to water sampled in the pit, which is also similar in concentration to a typical surface water. No odors were noted during this pumping. Changes for MW-1 water at higher volumes were not determined because of low well yield.

We interpret these results to indicate that some leaching or percolation of elevated-conductivity water has occurred beneath the pit. Expansion of the cone of depression at MW-2 drew some of this water into the well. Other sources, such as current or former oil wells in the area, may also have influence. These conductivity values are in excess of the expected conductivities of shallow ground waters in the region (Thompson, 1966), where the base of the fresh- to saline-water transition is at about 2,200 ft below msl. The EM-34 data show that the zone of elevated conductivity has not migrated laterally from beneath the pit area within the upper 80 ft. These data also imply that present water quality in the pit differs from previous water quality.

4.2 Waste Package

The waste material appears to be oil-contaminated, water-wet drilling mud, composed primarily of bentonite clay. The material is very soft and has little or no compressive strength. The surface material is characterized by a layer of wet or damp, tan, silty clay material having roots and oil and tar encrustation. The surface zone is about 2 to 4 inches deep. Below this zone is gray bentonite clay having black streaks and zones and some evidence of minor amounts of free oil interbedded in the clay.

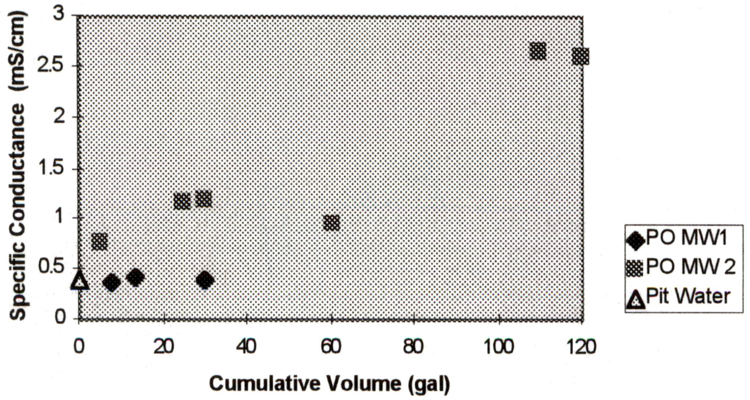


Figure 4.4. Specific conductance versus cumulative gallons pumped in ground water from MW-1 and MW-2 and pit water, July 9, 1997.

The horizontal extent of the waste material is limited by the walls of the quarry and a berm on the north and east sides of the disposal area (fig. 3.1). Figure 4.5 shows the contoured, measured thickness of the wastes. Total waste volume in the bermed disposal area was calculated to be 20,500 yd^3. Total pit-fluid volume was estimated to be about 6,000 bbl at the time of sampling. This volume varies according to weather conditions, however.

The summary results of chemical analyses of the composite waste samples are shown in table 4.1. Sample numbers corresponding to the sample points are shown in figure 3.1. Most samples were analyzed for TPH, chloride, RCRA 8 metals, and moisture content. Sample number 4007 was also analyzed for TCLP organic and inorganic parameters, pesticides and PCB's, VOC's, PAH's, and TOX. One sample, number 4009, was analyzed for landfarm parameters. These data are shown in table 4.2. One composite oil crust sample, number 4016, was analyzed for VOC's. Water samples numbered 4011, 4012, and 4013 from the middle of the pond area were analyzed for TPH, chloride, VOC's, and RCRA 8 metals. These data are also shown in table 4.1. Copies of the full analytical data reports are provided in appendix B. Although all core samples were scanned for the presence of NORM, no radiation was detected above background levels of 9 μR/hr.

The presence and quantity of TPH in the waste material are important factors for remediation purposes. These values, although not compound-specific, indicate the potential presence of petroleum-related volatile and semivolatile petroleum components. In past cases (personal communication, Jill Hybner, RRC, 1997), the RRC has applied maximum values of 1 to 5 percent TPH as a requisite for cleanup. Guidance from TNRCC suggests a maximum level of 1,500 mg/kg (0.15 percent) TPH in soil for municipal solid-waste disposal purposes (TNRCC, 1996). The maximum level of TPH detected in Post Oak waste composites was 1,000 mg/kg (0.1 percent), and the mean was 0.096 percent (standard deviation (s): ± 0.097 percent, 15 samples). TPH concentrations from the composite subsurface samples are shown in figure 4.6. The water sample contained 0.54 mg/L TPH, typical for natural waters (Thurman, 1985).

The presence of chloride is expected in oil-field wastes containing brines. Chloride can restrict soil biodegradation processes, harm vegetation, and degrade surface water and ground water via

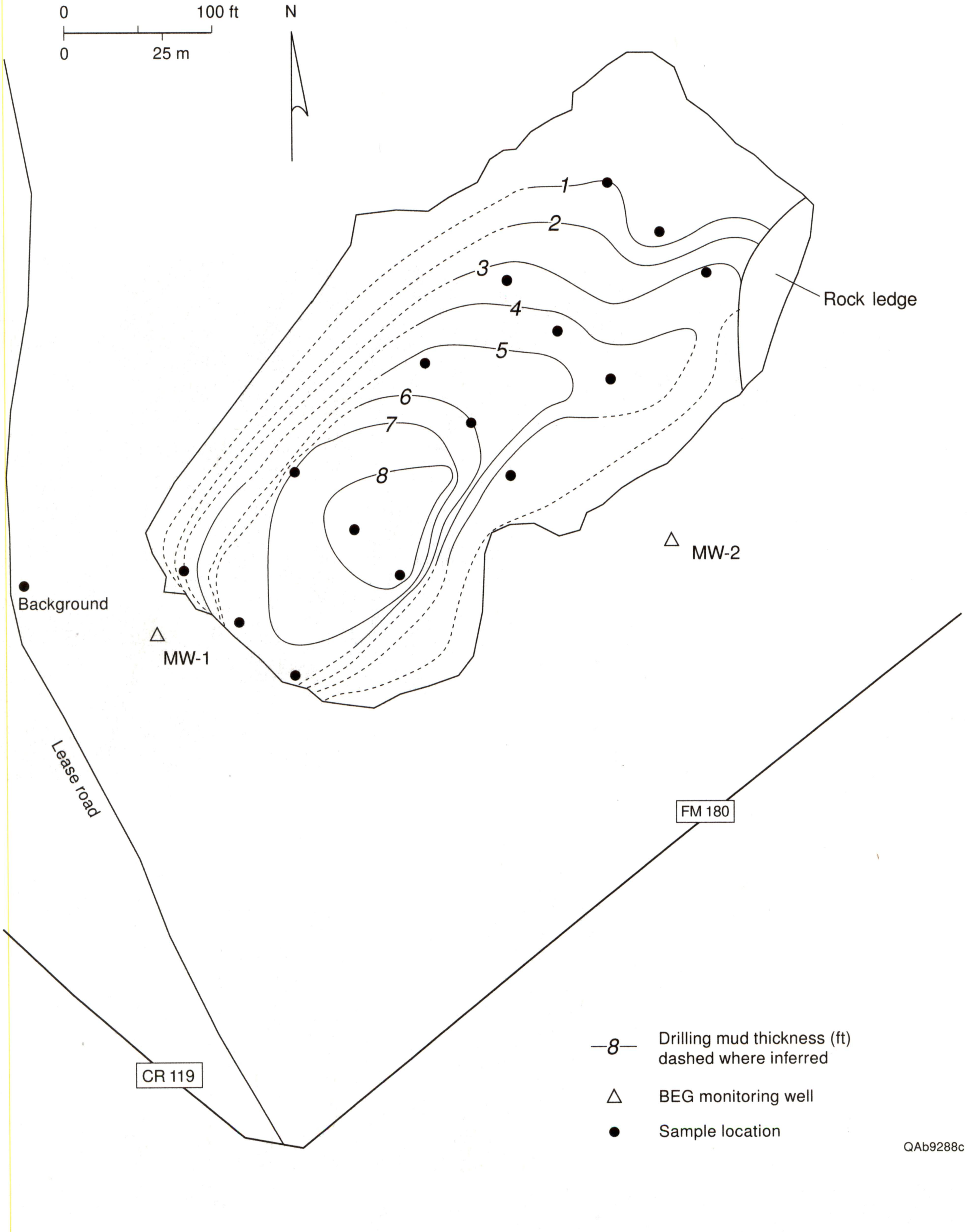


Figure 4.5. Drilling-mud thickness contours in the waste-disposal area.

Table 4.1. Summary of analyses of waste-material samples from Post Oak site. Units are mg/kg, except where shown.

Location	Regulatory or guidance limit[1, 2]	Pit 1	Pit 2	Pit 3	Pit 4	Pit 5	Pit 6	Pit 7	Pit 8	Pit 9	Pit 10
Sample number		4000	4001	4002	4003	4004	4005	4006	4007	4009	4008
Arsenic	36	3.8	4.2	4.4	3.6	3	5.7	4	N/A	3.6	3.2
Barium	2000	270	1200	280	760	1100	380	480	N/A	1200	1000
Cadmium	10	0.19	0.3	0.29	0.42	0.15	0.22	0.35	N/A	0.36	0.37
Chromium	100	30	2	18	19	8.5	14	18	N/A	16	10
Lead	30	33	20	35	21	26	27	31	N/A	17	18
Mercury	4	0.056	<0.004	0.012	0.024	0.017	0.039	0.019	N/A	<0.004	0.037
Selenium	20	0.33	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	N/A	<0.1	<0.1
Silver	100	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	N/A	0.1	<0.1
Chloride (mg/kg)	n/a	2200	1400	960	1000	2500	1800	370	470	1700	140
Conductivity (mS/cm)	n/a	7.35	6.01	5.22	5.38	8.52	6.85	3.98	0.188	5.93	3.72
TPH (%)	1%	0.066	0.07	0.068	0.013	0.09	0.028	0.043	0.04	0.1	0.044
Moisture (% dry wt)	n/a	38.9	60.1	67.8	69.9	82.4	108	83.8	N/A	110.5	96.5
pH	n/a	N/A	N/A	N/A	N/A	N/A	N/A	N/A	7.5	N/A	N/A

n/a = not applicable

N/A = not analyzed

[1] Landfarm results for sample number 4009 (mg/kg): ortho-phosphate 328; potassium 328; total organic nitrogen: 610; zinc 61; copper <1; nickel 20; nitrate-N <0.5; ammonia-N 15.1; Kjeldahl-N 15.

[2] Metals limits are for a total analysis. If a total analysis exceeds the limits listed, then TCLP must be performed (TNRCC, 1996). Total limits are for MSW landfill disposal.

Note: all samples analyzed by Chemsolve.

Table 4.1. continued.

Location Sample number	Regulatory or guidance limit[1,2]	Pit 11 4014	Pit 12 4015	Pit 13 4017	Pit 14 4018	Pit 15 4019	Pit Water[3] 4012 (mg/L)	Oil material composite 4016
Arsenic	36	4.1	1.8	2.6	2.4	2.4	<0.005	3.1
Barium	2000	940	1200	660	1900	2300	0.61	840
Cadmium	10	0.41	0.17	0.23	<0.1	0.21	<0.005	0.26
Chromium	100	14	4.7	17	9.7	19	<0.005	9.6
Lead	30	14	14	24	20	28	<0.005	190
Mercury	4	0.036	0.025	0.017	0.0065	0.014	0.0009	0.081
Selenium	20	<0.1	<0.1	<0.1	<0.1	<0.1	<0.005	<0.1
Silver	100	<0.1	<0.1	<0.1	<0.1	<0.1	<0.005	<0.1
Chloride (mg/kg)	n/a	820	400	390	61	81	150	N/A
Conductivity (mS/cm)	n/a	4.44	2.95	3.35	3.02	3.41	0.717	N/A
TPH (%)	1%	0.14	0.052	0.091	0.41	0.19	0.54	N/A
Moisture (% dry wt)	n/a	97.8	153.2	100.7	60.5	45.8	n/a	N/A
pH	n/a	N/A	N/A	N/A	N/A	N/A	7.26	N/A

n/a = not applicable
N/A = not analyzed

[1] Landfarm results for sample number 4009 (mg/kg): ortho-phosphate 328; potassium 328; total organic nitrogen: 610; zinc 61; copper <1; nickel 20; nitrate-N <0.5; ammonia-N 15.1; Kjeldahl-N 15.

[2] Metals limits are for a total analysis. If a total analysis exceeds the limits listed, then TCLP must be performed (TNRCC, 1996). Total limits are for MSW landfill disposal.

[3] No guidance/regulatory limits exceeded by pit waters. See table 4.3 for guidance limits.

Note: all samples analyzed by Chemsolve.

Table 4.2. Summary of TCLP, PAH, TOX, and VOC results for waste sample 4007 and water samples 4010 and 4011. Units are as noted (mg/kg or mg/L).

Volatile and semivolatile organic compounds	**Sample no. 4007 Location 8**[1] ***Result***	***Units***	***PQL***	***Method***	***Regulatory guideline or limit***[2]	***Reference***	**Water samples**[1] **4010, 4011** ***Result***	***Units***	***PQL***	***Regulatory guideline or limit***[2]
Naphthalene	0.79	mg/kg	0.25	8260	389	TNRCC[2]	0.011	mg/L	0.005	0.01
Petroleum hydrocarbons	400	mg/kg	10	418.1	1500	TNRCC[2]	0.54	mg/L	0.2	5
TCLP parameters										
TC barium	8.8	mg/L	0.05	6010	100	TNRCC[3]	n/a			
TC cadmium	0.063	mg/L	0.005	6010	1	TNRCC[3]	n/a			
TC chromium	0.037	mg/L	0.005	6010	5	TNRCC[3]	n/a			
TC lead	0.19	mg/L	0.005	6010	5	TNRCC[3]	n/a			
TC silver	0.063	mg/L	0.005	6010	5	TNRCC[3]	n/a			
Reactivity cyanide	<10	mg/kg	10	7.3.3.1	10	EPA[4]	n/a			
Reactivity sulfide	<10	mg/kg	10	7.3.3.2	10	EPA[4]	n/a			
Ignitability	>150	° F/kg	75	1010	<140	EPA[4]	n/a			
pH	7.5	/kg		9045	<2 or >12	EPA[4]	n/a			
Total organic halogens	2.8	mg/kg	1	9020	50	TNRCC	n/a			

[1] Shaded analyzed values are those above regulatory or guidance values.

n/a: not applicable

[2] TNRCC: RG 17 Action Levels for LPST sites, fine-grained soils and water, October 1996.

[3] TNRCC: RG 03 Disposal of special wastes associated with development of oil, gas, and geothermal resources, September 1996.

[4] EPA: 40 CFR Sect. 261.21-24 Subpart C.

Note: all samples analyzed by Chemsolve.

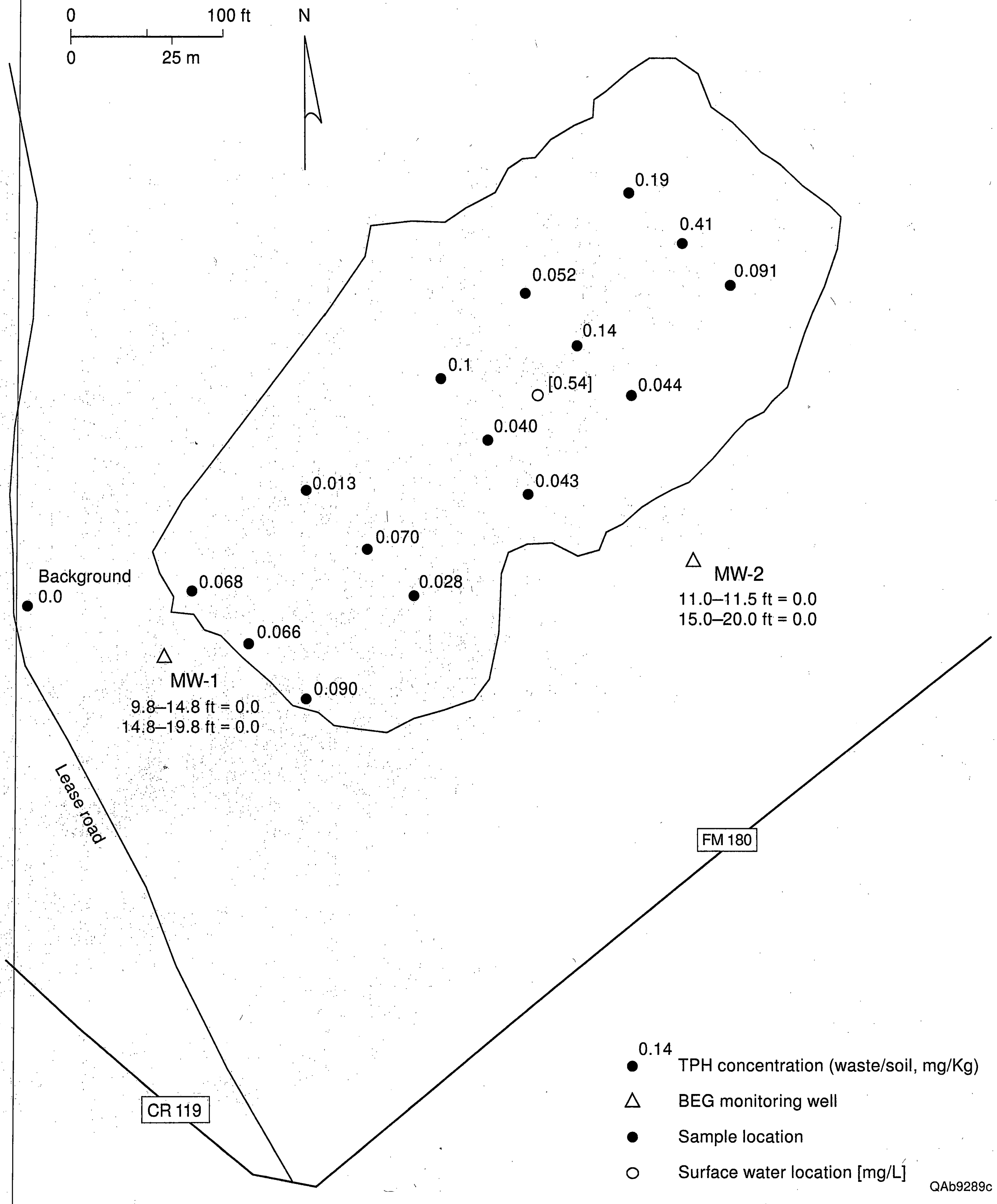


Figure 4.6. TPH concentration data in soils, water, and the waste-disposal area.

leaching and runoff. The maximum chloride concentration in the composite waste samples was 2,500 mg/kg (mean: 953 mg/kg, s: ± 795, 15 samples). Background soil chloride levels were 2.0 mg/kg. Chloride in the water sample was measured at 150 mg/L. The secondary maximum contaminant level (SMCL) for chloride is 250 mg/L. The Texas secondary constituent level is 300 mg/L (30 TAC 290.113). Composite results are shown in figure 4.7. These waste materials exhibit the potential to release chloride to surface and ground waters because the chloride concentrations are significantly higher than natural background soil concentrations (table 4.3).

Composite waste samples were submitted for RCRA 8 metals analysis. The metals arsenic, barium, cadmium, chromium, lead, mercury, selenium, and silver were detected in one or more samples. Results are listed in table 4.1. In one of 14 samples, barium was noted to exceed the TNRCC's total limit (TNRCC, 1996), which is used to indicate the need for follow-up TCLP analysis prior to landfill disposal. Lead exceeded the limit in 2 of 14 waste samples. In the oil-crust sample, only lead was noted to exceed the total limit. No limits were exceeded for metals in the water sample. TCLP metals-analysis results from the wastes are discussed later.

Volatile and semivolatile organic compounds were analyzed from one sample location (number 4007) randomly selected from the disposal area (fig. 3.1) and from water samples 4010 and 4011. Table 4.2 shows the results obtained from these samples. Only naphthalene was detected above the method detection limit for sample 4007 (0.79 mg/kg). The naphthalene in the waste falls well below the LPST soil action level of 389 mg/kg for fine-grained soils (TNRCC, 1996). Naphthalene was detected in the pit water at 0.011 mg/L. The naphthalene in the water is only slightly above the LPST water action level of 0.010 mg/L.

The waste-sample number 4007 discussed earlier was also analyzed for pesticides and Aroclor PCB's. Results are provided in appendix B. None of these analyzed compounds was measured above method detection limits. Total organic halogen (TOX) analysis on this sample produced a value of 2.8 mg/kg (table 4.2), which was well below the regulatory limit of 50 mg/kg for disposal as municipal solid waste. The pH noted for the sample was near neutral, at 7.5 pH units. Summary results of the TCLP extraction values for the sample are listed also (table 4.2). No

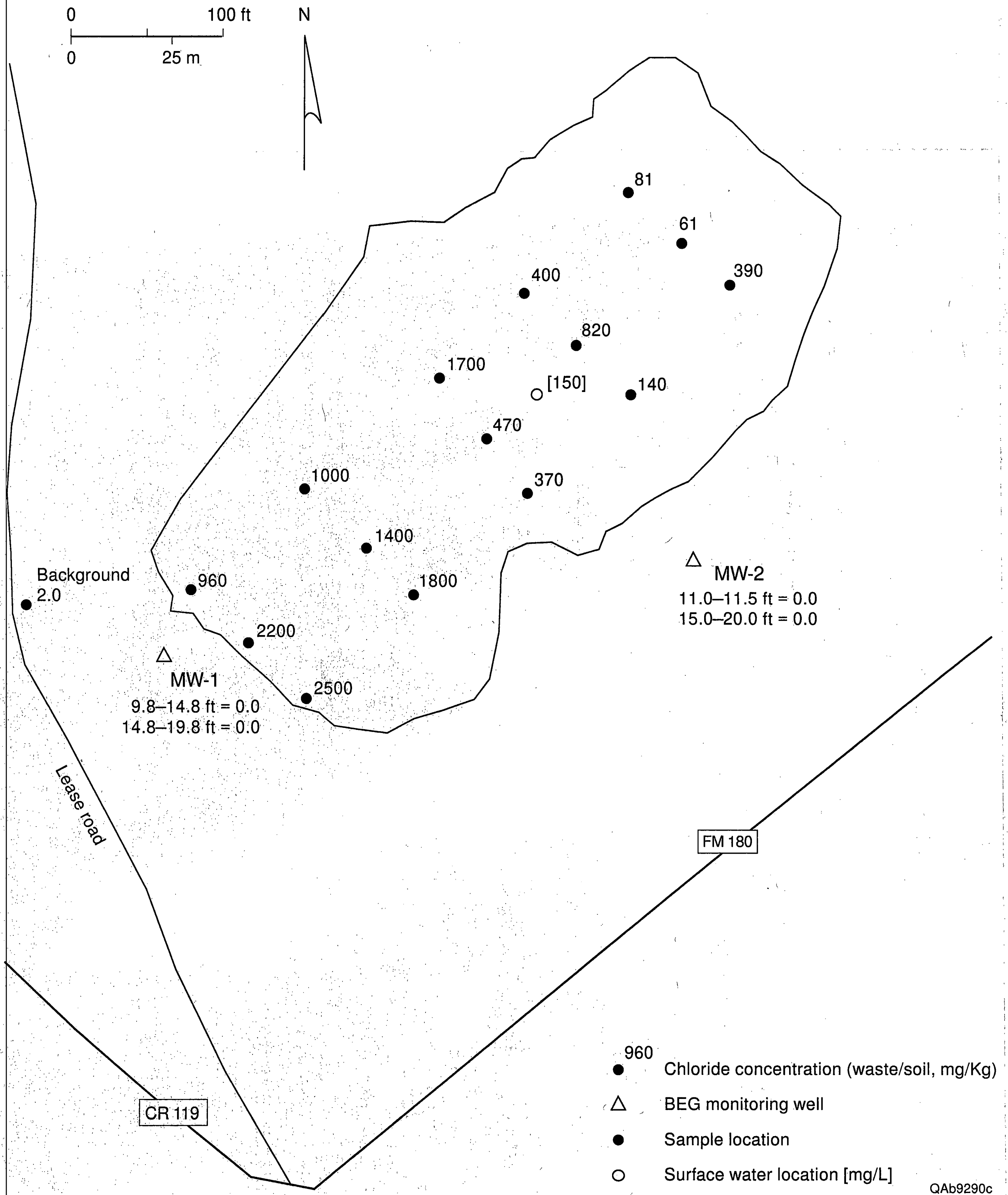


Figure 4.7. Chloride concentration data in soils, water, and the waste-disposal area.

Table 4.3. Summary of soil-sample analyses from the Post Oak site. Units are mg/kg except where noted.

Location	**Background**	**MW-1**	**MW-1**	**MW-2**	**MW-2**	**Regulatory or guidance limit**[1]
Sample number	**4024**	**4020**	**4021**	**4022**	**4023**	
depth range (feet)	**5-5.5**	**9.8-14.8**	**14.8-19.8**	**11-11.5**	**15-20**	
Arsenic	<0.5	N/A	N/A	N/A	N/A	36
Barium	439	N/A	N/A	N/A	N/A	2000
Cadmium	<0.5	N/A	N/A	N/A	N/A	10
Chromium	<0.5	N/A	N/A	N/A	N/A	100
Lead	<0.5	N/A	N/A	N/A	N/A	30
Mercury	<0.1	N/A	N/A	N/A	N/A	4
Selenium	<0.5	N/A	N/A	N/A	N/A	20
Silver	<0.5	N/A	N/A	N/A	N/A	100
Chloride	2	24	17	26	18	n/a
Conductivity (mS/cm)	0.07	N/A	N/A	N/A	N/A	n/a
TPH (%)	0.00	0.0	0.00	0.00	0.00	1%
Oil and grease (%)	0.00	0.01	0.00	0.01	0.00	n/a
Moisture (%)	3.7	N/A	N/A	N/A	N/A	n/a

n/a = not applicable
N/A = not analyzed
[1] TNRCC: RG 03 Disposal of special wastes associated with development of oil, gas, and geothermal resources, September 1996.
Note: all samples analyzed by Chemsolve.

TCLP, VOC's, or SVOC's were detected above method detection limits in the TCLP extract. Detection limits for VOC's were less than TNRCC landfill TCLP requirements. Although barium, cadmium, chromium, and lead were detected above method detection limits, they did not exceed TNRCC TCLP limits (TNRCC, 1996). Some of the barium levels were below those found in the background soil sample, discussed in section 4.3. It should be noted that TCLP leaching results are solely for the purpose of evaluating leaching potential in a landfill environment. Because in situ geochemistry of an individual site can differ markedly from these conditions, so can the likelihood of compounds leaching from in-place soils or wastes. It is likely that the TCLP results are a worst-case scenario of the wastes at the site. In addition, these TCLP results cannot be compared with health-based criteria.

The oil composite sample showed no VOC's, pesticides, or PCB's above method detection limits. Results are provided in appendix B.

In general, the results of the waste-package sampling indicate that the waste material is nonhazardous and that it has relatively low levels of TPH that are below guidance levels and moderate concentrations of chloride that are below levels that might limit biodegradation. TCLP results indicate that the potential for leaching of organic or metal constituents for landfill disposal purposes is low. No NORM was detected at the site.

4.3 Soils

One background soil and four soil samples from the monitoring-well borings were analyzed, the former for TPH, chloride, RCRA 8 metals, EC, and moisture, and the latter for TPH and chloride only. Locations are shown in figures 3.1, 4.6, and 4.8, and results are provided in table 4.3.

The background sample was taken from a location south of the waste-disposal area in an area considered to have had minimal disturbance from site-related or quarrying operations. No TPH was detected above method detection limits in the background sample. In addition, no TPH was

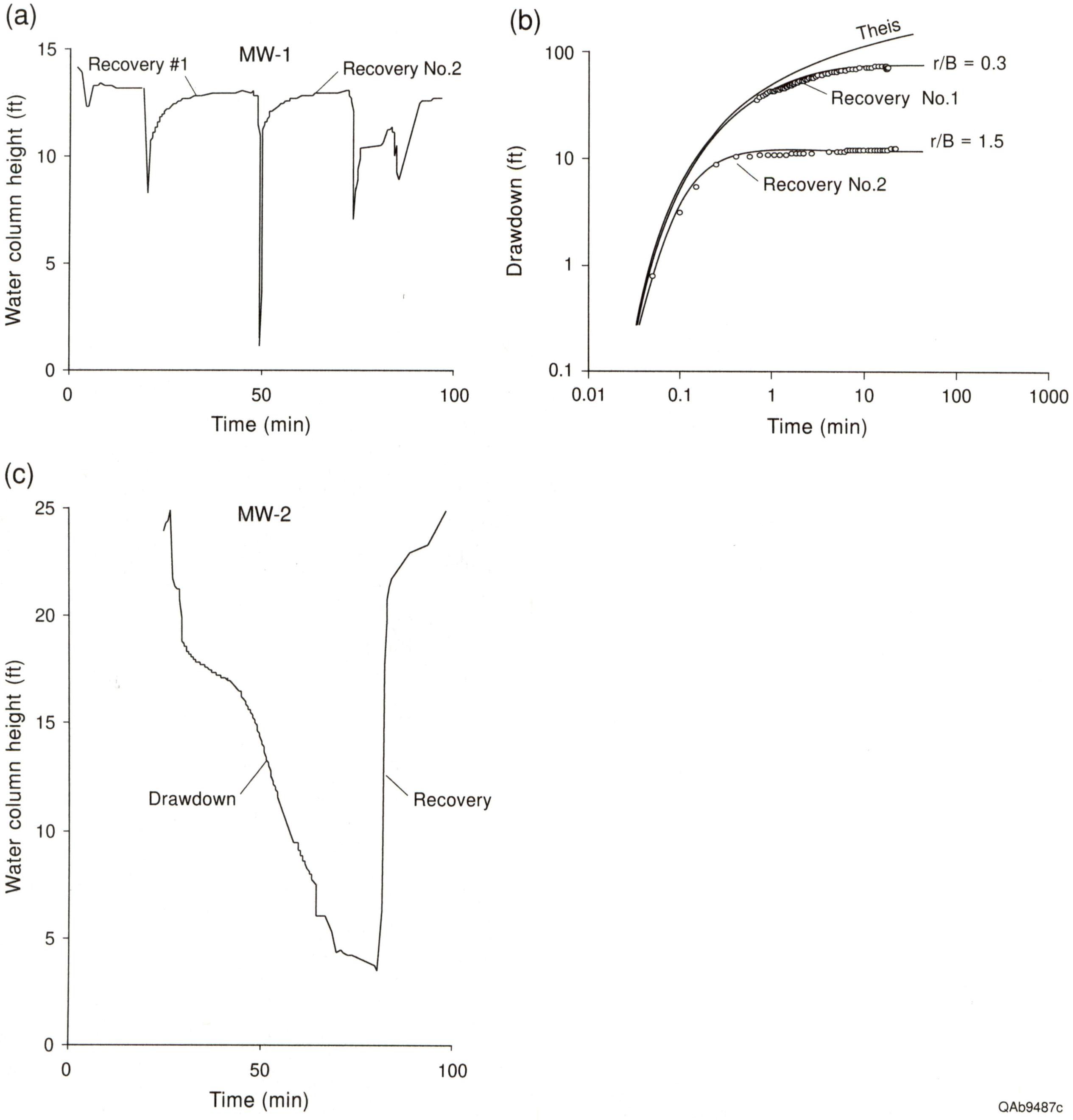


Figure 4.8. Graphical results of drawdown tests.

detected in any of the soil samples from the monitoring-well borings. Although chloride was low in all five of the samples, it was slightly higher in the well borings than in the background. Barium was detected above method detection limits in the background sample, but well below the regulatory limit. In summary, it appears that the site has had minimal impact on soils at depth adjacent to the quarry pit.

4.4 Ground Water

4.4.1 Ground-Water Hydraulic Properties

Depths to water were measured at the site on July 9 and July 30, 1997. Ground-water elevations (hydraulic head) are shown in table 4.4. Judging from the elevations given later, the head in MW-1 is slightly higher (0.2 ft) than that in MW-2. The site is located at the top of a surface-water divide and a topographic high point. Shallow ground-water flow in these locations is largely predicted by topography (Toth, 1963; Freeze and Witherspoon, 1967). Local flow near the site is thus expected to be approximately toward the northeast, toward Lake Somerville. Regional flow in the area of the site is expected to be toward the southeast (Yegua Creek drainage) (Thompson, 1966).

Analysis of water-level recovery in the test at MW-1 and information about subsurface stratigraphy and hydrologic setting suggest that the aquifer material at the Post Oak site is unconfined. Delayed yield from unsaturated zone drainage affected the results of hydraulic tests, with drawdown less than that predicted from the Theis equation (fig. 4.8b).

Transmissivity estimates made by matching drawdown data from the MW-1 test to the delayed-yield type curves ranged from 2 to 32 ft^2/d (geometric mean of 7 ft^2/d) (table 4.5; fig. 4.8). The 16-fold range comes from analysis of two successive recovery tests. Results from the second test are somewhat more reliable, with a better type-curve match over early and late data (recovery no. 2, fig. 4.8b) and a more accurate estimate of pumping rate. A transmissivity of 9 to 15 ft^2/d was derived from specific capacity for the test at MW-2. Transmissivity derived from

Table 4.4. Ground-water elevation data.

	Elevation[1,2]	**Ground-water elevation**[1] **7/9/97**	**Ground-water elevation**[1] **7/30/97**
MW-1	365.58	333.78	333.81
MW-2	358.81	333.61	333.51

[1] All elevations based on arbitrary datum.

[2] Top of PVC casing.

Table 4.5. Hydrologic properties estimated from tests at monitoring wells, July 30, 1997.

Well	Test period	Discharge (ft^3/d)*	r/B value	Specific capacity (ft^2/d)	T^1 (ft^2/d)	T^2 (ft^2/d)	T^3 (ft^2/d)
MW-1	Recovery	818^4	0.2 to 1.5	nd	1.6 to 31.6	nd	nd
MW-2	Drawdown	577	nd	26	nd	15	9

[1] Transmissivity determined from type-curve matching.
[2] Transmissivity determined from specific capacity assuming storativity of 0.01.
[3] Transmissivity determined from specific capacity assuming storativity of 0.1.
[4] Extrapolated from pumping period of less than 1 min.
nd: not determined
*ft^3/d can be converted to gpm by multiplying by 5.2×10^{-3}.

specific capacity can overestimate actual transmissivity where delayed yield is significant. Accordingly, the best estimate of transmissivity applicable to the Post Oak site is taken as 2 ft^2/d from the recovery test.

4.4.2 Onsite Ground Water

The monitoring wells were sampled on July 30, 1997. Well locations are shown in figure 3.1, and summary tables of chemistry results are shown in table 4.6. Detection-limit data and analytical results are provided in appendix B. Onsite monitoring wells were located to provide worst-case data on ground-water impacts at the site, not to evaluate changes along possible flow paths. Potential well locations were restricted by site physical limitations such as fences, berms, and rocks. Furthermore, complex flow patterns were anticipated because of the site's location at the top of a drainage divide.

Only one VOC, naphthalene, was detected above method detection limits and above regulatory guidelines in MW-2. No PAH's were detected above method detection limits in either of the wells (the detection limit for naphthalene in the PAH analysis is higher than for the VOC analysis; it is detectable in both methods). A VOC analysis on the Lake Somerville drilling water indicated no VOC's, including naphthalene, above method detection limits; a TPH analysis indicated a low level of TPH at 0.7 mg/L. This is within the typical range for natural waters (Thurman, 1985); extensive development of the wells was performed to remove any water that may have entered the formation during drilling.

RCRA 8 metals detected in the two wells were barium, cadmium, chromium, and lead. The latter three were measured above regulatory guidelines for drinking water. The detection limit for selenium in the wells was higher than the MCL, but selenium has not been detected in any other media onsite and, thus, is probably not a concern. There were no clear trends, however, in the concentration levels between the two wells.

Table 4.6. Onsite ground-water chemical-analysis summary.

	MW-1 *Result*[1]	MW-2 *Result*[1]	*PQL*	*Method*	*Regulatory guideline or limit*	*Reference*[2,3]
Sample no.	4023	4027				
Naphthalene	<0.005	0.042	0.005	8260	0.010	TNRCC
Sample no.	4020	4024				
Arsenic	<0.005	<0.005	0.005	6010	0.05	EPA-1°MCL
Barium	0.082	0.19	0.005	6010	2.0	EPA-1°MCL
Cadmium	0.031	0.018	0.005	6010	0.005	EPA-1°MCL
Chromium	0.15	0.32	0.005	6010	0.1	EPA-1°MCL
Lead	0.093	0.019	0.005	6010	0.015	EPA-action level
Mercury	<0.0002	<0.0002	0.0002	7470	0.002	EPA-1°MCL
Selenium	<0.1[5]	<0.1[5]	0.1	6010	0.05	EPA-1°MCL
Silver	<0.005	<0.005	0.005	6010	0.1	EPA-2°MCL
Sample no.	4020	4024				
Barium	0.082	0.19	0.0050	6010	2.0	EPA-1°MCL
Calcium	33	72	0.050	6010	n/a	
Magnesium	7.0	12	0.050	6010	n/a	
Potassium	6.1	13	0.050	6010	n/a	
Sodium	110	180	0.050	6010	n/a	
Strontium	0.24	0.88	0.0050	6010	n/a	
Sample no.	4021	4025				
Total alkalinity	275[6]	280	10	310.1	n/a	
Bromide	40	<1	1	300.1	n/a	
Chloride	110	550	0.5	300.1	250	EPA-2°MCL
Sulfate	130	120	0.5	300.1	500	EPA-1°MCL
Ion balance error (%)	-6.2	-22.4				
pH	6.42	6.38			6.5-8.5	EPA-2°MCL
TDS[4]	581	1109				
Specific conductance (mS/cm)[4]	0.7	1.3				

[1] Shaded values are those above guidance or regulatory limit.

[2] EPA drinking-water regulations and health advisories. EPA 822-B-96-002. October 1996.

[3] TNRCC: RG-17, Action levels for LPST sites, October 1996.

[4] Calculated from chemical analysis.

[5] Detection limit above regulatory guideline.

[6] Measured in field.

Note: all samples analyzed by Chemsolve.

Chloride was five times higher in MW-2 than in MW-1. This, and changes in conductivity measured during well development, indicate that MW-2 might be influenced by brackish-to-saline waters from the pit area. Chloride in MW-1, however, is within typical fresh ground-water ranges.

The waste package lies on top of an unconfined sand and sandstone unit and exists well above the static water table. A comparison of inorganic compound concentrations between MW-1 and MW-2 indicates that most compounds were slightly higher in the latter well. However, these differences (particularly, for metals) may fall within statistical ranges for variation in local water quality. The large difference in chloride concentration between the wells indicates that MW-2 is likely influenced by more saline water.

4.4.3 Offsite Ground Water

None of the wells in the area for which we found data are near the site. Most wells in the area are used either for domestic water supplies (WW on fig 2.2), or for oil-field water supply (OW on fig. 2.2). Typical well depths in the area are 300 ft deep or more and are completed in the Yegua or deeper units. Potential confining zones exist between this lower unit and the Wellborn sandstone, which contains the uppermost aquifer. Five ground-water wells were identified at offsite locations during a search of State well records, including TNRCC and TWDB files. Table 4.7 lists the wells identified from this survey and information about the wells. Four of the five wells were part of the data base of plotted wells (wells that have been reported to TNRCC, but for which locations have not been verified in the field). One was part of the data base of located wells (wells for which locations have been verified in the field by Texas Water Development Board personnel). The provided well locations are shown in figure 2.2. We were unable to verify the locations of these wells in the field. The last well listed is an abandoned oil and gas test well that was drilled at the site in the 1950's and is located in the well data base as being adjacent to the Sunnyside church.

Table 4.7. Well-inventory data for located and plotted wells near the Post Oak site.

State well number	Distance from site (ft)	Reported depth (ft)	Reported top of screen depth (ft)	Reported use	Comments
4959503D	1750	490	300	Industrial/oil field	plotted
4959503E	2250	500	200	Domestic	plotted
4959503H	4000	650	260	Industrial/oil field	plotted
4959503K	2000	324	304	Domestic	plotted
4959503C	4000	762	682	Industrial/oil field	plotted
495950301	200	9650	not applicable	Oil and gas test	located-abandoned

5.0 ENVIRONMENTAL ASSESSMENT

This section presents an assessment of potential human health risks that may be associated with the wastes disposed of at the Post Oak site. Information presented here will be used along with other factors, such as cost and feasibility, for selecting the appropriate remediation option for the site. We arrived at this assessment using a software model developed by Groundwater Services, Inc., for the TNRCC Petroleum Storage Tank (PST) Division. The software, based on guidance provided in "Risk-Based Corrective Action for Leaking Storage Tank Sites (RG-36)" (TNRCC, 1994), was selected because of the similarities in constituents between those detected at the site and those found at PST sites.

5.1 Site Summary and Classification

Potentially impacted environmental media include sediments and ground water directly beneath the waste-disposal area. No other soils in the vicinity appear to be impacted. No volatile or dust emissions from the waste materials were considered because the material is typically wet and because no volatile components were measured above detection limits in waste samples.

One important difference between the Post Oak site and a typical leaking PST site is that constituents of concern (COC's) are found in a waste package of disposed drilling mud. Another important difference is that no free petroleum product was found in the ground water or soils at the site, unlike many PST sites. The presence of the drilling mud is likely to increase sorption, decrease permeability, and decrease mobility of petroleum-related constituents in the waste package when compared with typical soil properties.

Current land usage surrounding the site is agricultural, including livestock grazing, and industrial, with an active oil well operating to the north (fig. 2.2) and an active tank battery to the west. There are residences to the east, southeast, and northeast, but these are mostly weekend cottages and not permanent residences (Robert Placke, Ledbetter Water Supply Company, personal communication, July 15, 1997).

There is evidence of occasional exposure of humans to impacted media at the site. Extensive trash dumped in the pit indicates that trespassers visit the area, although it is likely that contact with the pit waste materials is limited. Entrapment in the soft waste material is a potentially acute physical hazard at the site. Water trapped in the pit tends to keep the material quite soft, even in vegetated areas. The site is partly fenced and bermed, but there is nothing to prevent foot access to the pit area.

There is no water-supply well at the site. Known domestic wells used for water supply in the area are described in sections 3.3.4 and 4.4.2. Ground-water usage in the area is primarily for oil-field supply or domestic use, from deeper aquifers (250 ft or deeper). The closest identifiable well is approximately 2,000 ft northeast of the site. The closest potential receptor is a trailer residence approximately 750 ft to the east, directly across County Road 180 from the site.

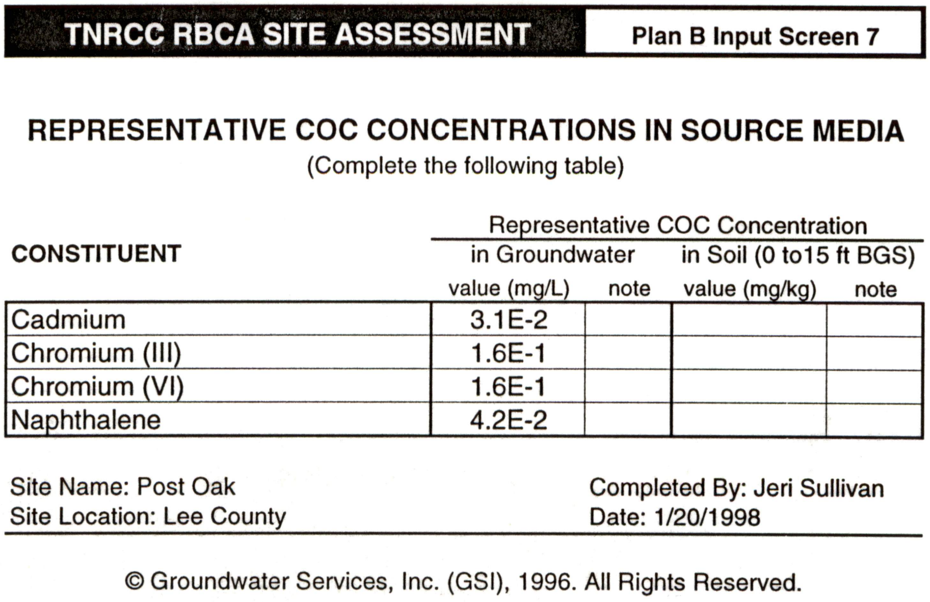
5.2 Constituents of Concern

Constituents of concern (COC's) include those organic and inorganic compounds detected above method detection limits in the ground water and waste materials. These include cadmium, chromium, lead, and naphthalene. Representative concentrations are shown in table 5.1. Physical properties of these constituents are given in appendix C. Background levels of these metals in local ground water, however, have not been determined, either for the shallow ground water (depth of less than 60 ft) or the deeper ground water (depth of more than 100 ft) used in the area but not near the site.

The RBCA assessment software requires a representative concentration for each parameter evaluated. As a conservative estimate, the maximum concentrations detected in the ground water were input as representative concentrations. Soils were not considered because of incomplete pathways, as discussed in section 5.3.

Some COC's require specific approaches outside of the RBCA model. Although lead was detected in onsite wastes and ground water, it was not included in the model because the methods

Table 5.1. Representative concentrations for constituents of concern.



TNRCC RBCA SITE ASSESSMENT | **Plan B Input Screen 7**

REPRESENTATIVE COC CONCENTRATIONS IN SOURCE MEDIA

(Complete the following table)

CONSTITUENT	Representative COC Concentration			
	in Groundwater		in Soil (0 to15 ft BGS)	
	value (mg/L)	note	value (mg/kg)	note
Cadmium	3.1E-2			
Chromium (III)	1.6E-1			
Chromium (VI)	1.6E-1			
Naphthalene	4.2E-2			

Site Name: Post Oak
Site Location: Lee County

Completed By: Jeri Sullivan
Date: 1/20/1998

for assessing lead impact in risk assessments are under development. A comparison of lead concentrations with health-based guidance values is given in section 5.5.

The speciation of chromate in the ground water is not known, and the differences in mobility and toxicity between chromium (VI) and chromium (III) are large. Because of these factors, chromium (VI) was added to the list of ground-water COC's. The highest concentration of chromium in the ground water was divided in half and distributed between chromium (VI) and chromium (III) because the exact distribution between species is not known. This assumption allows calculation of the potential health effects as if part of the chromium concentration is chromium (VI), and as such, is a conservative assumption. Both species may coexist at variable levels, depending on redox and pH conditions in the subsurface.

5.3 Potential Receptors and Migration Pathways

Potential receptors at the site include trespassers who might walk across the site and encounter the waste materials. Potential offsite receptors include persons residing within approximately .5 mi of the site who use ground water as their drinking-water supply. TWDB records list only one deep (324 ft) domestic supply well in this area (see section 4.3), which is 2,000 ft from the site boundary. A door-to-door canvass found no additional wells. Residences along Highway 180 north and south of the site are supplied by a water-supply company having sources more than 6 mi from the site. Pathways for exposure of incidental trespassers to the waste materials are incomplete in that they do not constitute a long-term exposure pathway. Although an acute exposure to the pit materials might occur, such as temporary immersion, it is likely to be a minimal risk, judging from the detected constituents in the wastes. Typical exposure routes, such as dermal contact with dusts, are incomplete because the pit materials are for the most part wet or held in place by vegetation or a surface crust. These also serve to minimize vaporization from the wastes; in any event, VOC concentrations in the waste materials are low. Finally, there are no long-term workers or residents at the site; most site use is by short-term site visitors for oil-field or agriculturally related work or by trespassers. As a result, the most significant chronic potential exposure route at the site is current or future ground-water use near the site. Most residences appear to be using a public water supply, but there may be undocumented wells in the area. Although most documented wells in the area are currently completed in deep aquifer units, there is the potential for future use of shallow ground water near the site.

The pathways for which individual risks were calculated are detailed in table 5.2, along with exposure parameters and target risks. Indoor and outdoor air pathways and soil-exposure pathways were not considered. The inclusion of the offsite ground-water ingestion and dermal-contact pathways necessitated the use of a limited Plan B assessment.

5.4 Assessment Assumptions

The Plan B process involves comparison of known onsite or calculated offsite constituent concentrations with risk-based exposure limits (RBEL's) at selected points of exposure. Target concentrations are generated by the software in accordance with the TNRCC RBCA guidance. Exposure points are located at some stated distance from the site for the various applicable pathways. For ground water, the nearest potential future well location was chosen, which was the trailer property east of the site, approximately 750 ft from the pit area. This location is likely down gradient or side gradient to the site, judging from local and intermediate gradient and site water-level data. This is a conservative estimate that also provides a contingency for increased residential development at that distance from the site. The ground-water gradient was input as 0.0015, and the hydraulic conductivity was estimated to be 0.075 ft/d (10^{-5} cm/s). The source area was input as the width of the pit area (450 ft; 37 m), and the source-area thickness as the screened interval below the water table (32 ft; 10 m). The onsite land use was entered as residential use. The ground-water-use category was classified as category II (beneficial use and TDS <10,000 mg/L). Default ground-water dispersivity calculations and default soil parameters were used. Table 5.2 lists the assumptions and input parameters.

Table 5.2. Target health risk values and RBCA model input data.

STATE OF TEXAS - TNRCC RBCA SITE ASSESSMENT

Plan B Output Table 1

Site Name: Post Oak
Site Location: Lee County

Job Identification: RRC Post Oak
Date Completed: 1/20/98
Completed By: Jeri Sullivan

Software: Texas RBCA
Version: 1.0

NOTE: values which differ from default values are shown in bold italics and underlined.

Exposure Parameter	Definition (Units)	RME (Current Exposure)			MLE (Future Exposure)			
		Res.	Child	Comm.	Res.	Child	Comm.	Const.
ATc	Averaging time for carcinogens (yr)	70			70			
ATn	Aver. time for non-carcin. - soil/air exp. (yr)	30	6	25	9	6	25	0.25
ATn.GW	Aver. time for non-carcin. - GW ing. (yr)	30		***30***	9		25	
ATn.GWd	Aver. time for non-carcin. - GW dermal (yr)	33			33			0.25
BW	Body weight (kg)	70	15	70	70	15	70	70
ED	Soil/Air exposure duration (yr)	30	6	25	9	6	25	0.25
t	Exposure interval (s)	9.5E+8		7.9E+8	--		--	7.9E+6
ED.GW	Groundwater ing. exposure duration (yr)	30		***30***	9		25	
ED.GWd	Groundwater dermal exposure duration (yr)	33			33			0.25
EF	Soil/Air exposure frequency (d/yr)	350		250	235		250	250
EF.D	Soil dermal exposure frequency (d/yr)	350		250	40		40	40
EF.GW	Groundwater ing. exposure frequency (d/yr)	350		250	235		250	
EF.GWd	Groundwater dermal exposure freq. (d/yr)	5			5			250
IRw	Ingestion Rate of Water (L/day)	2		1	1.4		1	
IRs	Ingestion Rate of Soil (mg/day)	100	200	50	100	200	50	480
AAFs	Use age adjustment on soil ingestion?	TRUE			TRUE			
IRadj	Age adjusted soil ing. rate (mg•yr/kg•d)	114			84			
IRa.I	Inhalation rate indoor (m^3/day)	15		20	15		20	
IRa.O	Inhalation rate outdoor (m^3/day)	15		20	15		20	20
SA	Skin surface area (soil dermal) (cm^2)	5.8E+3		5.8E+3	5.0E+3		5.0E+3	5.0E+3
M	Soil to skin adherence factor	1			0.2			0.12
SA.GWd	Skin surface area (GW dermal) (cm^2)	6.2E+3			6.2E+3			6.2E+3
ET.GWd	Duration of GW dermal exposure (hr/day)	3			3			4

Matrix of Exposed Persons to Complete Exposure Pathways		On-Site		Off-Site	Const.
		Current	Future	Current	Future
Groundwater Pathways:					
GW.i	Groundwater Ingestion	TRUE	FALSE	TRUE	--
GW.d	Groundwater Dermal Contact	FALSE	TRUE	TRUE	TRUE
Soil Pathways:					
S.i	Direct Ingestion and Dermal Contact	FALSE	TRUE	--	TRUE
Outdoor Air Pathways:					
S.v	Volatilization and Particulates from Soil	FALSE	TRUE	TRUE	TRUE
GW.v	Volatilization from Groundwater	FALSE	TRUE	TRUE	TRUE
Indoor Air Pathways:					
S.b	Vapor Intrusion to Buildings from Soil	FALSE	TRUE	--	--
GW.b	Vapor Intrusion to Buildings from GW	FALSE	TRUE	--	--

Distance to Off-Site Receptor		
GWdist	Distance to groundwater receptor (m)	2.3E+02
Sdist	Distance to inhalation receptor (m)	2.3E+02

		On-Site Current All Off-Site			On-Site Future		
		Individual		Cum.	Individual		Cum.
Target Risks		Soil/Air	GW		Soil/Air	GW	
TRab	Target Risk (class A&B carcinogens)	1.0E-6	1.0E-6	1.0E-4	1.0E-4	1.0E-4	1.0E-4
TRc	Target Risk (class C carcinogens)	1.0E-5	1.0E-5		1.0E-4	1.0E-4	
THQ	Target Hazard Quotient	1.0E+0	1.0E+0	1.0E+0	1.0E+0	1.0E+0	1.0E+0

Calculation Options		
LU_opt	On-site land use	Residential
LU_opt.off	Off-site land use	Residential
tox	Use PEL as industrial exposure limit in air?	FALSE
gwMCL?	Use MCL as exposure limit in groundwater?	TRUE
SPLP_opt	Use site-specific soil to leachate partitioning?	FALSE

Surface Parameters	Definition (Units)	Res.	Const.
A	Contaminated soil area (m^2)	1.5E+2	1.5E+2
W	Width of affected soil perpendicular to wind (m)	2.1E+1	2.1E+1
W.gw	Length of affected soil parallel to GW flow (m)		
Uair	Ambient air velocity in mixing zone (m/s)	2.3E+0	
delta	Air mixing zone height (m)	2.0E+0	
Pe	Particulate areal emission rate (g/cm^2/s)	2.2E-12	

Groundwater Parameters	Definition (Units)	Value
Ugw	Groundwater Darcy velocity (cm/yr)	1.3E+0
Ugw.tr	Groundwater seepage velocity (cm/yr)	3.9E+0
Ks	Saturated Hydraulic Conductivity(cm/s)	2.7E-5
grad	Groundwater Gradient (cm/cm)	1.5E-3
phi.eff	Effective Porosity in Water-Bearing Unit	3.2E-1
foc.sat	Fraction organic carbon in water-bearing unit	2.0E-3
Sw	Width of groundwater source zone (m)	1.4E+2
Sd	Depth of groundwater source zone (m)	1.0E+1
LDF	Leachate dilution factor (unitless)	1.0E+2
delta.gw	Groundwater mixing zone depth (m)	
I	Groundwater infiltration rate (cm/yr)	
BC	Biodegradation Capacity (mg/L)	
BIO?	Is Bioattenuation Considered	FALSE

Soil	Definition (Units)	Value		
hc	Capillary zone thickness (cm)	5.0E+0		
hv	Vadose zone thickness (cm)	3.0E+2		
Lgw	Depth to groundwater (cm)	3.0E+2		
Ls	Depth to top of affected soil (cm)	6.0E+1		
ds	Thickness of affected soil zone (cm)	6.0E+1		
rho	Soil density (g/cm^3)	1.8E+0		
phi	Soil porosity in vadose zone	3.2E-1		
foc	Fraction of organic carbon in vadose zone	2.0E-3		
pH	Soil/groundwater pH	7.0E+0		
		cap.	vadose	fndtn.
phi.w	Volumetric water content	2.9E-1	1.0E-1	1.2E-1
phi.a	Volumetric air content	3.2E-2	2.2E-1	2.6E-1

Building	Definition (Units)	Res.	Comm.
Lb	Building volume/area ratio (cm)	2.0E+2	3.0E+2
ER	Building air exchange rate (s^-1)	1.4E-4	2.3E-4
Lcrk	Foundation crack thickness (cm)	1.5E+1	
eta	Foundation crack fraction	1.0E-2	

Dispersive Transport Parameters	Definition (Units)	
Groundwater		
ax	Longitudinal dispersion coefficient (m)	6.6E+00
ay	Transverse dispersion coefficient (m)	6.6E-01
az	Vertical dispersion coefficient (m)	6.6E-02
Vapor		
dcy	Transverse dispersion coefficient (m)	
dcz	Vertical dispersion coefficient (m)	

Calculations are based on standard exposure factors for residents and standard intake values for ground-water consumption (TNRCC, 1998). These factors are listed in table 5.2 and appendix C.

Target health-risk values are shown in table 5.2. Individual values are for an individual exposure route, and cumulative values are for the combined routes. The cumulative cancer risks and hazard indices for various exposure pathways should be summed when the same individual or subpopulation is subject to the exposure over the same period of time (TNRCC, 1998). For example, if cumulative values fall below the target values for a site, the exposure limits may be assumed to be protective of human health. A cumulative hazard index greater than 1 or a cumulative carcinogenic risk greater than 1×10^{-4} is unacceptable and necessitates remediation or appropriate control measures, or both, according to the TNRCC (1998). However, if individual values simultaneously fall above the target values, then these particular pathways may be of concern and may be addressed if the RRC concludes that this is necessary or appropriate. This assessment is based on the reasonable maximum exposure expected under current and future land-use situations (TNRCC, 1998). Protective concentration limits (PCL's) can then be established as goal concentrations for the remedial process, and remedial actions can target particular pathways of concern.

5.5 Assessment Results

5.5.1 RBCA Model Results

Table 5.3 lists the summary results of the baseline-risk model calculations. Printouts of the individual pathway risk spreadsheets are given in appendix C. The only pathway evaluated here is the ground-water pathway. No individual carcinogenic risk levels were exceeded. The target hazard quotient for toxic effects of 1.0, however, was exceeded for this pathway, mostly because of the presence of cadmium. This quotient was 2.6 for onsite exposure and 2.4 for offsite residential exposure. Chromium (VI) also contributed to the toxicity value but would not have

Table 5.3. Summary RBCA model results.

STATE OF TEXAS - TNRCC RBCA SITE ASSESSMENT | **Plan B Output Table 4**

Site Name: Post Oak
Site Location: Lee County

Completed By: Jeri Sullivan
Date Completed: 1/20/1998

1 of 1

PLAN B BASELINE RISK SUMMARY TABLE

	BASELINE CARCINOGENIC RISK					BASELINE TOXIC EFFECTS				
	Individual COC Risk		Cumulative COC Risk		Risk Limit(s) Exceeded?	Hazard Quotient		Hazard Index		Toxicity Limit(s) Exceeded?
EXPOSURE PATHWAY	Maximum Value	Target Risk	Total Value	Target Risk		Maximum Value	Applicable Limit	Total Value	Applicable Limit	
OUTDOOR AIR EXPOSURE PATHWAYS										
On-Site:	0.0E+0	1.0E-4	0.0E+0	1.0E-4	☐	0.0E+0	1.0E+0	0.0E+0	1.0E+0	☐
Off-Site:	0.0E+0	1.0E-6	0.0E+0	1.0E-4	☐	0.0E+0	1.0E+0	0.0E+0	1.0E+0	☐
INDOOR AIR EXPOSURE PATHWAYS										
On-Site:	0.0E+0	1.0E-4	0.0E+0	1.0E-4	☐	0.0E+0	1.0E+0	0.0E+0	1.0E+0	☐
SOIL EXPOSURE PATHWAYS										
On-Site:	0.0E+0	1.0E-4	0.0E+0	1.0E-4	☐	0.0E+0	1.0E+0	0.0E+0	1.0E+0	☐
COMBINED SOIL/AIR EXPOSURE PATHWAY										
On-Site:	0.0E+0	1.0E-4	0.0E+0	1.0E-4	☐	0.0E+0	1.0E+0	0.0E+0	1.0E+0	☐
GROUNDWATER EXPOSURE PATHWAYS										
On-Site:	0.0E+0	1.0E-6	0.0E+0	1.0E-4	☐	1.7E+0	1.0E+0	2.6E+0	1.0E+0	■
Off-Site:	0.0E+0	1.0E-6	0.0E+0	1.0E-4	☐	1.6E+0	1.0E+0	2.4E+0	1.0E+0	■

CRITICAL EXPOSURE PATHWAY (Select Maximum Values From Applicable Pathways)										
On-Site:	0.0E+0	1.0E-6	0.0E+0	1.0E-4	☐	1.7E+0	1.0E+0	2.6E+0	1.0E+0	■
Off-Site:	0.0E+0	1.0E-6	0.0E+0	1.0E-4	☐	1.6E+0	1.0E+0	2.4E+0	1.0E+0	■

Software: Texas RBCA
Version: 1.0

Serial: G-437-SNX-750

exceeded the hazard quotient of 1.0 by itself. Currently there is no indication that this pathway is complete, according to available site information. There appear to be no current ground-water users at this time near the site, there is an alternate public drinking-water supply readily available, and most domestic wells in the county are screened in deeper aquifer zones.

Because assessment results indicate a basis for concern regarding cadmium, chromium, and lead in ground water, additional monitoring is warranted to define background levels of these metals in ground water. With the background levels unknown, the concentrations of metals cannot be attributed with certainty to the onsite waste materials and their constituents. The possibility remains that the pit contents could be the source of metals in ground water, although their levels did not exceed regulatory limits for disposal of nonhazardous waste. Additional data are needed, as well as repeated sampling of the monitoring wells and new wells in the area in order to establish background concentrations.

5.5.2 Additional Risk Comparisons

Lead was detected in onsite ground-water wells above the TNRCC PCL and the EPA action level. The RBCA model does not include lead. An estimation of the concentration of lead at the receptor point can be calculated by dividing the source concentration by the natural attenuation factor (NAF) calculated for other metals in the model (GSI, 1995). Table 5.4 compares this calculated concentration of lead with currently available health-based guidelines. The NAF is determined mostly by dispersive effects in the aquifer and is constant for nondegradable constituents. The resulting lead concentration is 0.085 mg/L, which remains above the EPA action level and the TNRCC PCL. This concentration indicates that lead may also be a concern of future ground-water users near the site. Background level of lead also needs to be determined.

The detection limit of benzo-a-pyrene in ground water was noted to be above the EPA MCL and the same as the recommended action limit, which is not a health-based guideline. The detection limit and other guidance values are also shown in table 5.4. These comparisons indicate that the

Table 5.4. Concentrations, soil-screening levels, and PCL values for constituents not included in risk-assessment modeling.

Constituent	**Medium**	**Concentration[1]**	**Screening or regulatory limit[1]**	**Source of limit**
Lead	Ground water	0.93 (on site) 0.085[#]	0.015	EPA[3] (action level)
			0.02	TNRCC PCL[2]
PAH (benzo-a-pyrene)	Ground water	0.010*	0.002	TNRCC PCL[2]
			0.0002	EPA[3]
			0.010	TNRCC[4]

[1] For ground water, mg/L. For soil/waste, mg/kg.

[2] TNRCC, 1998, Draft appendix V, mandatory pathways. Ground-water PCL's (permissible concentration limits) are the lowest mandatory PCL for residential sites.

[3] U.S. EPA, 1996b, Drinking-water regulations and health advisories, EPA 822-B-96-002.

[4] TNRCC, 1996. Disposal of special wastes associated with development of oil, gas, and geothermal resources.

*Detection limit.

[#] Maximum on-site value divided by NAF.

detection limit is not sufficiently protective of human health. Further sampling and analysis with improved detection limits could provide a better determination of the actual concentration of benzo-a-pyrene and whether it constitutes a potential health risk to future ground-water users.

6.0 REMEDIAL ALTERNATIVES

Both the site-investigation and risk-assessment results were considered when evaluating various site-remediation alternatives for the Post Oak site. These remediation options were ranked with respect to effectiveness in addressing the waste-package components, mitigating potential environmental impacts, and relative costs. In addition, site-specific constraints that may affect the viability of remedial options were considered.

6.1 General Site Considerations

The Post Oak site is not located in a floodplain nor floodway, according to the Flood Insurance Rate Map (FIRM) panel 480901-0009A, dated November 11, 1982 (FEMA, 1982). No wetlands are indicated at the Post Oak site on the Ledbetter, Texas, National Wetland Inventory (NWI) map prepared by the U.S. Department of Interior, Fish and Wildlife Service, 1992. Wetland maps, however, are not definitive authority as to the presence or absence of wetlands at a particular site. The Army Corps of Engineers administers permitting under Section 404 of the Clean Water Act, including wetland activities. Three wetlands indicators are used by the Corps of Engineers when making wetland determinations: hydrophytic vegetation, hydric soil, and hydrology that supports water at or above the soil surface for a sufficient part of the year. Except in unusual circumstances, all three characteristics must be present during some part of the growing season for an area to be a wetland. When one or more of the wetlands indicators are observed, assistance should be obtained from the local Corps office or a wetlands expert. The final determination of whether an area is a wetland and whether the activity requires a permit must be made by the appropriate Corps of Engineers District Office.

At the Post Oak site, some areas of hydrophytic vegetation, notably cattails, were present within the pit area. We recommend that the Fort Worth District of the Corps of Engineers be contacted to confirm the lack of jurisdictional wetlands at the sites. Areas that may be classified as a wetlands but that have a cumulative extent of less than 1 acre are generally not considered jurisdictional. The total area of the pit is estimated to be approximately 2.4 acres; however, the areas of hydrophytic vegetation are a small part of this area.

A National Pollutant Discharge Elimination System (NPDES) permit is required for point-source discharges and will apply to any onsite discharge of pit fluids that might be necessary. These permits may be individual, group, or general and may be for industrial activities or storm-water discharges from industrial facilities. In Texas, the Railroad Commission, in addition to the U.S. EPA, regulates point-source discharges from oil and gas exploration and production activities under Rule 3.75. The Railroad Commission also provides water-quality certification of Federal permits under Rule 93. If necessary, any pit-fluid discharges might be lowered or eliminated by proper timing of site remediation because pit-fluid volume was noted to decrease substantially in dry weather.

In addition to any permit requirements associated with oil and gas exploration and production activities, the NPDES General Permit for Storm Water Discharges Associated with Construction Sites covers construction activities that involve 5 or more acres of construction area. If the remedial action implemented at the Post Oak site involves construction activities affecting more than 5 acres, it may be necessary to file a notice of intent (NOI) for coverage under this general construction site permit. In conjunction with the NOI, an erosion control and sedimentation plan may be required.

6.2 Summary of Site-Investigation Results

Steps in site assessment include determining the contaminant source and its status, determining the types and concentrations of contaminants present and any existing environmental impact, assessing the risks presented by these contaminants, analyzing the potential for future risks and environmental impact, and evaluating remedial alternatives. The following summarize the points from the assessment that are pertinent to the remediation-selection process.

6.2.1 Waste Package

The oil and gas waste-disposal pit, primarily containing drilling muds, covers approximately 2.4 acres. Estimated in situ volume is 20,500 yd^3. The materials are very soft and have high moisture contents and low compressive strength. Free liquids are ponded seasonally above the waste package at Post Oak. Measurements of waste thickness in the pit ranged from less than 1 to 8.5 ft.

The mean level of TPH detected in subsurface waste samples was 0.096 percent (0.1 percent maximum). The TPH level in the pit-fluid sample was 0.54 mg/L. Guidance from TNRCC sets a maximum level of 1500 mg/kg (0.15 percent) TPH in soil for disposal as municipal solid waste (TNRCC, 1996). In past cases, the RRC has applied maximum soil values of 1 to 5 percent TPH as a requisite for cleanup (personal communication, Jill Hybner, RRC, 1997).

The maximum chloride concentration in the waste samples was 2,500 mg/kg, with a mean of 953 mg/kg. Railroad Commission Rule 8 limits chloride concentrations to 3,000 mg/kg or less for onsite landfarming or burial of drilling fluids without a permit. Elevated chlorides can restrict biodegradation processes and inhibit vegetative growth. They may also degrade surface water and ground water via runoff and leaching.

Arsenic, barium, cadmium, chromium, lead, mercury, selenium, and silver were detected in the waste samples. Barium, in one of 14 samples, exceeded the TNRCC's total limit used to indicate the need for follow-up TCLP analysis (TNRCC, 1996b). A TCLP analysis was performed, and barium, although detected, did not exceed the regulatory limit for nonhazardous waste. Cadmium, chromium, lead, and silver were detected at low levels in the TCLP analysis. The levels of these constituents did not exceed the regulatory limit for disposal of nonhazardous waste.

Naphthalene was the only VOC (or PAH) detected in a waste sample at a concentration (0.79 mg/kg) well below the TNRCC fine-grained soil action level for LPST sites (TNRCC, 1996). No TCLP VOC's or SVOC's were detected above method detection limits.

6.2.2 Pit Fluids

A pit-fluid sample was taken. Pit-fluid volume was estimated to be about 6,000 bbl at the time of the sampling event; however, this volume is highly variable and dependent upon weather conditions. Barium was measured at 0.61 mg/L in the pit fluids, and mercury was detected at 0.0009 mg/L in the pit fluids. Both values were well below drinking water MCL's. Chloride concentration in the pit fluid was 150 mg/L, below the drinking-water secondary MCL of 250 mg/L. TPH was measured at 0.54 mg/L, and naphthalene was detected at 0.011 mg/L. Neither of these constituents have MCL's. The naphthalene level in the pit water was only slightly above the level (0.011 versus 0.01 mg/L) used in ground-water testing to trigger additional site evaluation at LPST sites.

6.2.3 Ground Water

Two ground-water monitoring wells were installed onsite. Naphthalene was detected in MW-2 at a level exceeding the TNRCC guidance level. No other VOC's or PAH's were detected. Cadmium and chromium were detected above the EPA MCL in both wells, and lead was detected in both wells above the EPA action level. Although the chloride level in MW-2 exceeded the EPA secondary MCL, it did not exceed the TNRCC secondary constituent level. Background concentrations in ground water remain undefined and were beyond the scope of this study.

6.3 Considerations for Site Remediation

6.3.1 Waste Package

The waste package, consisting of low-strength drilling muds, is surface exposed within the pit area. A thin, tarlike crust layer is present intermittently across the quarry pit. Moisture content of the drilling mud ranged from 39 percent to essentially 100 percent. The low compressive strength and high moisture content of the waste package, however, pose physical concerns. Around the edges of this pit, the waste material supported foot traffic, but the material increased in moisture content and decreased in strength toward the center of the pit. Within 20 ft of the pit edges, the waste materials could not support foot traffic without planking. Waste thickness measured in the pit varied from 0.7 to 8.5 ft in depth. During the site investigation, a stray dog was seen attempting to walk on the pit. Although it became mired in the waste materials, it was able to extract itself. These characteristics indicate the potential for an entrapment hazard at the site.

Petroleum-related organic compounds were found to be below method detection limits and/or regulatory action levels for LPST sites. TCLP testing on waste samples did not detect VOC's or SVOC's; the metals detected in the TCLP analysis were all below regulatory guidance. These analytical results indicate that the waste material is suited to land spreading.

The chloride levels in the waste package at Post Oak are acceptable for land spreading of the waste materials. Elevated chloride levels can inhibit vegetation and may degrade surface water and ground water via leaching and runoff. The maximum chloride concentration in the waste samples was 2,500 mg/kg, with a mean concentration of 953 mg/kg, based on 15 samples. Under Rule 3.8, the RRC authorizes onsite disposal of oil and gas waste by landfarming or burial without a permit for chloride levels less than 3,000 mg/kg.

Some metals were detected in the waste materials. None were unexpected, considering the materials are oil and gas wastes. The total concentrations measured at Post Oak were compared with levels deemed acceptable for drilling mud pits in Louisiana (under Louisiana Rule 29-B), and all concentrations were below the acceptable limits.

The chemical hazards from the wastes themselves are generally low. The analytical data indicate that the oil and gas waste material has low TPH and chloride levels. Other constituents detected in the waste materials either are at total levels that are below regulatory guidance or have TCLP results indicating nonhazardous materials.

6.3.2 Pit Fluids

Pit-water results indicate low levels of TPH (0.54 mg/L), chlorides (150 mg/L), barium (0.61 mg/L), and naphthalene (0.011 mg/L). Recharging rainwater may cause leaching and subsequent downward movement of constituents from the pit wastes to ground water, providing a continuing source of contamination. For the purposes of cost estimation, the pit-fluid volume was estimated to be approximately 6,000 bbl. Remediation of pit water itself is not recommended because of the low levels of constituents detected. The quantity of pit water should be minimized to decrease the moisture content of the wastes and to increase their strength, or remediation should be staged to reduce the presence of pit water as much as possible.

6.3.3 Ground Water

No VOC's or PAH's were detected in the onsite wells. Naphthalene was detected in MW-2 at 0.042 mg/L. This value is above the action level and is used by TNRCC to designate further site evaluation for LPST sites (0.01 mg/L). There is no MCL for naphthalene. Elevated levels of chloride were noted in ground water. Cadmium, chromium, and lead were detected at levels above MCL's or action levels. Geophysical data, however, show no evidence of excursion of a conductive plume of brackish or saline ground water. Risk-assessment modeling indicated that these levels may be of concern to future users of shallow ground water in the vicinity of the site. Background concentrations, however, have not been defined.

6.4 Remedial Alternatives

At the Post Oak site, possible areas of concern include the physical hazards associated with the waste materials within the quarry pit, the potential for future use of potentially impacted ground water, and the current detection of metals and chloride in the ground-water samples from the onsite wells if confirmed to be above background concentrations.

Types of remedial activities and methods for addressing contaminant sources and physical hazards at the site fall into one of three categories: destruction, immobilization, or extraction. Destruction techniques are used to degrade the contamination to an acceptable level and include technologies such as bioremediation (attenuation), soil flushing, and treatment systems. Immobilization techniques seek to reduce the potential threat by containing, isolating, or fixing contamination. Immobilization methods include stabilization/solidification, capping, and slurry or cutoff walls. Extraction techniques remove the contamination from its location. Once extracted, the contaminated or physically hazardous media may be managed onsite or offsite and disposal, treatment, or destruction processes may be used to remediate the contaminated media. Common extraction and remediation techniques include excavation of contaminated material and removal for offsite treatment or disposal and vertical and horizontal wells for fluid-contaminant removal.

Ground-water monitoring is an important component of any remedial action where ground-water contamination is a concern. Monitoring of COC's in ground water provides evidence that the remedial option is effective and that risk goals are being met. Other constituents or parameters, such as total dissolved solids or conductivity, are monitored as indicators of potential plume movement or degradation. Monitoring can be accomplished through a combination of on- and offsite wells, which are sampled for selected constituents of concern. Previously installed monitoring wells and new wells sited to assess some particular aspect of the remediation design may be incorporated into the remedial monitoring network.

Options that were considered for managing the waste package included no action in conjunction with ground-water monitoring, onsite land treatment, solidification, dilution burial, capping, and excavation along with offsite management. These methods are described later.

6.4.1 No-Action Alternative

The no-action alternative means taking no action to remediate the site and leaving the site in its present condition, with natural processes controlling fate of waste and rate of remediation. Because of the already low concentrations of chloride and TPH, natural attenuation would be effective in further TPH concentration reduction. However, under a no-action alternative, the waste materials would remain in the pit and the risks posed by the physical condition of the site would also remain. Because of continued potential risk for physical harm posed by the current site conditions, the no-action alternative alone is not considered appropriate for the Post Oak site.

6.4.2 Land Treatment

Land treatment is a standard technology used for treatment and disposal of drilling muds. Predominant constituents in drilling-mud fluids are bentonite and barite, substances that are common in soils and that can be introduced into surface soils easily (Deuel and Holliday, 1994). Land treatment involves dilution and biodegradation to reduce constituents to an acceptable level. In land treatment, the drilling-fluid solids are spread upon the land surface to a designated thickness, the solids are mixed with the soil, the mixture is amended as necessary, and then adequate time for biodegradation of organic constituents is allowed. Nutrients and/or microbial cultures may be added as supplements to speed up the rate of bioremediation (U.S. EPA, 1991).

Although the TPH content of the waste package at Post Oak does not indicate a need for bioremediation, land spreading is still a feasible option for disposal of the large volume of wastes at the Post Oak site in order to reduce the risk of physical entrapment. The waste volume is estimated to be approximately 20,500 yd^3. For bioremediation concerns, thickness applications for land treatment are usually recommended to be less than 6 inches. At 6 inches in thickness, approximately 25.4 acres (1,107,000 ft^2) of surface area would be required for land treatment, in a single lift, of the waste volume at the Post Oak site. According to deed information obtained during the site investigation, the Post Oak site appears to be located on a property of approximately 250 acres. The area of the waste-pit area is approximately 2.4 acres, leaving adequate area for land spreading of the waste materials. The chloride concentration in the waste package is below that allowed by the RRC for onsite land spreading of oil and gas wastes without a permit. Although removal and land spreading of the wastes would remove the physical hazard at the site, the remedial option is contingent upon both landowner approval and approval based on a wetlands delineation by the Army Corps of Engineers.

6.4.3 Solidification and Stabilization

Solidification and stabilization processes use additives to physically or chemically immobilize certain constituents of concern in the contaminated material. These processes do not destroy the contaminants but stabilize and reduce the mobility of the constituents.

Solidification processes could be considered at Post Oak as a means of increasing the strength of the waste material in place; it would also increase the waste volume. The high moisture content of the wastes would increase the quantity of solidifying materials needed over typical soil materials. The nature and configuration of the Post Oak waste pit would make in situ solidification difficult. The pit length extends over 470 ft, and the pit width extends up to 270 ft. To solidify the material in place without directly operating on the pit area, it would be necessary for construction equipment to reach at least 135 ft from the quarry edges into the pit. Alternatively, in situ solidification of the waste material by direct operation on the pit area itself would require specialized equipment, if available. Either of these options would be more expensive than standard waste-handling techniques.

Ex situ solidification of the waste materials would require excavation of the materials, solidification, and, presumably, replacement of the increased volume of material back into the quarry pit. Because this method incurs the cost of excavating the material, no benefit is gained by the additional solidification and replacement costs, as opposed to land spreading the material without solidification or removal of the material for offsite handling. Stabilization processes are therefore not recommended at Post Oak because of the high moisture content of the waste materials, the large volume of waste materials, the low concentrations of constituents present, the difficulty in handling the waste materials, and the relatively high costs of the stabilization process. Landowner approval is needed for this option.

6.4.4 Dilution Burial

Dilution burial is another technique frequently used for treatment/disposal of drilling muds. In dilution burial, the waste is mixed with soil, diluting the concentration below an acceptable contaminant level, and the resulting mixture is buried in trenches. Dilution burial is not recommended when the depth to ground water from the base of the waste/soil mixture is less than 5 ft; in addition, it is normally recommended that a minimum of 5 ft of soil cover be placed above the waste/soil mixture (Deuel and Holliday, 1994).

Although the Post Oak waste material would satisfy the recommended constituent levels for dilution burial, the method is not recommended at this site. If an excavation is made and the waste materials are transferred to that excavation, the depth of material would need to be shallow or the waste would need to be mixed with soil to avoid the physical risks due to low material strength. Alternatively the material in the pit could be mixed in situ with soil to provide a stronger waste package. The implementation issues just discussed with respect to solidification would also pertain to in situ mixing of soil with the waste. This option is also contingent upon landowner and Army Corps of Engineers approval for the excavation.

6.4.5 Capping

Capping is a containment technique that provides a separation layer between the waste material and the surface, removing the risk of casual surface contact with waste and preventing surface water from contacting the waste mass. Capping is not recommended at Post Oak because of the configuration of the quarry pit. An integral factor in successful capping is the ability to grade the cap to drain away from the waste area. At Post Oak, the waste materials are in the quarry pit, approximately 5 ft below the ground surface. To establish positive drainage off of the capped area, either the pit would need to be filled to surface grade or a sump area would be required where diverted precipitation would be collected and pumped from the quarry pit. Neither of these alternatives is readily feasible.

The low strength and high moisture content of the pit materials would also undermine the integrity of a cap unless particular steps are taken. A soil layer would be required to provide a stable base for a cap. The thickness of this soil layer required to provide a competent layer and the construction difficulties in placing this soil layer would be great. Capping is not a recommended technology for use at the Post Oak site.

6.4.6 Excavation and Offsite Disposal

Excavation of the waste material at the Post Oak site and disposal of the material at an offsite facility are a feasible option. It is anticipated that removal of the waste materials from the quarry pit would be sufficient for pit closure and that no backfilling of the pit or site grading would be required.

The advantage to excavation and offsite disposal of the waste material is that the potential for future exposure or contamination is eliminated. The risk of exposure or contamination at this site naturally needs to be verified. The disadvantages are cost and the number of steps necessary for handling the wastes.

The volume of waste materials in the disposal area is estimated at 20,500 yd^3. No RRC-permitted commercial disposal facility exists in Lee County. RRC-permitted facilities located in nearby counties accept drilling muds. As an alternative to RRC-permitted facilities, the Post Oak waste may be considered for disposal at TNRCC permitted facilities. Generally TPH is limited to 600 mg/kg (0.06 percent) for waste disposed in municipal solid waste (MSW) landfills; select MSW landfills accept waste containing TPH to as much as 1,500 mg/kg (0.15 percent). With the exception of one sample, the TPH of the waste materials at Post Oak was below this limit. Army Corps of Engineers wetland delineation and approval would be needed before implementation of this option.

6.4.7 Ground-Water Monitoring

At this time, active remediation of the ground water at the Post Oak site is not recommended. Reasons include:

- no receptors for shallow ground water are currently known
- no history of shallow ground-water use exists in the area
- an alternate drinking water source is readily available in the area for future users
- levels of metals and chloride, although above MCL's, are relatively low (background levels remain unknown for the shallow aquifer)
- levels of any contamination are likely to decrease with remediation of pit waste

Continued ground-water monitoring is recommended in place of ground-water remediation, particularly to establish background levels of metals and chloride and to verify and further quantify the impact of chloride and metals on the local ground water. Monitoring will help better define flow directions at the site and the statistical significance of the known constituent concentrations. Monitoring will also help track the effectiveness of any remedial actions taken in the pit and help determine actual risks that might arise from future offsite ground-water use, if it occurs.

It should be noted that a ground-water recovery and treatment system might be considered necessary in the future if additional data indicate the potential for offsite migration. Under the RRC oil-field cleanup program, a number of options are available to address risks to potential future users of ground water, including site closure, remediation with controls, and ground-water monitoring. Target concentrations for future onsite users are the MCL exposure limits, which may result in the need for as much as a six-fold reduction (contaminant reduction factor, CRF) in the concentration of cadmium and a one-fold reduction in the concentrations of chromium, and a likely one-fold reduction in lead (see table 5.4) if background concentrations prove to be low. Data from monitoring can be used to evaluate whether natural attenuation leads to reductions in the concentrations of these constituents and whether migration offsite might occur in the future. There is, however, little likelihood of onsite shallow-water consumption because the area is serviced by a drinking-water provider.

Installation of one or more wells that will indicate local background water quality is recommended to determine whether constituents detected in the onsite wells are above background. One or more wells will also need to be installed to further delineate flow patterns that may be complex because of the site's location at the top of a drainage divided.

Quarterly monitoring allows documentation of seasonal changes in ground-water gradients and provides a statistically significant number of points to determine fluctuation in chemical composition. Specific goals of the monitoring process, such as implementation of a remedial action or ending the monitoring process, are based on the results of the tests. Quarterly monitoring for 1 or more years would indicate whether the constituent levels detected at the site are statistically significant.

7.0 CONCLUSIONS

This assessment of the Post Oak site included characterization of spent drilling-mud materials and onsite surface water, surface and subsurface soils, and onsite ground water. Constituents of concern detected in media at the site included petroleum hydrocarbons, chloride, and metals, including cadmium, chromium, and lead. The waste materials, contained within the pit area, have not affected soils laterally outside the pit. At the Post Oak site, the presence of waste materials poses the following issues:

- a physical entrapment hazard at the disposal area owing to the thickness and low load-bearing strength of the waste material;
- concentrations of lead, cadmium, and chloride above MCL's, SMCL's, or recommended risk levels in onsite ground water, assuming that background concentrations are low; and
- the potential for continued impacts from the pit wastes on shallow ground water.

The significance of these issues should be verified—additional data are needed to support remediation decisions. These data include

- background levels of the concentrations of metals and chloride in shallow ground water in the area;
- a longer record of data showing the temporal trend or fluctuation in the concentration of potential contaminants at the site; and
- data to evaluate the potential for in situ treatment of waste materials as a remediation alternative.

Collecting these data requires sampling of existing, and several additional, monitoring wells. Four to six additional monitoring wells, including wells located at the site and in the area, should suffice to provide the needed data.

Ground-water remediation is not justified on the basis of existing data. There are no known receptors for shallow ground water in the area, and calculated risks from ground water under current conditions are low. Background levels of these potential contaminants remain to be determined to both verify impact and set appropriate cleanup goals if remediation is deemed necessary. Whereas some dissolved metals and chloride appear in onsite ground water above MCL's or action levels, geophysical data show no evidence of migration of a plume of brackish-to-saline water. If ground-water contamination is found to be above background (and additional detections above MCL's or other health-based guidelines are statistically significant) and if future development of local shallow ground water occurs, then a ground-water remediation system might need to be considered.

As an interim measure, fencing of the pit would keep out livestock and people and thereby reduce risk of exposure to the entrapment hazard. Should additional data verify the need to remediate the waste materials to remove the source of ground-water contamination, removal of the waste from the pit and land spreading onsite would probably be the most cost-effective option. These would, however, require approval of the landowner and, concerning wetland issues, the Army Corps of Engineers. Offsite disposal is also feasible but more costly. In situ treatment may be feasible if emerging technologies succeed.

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