Final Technical Report

Site Investigation and Evaluation of Remediation Alternatives for the Roeling Vacuum Site, Liberty County, Texas

(RRC Site No. 03-50216)

Volume I—Technical Report

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1.0 EXECUTIVE SUMMARY

The Roeling Vacuum site (RRC Site Code 03-50216) in Liberty County, Texas, is a former borrow pit and vacuum-truck-washout site. Salt-based drill cuttings were disposed of in the late 1970's, and the site was permitted for drilling-fluid disposal between 1985 and 1990. A complaint from a nearby landowner, along with permit violations, triggered Railroad Commission of Texas (RRC) action that led to site closure in 1991. Since then, the RRC has conducted cleanup operations, including removal of storage tanks. The scope of this study was to determine the extent and composition of waste materials, identify impacted areas, determine effects on ground-water quality, and evaluate risk-based options for site remediation. Remedial standards used in this assessment include disposal criteria from the RRC and Texas Natural Resource Conservation Commission (TNRCC) (1996b, 1996c), health-based standards (U.S. EPA, 1996a, b; TNRCC, 1996a, 1998), and other guidance, such as secondary maximum contaminant levels (U.S. EPA, 1996b), to address the range of constituents found at the site.

The buried waste materials at the site are spent drilling fluids in excavated pits that are contained by a berm. Most areas of the site are underlain by several feet of clay in the Beaumont Formation, except for one deeper area, which may have received salt-based drill cuttings. Other areas of onsite waste disposal or potential impact include eight pits on the east side of the site, two vacuum-truck washout ponds, and a pond on the north side of the site. There also has been unauthorized trash disposal unrelated to the oil and gas operation.

Constituents identified at the site during this study include elevated chloride, petroleum hydrocarbons, and metals including arsenic, barium, chromium, silver, and lead. Chloride concentrations in the waste materials ranged from 120 to 42,000 mg/kg, had a median of approximately 3,700 mg/kg, and tended to increases with depth beneath ground surface. More than half of the samples exceeded the RRC disposal guideline of 3,000 mg/kg. Electromagnetic (EM) surveys and information from borehole samples at the site suggest that there has been some

subsurface movement of saltwater outside of the waste-disposal area. Some subsurface soils onsite have been impacted by chloride. Metals, petroleum hydrocarbons, and other organics in the waste-disposal area generally were below various (RRC and TNRLC) regulatory action levels. No pesticides or PCB's were detected. The waste materials also exhibited low leaching potentials for organic compounds and metals, according to TCLP methods for disposal characterization. Sediments in a pond at the north side of the site had lead levels of 89 mg/kg. These exceed the 30 mg/kg limit for total lead content in waste for disposal in a municipal solid-waste facility; however, this is not a health-based risk criterion.

The only confirmed ground-water quality issue at the site is the presence of chloride and salinity in onsite and some offsite wells that exceeded EPA's secondary maximum contaminant level (MCL) for drinking water. No dissolved metals or organics were confirmed at concentrations above EPA's primary MCL's.

The first recommended action, securing the site, has already been done by the RRC, which included installation of an improved fence and gate to prevent unauthorized access and dumping. No remediation of ground water is recommended at this time because current information indicates no exceedances of health-based criteria in onsite or offsite wells. Additional sampling of existing and new onsite monitoring wells, however, are recommended to (a) address reported concerns about potential drinking-water impacts around the site and (b) determine whether remediation is justified to reduce the potential for ground-water impact associated with elevated chloride concentration in waste materials. If remediation is deemed necessary, elevated-chloride wastes could be removed from the central site area by excavation to prevent future impacts to ground water. Limited surface remediation might also be performed to mitigate the effects of salt on surface vegetation, remove the entrapment hazard from soft waste materials, and deal with the lead content of the north-pond sediments. Additional monitoring wells can be phased in and positioned on the basis of interim monitoring results.

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 have had observable releases, occur in ground-water recharge zones having high soil permeability, lie near surface-water bodies or water-supply wells, or both, have high public profile and have received complaints, and lie near population centers. Straightforward solutions for cleanup are readily apparent at many of the sites. At some oil-field sites, however, outlining cost-effective approaches to cleanup requires more complete information on the surface and subsurface extent of the contamination and local geological conditions.

The Roeling Vacuum site in Liberty County (RRC Site Code 03-50216) was used formerly as disposal pits for oil-field wastes, such as salt water, drilling fluids, and oil-contaminated drilling materials. Potential site contaminants include petroleum hydrocarbons, salts, metals associated with drilling practices, such as barium. This report describes the investigation performed at the Roeling Vacuum site and reviews options for remediating this site.

The principal tasks performed for this investigation were: (1) determination of the extent and composition of the solid waste materials present on 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) sampling of local domestic wells to determine potential influence by the site on local water quality; and (5) evaluation of risk-based options for site remediation and closure. A thorough review of the RRC case files for the site was performed between June 1996 and March 1997. A site-reconnaissance visit was made to the site by BEG personnel in March 1997. Site-investigation work was performed from April through August 1997.

Work was designed specifically to address the presence of oil and gas wastes at the Roeling Vacuum 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 Roeling Vacuum site is located in Liberty County, approximately 6 mi northeast of Liberty, and 1 mi north of Daisetta. It is shown on the Hull USGS 7.5-minute quadrangle about 0.5 mi west of the intersection of FM 770 and "old" FM 834, about .25 mi west of Hull (fig. 2.1). The site was originally used as a quarry for fill dirt for oil-field roads (Ronnie Key, Shivers Well Service, personal communication, July 1997). It was subsequently used as a washout yard and disposal site for drilling fluids discharged from vacuum trucks. It now includes two former washout pits filled with water, an area containing several small (approximately 11 ft in diameter by 4 ft in depth) mud-disposal pits that are now partly filled with water, and several low, wetland-type areas bordering the pits and in the north half of the site. The site is heavily vegetated by grass, shrubs, and trees, with the exception of some barren soil areas and a site road. There is an unauthorized and uncontrolled trash dump near a zone of trees along the east side of the site (fig. 2.2).

2.2 Site Geology

The Roeling Vacuum site lies on the Pleistocene Beaumont Formation. At the surface the Beaumont Formation is composed of fluvial meanderbelt sand and floodplain overbank mud. The surficial sediments are predominantly clay having a well-developed soil profile. The site lies in an area mapped as overbank mud, which is described as having low permeability, high water-holding capacity, high compressibility, high to very high shrink–swell potential, poor drainage, level to

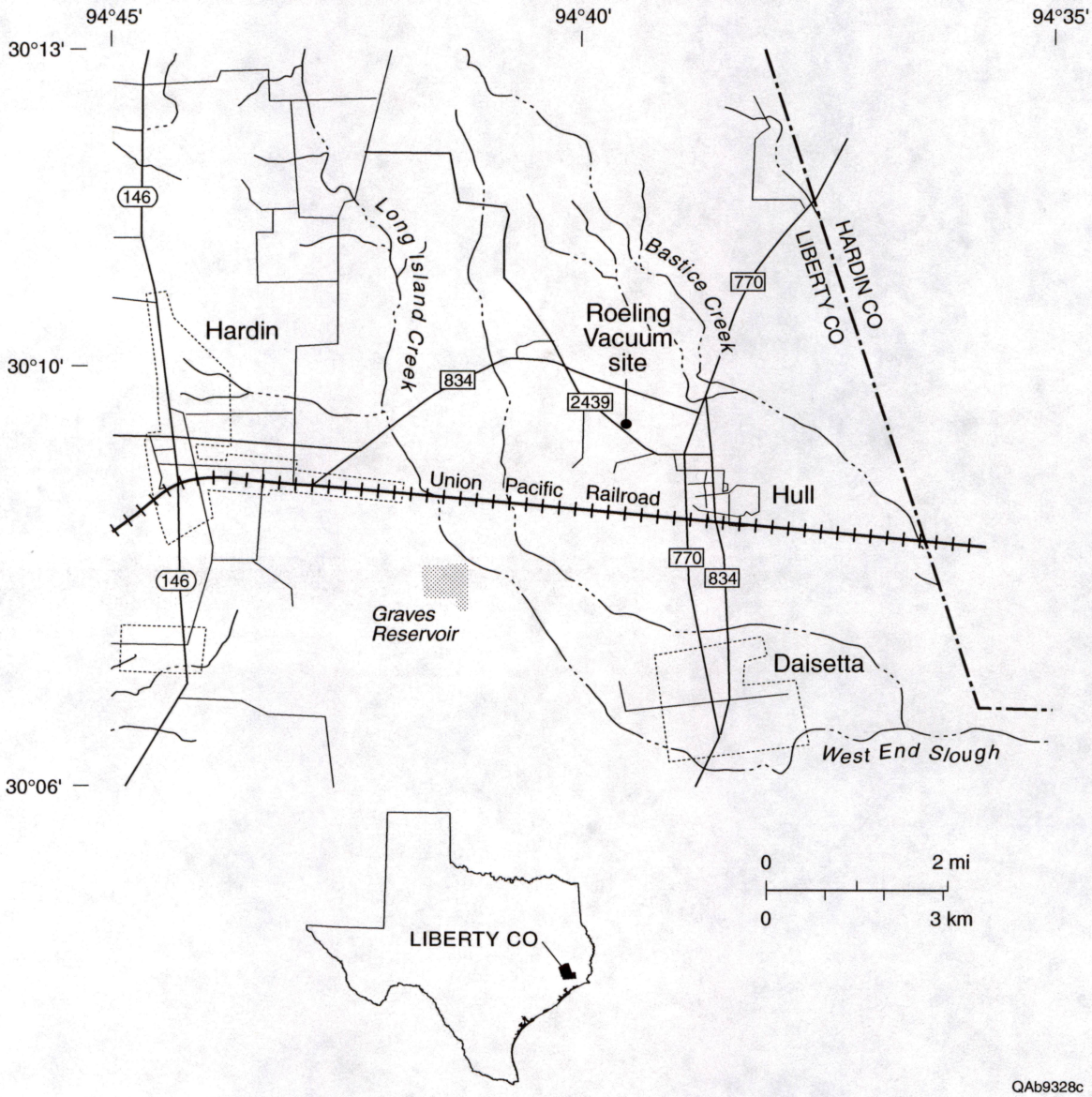


Figure 2.1. Location of the Roeling Vacuum site, Liberty County, Texas.

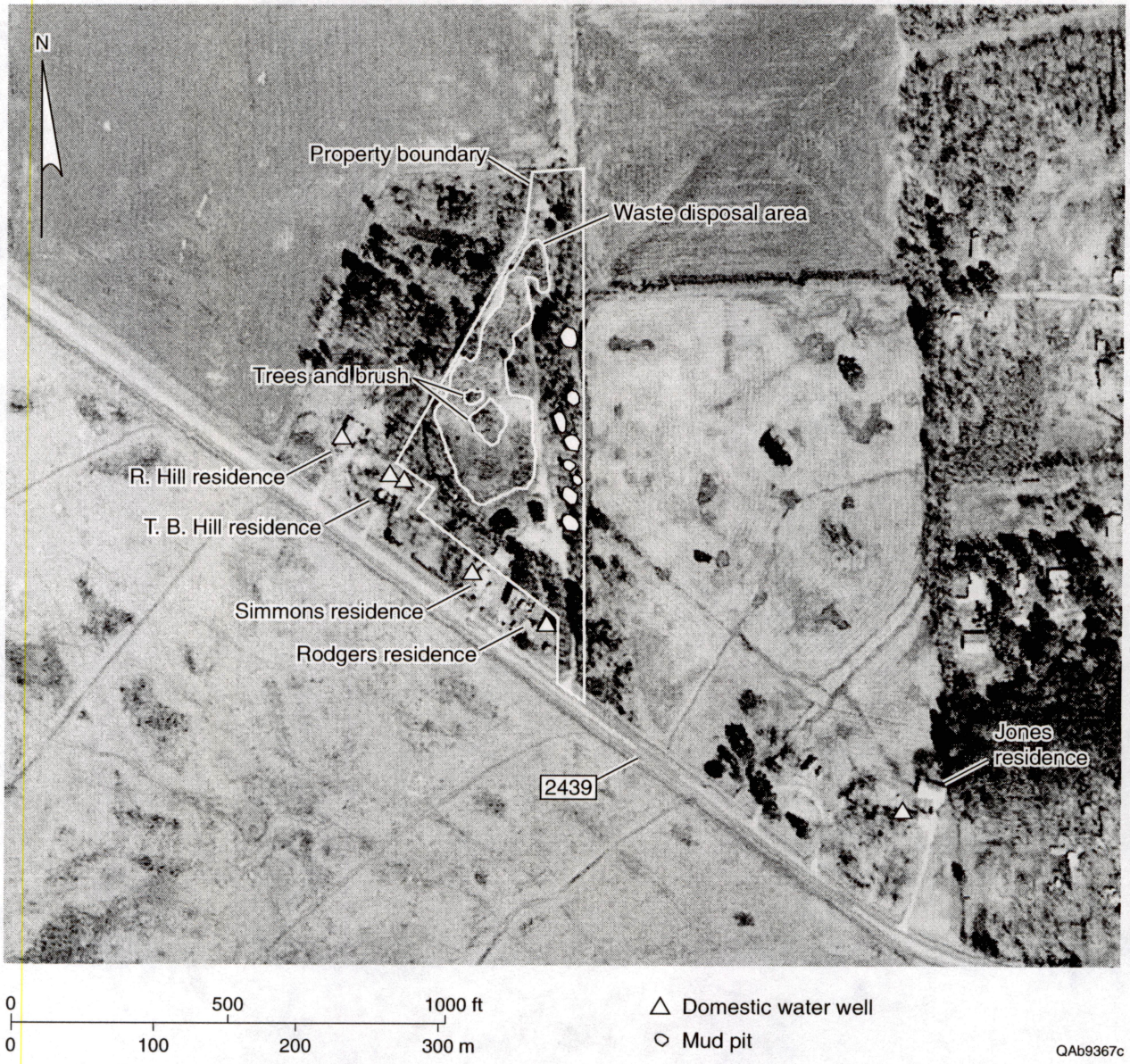
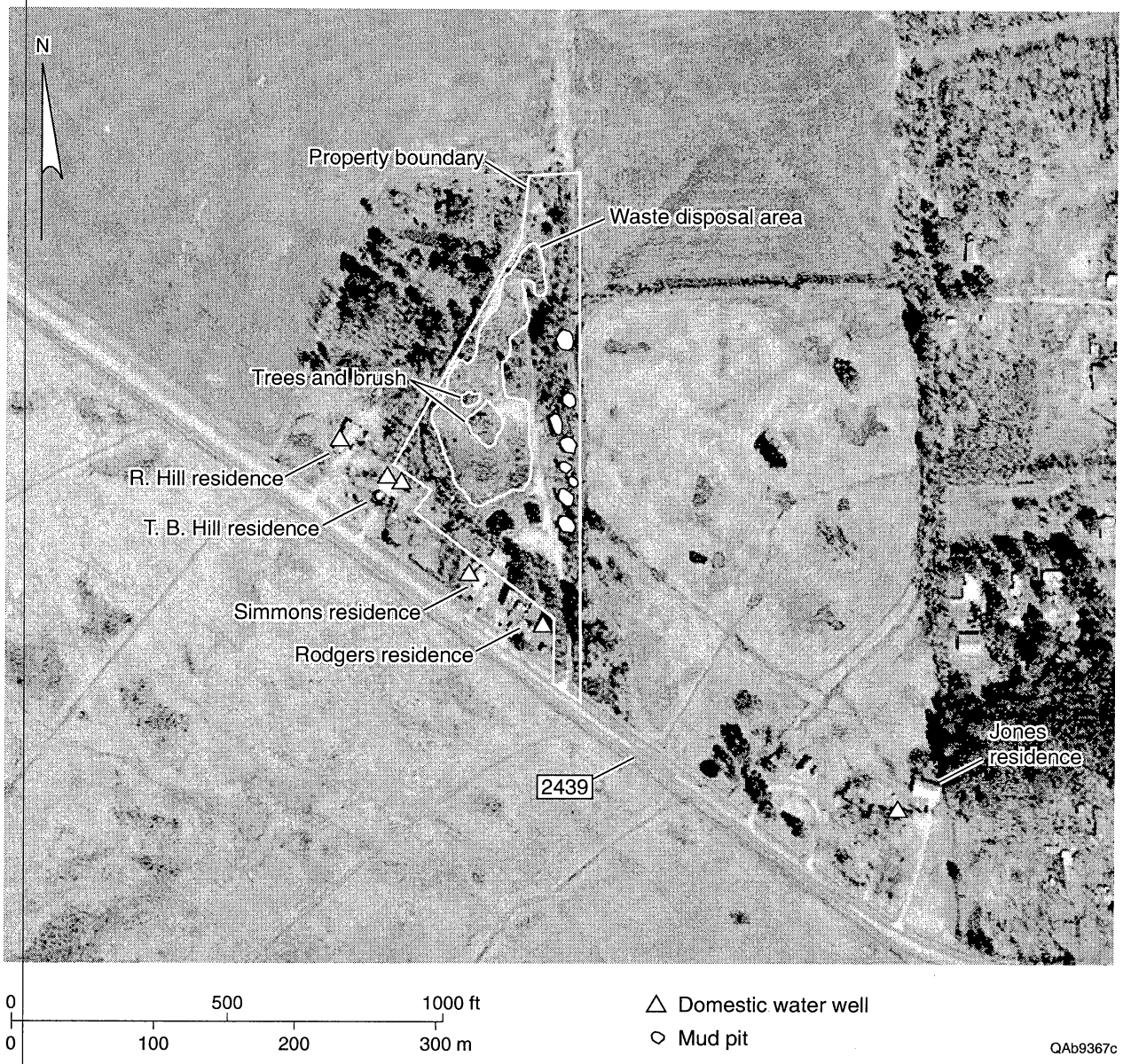


Figure 2.2. Layout of the Roeling Vacuum site, showing surrounding property use, domestic wells, and the approximate property boundary.



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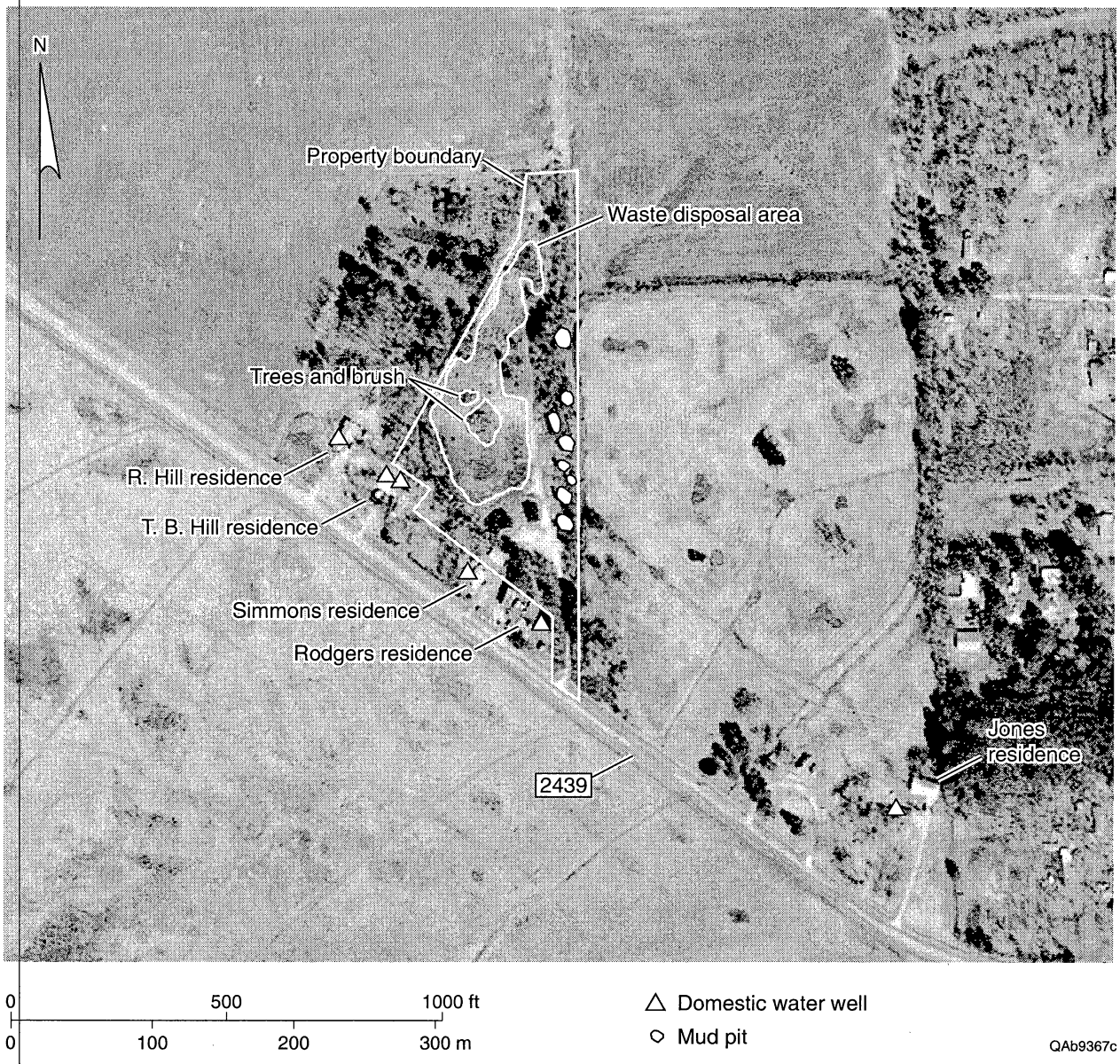

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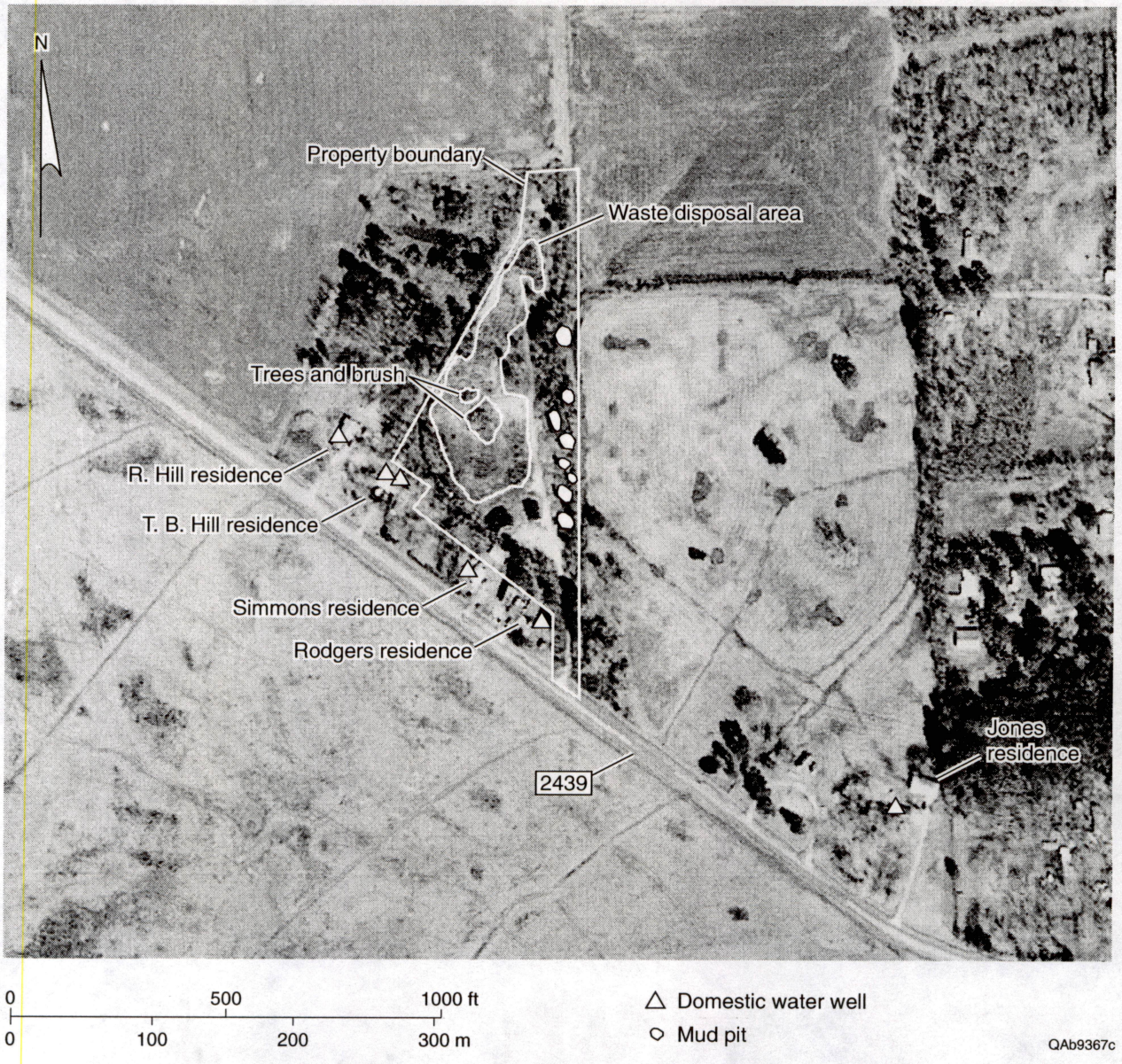

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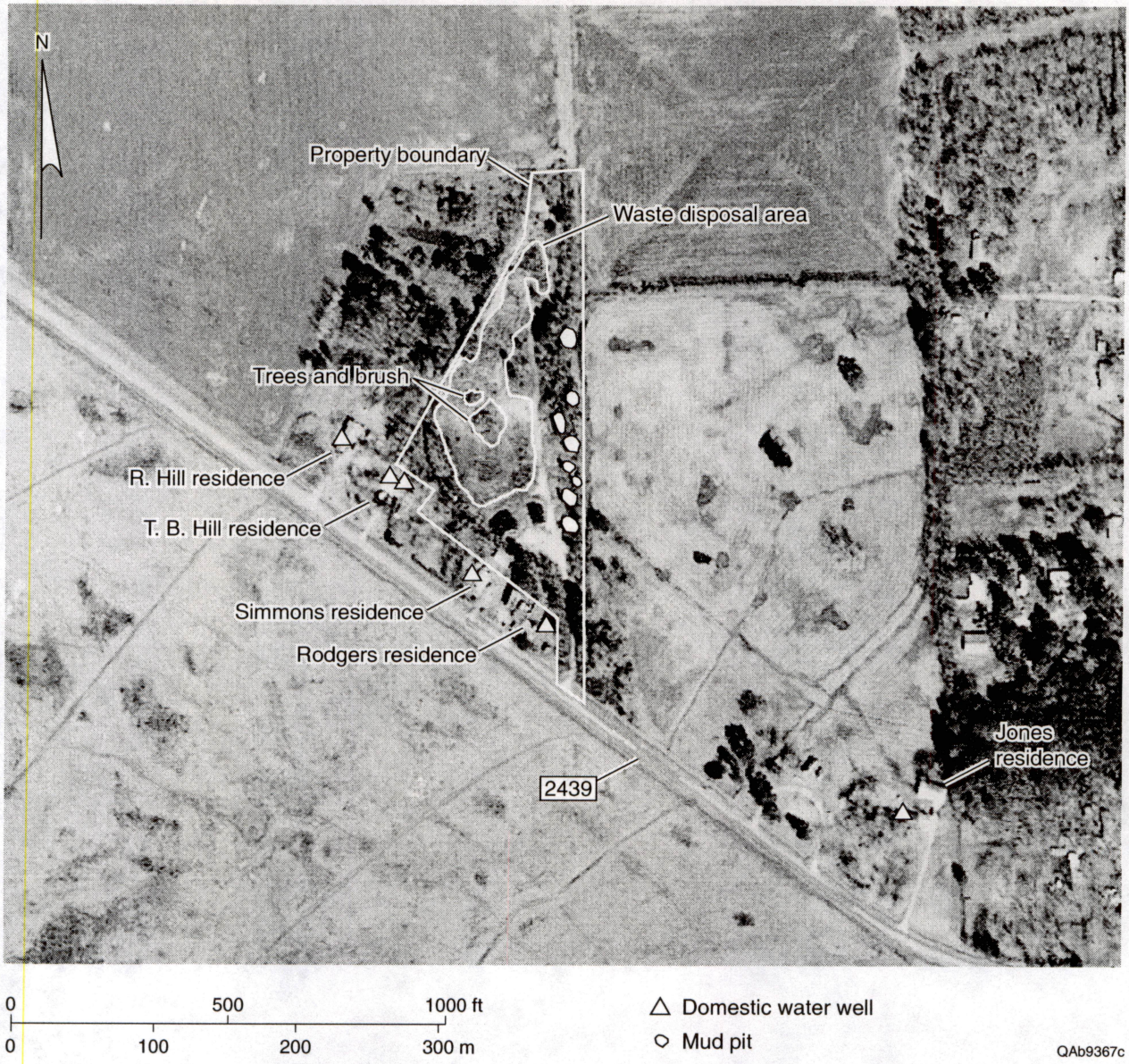

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depressed relief, low shear strength, and high plasticity (Harris, 1941; Shelby and others, 1968). The site lies north of the Hull salt dome, which is a piercement dome that significantly impacts the geologic and hydrologic setting. Salt in the dome exists as shallow as 400 ft below mean sea level (msl). Fluvial channels skirted the slight topographic high over the dome, depositing fine-grained overbank units over the dome area. The salt dome presence may be a factor in the relatively decreased thickness of fresh water bearing sand beneath the site (Anders and others, 1968; Solis, 1981).

Soils in the site area are mapped as the Aris–Ardine–Anahuac assemblage (TNRCC, 1997). These soils are silt loams having poor to somewhat poor drainage. Soil water levels range from 0 to 2.5 ft in depth and depend on the high water levels during November through May. Infiltration rates are slow. The shallow zone of saturated ground reflects a perennially perched water table lying above the regional potentiometric surface.

Oil fields were discovered in the area mainly between 1935 and 1950. These fields produce from reservoirs in the Yegua Formation around salt domes and from Eocene deltaic sandstones. Salt water is produced during oil production (Galloway and others, 1983).

2.3 Site Hydrology

2.3.1 Surface Water

The site is located within the Neches River watershed. Regional drainage flows eastward toward the West Fork of Pine Island Bayou, a tributary of the Neches River. The site is located between two stream drainages, Bastice Creek to the northeast and an unnamed tributary of the West End Slough to the west and south. The region is subject to flooding during wet seasons; drainage is poor and most local drainage is controlled by man-made ditches and elevated structures, such as roadways. The Roeling Vacuum site is located in neither a floodplain nor floodway, according to the Flood Insurance Rate Map (FIRM) panel 480438-0225B, dated September 30,

1988. The site is not included within the coastal management program boundary either (Carman, 1995). Average annual precipitation is approximately 50 inches (Larkin and Bomar, 1983).

Marshy areas are common. Although no streams are onsite, several ditches surround the site both within and outside of the property boundary, and several areas of low-lying ephemerally wet areas exist onsite. Some of these areas were constructed while the site was active. Although wet during the period from March to June of 1997, some of the low areas were dry during July and August. Two man-made washout ponds or pits are on the south end of the site (fig 2.2), which contain water during all seasons and receive runoff from the south part of the site. The one pond area on the north end of the site was observed to contain water during the course of the site work; however, the water was very shallow and it appeared likely that this area might dry out at times. Two small wetland areas adjacent to the Roeling Vacuum site are indicated on the Hardin, Texas, national wetland inventory (NWI) map prepared by the U.S. Department of the Interior (1987). Both areas combined are less than 1 acre in area. Located immediately west of the site, they correspond in location to the offsite ponds located on the northwest side of the site, north of the R. Hill residence. One area is designated as palustrine, emergent, persistent, and seasonally flooded. The other area is designated as palustrine, unconsolidated bottom, semipermanently flooded, and excavated.

2.3.2 Ground Water

The principal ground-water source near the site is the shallow part of the Gulf Coast aquifer, similar to that described in Matagorda County by Dutton (1994). It was identified previously as the Chicot aquifer by Anders and others (1968). The uppermost part of the aquifer is hosted by the fluvial-deltaic Beaumont and Lissie Formations (Shelby and others, 1968; Dutton, 1994). Thickness of the aquifer ranges from 100 to 400 ft from north to south in the county and is about 220 ft thick near the site. Rice irrigation and municipal water supply are the principal regional ground-water uses. Water-level decline and subsidence are issues of concern in the county (Anders

and others, 1968). The Hull salt dome south of the site decreases fresh-water thickness beneath the area because of the saline water around the dome (Anders and others, 1968).

Water levels in the regional aquifer near the site are mapped at an elevation of 20 to 30 ft above sea level (Anders and others, 1968), although ground water also occurs in shallower zones. Shallow ground water near the site has a hydraulic head of about 70 ft msl, or about 15 ft bgs (see section 4). The regional gradient is typically to the southeast in the area (Anders and others, 1968). The gradient is very flat and may vary because of local pumping and recharge conditions (section 4). Anders and others (1968) and the authors of an RRC site-assessment study (unpublished report) noted that the regional flow direction is influenced by ground-water withdrawal at the city of Liberty and by the surface-water divide between the Trinity and Neches River basins. This withdrawal may at times produce a more southerly flow near the site.

Water quality in the Chicot aquifer is reported as a calcium bicarbonate type, mixed sodium chloride and calcium bicarbonate type, or mixed sodium chloride and sodium bicarbonate type. Although sulfate content is low, chloride contents may be elevated in some areas (Anders and others, 1968). Site and near-site water chemistry also falls into these groupings, with no clear trends in water types (section 4).

2.4 Site History

RRC records indicate that a large pit to the north of the current roadway and residences, possibly part of the Roeling site, existed in the late 1970's for disposal of "salt-based drill cuttings." This pit was apparently closed in 1977 (RRC records). Surface-soil samples from this area yielded a chloride concentration of 1,176 mg/L (1:1 soil extract, reported December 3, 1992, RRC sample). At one time a large ditch was dug on the west and south sides of the pit; an RRC water sample from the ditch had a chloride concentration of 229 mg/L (reported December 3, 1992, RRC). To the east of the site a series of approximately 15- × 15- × 4-ft-deep mud pits existed, which were filled with drill fluid, having chloride concentration of 486 mg/L (RRC files, 1992).

Trash was also noted at the site (RRC files, 1992). The former existence of the large disposal pit and a ditch was verified by a neighbor, Mr. Randall Hill, during the BEG site visit (personal communication, March 1997). Samples of subsurface sediments taken by the RRC at the site on December 12, 1992, indicated levels of TPH to as much as 17,339 mg/kg (method 418.1) and chloride to as much as 160.2 mg/kg in or below the waste package. RCRA metals in the sediments were below detection limits.

The site was most recently permitted for a washout pit on June 21, 1985, when a permit for "storage of waste water from the internal washing of trailers hauling spent drilling fluid" was approved by the RRC for Roeling Vacuum, Inc. The approved pit volume was 7,000 gal. No other oil-field fluids were permitted to be stored or disposed of at the site. A complaint (RRC No. 03-03119) against the site was filed on December 17, 1990, by Robert Taggert, a neighboring landowner. At the time, Roeling Vacuum was no longer in business at the site because they apparently had ended work in 1988. A water sample taken by the RRC from Mr. Taggert's well yielded a value of 2,326 mg/L chloride and a conductivity of 6,300 μmhos/cm (RRC laboratory report, February 6, 1991). A field test by RRC at the time of sampling showed 6,000 ppm chloride in the Taggert well and 5,500 ppm in onsite pit water (RRC memorandum, December 20, 1990). A number of permit violations were noted at the site by RRC personnel at the time of the complaint. The complainant's property has since been sold to a Mr. Able and is currently occupied by the Rogers family. The former well (98 ft deep) has been replaced by a shallower well (34 ft deep) (RRC file report, 1995).

A number of pit-fluid and sediment samples were analyzed by RRC in 1992 and 1993 (RRC file reports), with results indicating elevated chloride and low detected levels of some TCLP metals and petroleum hydrocarbons in the disposed drill-fluid materials and elevated conductivity values in some pit waters. The above-ground tanks and material in the tanks were removed from the site by an RRC contractor in June 1995. The large pits were not drained or backfilled, however, and were still in existence in March 1997.

3.0 METHODOLOGY

A combination of nonintrusive techniques, such as surface geophysical methods, and in situ techniques, such as monitoring-well installation, were used to assess different environmental media at the Roeling Vacuum site. These methods, described later, were used to characterize both chemical and physical properties of these media and to determine the potential extent of contamination. Sampling and testing locations are shown in figures 3.1 and 3.2.

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 and within the waste-disposal area. EM determines lateral and vertical trends in conductivity in subsurface soils and ground water. We ran six survey lines at coil separations of 32.8, 65.6, and 131.2 ft (10, 20, and 40 m) between the transmitter and receiver coils and two coil orientations (horizontal and vertical dipole) using the Geonics EM 34-3 m (fig. 3.2). The effective penetration depth was 19.7 to 82 ft for the horizontal dipole orientation and 39.4 to 164 ft for the vertical dipole orientation. Station spacing was 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 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 deeper 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 conductivity anomalies, 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 (sections 3.1.2 and 4.1), 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 (BH-4) placed near the center of the site area. This instrument detects changes in apparent ground conductivity consistent with observed lithology changes (for example, clay versus sand), as well as enhanced conductivity changes resulting from salt contamination, within soils and rock laterally surrounding the borehole. It functions like 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, or grout. The monitoring wells were located so that the EM 39 logs could be correlated with the surface EM 34 readings. Results are shown and discussed in section 4.1.

3.2 Global Positioning System Survey

Global positioning survey (GPS) data, compass bearing and distance, and aerial-photography data were combined to generate preliminary maps of the Roeling Vacuum 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 the site was georeferenced and mathematically corrected for distortion. These images were then imported into a layer in the GIS. Photographs serve as a backdrop to site maps and also allow on-screen digitizing of features not measured in the field, such as roads and buildings. When available, property boundaries from plat maps were added electronically to the GIS files. These plat data were not field checked, but they are nonetheless provided for information.

3.3 Sampling Methods

3.3.1 Probing/Trenching

Both trenching and mechanical drilling methods were used to sample wastes at the Roeling Vacuum site. The surface of the wastes was hard because of encrustation and because fill material was placed over part of the site before closure of the operation. This fill prevented the use of hand-coring devices onsite, although site access for heavy equipment was difficult in some areas because of the very soft subcrustal materials.

For the mud-filled pit areas on the east side of the site, and for pond sediments, a graduated steel probe was used to measure penetrable thickness (as much as ~8 ft) of the waste materials at each sampling point. A minitrackhoe was then used to excavate a trench as much as 2 ft deep from each mud pit, and a sample composite was taken from this trench. The trackhoe was also used to excavate a number of exploratory trenches around the perim of the site to determine the lateral extent and approximate depth of the waste materials. Trench and pit sample locations are shown in figure 3.1. Trench samples were taken only when it was unclear whether the material was actual waste material or whether special characteristics, such as total petroleum hydrocarbon (TPH) content, were of interest. Each trench was first described stratigraphically and photographed. We took composite samples in a consistent manner from the sidewall of each trench using a stainless steel scoop, from approximately 6 inches below the ground surface to the bottom of the trench, penetrating approximately 1 inch into the sidewall.

The sidewall material was then composited in a stainless steel bowl, placed in precleaned glass containers, and stored and shipped on ice at 4°C. All samples taken were analyzed for TPH, chloride, electrical conductance (EC), and moisture. Selected samples were analyzed for RCRA 8 metals. We analyzed one sample composite from pits 1 through 8 using the toxicity characteristic leaching procedure (TCLP) for RCRA 8 metals. One sample composite from surface soils beneath the largest trash pile area (see fig. 3.1 for location) was analyzed for TPH, chloride, conductivity, moisture, RCRA 8 metals, pesticides, and PCB's.

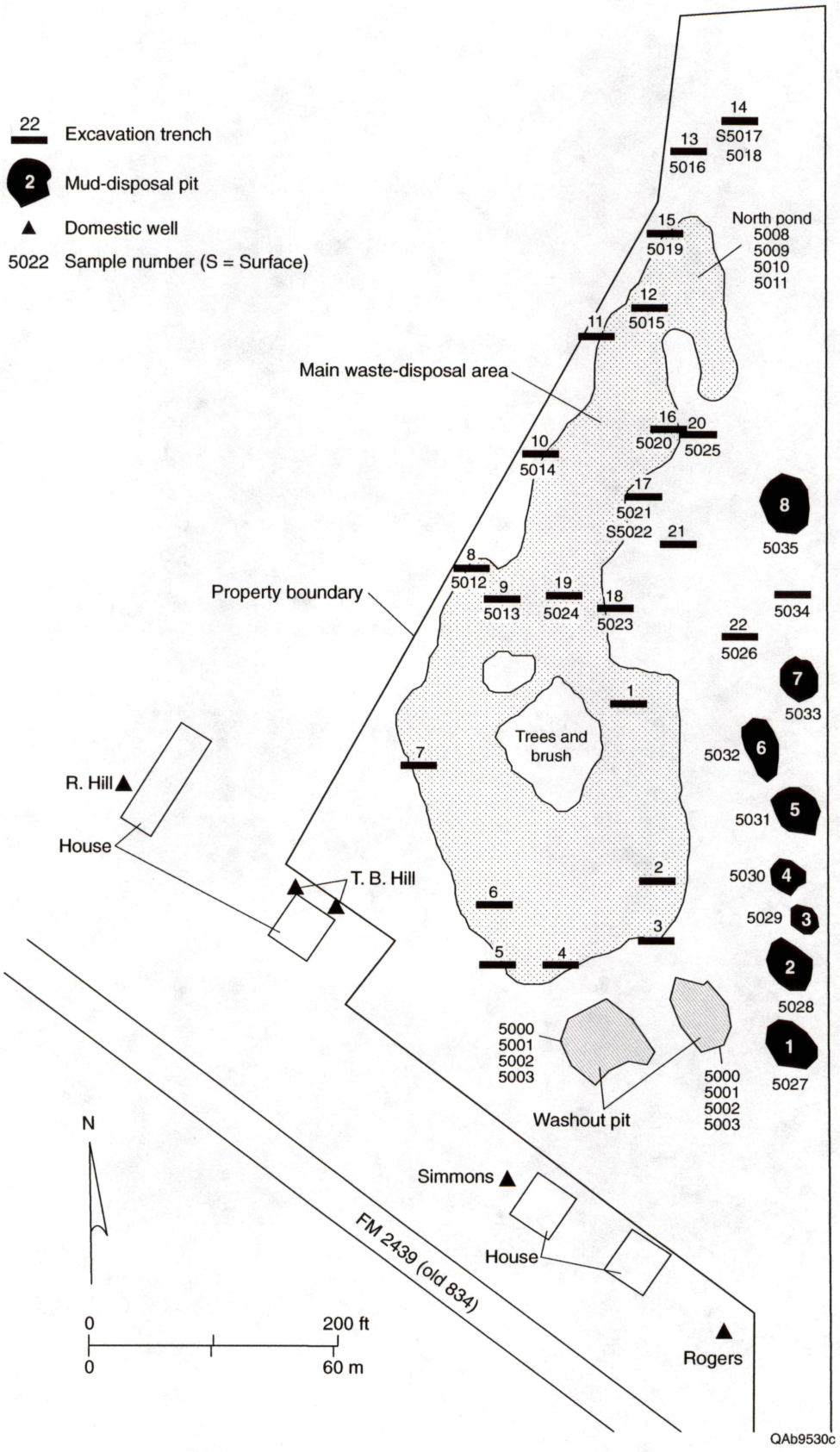

Figure 3.1. Trench and surface impoundment sample locations, Roeling Vacuum site.

A "buggy"-mounted Mobil B-57 drilling rig supplied by Master Monitoring Services, Inc., of Houston, Texas, was used to drill a number of boreholes at the site (fig. 3.2). Although access limitations dictated locations where samples could be taken, a range of locations across the site and one background location offsite (BH-12) were drilled. Borings were drilled with 7.5-inch-diameter (O.D.) hollow-stem augers (14-inch I.D.). Cores were taken simultaneously with a 5-foot-long (3-inch I.D.) detachable rod-mounted core barrel. We decontaminated the drill rig, augers, and all drilling equipment before drilling and between boreholes using a high-pressure steam cleaner. Each borehole was backfilled or tremie-grouted with a 2 percent bentonite-grout mixture. Borehole depths and relative surface elevations are given in table 3.1. One sample was analyzed for TCLP parameters, volatile organic compounds (VOC's), semivolatile polynuclear aromatic hydrocarbons (PAH's), and total organic halogens (TOX), in addition to TPH, chloride, conductivity, and moisture, which were analyzed for all subsurface borehole waste composites. RCRA 8 metals were analyzed for selected samples. The VOC samples were extruded directly from the end of the core barrel, and other samples were composited in a precleaned stainless steel bowl.

All samples from the core barrel were documented, extruded or composited, and placed in precleaned glass containers. Samples were shipped on ice at 4°C and were received and analyzed at the laboratories within maximum holding times. Samples were analyzed either by Chemsolve or the RRC Surface Mining and Reclamation Laboratory. All borehole samples taken were analyzed for TPH, chloride, EC, and moisture. Selected borehole samples were analyzed for RCRA 8 metals. One sample from the east-central (deepest) part of the waste-disposal area was selected for analysis of TOX, PAH's, VOC's, pesticides/PCB's, and TCLP analytes, which included VOC's, semivolatile organic compounds (SVOC's), leachable RCRA 8 metals, reactivity, corrosivity (pH), and ignitability. One sample from this area was also analyzed for additional 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.

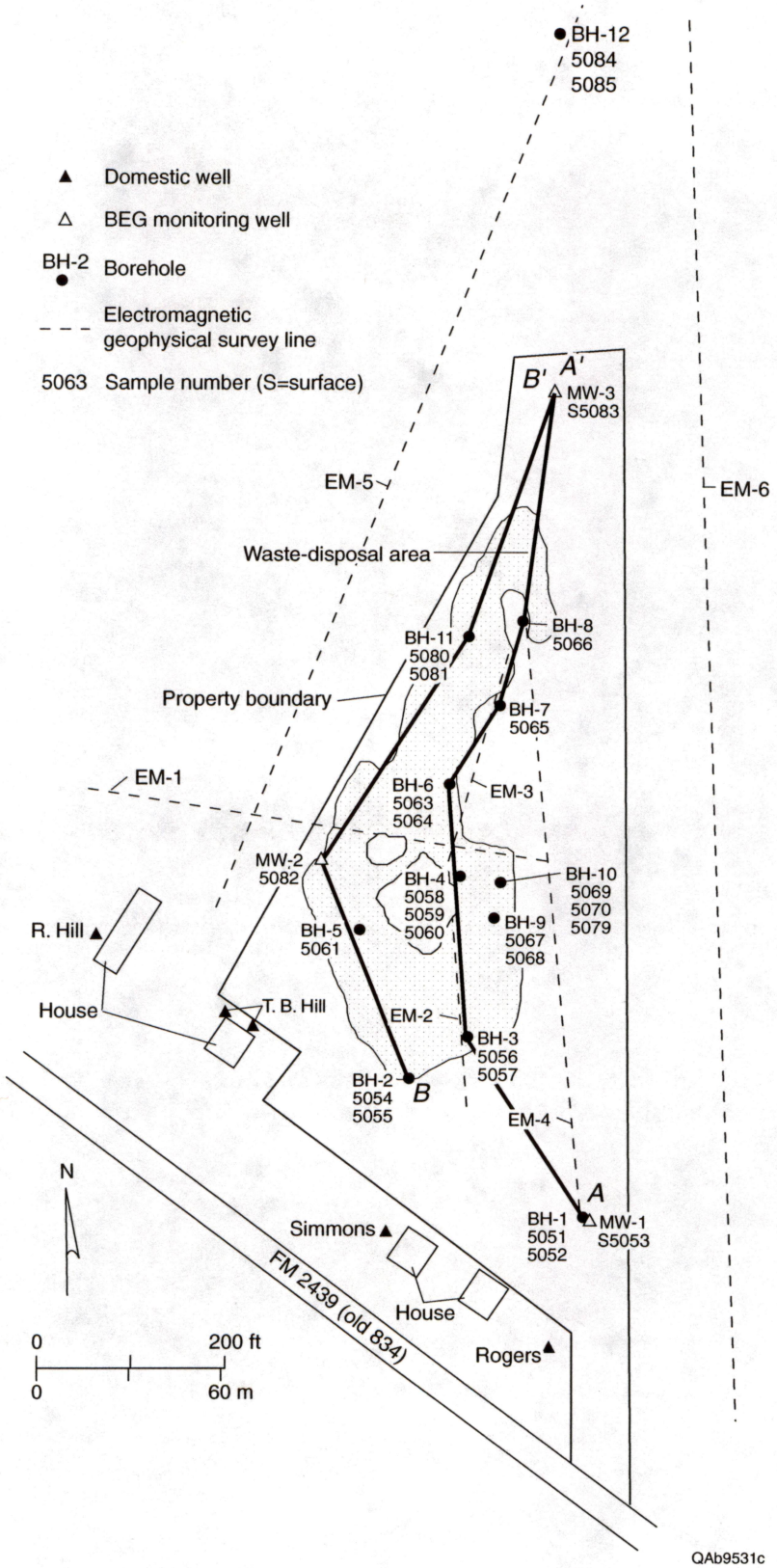

Figure 3.2. Domestic-well, monitoring-well, borehole, and EM survey line locations at the Roeling Vacuum site, including borehole sample numbers. Section lines A–A′ and B–B′ shown in figures 4.4 and 4.5.

Table 3.1. Waste-package boring data. All data in feet from ground surface.

Boring number	Total depth	Approximate depth to water	Relative ground surface elevation[1]
BH-1	50	16	78.05
BH-2	10	not observed	83.07
BH-3	20	11	84.93
BH-4	15	5	78.43
BH-5	10	not observed	78.69
BH-6	10	not observed	77.56
BH-7	10	not observed	77.59
BH-8	5	not observed	77.16
BH-9	10	5	79.13
BH-10	17	3	78.87
BH-11	10	not observed	76.97
BH-12	25	15	75.96

[1]All elevations relative to arbitrary local elevation datum. Not surveyed into offsite grid.

3.3.2 Surface Impoundment Sampling

Three impounded surface-water samples were taken at the Roeling Vacuum site. One was taken from shallow water collected in a low ponded area on the north side of the site, and one sample was taken from each of the two washout pits on the south end of the waste-disposal area. We took the samples from the center of each water body by boat. At each location the water sample was taken by filling a bailer with a water column and sequentially filling the sample containers in the following order: VOC's, TPH, chloride, RCRA 8 metals, and field parameters (pH and specific conductance). A sludge sampler was used to remove a sediment/sludge sample from the center of each pond. These samples were analyzed for TPH, chloride, RCRA 8 metals, and specific conductance. All samples were shipped on ice at 4°C to Chemsolve and were received and analyzed within maximum holding times. Sampling points are shown in figure 3.1.

3.3.3 Soil Borings and Monitoring-Well Installation

Three monitoring well borings were drilled by Master Monitoring Services, using 7-inch I.D. (11-inch O.D.) hollow-stem augers on a "buggy"-mounted Mobil B-57 drilling rig. Cores were taken simultaneously with a 5-ft-long detachable rod-mounted core barrel. The drill rig, augers, and all drilling equipment were decontaminated before drilling and between boreholes by a high-pressure steam cleaner. We constructed monitoring wells of nominal 2-inch-I.D. PVC casing having a 0.010-inch slotted screen, sand-packed them using clean, 20/40 silica sand, and sealed them with Hole-Plug™ brand 100-percent bentonite pellets and 2-percent bentonite-cement grout. Water was added to the hole during installation of the well casings to prevent sand lockup. The water source, the public supply of Hull, Texas, was transported to the site in a prerinsed polyethylene water storage tank. This water was analyzed for background presence of VOC's (sample number 5079, appendix B), and none was detected above method detection limits. We completed each monitoring well using a 4-inch × 4-inch × 4-ft-long steel protector casing having a minimum 2-ft stickup and a 4-ft × 4-ft-wide × 4-inch-thick concrete pad. All wells were equipped

with a sealed internal cap and a protective padlock. Figure 3.3 illustrates monitoring-well construction information. Wells were developed to visual clarity (~1 hr of pumping per well). Details of the well-completion data are shown in table 3.2. Boring logs and well-completion diagrams are provided in appendix A. Results of the boring and monitoring-well sampling are discussed in sections 4.2 and 4.3, and a potentiometric surface map is provided as figure 4.8.

3.3.5 Domestic-Well Inventory

State well records (Texas Department of Water Resources and TNRCC) of wells within a 0.5-mi radius of the site were found to be incomplete. A door-to-door domestic-well inventory of the area surrounding the site was therefore performed with the assistance of Mr. Mark Osterman of the RRC District 3 office. Each dwelling within a 0.5-mi radius of the site was identified by maps and visual identification. Residents were contacted on June 19 and July 24, 1997. A total of five domestic wells were identified and sampled for VOC's, TPH, RCRA 8 metals, pH, specific conductance, major cations, and anions. Well locations are shown in figure 2.2. Depth and ownership information is shown in table 3.3. Total coliform was sampled at two wells. Sample containers were filled directly from either an inside or outside tap after the lines were flushed for 10 minutes. The tap was sterilized with isopropyl alcohol before the coliform sample collection then thoroughly rinsed to remove all traces of alcohol. All samples were shipped on ice at 4°C to the Chemsolve laboratory and were received and analyzed within maximum holding times. Coliform samples were transported at ambient temperature and analyzed by the LCRA laboratory. Analytical results are shown and discussed in section 4.4.3.

Once analytical results of these grab samples were available, RRC staff collected additional water samples for verification from the Simmons well on October 9, 1997. Four sample aliquots were taken from either the kitchen tap or a faucet between the pump and pressure tank. Two of the sets were collected after the pressure tank was twice drained and refilled.

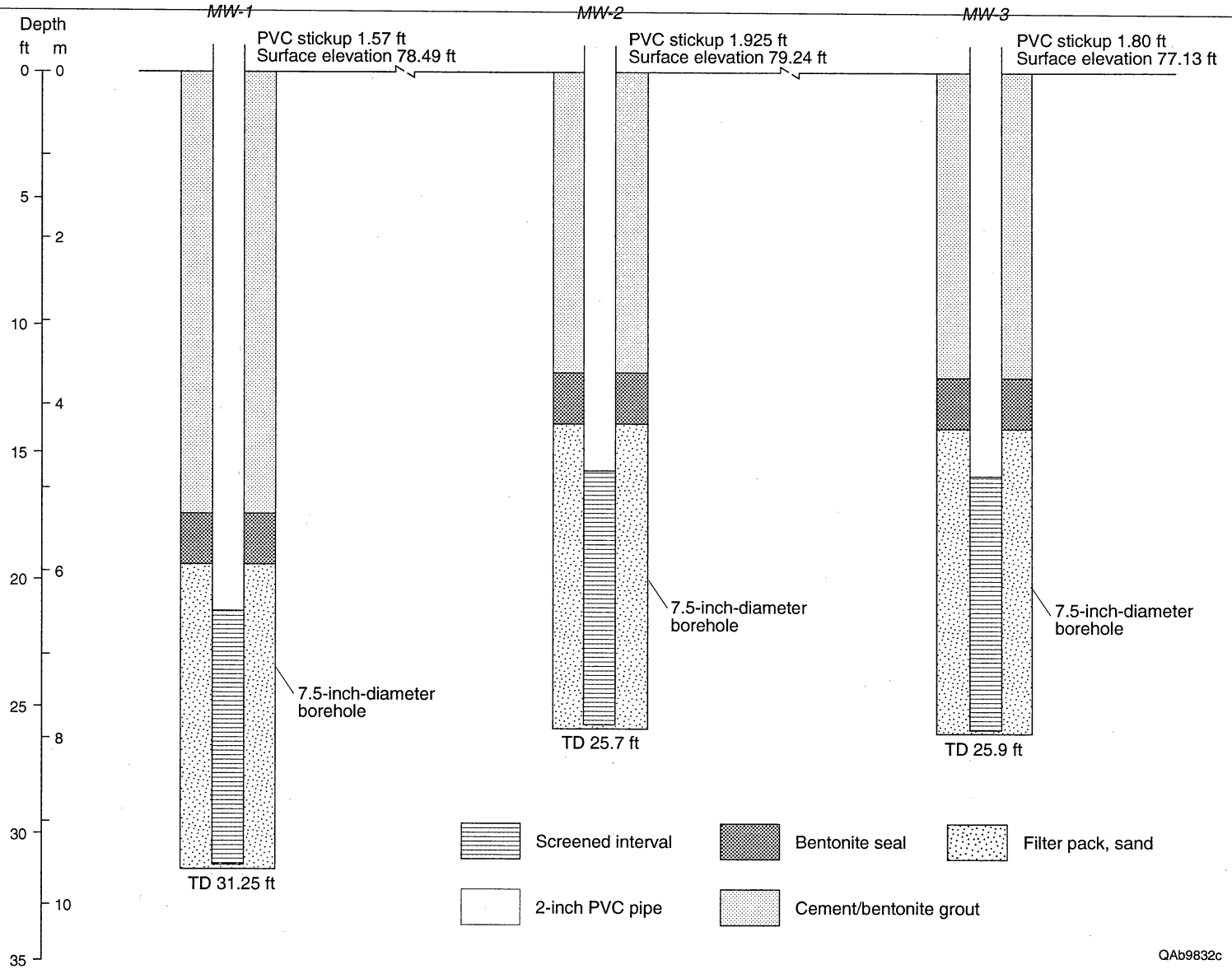

Figure 3.3. Monitoring-well construction information.

Table 3.2. 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 (7/31/97) [2]	Relative ground surface elevation[1]
MW-1	31.25	21–31	19–31	0–17 (grout) 17–19 (bentonite)	9.63	78.49
MW-2	25.7	15.7–25.7	13.7–25.7	0–11.5 (grout) 11.5–13.7 (bentonite)	9.96	79.24
MW-3	25.9	15.9–25.9	13.8–25.9	0–11.8 (grout) 11.8–13.8 (bentonite)	7.85	77.13

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

Table 3.3. Domestic ground-water well survey data.

Owner	Address[1]	Depth (ft)	Diameter (ft)	Treatment system	Sample location	Aquifer
C. J. Jones	Rt. 1 Box 212	82	n/a	filter and softener	outside tap	Beaumont (Chicot)
Dorothy and James Rogers (former Taggert well)	Rt. 1 Box 211A, Hull, Texas, *or* P.O Box 1894, Liberty, Texas 77575	106 or 116	0.3	no	inside tap	Beaumont (Chicot)
Terry and James Simmons	Rt. 1. Box 211	30-36	0.3	no	inside tap	Beaumont (Chicot)
T. B. Hill (well in use)	Rt. 1 Box 210 M	24	0.3	no	inside tap	Beaumont (Chicot)
T. B. Hill (old well)	same	64	0.5	no	not accessible[2]	Beaumont (Chicot)
Randall Hill	Rt. 1 Box 210 K	<30	n/a	no	inside tap	Beaumont (Chicot)

[1]All addresses are Hull, Texas 77564, except where noted
n/a: not available
[2]Collapsed casing above water level

3.3.6 Ground-Water Sampling

Ground water was sampled at the three onsite monitoring wells on July 31, 1997. A Redi-Flo 2 submersible pump was used to purge the wells and to conduct hydrologic tests. The ground-water samples were collected at the end of the drawdown periods of the hydrologic tests. More than 10 well-bore volumes of water were removed in each drawdown test before collection of water samples. Temperature and pH were measured at the well sites. We measured alkalinity at well sites by titration of unfiltered samples in a standard dilute (~0.16 N) H_2SO_4 solution using a Hach digital titrator. We filtered samples for RCRA 8 metals, total cations, and total anions using an inline 0.45-μm Geotech high-flow filter attached at a tee in the discharge line. Metals and cation samples were acidified with 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 was measured at the wellhead in an unfiltered sample. All samples were shipped on ice at 4°C to Chemsolve and were received and analyzed within maximum holding times. Results are shown and discussed in section 4.4.1.

3.4 Ground-Water Hydrologic Testing

Tests to determine transmissivity were conducted at the three monitoring wells in conjunction with collection of water samples for chemical analysis. The hydrologic tests consisted of unsteady-state drawdown and recovery tests, water-level changes being measured in the pumping well. The test at MW-1 was performed as a step-drawdown test to determine how great a pumping rate could be sustained, whereas the tests at MW-2 and MW-3 were performed as constant-discharge tests. We measured discharge rate using a 5-gal (18.93-L) calibrated bucket and stopwatch. We recorded water levels during tests using a pressure transducer and programmable data logger attached to a laptop computer. Pumped water was discharged to the waste-disposal area. At completion of the

drawdown phase of the test, ground-water samples were collected, the pump was turned off, and then water-level recovery was monitored.

Hydrologic test data were evaluated by comparison with standard type curves showing the Theis equation. The equation describes the idealized transient response of water level in an aquifer to pumping from a well, assuming that (1) the aquifer is homogeneous and isotropic and of infinite extent, (2) the well fully penetrates the aquifer and has an infinitesimally small diameter, (3) water removed from storage is instantly discharged, and (4) flow in the aquifer to the well is horizontal only, without vertical components of movement. If these assumptions are not met by actual conditions, water levels observed during a test will not match those predicted by the Theis equation. Evaluation of these assumptions and hydrologic test data superposed on standard type curves can yield insight into hydrologic conditions affecting a test.

Comparison of the test data at MW-2 and MW-3 with the type curves showed that drawdown was less than predicted by the Theis equation. Information about subsurface stratigraphy, water-level change during drilling, and the hydrologic setting at the Roeling Vacuum site suggests that the drawdown response results from leakage from water-bearing deposits having a permeability lower than that of the main aquifer zone. Accordingly, data on the drawdown period of the tests, which lasted from 21 to 50 min, were analyzed by comparison with standard type curves for a leaky (semiconfined) aquifer (Walton's method [Kruseman and De Ridder, 1992]). Because there was significant leakage in tests at the monitoring wells analyzed with type curves, transmissivity at MW-1 was estimated on the basis of specific capacity from the step-drawdown data. Results of the hydrologic tests are summarized in section 4.4.1 of this report.

4.0 RESULTS

4.1 Geophysical Survey

Data for the six surface geophysical survey lines are shown in figures 4.1 (horizontal dipole) and 4.2 (vertical dipole). Results from the surface geophysics were used to help select locations for

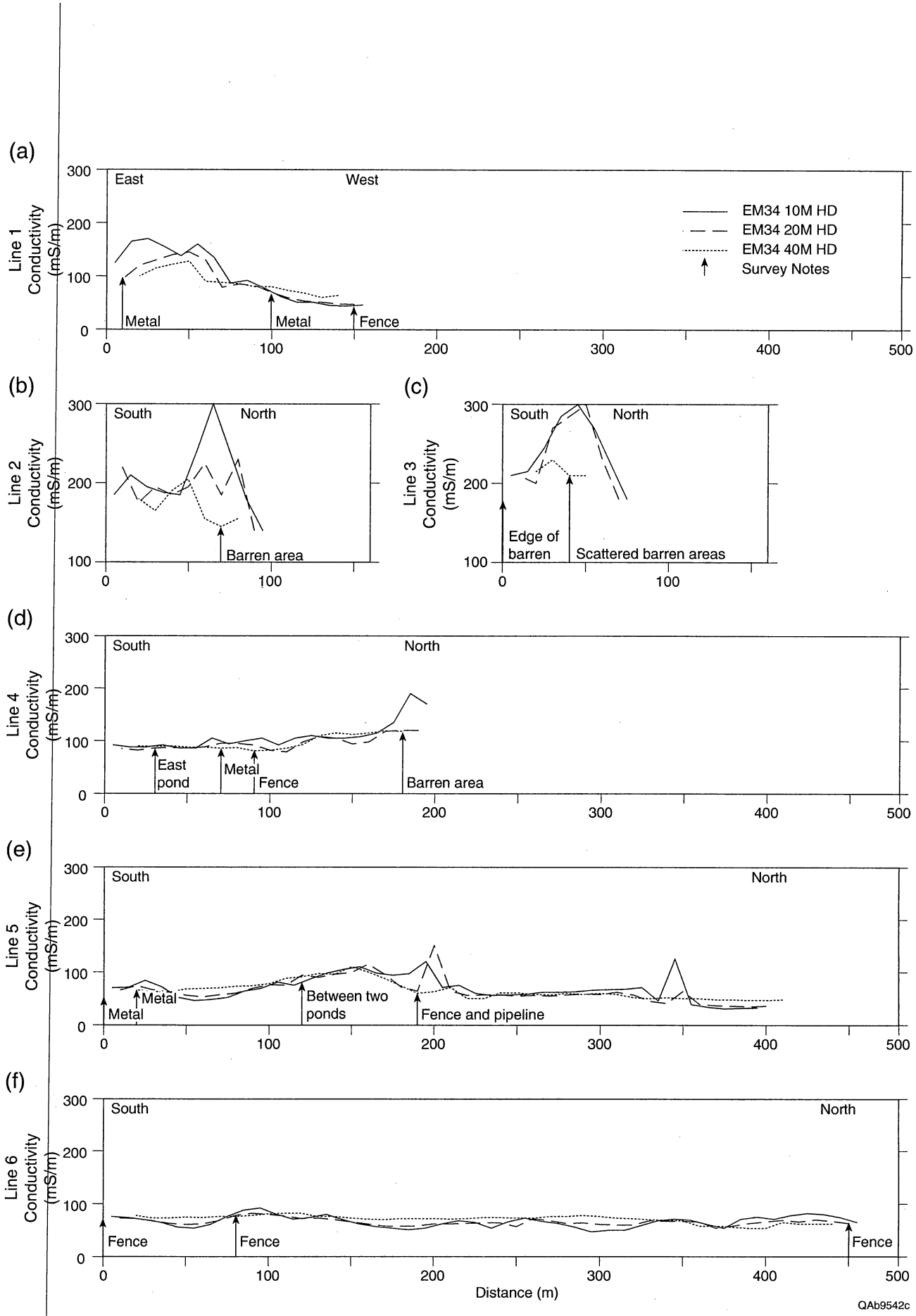

Figure 4.1. EM 34-3 electromagnetic geophysical-survey data, horizontal dipole.

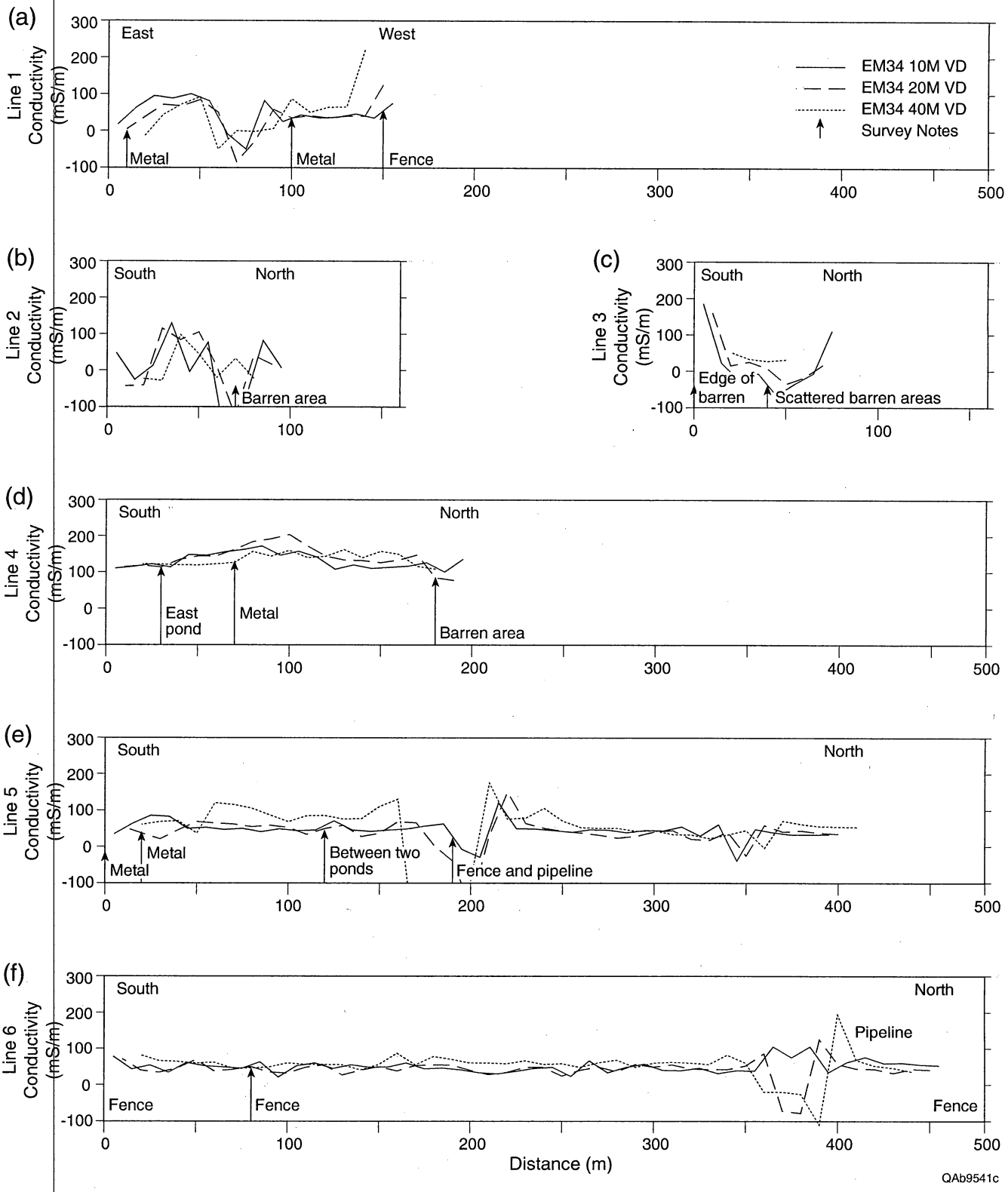

Figure 4.2. EM 34-3 electromagnetic geophysical-survey data, vertical dipole.

the monitoring wells and the borehole. Downhole geophysical logs and soil-chloride measurements from these locations were then compared with the surface/EM data (fig. 4.3).

The horizontal dipole data tend to be weighted toward the surface, and, thus, were most indicative of the effects of the waste on soil and the shallow ground water to a depth of about 80 ft. Because vertical dipole data are weighted toward the center of the penetrated depth, they tend to indicate deeper zones. EM line 1 ran from east to west across the site and across the largest barren area in the central part of the site. Horizontal dipole data showed conductivity values that were elevated across the barren area, particularly for shallower depths. Once offsite, an inversion occurred, indicating slightly greater conductivities at deeper depths in the saturated zone, albeit within normal ranges for pore waters in the Beaumont Formation. This west part of the line is located in an upgradient flow direction from the waste-disposal area.

Lines 2 and 3 are connected lines that ran from south to north along the axis of the waste area. They connect just north of line 1, and line 3 runs slightly more to the northeast. Both lines show elevated readings throughout the sections—particularly a shallow, high-conductivity zone near the central barren area. According to local property owners (Randall Hill, July 1997; Ronnie Key, July 1997), this was the area of deepest excavation at the site and a primary dumping location of the vacuum trucks. This location may also coincide with the "salt-water-based drill mud disposal area" from the 1970's that was noted in RRC files.

Line 4 ran from south to north along the site road, which was not a disposal location but part of the berm system at the site. A large amount of metal trash and debris lies along this road on the east side, although it did not appear to affect the signal significantly. There was little difference between the three horizontal dipole signals; all were slightly elevated over offsite signals. The vertical dipole signals were probably affected by the metal trash but showed a significant increase in the 20-m spacing line adjacent to the barren area, above both the 10- and 40-m spacings. This increase indicates an intermediate zone of higher conductivity approximately 20 to 40 ft below ground surface. Although the direction of ground-water flow was not known at the time of the EM

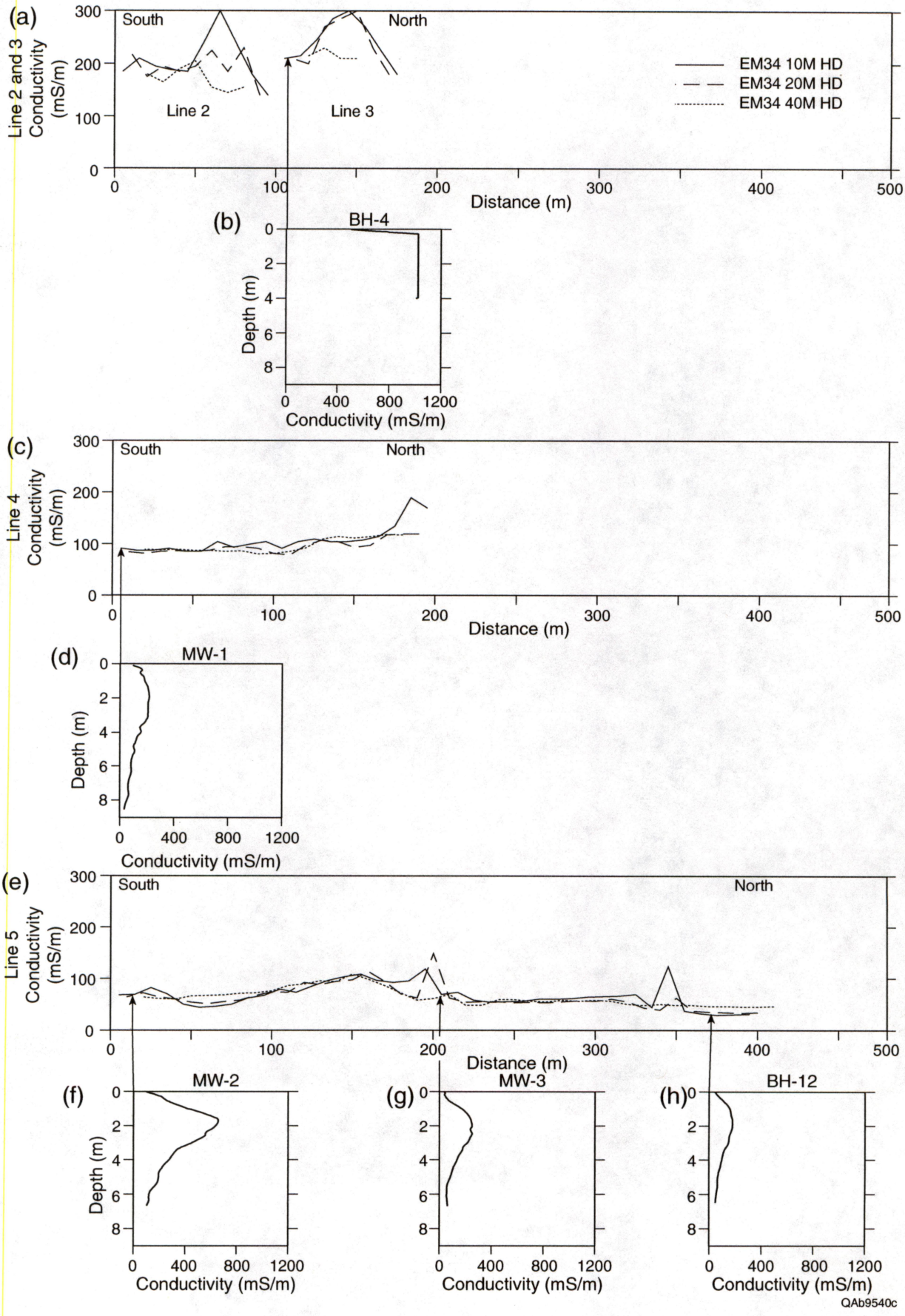

Figure 4.3. EM 34-3 and EM 39 combined electromagnetic geophysical-survey data.

survey, current data indicate that some migration of chloride to the southeast at this location on EM line 4 is likely, within the shallow aquifer.

Line 5 ran from south to north on the west side of the site to approximately 750 ft past the northernmost site boundary (fig. 3.2). The line was located approximately 150 ft west of the site boundary. Most locations along the line tended to be within normal ranges, with some elevated readings in areas of standing water and anomalies at fence lines. Readings between the anomalies at 480 ft along the line were slightly high, but the remainder of the readings generally fell within normal ranges for the Beaumont. These readings indicate some effect from site runoff toward the north.

Line 6 ran from south to north on the east side of the site, approximately 150 ft east of the site boundary (fig. 3.2). The horizontal dipole data were consistent and within normal ranges for the Beaumont. The vertical dipole data were also within normal ranges but showed anomalies where the line crossed an underground gas pipeline that runs on the north side of the property. There was no indication of elevated conductivity along this line in either the vertical or horizontal dipole data, which means that the elevated conductivity zone shown in line 4 most likely does not extend this far offsite.

Vertical EM-39 logs were taken from each monitoring-well boring, from BH-4, located within the central barren area, and from BH-12, located offsite on the north side of the property. This latter location was expected to approximate background conditions in this area. Results from BH-12 indicated a peak conductivity value of 180 mS/m at a depth of about 4 ft, which coincides with the saturated part of the surficial clay unit underlying the area and typifies saturated clays in this region. This value decreases with depth and with decreasing clay content to about 60 mS/m in the sand zone of the boring. This value is typical for sands saturated with low-conductivity pore waters, which would be expected in a background area. The log from MW-1 also showed near-background conductivity levels both in the clay zone and the saturated sands. This log also showed some variability between 3.7 and 8.5 m, which is likely from interfingering clays noted in the core strata. Neither of these borings showed evidence of deep movement of chloride into the saturated

sand zone. Chloride sample data in ground water at MW-1 (section 4.4.1) are consistent with these results.

The upper clay soils in the MW-3 borehole showed moderately increased conductivity when compared with the clay in BH-12, indicating some potential for chloride movement downward within the clay zone. MW-3 is located in an area that may have received outwash from the site and that was reported to be within a zone of historic vegetation kill (Ronnie Key, personal communication, July 1997). No elevated conductivity was noted at depth in this boring within the saturated sands, although the chloride level was slightly higher in the ground water at this location than at MW-1 (section 4.4.1).

MW-2 had the highest conductivity of the four borings measured. This location is on the berm immediately adjacent to the waste-disposal area. The shallow clay zone in the boring exhibited conductivities as high as 660 mS/m. These values most likely stem from the proximity of the wet, saline wastes. Conductivity decreased markedly with depth, however, to near-normal levels at 6.8 m, which is well within the sandy saturated zone.

BH-4 was located near the center of the elevated zone noted on EM-34 line 2 and within the central barren area. As such, the values peaked at above 1,000 mS/m within the top m of the surface and remained this high throughout the borehole to the measured depth of more than 13 ft. Because this was the maximum conductivity m value at the given settings, actual values are higher. All but the bottom few feet of this borehole were in the waste material; the sample from BH-4 exhibited the highest chloride values found at the site. These values are much higher than would be expected normally from clay materials and indicate the presence of brine or salts. BH-4 was not extended deeper to prevent connecting this highly saline zone with the uppermost aquifer. The borehole was grouted immediately upon completion of logging.

4.2 Waste Package

The waste materials in the large central-disposal area onsite appear to be predominantly oil-contaminated, water-wet drilling muds, composed primarily of bentonite clay in most locations, although according to EM data, evidence of saltwater-based fluids exists in some areas. The upper surface is characterized by a variably thick crust of fill dirt that is predominantly tan, sandy clay material with roots, salt encrustation, and evidence of pipe scale; fractured grout; and fine gravel in some areas. No oil or oil stains were observed on this surface crust, which varies in thickness from 2 inches to approximately 2 ft. The materials below the crust, generally very soft, have little or no compressive strength, although some parts of the crust can support light vehicles and foot traffic.

Wastes in the eight mud pits on the east side of the site were found to be similar in appearance to that of the main waste package, but with some variation in color. Pits farther to the south appeared to be darker in color than the northerly pits, possibly because of variation in mud additives or waste oxidation states. Local residents noted that the pits were established to separate different types of muds (Ronnie Key, personal communication, July 1997).

Sediments in all three ponds also appear to be spent drilling mud. Sediment samples were medium to light gray with black streaks and a distinct petroleum odor. The horizontal extent of the waste materials in the large, central disposal area is limited by berms emplaced by the former facility operator and by natural topography. Total waste volume in this main bermed disposal area was calculated to be 16,500 yd^3. Figures 4.4 and 4.5 show cross sections of the waste package, including the thickness of the underlying clay and sandy clay zones and the monitoring well and boring depths (see fig. 3.2 for cross-section locations). The waste package lies for the most part on top of a clay unit in the Beaumont Formation and above the static water table, with the exception of the deepest waste zone near boreholes BH-4, BH-9, and BH-10.

The summary results of chemical analyses of the composite waste samples are shown in tables 4.1 through 4.3. Sample numbers corresponding to the sample points are shown in

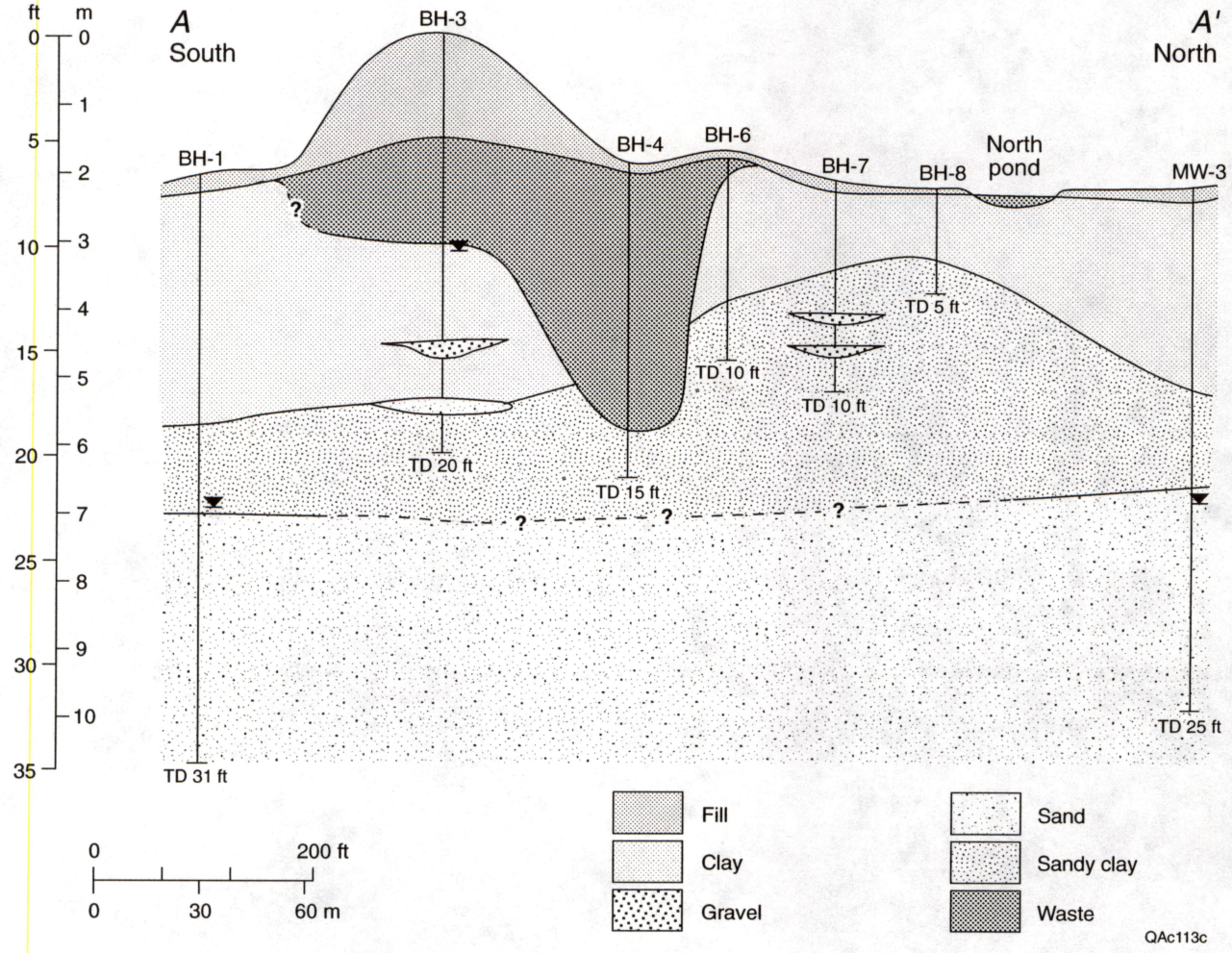

Figure 4.4. South-north cross section A–A′ of the waste-disposal area and local stratigraphy. Line of section shown in figure 3.2. Initial water levels shown.

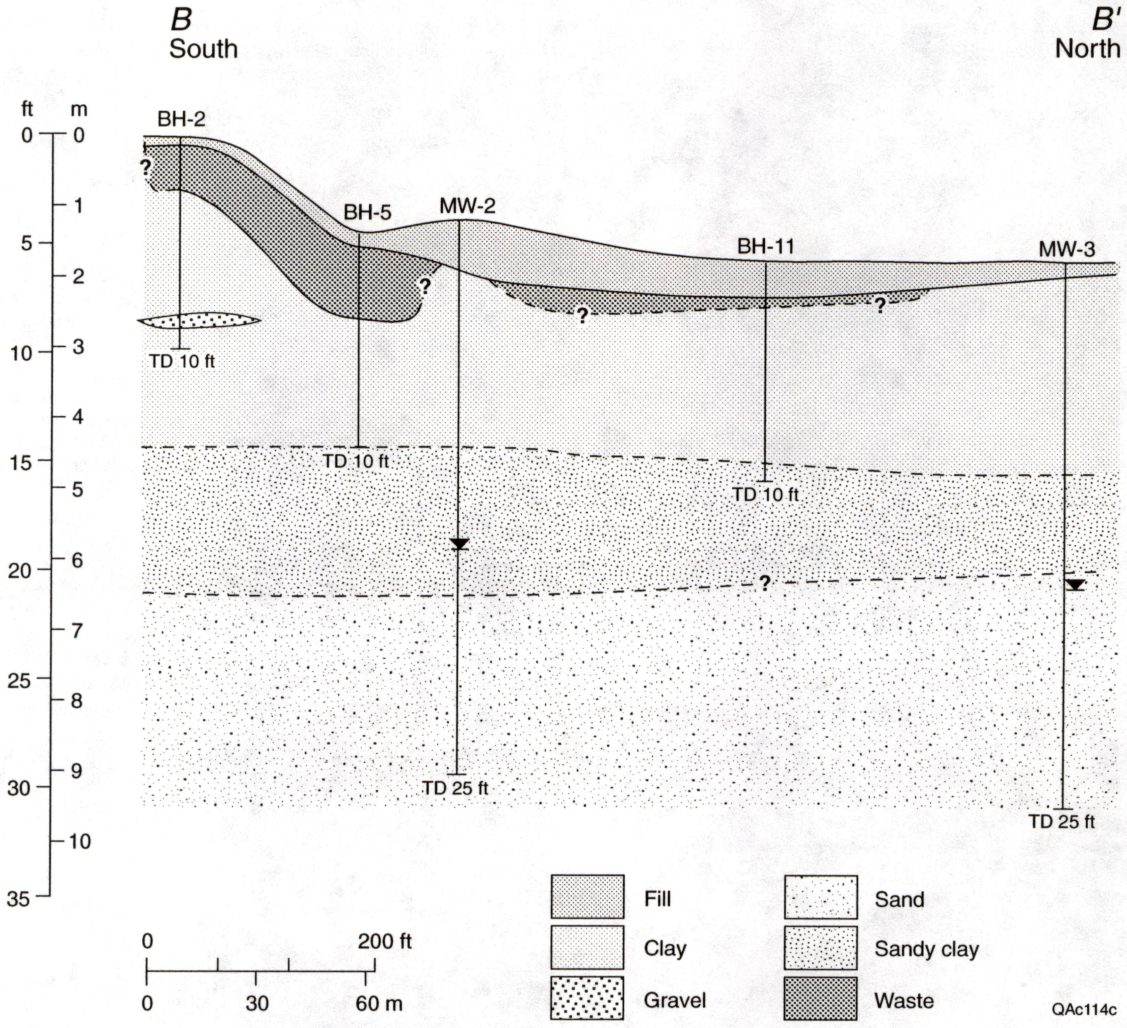

Figure 4.5. South-north cross section B–B′ of the waste-disposal area and local stratigraphy. Line of section shown in figure 3.2. Initial water levels shown.

Table 4.1. Summary of analyses of samples and depth data from Roeling Vacuum solid-waste pits. Units are in mg/kg except where noted.

Location	Pit 1	Pit 2	Pit 3	Pit 4	Pit 5	Pit 6	Pit 7	Wooded area	Pit 8	Regulatory or guidance limit[1]
Sample number[2]	**5027**	**5028**	**5029**	**5030**	**5031**	**5032**	**5033**	**5034**	**5035**	
Sample depth (ft)	**0–2**	**0–2**	**0–2**	**0–2**	**0–2**	**0–2**	**0–2**	**0–2**	**0–2**	
Pit depth (ft)	5.9	9.7	4.5	6.5	7.3	5.1	3.4	n/a	2.7	
Arsenic	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	36
Barium	55	24	28	9.7	50	24	5.5	44	325	2000
Cadmium	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	10
Chromium	237	237	197	77	125	68	40	92	34	100
Lead	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	30
Mercury	<0.5	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	4
Selenium	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	20
Silver	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	100
Chloride	1291	3192	1154	1154	438	1397	1113	192	17	n/a
TPH (%)	0.28	0.1	0.36	0.45	0.29	0.49	0.76	0.39	0.1	1% (RRC)
Oil and grease (%)	0.32	0.25	0.6	0.46	0.31	0.52	1.2	0.59	0.16	n/a
Moisture (%)	36	52	50	44	36	45	43	33	31	n/a
Conductivity 1:1 (mS/cm)	5	12	7.2	8.7	6	8.5	8.6	3.5	0.38	n/a
Conductivity sat. paste (mS/cm)	7.9	16	8.5	11	9.6	12	10	4.2	0.72	n/a

n/a = not applicable
N/A = not analyzed
[1]Metals limits are for a totals analysis. If a total analysis exceeds the limits listed, then TCLP must be performed before wastes can be disposed of in a municipal solid-waste facility (TNRCC, 1996b).
[2]All analyses in this table performed by RRC laboratory.

Table 4.2. Summary of analyses of trench samples from Roeling Vacuum waste-disposal area. Units are in mg/kg except where noted.

Location	Trench 8	Trench 9	Trench 10	Trench 12	Trench 13	Trench 14	Trench 14	Trench 15	Trench 16	Regulatory
Sample number[2]	5012	5013	5014	5015	5016	5017	5018	5019	5020	or guidance
Depth range (ft)	0–2	0–2	0–2	0–2	0–2	0–0.5	0–2	0–2	0–2	limit[1]
Arsenic	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	36
Barium	186	80	20	279	276	373	297	9	18	2000
Cadmium	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	10
Chromium	<0.5	213	39	12	20	13	25	81	102	100
Lead	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	30
Mercury	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	4
Selenium	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	20
Silver	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	100
Chloride	3423	1456	1476	860	1552	3047	6245	804	916	n/a
TPH (%)	0.04	1.5	0.23	0.02	0.02	0.01	0	1.7	0.77	1% (RRC)
Oil and grease (%)	0.07	1.9	0.35	0.05	0.03	0.02	0.01	2.6	1.2	n/a
Moisture (%)	14	49	44	17	21	36	20	62	47	n/a
Conductivity 1:1 (mS/cm)	11	9.5	9.4	4	5.3	11	20	6.1	7	n/a

n/a = not applicable
N/A = not analyzed
[1]Metals limits are for a totals analysis. If a total analysis exceeds the limits listed, then TCLP must be performed before wastes can be disposed of in a municipal solid-waste facility (TNRCC, 1996b).
[2]All analyses this table performed by RRC laboratory.

Table 4.2. Continued.

Location	Trench 17	Trench 17	Trench 18	Trench 19	Trench 20	Trench 21	Regulatory
Sample number[2]	5021	5022	5023	5024	5025	5026	or guidance
Depth range (ft)	0–2	0–0.5	0–2	0–2	0–2	0–2	limit[1]
Arsenic	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	36
Barium	32	9.5	223	213	180	1045	2000
Cadmium	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	10
Chromium	185	40	22	19	13	20	100
Lead	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	30
Mercury	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	4
Selenium	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	20
Silver	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	100
Chloride	6712	7855	4616	561	3768	14	n/a
TPH (%)	1.3	0.71	0.05	0.05	0	0.18	1% (RRC)
Oil and grease (%)	1.8	1.2	0.09	0.07	0	0.23	n/a
Moisture (%)	56	57	29	40	13	16	n/a
Conductivity 1:1 (mS/cm)	26	27	18	4.7	13	0.32	n/a

n/a = not applicable
N/A = not analyzed
[1]Metals limits are for a totals analysis. If a total analysis exceeds the limits listed, then TCLP must be performed before wastes can be disposed of in a municipal solid-waste facility (TNRCC, 1996b).
[2]All analyses this table performed by RRC laboratory.

Table 4.3. Summary of analyses of samples from Roeling Vacuum boreholes. Units are in mg/kg except where noted.

Location Analyzed by: Sample number Sample depth (ft)	MW-1 Chemsolve 5053 0–2	BH-1 RRC 5051 4–5	BH-1 RRC 5052 23–24	BH-2 Chemsolve 5054 2–3	BH-2 Chemsolve 5055 5–6	BH-3 RRC 5056 8–9	BH-3 RRC 5057 12–13	BH-4 Chemsolve 5058 5–6	BH-4 Chemsolve 5059 10–11	Regulatory or guidance limit[1]
Arsenic	0.93	<0.5	<0.5	1.7	N/A	<0.5	<0.5	3.6	2.1	36
Barium	220	389	315	52	N/A	237	293	19	81	2000
Cadmium	<0.1	<0.5	<0.5	0.27	N/A	<0.5	<0.5	0.28	<0.1	10
Chromium	0.95	25	19	26	N/A	45	23	25	2.6	100
Lead	5.4	<0.5	<0.5	130	N/A	<0.5	<0.5	150	<0.1	30
Mercury	0.045	<0.1	<0.1	0.039	N/A	<0.1	<0.1	0.078	0.042	4
Selenium	<0.1	<0.5	<0.5	<0.1	N/A	<0.5	<0.5	<0.1	<0.1	20
Silver	<0.1	<0.5	<0.5	<0.1	N/A	<0.5	<0.5	0.43	<0.1	100
Chloride	490	33	21	4,800	5,200	5612	3913	18,000	42,000	n/a
TPH (%)	0.018	0	0	0.25	<0.0010	0.1	0	0.072	0.035	1% (RRC)
Oil and grease (%)	N/A	0	0	N/A	N/A	0.12	0	N/A	N/A	n/a
Moisture (%)	18.9	16	17	59.7	16.3	37	19	84.1	16	n/a
Conductivity 1:1 (mS/cm)	3.8	0.51	0.26	7.6	17	22	13	57.9	75	n/a

n/a = not applicable
N/A = not analyzed
[1]Metals limits are for a totals analysis. If a total analysis exceeds the limits listed, then TCLP must be performed before wastes can be disposed of in a municipal solid-waste facility (TNRCC, 1996b).
[2]Landfarm results for sample number 2018 (mg/Kg): ortho-phosphate <0.5; potassium 1,300; total organic nitrogen 328; zinc 610; copper 15; nitrate-N 20; ammonia-N <1.

Table 4.3. Continued.

Location Analyzed by: Sample number Sample depth (ft)	BH-4 Chemsolve 5060 5–8	BH-5 Chemsolve 5061 0–5	BH-5 Chemsolve 5062 5–6	BH-6 Chemsolve 5063 0–5	BH-6 Chemsolve 5064 5–7	BH-7 RRC 5065 0–5	MW-2 RRC 5082 6–7	BH-8 RRC 5066 0–1	BH-9 Chemsolve 5067 4–7	Regulatory or guidance limit[1]
Arsenic	0.65	1.2	N/A	1.3	N/A	<0.5	<0.5	<0.5	2.3	36
Barium	33	37	N/A	22	N/A	115	224	261	19	2000
Cadmium	0.12	0.28	N/A	0.29	N/A	<0.5	<0.5	<0.5	0.24	10
Chromium	210	29	N/A	24	N/A	21	22	11	120	100
Lead	38	63	N/A	38	N/A	<0.5	<0.5	<0.5	26	30
Mercury	0.017	0.006	N/A	0.053	N/A	<0.1	<0.1	<0.1	0.14	4
Selenium	<0.1	<0.1	N/A	<0.1	N/A	<0.5	<0.5	<0.5	<0.1	20
Silver	<0.1	<0.1	N/A	<0.1	N/A	<0.5	<0.5	<0.5	<0.1	100
Chloride	20,000	120	220	1,100	960	1741	1626	1184	16,000	n/a
TPH (%)	0.022	0.018	0.016	0.015	0.12	0	0.0	0	0.06	1% (RRC)
Oil and grease (%)	N/A	N/A	N/A	N/A	N/A	0	0.0	0	N/A	n/a
Moisture (%)	100.8	24.6	18.1	17	18.1	23	23	16	82.5	n/a
Conductivity 1:1 (mS/cm)	61.6	6.98	7.1	7.9	5.4	7.5	11	6	29.1	n/a

n/a = not applicable
N/A = not analyzed
[1]Metals limits are for a totals analysis. If a total analysis exceeds the limits listed, then TCLP must be performed before wastes can be disposed of in a municipal solid-waste facility (TNRCC, 1996b).

Table 4.3. Continued.

Location Analyzed by: Sample number Sample depth (ft)	BH-9 Chemsolve 5068 9–10	BH-10 RRC 5069 0–5	BH-10 RRC 5070 11–12	BH-10 RRC 5079 15–17	BH-11 RRC 5080 0–5	BH-11 RRC 5081 0–1	BH-12 Chemsolve 5084 0–1	MW-3 Chemsolve 5083 0–1	Barren area surface Chemsolve 5082 0–0.5 inch	Trash pile surface Chemsolve 5083 0–1	Regulatory or guidance limit[1]
Arsenic	<0.1	<0.5	<0.5	<0.5	<0.5	<0.5	<0.1	0.52	<0.5	0.52	36
Barium	190	98	502	376	323	241	26	62	224	62	2000
Cadmium	<0.1	<0.5	<0.5	<0.5	<0.5	<0.5	<0.1	<0.1	<0.5	<0.1	10
Chromium	3.2	30	54	20	46	30	2.7	8.9	22	8.9	100
Lead	<0.1	<0.5	<0.5	<0.5	<0.5	<0.5	<0.1	3.7	<0.5	3.7	30
Mercury	0.033	<0.1	<0.1	<0.1	<0.1	<0.1	0.061	0.047	<0.1	0.047	4
Selenium	<0.1	<0.5	<0.5	<0.5	<0.5	<0.5	<0.1	<0.1	<0.5	<0.1	20
Silver	<0.1	<0.5	<0.5	<0.5	<0.5	<0.5	<0.1	<0.1	<0.5	<0.1	100
Chloride	7800	23556	27830	6178	6793	3511	18	23	1626	23	n/a
TPH (%)	0.0063	0.26	0.26	0	0.12	0	<0.0010	0.037	0	0.0051	1% (RRC)
Oil and grease (%)	N/A	0.43	0.46	0	0.13	0	N/A	N/A	0	N/A	n/a
Moisture (%)	19.4	42	54	17	32	19	8.2	4.9	23	4.9	n/a
Conductivity 1:1 (mS/cm)	9.7	66	73	20	26	13	0.024	0.024	11	0.024	n/a

n/a = not applicable
N/A = not analyzed
[1]Metals limits are for a totals analysis. If a total analysis exceeds the limits listed, then TCLP must be performed before wastes can be disposed of in a municipal solid-waste facility (TNRCC, 1996b).

figures 3.1 and 3.2. Figures 4.6 and 4.7 show values of TPH and chloride analyzed for the trenches, borings, and surface samples.

The area encompassing the eight waste pits is approximately 0.6 acre (fig. 3.1). Although the pits were depressed, no standing water or free liquids were observed on these pits during the field investigation. The pits range in approximate size from 19 by 21 ft to 38 by 28 ft. The waste materials in the pits were probed, and waste thickness ranged from 2.7 to 9.7 ft, averaging 5.6 ft in thickness. Estimated total volume of the pits is about 950 yd^3. The material in the pits resembled the material in the main waste area, with some variation in color between pits. Some pit materials were light gray, and others were dark or variably stained.

RCRA 8 metals were analyzed for all waste samples. Results are compared here with the TNRCC (1996b) guidance levels for disposal of special wastes associated with oil and gas resources. Total metal concentrations are used as a screening device to determine the need for additional TCLP analysis before municipal solid-waste landfill disposal, and are not by themselves considered health-based remediation criteria. Most samples were found to be below the screening levels, indicating that TCLP analysis is unnecessary for this type of disposal option.

Total chromium was above the TCLP screening level in pits 1, 2, 3, and 5. This occurrence may result from the presence of chromium lignosulfate, according to local residents familiar with site operations and local drilling methods (Ronnie Key, personal communication, July 1997). Generally pits having lower chromium exhibited lighter waste colors. No other metals in the pits were found above TCLP screening levels for waste disposal in a municipal solid-waste (MSW) facility (table 4.1). A composite sample was prepared from three of the individual pit samples, and a TCLP test was performed. The only constituents detected in the TCLP analysis were barium and chromium. Both were measured significantly below the level required for nonhazardous designation.

TPH was generally quite low in the pit samples, less than 1 percent in all cases. Chloride was elevated slightly above the RRC landfarm limit of 3,000 mg/kg only in pit 2. Although another wooded area between pits 7 and 8 was suspected of being a pit, it contained no waste materials.

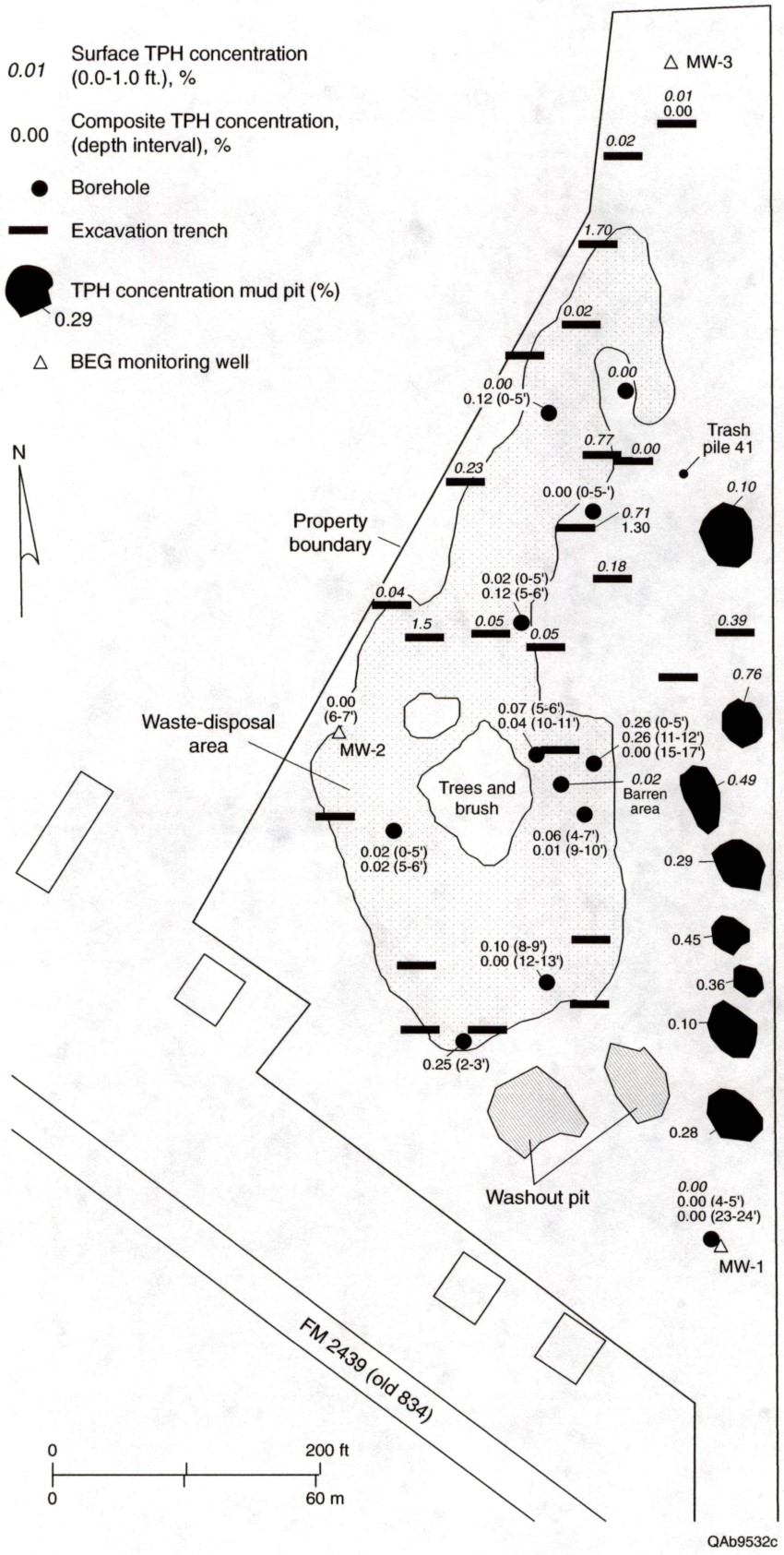

Figure 4.6. Results of TPH analyses in boreholes, trenches, and surface soils.

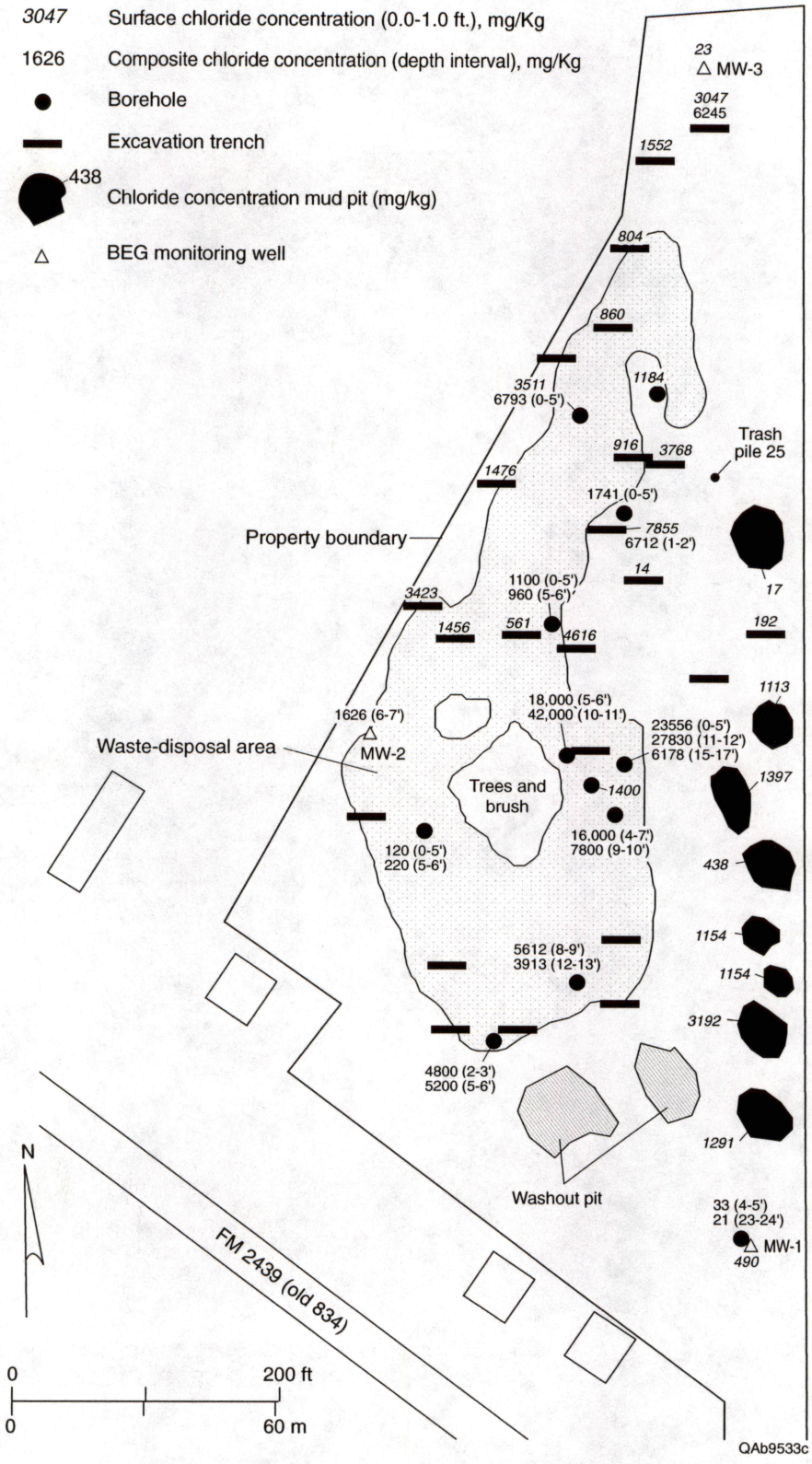

Figure 4.7. Results of chloride analyses in boreholes, trenches, and surface soils.

Levels of barium and chromium in a sample from this area, however, were above levels found in some of the pit-waste samples.

Trench samples (fig. 3.1; table 4.2) were taken to confirm or deny presence of waste at the inferred waste-area perimeter. Some trench samples were submitted for analysis. Chromium in trench locations 9, 16, and 17 was detected above the guidance limit of 100 mg/kg for total metal in waste for disposal in an MSW facility (TNRCC, 1996b). TPH was found above 1 percent in trenches 9, 15, and 17, although levels were low (<2 percent). Barium was elevated above the other trenches in trench 21 but was below the limit for total metal for MSW disposal (2,000 mg/kg, TNRCC, 1996b). No other metals were detected above method detection limits. Chloride was elevated in a number of trenches above 3,000 mg/kg. Only trench 21, near the eastern site road, exhibited chloride near levels that can be considered to be background, less than 100 mg/kg (see BH-12 surface or MW-3 surface values).

In borehole samples (fig. 3.2; table 4.3), most RCRA 8 metals were below guidance limits (TNRCC, 1996b). Selenium was not detected. Total lead was detected above the guidance level for MSW disposal in boreholes 2, 4, 5, and 6; total chromium was detected above the guidance level in boreholes 4 and 9. TPH values were quite low; none was above 1 percent, which is in contrast with previous RRC data from 1992 of as much as 1.7 percent, indicating that some bioremediation of organic compounds may have occurred within the wastes.

The highest levels of chloride, from 3,500 to 42,000 mg/kg, were measured in boreholes BH-2, -3, -4, -9, -10, and -11 within the main (central) waste-disposal area (see fig. 3.2). The region near BH-4, BH-9, and BH-10 is likely the disposal pit for salt-based drilling fluid noted in RRC documents. The two areas around BH-3 and BH-11 were likely used for disposal of salt-based fluid as well. BH-1, MW-3, and BH-12 contained surface soils with very low chloride levels, which are within background range at 18 to 33 mg/kg. This low chloride level is of interest in the vicinity of MW-3 because the owner of the adjacent property to the north (Ronnie Key, personal communication, July 1997) recalled that there had been an area of vegetation kill offsite for several years in the 1980's as a result of runoff from the site. This area was reportedly at least

100 × 100 yd^2; it now exhibits normal vegetative growth, although chloride is still elevated in the subsurface, as indicated by the EM borehole log for MW-3. The chloride has apparently leached downward in the soils along with precipitation.

There are five notable barren areas onsite at this time: one in the south, which is part of the site road, just south of the washout pits; another in the central area of the site (areas of high EM readings; BH-4, -9, and -10); a small area on the west side of the site in the location of trenches 8 and 9; an area surrounding BH-8; and an area just southeast of MW-3 (trench 14). Most of the surface chloride values in these areas exceeded 3,000 mg/kg, with the exception of the road area (see fig. 4.7 and tables 4.1 through 4.3).

Table 4.4 shows the results of the VOC, SVOC, and TCLP analyses. The landfarm analysis results are shown in the footnotes. Naphthalene was the only organic detected; it slightly exceeded the TNRCC action level for LPST sites (TNRCC, 1996c), which is used as a guidance level. No pesticides or PCB's were detected in the sample. No organics were found to leach in the TCLP; metals detected above method detection limits exhibited low leaching potentials and did not exceed regulatory criteria for disposal in an MSW facility (TNRCC, 1996c; see table 4.4). The same was true for the TCLP metals in the pit sample composite (table 4.4).

4.3 Soils

Few areas onsite were unaffected by site activities. Trenching was used to locate the edges of the waste area, and the estimated boundaries of the wastes are shown in fig. 3.1. Outside of this area, although no wastes were found, there may be influences in native soils from runoff, which appears to have moved predominantly toward the north part of the site. Areas east of the north–south site road, and outside of the well-defined mud pits, generally appear unaffected by the wastes. Heavy vegetative growth characterizes the areas in which no waste has been disposed of. Trees can survive outside of the waste area but do not root in the wastes, although grasses, cattails,

Table 4.4. Summary of TCLP, TOX, and VOC results for waste samples 5060, 5054, 5058, and a pit-composite sample. Units are as noted (mg/kg or mg/L).

	Result[1]	*Result*[1]	*Result*[1]	*Result*[1]	*PQL*	*Method*	*Regulatory guideline or limit*	*Reference*
Sample no.	5060	composite 5027- 5033 + 5035	5054	5058				
VOC's and SVOC's (mg/kg)								
Naphthalene	420	N/A	N/A	N/A	250	8260	389	TNRCC[2]
Petroleum hydrocarbons	220	N/A	N/A	N/A	10	418.1	1500 1 percent	TNRCC[3] RRC
TCLP Parameters (mg/L)								
TC Arsenic	<0.005	<0.01	0.039	0.011	0.005	6010	5.0	
TC Barium	0.86	0.22	0.049	0.21	0.001/ 0.005	6010	100	TNRCC[3]
TC Cadmium	0.041	<0.01	<0.005	0.0064	0.005	6010	1.0	EPA[4]
TC Chromium	0.035	0.43	0.0055	0.066	0.005	6010	5.0	EPA[4]
TC Lead	0.098	<0.01	<0.005	1.1	0.005	6010	5.0	EPA[4]
TC Mercury	0.00030	<0.0002	<0.0002	<0.0002	0.0002	7470	0.2	TNRCC[3]
TC Selenium	<0.005	<0.01	0.033	0.0083	0.005	6010	1.0	
TC Silver	0.025	<0.01	<0.0050	<0.0050	0.005	6010	5	EPA[4]
Reactivity cyanide (mg/kg)	<10	N/A	N/A	N/A	0.02	7.3.3.1	presence	EPA[4]
Reactivity sulfide (mg/kg)	<10	N/A	N/A	N/A	10	7.3.3.2	presence	EPA[4]
Ignitability (° F/kg)	>150	N/A	N/A	N/A	0	1010	<140	EPA[4]
pH	7.2	N/A	N/A	N/A	n/a	9045	<2 or >12	EPA[4]
Total organic halogens (mg/kg)	<1	N/A	N/A	N/A	1	9020	< 50	TNRCC[3]

[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, 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.
[5]Landfarm parameter results (mg/kg): copper 5.8; nickel 3.6; potassium 480; zinc 110; ammonia-N 9; Kjeldahl-N 700; nitrate-N <12.5; nitrite-N 1,600; phosphate <12.5; total organic nitrogen 691.
Note: All samples analyzed by Chemsolve except for pit composite (RRC).

and shrubs were growing on most of the waste-disposal area. These areas are likely less saline than the more barren areas onsite.

One background soil sample from offsite boring BH-12 was taken (fig. 3.2; table 4.3). Although MW-3 is a background ground-water location, the surface soil at MW-3

cannot be classified as background because of former site runoff impacts in that area. A statistically complete background-sampling program was beyond the scope of this project; the background sample is intended to be an indication of typical soil concentrations in the area for the purpose of comparison.

One selected composite sample from the soils beneath the north part of the trash-disposal area was sampled for pesticides/PCB's, TPH, chloride, RCRA 8 metals, moisture, and conductivity (table 4.3; fig. 4.6). This location was chosen because of the types of trash disposed, including old pesticide spray containers, oil filters, drums, and other potentially hazardous material containers. A surface-soil sample was taken from the large, central barren area near BH-4 and BH-9 (fig. 4.7) to characterize the salinity of the surface soils.

Low levels of barium, chromium, and mercury were found in BH-12. The levels of barium and chromium, most likely background levels, are quite low, although the mercury concentration was higher than all other mercury concentrations found in onsite wastes, with the exception of one sample from BH-9. Mercury was also detected (0.047 mg/kg) in the soil sample from MW-3. The background concentration of mercury in Texas soil ranges from 0.01 to 0.69 mg/kg, with a median of 0.04 mg/kg (Boerngen and Shacklette, 1981). Other RCRA 8 metal concentrations in BH-12 were below method detection limits. Chloride and soil conductivity in the background soil were also low in BH-12. Petroleum hydrocarbons were below method detection limits. Arsenic and lead were below method detection limits in this and other surface-soil samples from BH-1, BH-7, and BH-8, indicating that the low end of the background range of these metals is near or below method detection limits in this area.

In the trash-pile composite sample, arsenic, barium, chromium, lead, and mercury were detected above method detection limits; of these compounds, all but mercury were elevated above

background levels, but none exceeded TNRCC regulatory limits for waste disposal in an MSW facility. Chloride was near background and petroleum hydrocarbons were very low (0.0051 mg/kg). No pesticides were detected above method detection limits (appendix B).

The surface soil from the barren area was chosen as a worst-case surface sample because of extensive salt crusting at the surface, an absence of surface vegetation, and because of the deep zone of contaminated material found beneath the surface in this location. Barium and chromium were elevated at levels found in the wastes but did not exceed TNRCC regulatory limits for MSW waste disposal (2,000 and 100 mg/kg, respectively, TNRCC, 1996b). Although chloride was high, at 1,626 mg/kg it did not exceed the RRC guidance value of 3,000 mg/kg for landfarm disposal. Surface samples from the top 1 ft of BH-4, -9, and -10, however, exceeded 15,000 mg/kg. The upper 6 inches of the soil may be leached from precipitation. One reason for the low vegetative cover in this area may be the presence of a shallow zone of grout, which was found during trenching, that may be inhibiting plant rooting.

4.4 Ground Water

4.4.1 Hydrologic Properties

Depths to water were measured at the site on July 25 and July 31, 1997. July 31 ground-water elevations (hydraulic head) are shown graphically in figure 4.8. All of the data are shown in table 4.5. The measured gradient of hydraulic head of shallow ground water is to the southeast and was calculated to be 0.00077 on the basis of data from July 31, 1997. No gradient was calculated from the July 25 data because the wells were not yet developed. Wells MW-2 and MW-3 are located on the same elevation contour, and MW-1 was downgradient on July 31. From the contours shown in figure 4.8, MW-2 can be interpreted as being upgradient of the central disposal area, MW-1 is downgradient, and MW-3 is side-gradient.

When the wells were drilled, a rise of water in the well bore from approximately 16 to 9 ft below ground surface was observed. This, along with the hydrologic setting and the results of the

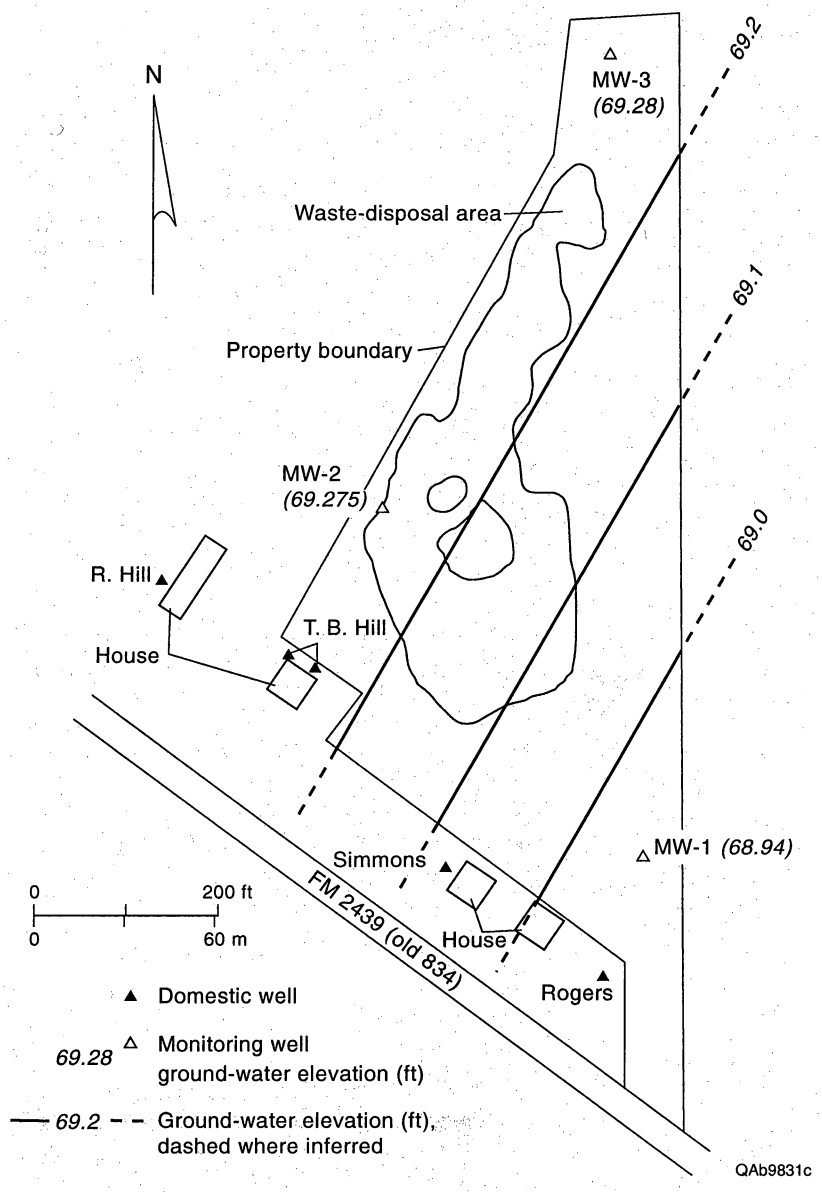

Figure 4.8. Ground-water elevation data from the uppermost aquifer beneath the Roeling Vacuum site, July 31, 1997.

Table 4.5. Ground-water-elevation and gradient data.

	Elevation[1], top of casing[2]	Ground-water elevation[1] 7/25/97	Ground-water elevation[1] 7/31/97
MW-1	80.06	69.49	68.94
MW-2	81.17	69.30	69.28
MW-3	78.93	69.33	69.28
Gradient	--	not calculated	0.00077

[1]All elevations based on arbitrary datum.
[2]Top of PVC casing.

hydrologic tests (fig. 4.9), suggests that there is some degree of confinement of shallow ground water at the site. Vertical textural heterogeneity can include fine-grained material with lower permeability than that of the main water-yielding zones. Ground water can move from the low-permeability material at a slow rate. This yield of water from a less-permeable layer typically affects the rate of drawdown in hydrologic tests.

Transmissivity estimates made by matching drawdown data from the MW-2 and MW-3 tests to the Boulton delayed-yield type curves were 10.7 and 3.7 ft^2/d, respectively (table 4.5). Specific capacity (amount of discharge obtained per unit amount of drawdown) measured at these two wells was similar (~150 ft^2/d). Transmissivity of 340 to 460 ft^2/d, which was derived from specific capacity for the test at MW-1, however, most likely overestimates actual transmissivity because of the effect of delayed yield. Note that the transmissivities derived from specific capacity for the tests at MW-2 and MW-3 are 5 to 50 times greater than the more reliable estimates based on matching type curves (table 4.6). Specific capacity, however, was greater at MW-1 than at the other two test wells. One might therefore assume that the transmissivity is greater at MW-1 than at MW-2 and MW-3, although perhaps by a factor of only 3 or 4. We assume that 5 to 10 ft^2/d is a reasonable estimate of average transmissivity at the Roeling Vacuum site.

4.4.2 Onsite Ground Water

Three onsite monitoring wells were sampled on July 31, 1997. Well locations are shown in figure 3.1 and a summary of chemistry results is shown in table 4.7. Detection-limit data and analytical results are provided in appendix B.

No VOC's or PAH's were detected above method detection limits in any of the onsite ground-water samples. Arsenic, barium, chromium, and mercury were detected in the ground-water samples above method detection limits, but none of the values exceeded regulatory limits (see table 4.7). No other RCRA 8 metals were detected above method detection limits. Barium and

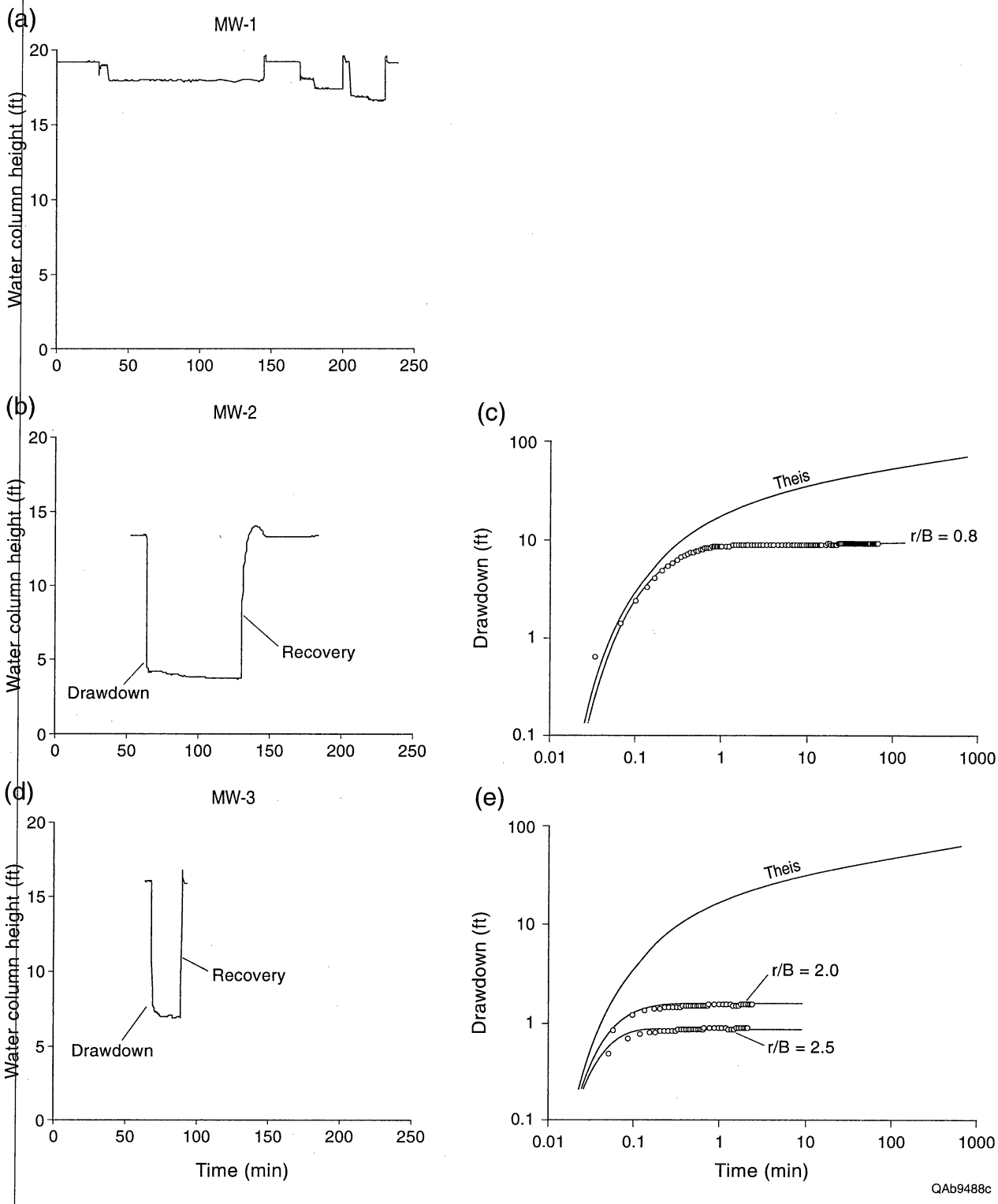

Figure 4.9. Graphical results of drawdown tests.

Table 4.6. Data on hydrologic properties estimated from tests at monitoring wells at the Roeling Vacuum site.

Well	Test period	Discharge (ft^3/d)	Boulton r/B value	Specific capacity (ft^2/d)	T^1 (ft^2/d)	T^2 (ft^2/d)	T^3 (ft^2/d)
RVMW-1	Drawdown	617[4]	nd	565	nd	460	344
RVMW-2	Drawdown	1,465	0.8	151	10.7	113	81
RVMW-3	Drawdown	1,365	2 to 2.5	150	2.7 to 5.1	112	81

[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]Weighted average of multiple-rate discharge.

nd=not determined

Table 4.7. Onsite ground-water chemical-analysis summary. Units mg/L where applicable, unless otherwise noted.

	MW-1 *result*	MW-2 *result*[1]	MW-3 *result*[1]	*PQL*	*Method*	*Regulatory guideline or limit*	*reference*[2]
Sample no.	5088	5093	5097				
Arsenic	0.043	<0.005	<0.005	0.005	6010	0.05	EPA-1°MCL
Barium	0.33	0.30	0.65	0.005	6010	2.0	EPA-1°MCL
Cadmium	<0.005	<0.005	<0.005	0.005	6010	0.005	EPA-1°MCL
Chromium	0.014	0.029	<0.005	0.005	6010	0.1	EPA-1°MCL
Lead	<0.005	<0.005	<0.005	0.005	6010	0.015	EPA-action level
Mercury	0.00060	0.00060	0.0014	0.0002	7470	0.002	EPA-1°MCL
Selenium	<0.005	<0.005	<0.005	0.005	6010	0.05	EPA-1°MCL
Silver	<0.005	<0.005	<0.005	0.005	6010	0.1	EPA-2°MCL
Sample no.	5084	5089	5098				
Barium	0.26	0.28	0.59	0.0050	6010	2.0	EPA-1°MCL
Calcium	80	250	150	0.050	6010	n/a	n/a
Magnesium	6.6	20	8.9	0.050	6010	n/a	n/a
Potassium	1.2	6.0	4.4	0.050	6010	n/a	n/a
Sodium	110	320	120	0.050	6010	n/a	n/a
Strontium	0.15	0.61	0.36	0.0050	6010	n/a	n/a
Sample no.	5085	5090	5098				
Total alkalinity	320	250	250	10	310.1	n/a	
Bromide	<0.1	<1	<1	0.1/1	300.1	n/a	
Chloride	140	710	360	0.5	300.1	250	EPA-2°MCL
Sulfate	54	<0.5	<0.5	0.5	300.1	500	EPA-1°MCL
Ion balance error (%)	–4.9	+7.8	–2.5	n/a	n/a	n/a	n/a
pH	7.04	6.78	7.15	n/a	n/a	6.5–8.5	EPA-2°MCL
TDS[3]	712	1558	896	n/a	n/a	500 1000	EPA-2°MCL TNRCC[4]
Specific conductance (mS/cm)[3]	0.94	2.8	1.4	n/a	n/a	n/a	n/a

[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]Calculated from chemical analysis.
[4]TNRCC: 30 TAC 290.113.
Note: all samples listed analyzed by Chemsolve.

mercury were slightly higher in MW-3, and chromium was highest in MW-2 and not detected in MW-3.

Chloride was highest in MW-2 and above the secondary MCL in both MW-2 and MW-3. Although the wells are either side-gradient or upgradient of the site, they are located within a few feet of the waste package at MW-2 or within a zone that has received runoff from the site (MW-3). These influences may elevate the chloride content in these samples. Because MW-1 is farther from the waste package, it may be more likely to intercept lower chloride recharge from upgradient of the site.

4.4.3 Offsite Ground Water

Five ground-water wells at residential locations were sampled for chemistry data. A summary of results is shown in table 4.8. All results and method detection limits are shown in appendix B, and well locations are shown in figure 2.2. Depth and geologic information on these wells is given in table 3.3. According to available geologic and hydraulic-head information, the R. Hill well is upgradient of the site in the shallow Beaumont aquifer; the Simmons and T. B. Hill wells are side-gradient in the shallow Beaumont. The Rogers well is screened in a deeper zone of the Beaumont and is either side-gradient or downgradient of at least part of the site, according to monitoring data, but at a greater depth. The Jones well is downgradient of the site in a deeper part of the Beaumont. Because the gradient in the area is so small, it may change in direction with seasonal variation in recharge or with local or regional pumping. Judging from their proximity to the site, all of the wells, with the possible exception of the Jones well, were considered to be potentially influenced by the site.

No VOC's were detected above method detection limits in any offsite wells. PAH's were analyzed in lieu of a TPH analysis in each well. Two PAH's, fluoranthene and pyrene, were detected above method detection limits in the R. Hill well at levels of 0.0014 and 0.0017 mg/L, respectively. This is below the TNRCC action level of 0.01 mg/L for leaking underground PST

Table 4.8. Residential well ground-water chemical-analysis summary. All values in mg/L unless otherwise noted.

Well name	Rogers *result*[1]	T. B. Hill *result*[1]	C. J. Jones *result*[1]	Simmons *result*[1]	R. Hill *result*[1]	*PQL*	*Method*	Regulatory guideline or limit	Reference[2,3]
Sample no.	5037	5042	5047	5072	5076				
Fluoranthene	<0.0004	<0.0004	<0.0004	<0.0004	0.0014	0.0004	8310	0.010	TNRCC
Pyrene	<0.0004	<0.0004	<0.0004	<0.0004	0.0017	0.0004	8310	0.010	TNRCC
Sample no.	5038	5043	5048	5073	5076				
Arsenic	0.030	0.013	0.028	0.0081	<0.005	0.005	6010	0.05	EPA-1°MCL
Barium	0.87	0.29	0.30	0.47	0.17	0.005/0.001	6010	2	EPA-1°MCL
Cadmium	<0.005	<0.005	<0.005	<0.005	<0.005	0.005	6010	0.005	EPA-1°MCL
Chromium	<0.005	<0.005	<0.005	0.15*	<0.005	0.005	6010	0.1	EPA-1°MCL
Lead	<0.005	<0.005	<0.005	0.27*	<0.005	0.005	6010	0.015	EPA-action level
Mercury	<0.0002	<0.0002	<0.0002	0.00020	<0.0002	0.0002	7470	0.002	EPA-1°MCL
Selenium	0.050	0.027	0.030	<0.005	0.0081	0.005	6010	0.05	EPA-1°MCL
Silver	0.028	0.0093	<0.005	0.038	<0.005	0.005	6010	0.1	EPA-2°MCL
Sample no.	5039	5044	5049	5074	5078				
Barium	0.83	0.29	0.30	0.25	0.21	0.001	6010	2	EPA-1°MCL
Calcium	230	94	93	160	100	0.125/0.025	6010	n/a	note
Magnesium	17	11	4.2	6.0	5.2	0.01	6010	n/a	note
Potassium	4.6	1.9	0.69	4.8	2.8	0.01/0.1	6010	n/a	note
Sodium	130	410	150	70	82	2.5/1.25	6010	n/a	note
Strontium	0.91	0.23	0.31	0.27	0.2	0.005	6010	n/a	note
Total alkalinity	260	250	300	280	250	10	310.1	n/a	
Bromide	<1	<1	<0.1	<0.1	<0.1	1	300.1	n/a	note
Chloride/duplicate	540/560	58/380	120/180	43	39	0.5	300.1	250	EPA-2°MCL
Sulfate	<0.5	560	48	19	9.3	0.5	300.1	500	EPA-1°MCL
Charge balance error (%)	–3.6	–6	+2.4	+30.6	+25.4	n/a	n/a	n/a	
Coliform	absent	absent	absent	N/A	N/A	n/a	n/a	absent	
pH	6.66	6.90	6.91	6.27	6.17	n/a	n/a	6.5-8.5	EPA-2°MCL
TDS (mg/L) (calculated)	1205	1708	777	375	320	n/a	n/a	500	EPA-2°MCL
Specific conductance (mS/cm)	1.9	2.35	1.15	0.76	0.64	n/a	120.1	1000 n/a	TNRCC[4]

[1]All shaded values above regulatory or guidance limits.
[2]TNRCC: RG-17, action levels for LPST sites, October 1996.
[3]EPA: Drinking water regulations and health advisories, EPA 822-B-96-002
[4]TNRCC: 30 TAC 290.113.
n/a: not applicable
*retested by RRC, October 1997.

sites (TNRCC, 1996c), which is used by TNRCC to designate further site evaluation. There is no Federal MCL or MCLG (guidance MCL) for either of these compounds. Neither of these compounds was detected above the method detection limit of 0.005 mg/L in the onsite wells, suggesting that these compounds in this upgradient well might be unrelated to the site. No other volatile or semivolatile organic compounds were detected in the wells above method detection limits (appendix B).

The metals arsenic, barium, chromium, lead, mercury, and silver were detected in one or more offsite wells above the method detection limits. None of these were detected above EPA primary MCL's or action levels, with the exception of lead, which in BEG samples was detected in the Simmons well at 0.27 mg/L, and chromium, detected in the same well at 0.15 mg/L. Follow-up RRC samples of the Simmons well, however, showed lead and chromium concentrations between the method detection limit (<0.005 mg/L) and 0.019 mg/L (table 4.9), which exceeds the EPA action level of 0.015 mg/L. It is important to note that lead was detected only in filtered samples, which suggests that sampling procedures influenced analytical results. After review of analytical reports of the samples, the Texas Department of Health (TDH) concluded that the elevated lead concentration detected in the July 1997 sample from the Simmons well was due to sampling or laboratory error.

Analysis of the cation:anion ratios for the onsite wells indicated that all of the waters were of a mixed-cation-Cl or mixed-cation-bicarbonate type. The deepest offsite well (Rogers) was a Ca-Cl type. Shallower offsite wells (R. Hill, T. B. Hill, and Simmons) contained more sodium, thus producing a mixed-cation-Cl or Na-Cl type. The Jones well was not compared with the others because it has a treatment system that alters the natural ion balance.

4.5 Surface Water

Three surface water samples from the onsite ponds were collected at the site on June 17, 1997. Sample locations are shown in figure 3.1; results are given in table 4.10. Two of the ponds

Table 4.9. RRC resampling of Simmons well, October 9, 1997.

Sample no.[1]	Location	Purge method	Result lead (mg/L)[2,3]	Result chromium (mg/L)[2]
K-5	kitchen tap	5 min	<0.005	<0.005
K-5F	kitchen tap	5 min	<0.005	<0.005
WH-5	wellhead	5 min	<0.005	<0.005
WH-5F	wellhead	5 min	<0.005	<0.005
K-ADR	kitchen	drain purge tank twice	<0.005	<0.005
K-ADR-F	kitchen	drain purge tank twice	0.015	<0.005
WH-ADR	wellhead	drain purge tank twice	<0.005	<0.005
WH-ADR-F	wellhead	drain purge tank twice	0.019	<0.005

[1]F = filtered sample; K = kitchen; WH = wellhead; ADR = after draining purge tank twice.
[2]PQL = 0.005 mg/L, EPA method 6010, chromium is trivalent.
[3]Shaded values meet or exceed EPA action level of 0.015 mg/L.

Table 4.10. Surface-water chemical-analysis summary. All units in mg/L unless otherwise noted.

	East washout pit *result*	West washout pit *result*	North pond *result*[1]	*PQL*	*Method*	*Regulatory guideline or limit (mg/L)*	*Reference*[2,3]
Sample no.	5002	5006	5010				
Petroleum hydrocarbons	<0.2	<0.2	0.36	0.2	418.1	5	TNRCC
Chloride	160	55	260	0.5	300.1	250	EPA-2°MCL
pH	6.5	6.52	6.52	n/a	n/a	6.5-8.5	EPA-2°MCL
TDS	824	543	921	n/a	n/a	500	EPA-2°MCL
						1000	TNRCC[4]
Specific conductance (mS/cm)	1.65	1.07	1.84	n/a	n/a	n/a	n/a
Sample no.	5003	5007	5011				
Arsenic	0.011	0.035	0.018	0.005	6010	0.05	EPA-1°MCL
Barium	0.21	0.37	0.12	0.001	6010	2.0	EPA-1°MCL
Cadmium	<0.005	<0.005	<0.005	0.005	6010	0.005	EPA-1°MCL
Chromium	<0.005	<0.005	<0.005	0.005	6010	0.1	EPA-1°MCL
Lead	<0.005	0.0057	0.013	0.005	6010	0.015	EPA-action level
Mercury	<0.0002	<0.0002	<0.0002	0.0002	7470	0.002	EPA-1°MCL
Selenium	<0.005	0.023	0.0091	0.005	6010	0.05	EPA-1°MCL
Silver	0.019	0.028	0.028	0.005	6010	0.1	EPA-2°MCL

Note: EPA secondary MCL for total dissolved solids is 500 mg/L.
[1]Shaded values are those above regulatory or guidance limit.
[2]TNRCC: RG-17, action levels for LPST sites, October 1996.
[3]EPA: Drinking water regulations and health advisories, EPA 822-B-96-002
[4]TNRCC: 30 TAC 290.113.
n/a: not applicable.
Note: all samples analyzed by Chemsolve.

are former washout pits on the south end of the site; one is a low area that may or may not be naturally occurring on the north end of the site. Other locations of standing water onsite were noted to be ephemeral. No flowing surface water was found near or on the site. In general the region is poorly drained, and standing water is a common occurrence in low areas and ditches. The north pond water was 1 ft deep at the deepest point; the west and east pond waters were 3.8 and 4.5 ft deep, respectively. Penetrable sediment thickness in the north pond was 6.1 ft, 2.7 ft in the east pond, and 4.0 ft in the west pond. This most likely includes both disposed drill mud as well as soft clay, which underlies the ponds. Because of the depth of the north pond sediments, it is possible that this was also a disposal-pit area at some time.

Surface water samples were analyzed for TPH, chloride, RCRA 8 metals, and VOC's. Results are shown in table 4.10. No VOC's were detected in any surface water samples. Chloride was slightly elevated in the north pond; other sample values were within normal surface water ranges. No TPH was detected in the washout pit waters, and a low TPH value was detected in the north pond water. Metals detected included arsenic, barium, lead, selenium, and silver, but none was detected above regulatory or advisory limits (U.S. EPA, 1996a; see table 4.10). In general, the surface water at the site appears to receive a low impact from site waste materials.

Pit/pond sediments were taken at the same time as the water samples. Results are shown in table 4.11. All pond-sediment samples resembled drilling mud and had a distinct petroleumlike odor and some dark staining. Samples were analyzed for TPH, chloride, RCRA 8 metals, conductivity, and moisture. TPH was below the 1-percent detection limit used by RRC. Barium, lead, and chromium in the north pond were elevated over the east and west pit samples, suggesting that the north pond has received some influence from pit-waste disposal or site runoff. For soil disposal purposes, only the lead value (89 mg/kg) was over recommended metal limits (30 mg/kg) for waste characterization (TNRCC, 1996b). Although a slightly elevated value of arsenic was noted in the west pond, it did not exceed regulatory limits. Chloride values in the sediments were moderate.

Table 4.11. Sediment analysis summary data from onsite washout pits and the north pond. Units are in mg/kg unless otherwise noted.

	East washout pit *result*[1]	West washout pit *result*[1]	North pond *result*[1]	*PQL*	*Method*	*Regulatory guideline or limit (mg/kg)*[2]
Sample no.	5000	5004	5008			
Petroleum hydrocarbons (%)	0.45	0.50	0.055	150	418.1	1% (RRC)
Chloride	190	360	500	0.5	300.1	n/a
Specific conductance (mS/cm)	3.68	3.88	4.7	n/a	n/a	n/a
Moisture	76.8	104.1	71.8	0.1	n/a	n/a
Sample no.	5000	5004	5008			
Arsenic	2.5	<0.1	2.9	0.1	6010	36
Barium	96	<0.02	220	0.02	6010	2000
Cadmium	0.25	<0.1	0.49	0.1	6010	10
Chromium	2.3	<0.1	53	0.1	6010	100
Lead	2.3	0.79	89	0.1	6010	30
Mercury	0.32	0.17	0.081	0.0004	7470	4
Selenium	<0.1	0.95	<0.1	0.1	6010	20
Silver	1.4	2.1	0.37	0.1	6010	100

[1]Shaded values are those above regulatory or guidance limit.
[2]Metals limits are for a totals analysis. If a total analysis exceeds the limits listed, then TCLP must be performed before wastes can be disposed of in a municipal solid-waste facility (TNRCC, 1996b).
n/a: not applicable.
Note: all samples analyzed by Chemsolve.

Selenium was detected in the west and north pond fluids and in west pond sediments. Selenium was not detected in any waste materials or site soils nor was it detected in the ground-water samples from the onsite monitoring wells. Four of five offsite domestic wells sampled contained detectable selenium; at one well (Rogers), the detection was at the EPA primary MCL.

Silver was detected in fluid and sediment samples in all three ponds; the highest concentrations were in the west pond. Silver was detected in only one waste sample at 0.43 mg/kg. By comparison, the silver concentration in the pond sediments was 2.1 mg/kg (west), 1.4 mg/kg (east) and 0.37 mg/kg (north). Silver concentrations ranged from 0.019 mg/L to 0.028 mg/L in the pond fluids. It was detected neither in the ground-water samples from the onsite monitoring wells nor in the waste materials. Silver was detected in three of the five offsite domestic wells at levels consistently below EPA's secondary MCL of 0.1 mg/L.

These data suggest that waste-truck washout may not be the source, or the sole source, of fluids in the washout ponds, particularly the west pond. The detection of selenium in the west pond and of silver in all three pond fluids and sediments implies that materials other than the wastes in the disposal area and pits were disposed of onsite. Note, however, that none of the constituents in the existing pond fluids in the west pond exceeds a primary or secondary MCL, and none of the constituents in the west pond sediments exceeds the TNRCC's total limit regulatory guidance for LPST sites.

Mercury was detected in all three pond-sediment samples but was not detected in any of the pond fluids. Although mercury was detected in some waste samples (0.006 mg/kg minimum; 0.14 kg/mg maximum.), it was also detected in similar concentrations in soil samples (0.045 mg/kg minimum, 0.061 mg/kg maximum.). Notably the soil sample having the greatest mercury level was the background soil sample (BH-12) located north of the Roeling Vacuum site. Mercury was detected in all three onsite ground-water samples, and the ground-water sample from upgradient MW-3 had the highest mercury concentration of the onsite wells. Only one offsite domestic well detected mercury at the method detection limit.

Mercury occurs naturally in soils in concentrations of less than 0.2 ppm (Deuel and Holliday, 1994). The background concentration of mercury in Texas soil ranges from 0.01 to 0.69 mg/kg, with a median of 0.04 mg/kg (Boerngen and Shacklette, 1981). Mercury is also a common additive to agricultural products, such as herbicides, which presumably are used in this agricultural area. On the basis of the low concentration detected, the similarity in concentration between wastes and soils, and the detection of mercury in background soil and ground-water samples, we attribute the mercury detection to natural condition, agricultural inputs, or activities other than oil and gas waste treatment and disposal.

5.0 ENVIRONMENTAL ASSESSMENT

This section summarizes an assessment of potential human health risks associated with the wastes disposed of at the Roeling Vacuum site. The assessment is based on both comparison of contaminant concentrations in soil and water to regulatory limits and also results of conservative model calculations. The model was developed by Groundwater Services, Inc., for the TNRCC Petroleum Storage Tank (PST) Division. The software is based on guidance provided in "Risk-Based Corrective Action for Leaking Storage Tank Sites (RG-36)" (TNRCC, 1994) and was used because of the similarities in constituents between those detected at the site and those found at PST sites. Modeling procedures and calculations are presented in appendix D.

Risk-assessment pathways considered for this site include:

- soil/air exposure, including soil ingestion and dermal contact,
- ground-water ingestion, and
- ground-water dermal contact.

If risk factors calculated using the model fall below the target values for a site, exposure limits may be assumed to be protective of human health, in particular because conservative input values used tend to exaggerate risk. A cumulative hazard index less than 1, or a cumulative carcinogenic risk less than 1×10^{-4}, for example, is acceptable and indicates that remediation or other control

measures may be unnecessary, according to TNRCC (1996a). Also, if individual constituent concentrations fall below MCL's in ground water or other regulatory limits for waste, then these concentrations are also assumed to be protective of human health.

5.1 Assessment Results

Model results found that arsenic is the main constituent of concern in solid waste and ground water, although arsenic was below regulatory limits and as such is not considered a health-risk concern. For the onsite soil pathway, the model-calculated carcinogenic risk is slightly above the acceptable risk level of 1×10^{-6}. The calculated risk of 3.5×10^{-6} and 8.5×10^{-6} is dominated by arsenic ingestion and by inhalation of particulates from surface soils. Its exact value depends on the input value assumed for arsenic concentration in soil (appendix D). The most protective concentration level for arsenic, however, which covers all pathways resulting from soil exposure, is 20 mg/kg (TNRCC, 1998). Because the measured concentrations of arsenic in onsite waste and soil are less than 20 mg/kg, arsenic in solid waste at the site is not considered a health-risk concern. The model results thus ended up being more conservative than health-based regulatory limits.

For ground water, the model calculated an individual carcinogenic risk for the onsite exposure pathway, which includes soil leaching to ground water and subsequent ingestion, ingestion of constituents already in ground water, and ground-water dermal contact (appendix D). The individual carcinogenic risk calculated by the model for onsite exposure was 7.6×10^{-4}, versus a target risk of 1.0×10^{-6}. The carcinogenic risk was again dominated by arsenic. The highest measured ground-water concentration of arsenic, however, was 0.043 mg/L (at MW-1), which is below the MCL (0.05 mg/L), indicating that dissolved arsenic concentration does not pose a health-risk concern. The model run again was overly conservative because the maximum dissolved arsenic concentration was used as input to the model.

The hazard index calculated by the model for onsite ground-water exposure is of low concern, judging from criteria given in TNRCC (1998). The calculated hazard index for onsite ground-water exposure was 4.6, versus an applicable limit of 1.0 (appendix D). The calculated hazard index was again dominated by arsenic but also influenced by conservatively assumed contributions from chromium (VI) and selenium (appendix D). Again, the maximum dissolved arsenic concentration is below the MCL; also chromium (VI) was not detected in site ground waters and selenium was not detected in waste materials. For offsite ground water, the reported concentration of selenium in the Rogers well (0.05 mg/L) was the same as that of the MCL; however, the hazard index would not exceed the limit if selenium alone were evaluated (individual hazard index of 0.27). The same was true of chromium (VI) and chromium (III), with individual hazard indices of 0.0021 and 0.41, respectively.

Barium, lead, mercury, and silver were not evaluated by the model. One means of evaluating the expected risk from these constituents in ground water is to compare them with MCL's (table 5.1). None of these constituents exceeded MCL's in ground water. A reported lead concentration (sample 5072; table 4.8) in the Simmons well was determined by the TDH to have resulted from sampling or laboratory error and is not indicative of site values. Also, none of the evaluated metals in soil or waste material showed maximum concentrations above the regulatory guideline or limit for waste disposal (TNRCC, 1996b). The presence of these metals is unlikely to contribute to site risk according to this information.

6.0 REMEDIAL ALTERNATIVES

The results of both site investigation and risk assessment were considered when various site-remediation alternatives for the Roeling Vacuum site were considered. These remediation options were evaluated with respect to effectiveness in addressing the waste-package components and in mitigating potential environmental impacts. In addition, site-specific constraints that may affect the viability of remedial options were considered.

Table 5.1. Maximum concentrations for constituents of concern not included in risk-assessment modeling.

Constituent	Medium	Maximum concentration[1]	Regulatory limit[1]	Reference
Barium	Ground water	0.87	2.0	EPA –1° MCL[2]
Lead	Ground water	0.019*	0.015	EPA –action level[2]
Mercury	Ground water	0.0006	0.002	EPA –1° MCL[2]
Silver	Ground water	0.038	0.1	EPA –1° MCL[2]
Barium	Soil/waste	1045	2000	TNRCC (1996b) [3]
Lead	Soil/waste	150	30	TNRCC (1996b) [3]
Mercury	Soil/waste	0.14	4	TNRCC (1996b) [3]
Silver	Soil/waste	0.43	100	TNRCC (1996b) [3]

[1]For ground water, mg/L; for soil/waste, mg/kg.
[2]EPA drinking water regulations and health advisories, EPA 822-B-96-002, October 1996.
[3]Metals limits are for a totals analysis. If a total analysis exceeds the limits listed, then TCLP must be performed before wastes can be disposed of in a municipal solid-waste facility (TNRCC, 1996b).
*RRC result, filtered sample, October 9, 1997.

The central, deepest part of the waste drill-fluid disposal area, roughly centered around BH-4, comprises the bulk of the high-chloride waste onsite. Other areas considered for remediation include the east, west, and north ponds (water and sediment), and the eight waste pits on the east side of the site. Figure 6.1 shows the approximate outlines of these areas. Ground water that exists beneath the site and surrounding areas is also considered.

6.1 General Site-Remediation Considerations

6.1.1 Adjacent Land Use

Current adjacent land use is primarily agricultural to the north, east, and west of the Roeling Vacuum site. Several residences border the south boundary of the site. The water source for each home is a domestic ground-water well. Septic tanks are used for wastewater. Surrounding topography is very flat. FM 2439 (old FM 834) with its associated drainage ditches lies to the south of these residential properties. The drainage ditches are large enough to require the use of culverts for driveway crossings.

6.1.2 Site Security

At the time of the site investigation, access to the site was unrestricted via a small road from FM 2439. A barbed-wire fence was present intermittently around the site perim. Trash had been dumped in the east part of the site, and some of the dumping was noted to be very recent. New dumping of household trash and scrap metal occurred during the course of the site investigation. Anecdotal information (T. Rogers, personal communication, March 1997) indicates that children frequently play on the site. The low compressive strength of the materials in the waste-disposal area poses a physical hazard. Access to the site should be restricted and signs prohibiting entrance should be posted. RRC installed an improved fence and gate during this investigation.

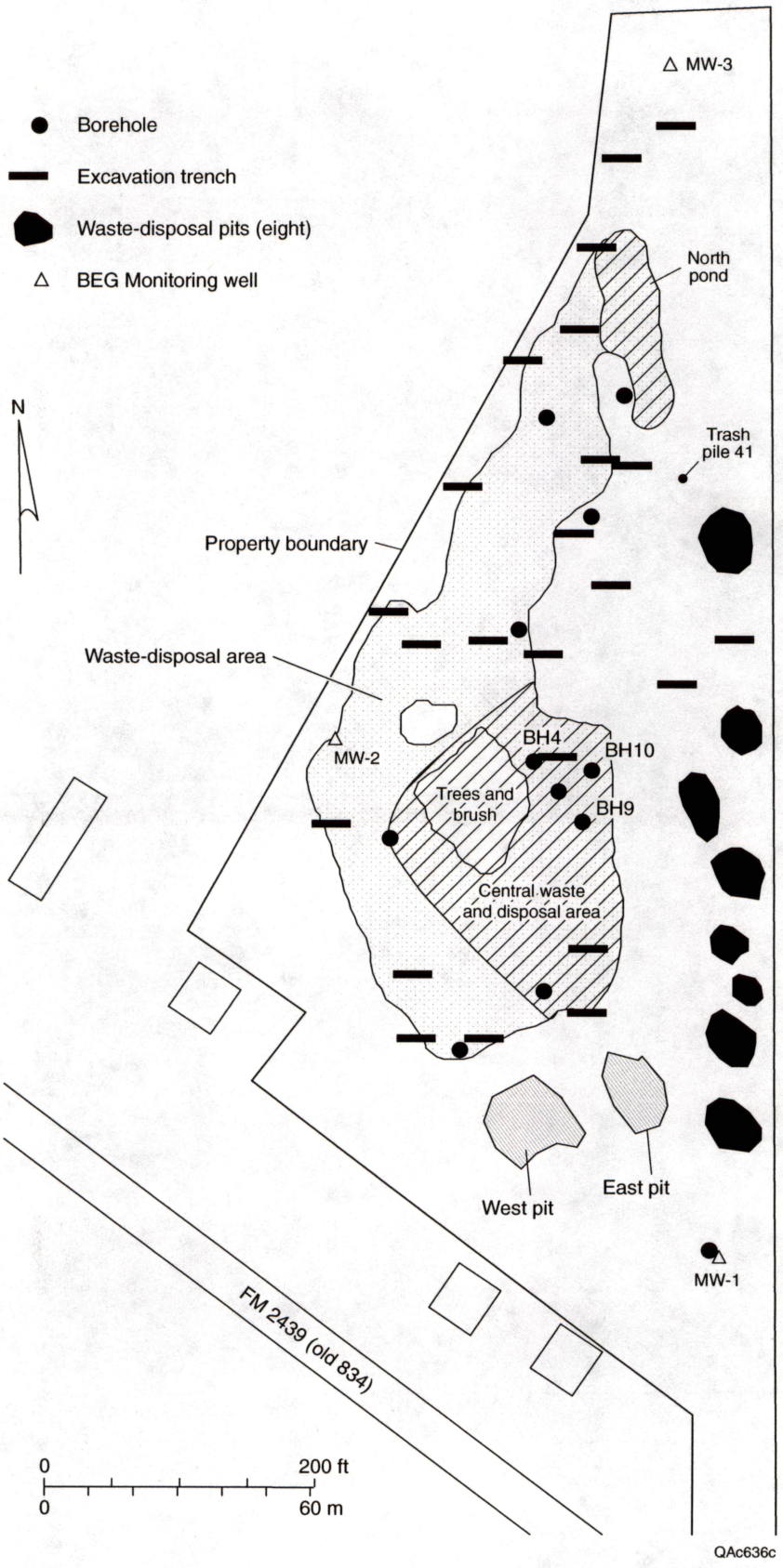

Figure 6.1. Location of the north pond area and central waste-disposal area.

6.1.3 Wetlands

Wetland maps identify two wetland areas adjacent to the site, but none were designated on the site (section 2.3.1; U.S. Department of the Interior, 1987). Wetland maps 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, which includes wetland activities. Three wetland 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 period 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 definitely observed, assistance should be obtained from the local Corps office or a wetlands expert.

At the Roeling Vacuum site, some areas of hydrophytic vegetation, notably cattails, were present within the pit area. Some site soils had hydric characteristics such as decomposed plant material, organic streaks, and a slight organic odor. It is recommended that the Galveston District of the Corps of Engineers be contacted regarding the presence or absence of jurisdictional wetlands at the site before further remediation design work is conducted.

6.1.4 Site Drainage and Surface Hydrology

Site drainage varies with location on the property and is generally poor. The south part of the site, south of the high central berm, drains mostly to the east and west washout ponds. The remainder of the site drains toward the north. Aerial photographs (1988) show drainage from the waste-disposal area toward the north part of the site. A complaint regarding crop damage on the property north and northeast of the site due to site runoff was noted in RRC files. To the northwest, the property adjacent to the Roeling Vacuum site has a pond and a surrounding depressed area that holds water. A man-made drainage swale exists along a part of the east

boundary of the site and another man-made drainage swale is present between the washout ponds and the residences to the south of the site. The washout ponds and the south edge of the waste-disposal area are separated by a filled (bermed) area that has irregular surface expression.

Site surface waters include two washout ponds, a north pond, and ephemeral fluids perched above the waste in the waste-disposal area. Point-source discharge of these fluids under any remedial action may require a National Pollutant Discharge Elimination System (NPDES) permit. NPDES permits may be individual, group, or general and may be for industrial activities or storm-water discharges from industrial facilities. In Texas, the RRC, in addition to the U.S. EPA, regulates point-source discharges from oil and gas exploration and production activities under Rule 3.75. The RRC also provides water-quality certification of Federal permits under Rule 93.

In addition to point-source discharges or discharges associated with oil and gas exploration and production activities, a NPDES general permit is needed for storm-water discharges associated with construction activities that involve 5 or more acres of disturbed area. A site area of 6.19 acres is indicated on the Roeling Vacuum plat map. The waste-disposal area covers approximately 1.7 acres, and approximately 0.6 acres encompasses the waste-pit area. If remedial action implemented at the Roeling Vacuum site will affect more than 5 acres, a notice of intent (NOI) for coverage under this general construction-site permit may be required. An erosion and sedimentation plan may be required in conjunction with this NOI.

6.2 Specific Site-Remediation Considerations

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, evaluating remedial alternatives, and addressing the contaminant source. The following summarizes points from the assessment for specific site areas.

6.2.1 Waste-disposal area

Physical considerations

The oil and gas waste-disposal area, containing primarily saline drilling fluids, some petroleum hydrocarbons, and salt water, covers approximately 1.7 acres. Estimated in-place volume of waste in the entire disposal area is 16,500 yd^3. No single surface feature or expression clearly defines the extent of the waste-disposal area. The waste ranges from a few inches to 13 ft in thickness. The central part of the disposal area (fig. 6.1) contains the greatest thickness of waste, near BH-4, BH-9 and BH-10, but only a thin layer was noted in the north part of the site (see figs. 4.4 and 4.5). The volume of waste in this central area is estimated to be 12,000 yd^3. Waste thickness to the north shallows rapidly away from this central area, with the exception of the north pond, which might also have been a disposal pit. The wastes encountered in BH-6 and in our exploration trenches in the north part of the waste-disposal area are considered to be overflow and washout from the south part of the waste-disposal area. In the southern portion of the waste-disposal area, waste thickness decreases from the BH-10 area to approximately 6 ft in BH-3 and 2.5 ft in BH-2.

A potential physical hazard is posed by the low compressive strength of the waste package. Moisture content of the waste ranges from 25 percent to essentially 100 percent. In some areas, cover soil has been placed on the waste materials. Although this cover is sufficient to support foot traffic, heavier traffic, including vehicles, can easily break through the cover soil and mire in the underlying soft mud.

At some locations within the waste-disposal area at the site, free liquids exist above the waste package, fluctuating seasonally. The surface in the disposal area does not grade uniformly, and precipitation accumulates in depressions in the disposal area. Water is consistently present over some parts of the disposal area and is expected to pond in other depressions during heavy precipitation.

Organics

On the basis of our results, we do not consider remediation directed toward organic constituents or TPH necessary in the waste-disposal area. The material in the waste-disposal area has low TPH levels. The mean TPH level (boring and trench samples combined) detected in the waste-disposal area was 0.28 percent. There was no apparent relationship between TPH concentrations and horizontal or vertical distance across the site. The mean TPH level in the waste-disposal area already satisfies RRC cleanup guidance of 1.0 percent (10,000 mg/kg). Three of the individual trench samples, however, exceeded 1 percent but were less than 2 percent TPH. TPH levels in surface soils and pond sediments were all less than 1 percent. The cleanup guidance of 1 percent is not a fixed regulatory standard but rather a target level below which the potential impact of TPH at RRC facilities is considered nominal. In other, similar cases, the RRC has applied maximum soil values of 1 to 5 percent TPH as a requisite for cleanup (Jill Hybner, RRC, personal communication, 1997). Guidance from TNRCC sets a maximum level of 1,500 mg/kg (0.15 percent) TPH in soil for disposal as municipal solid waste (TNRCC, 1996b).

Although TPH is often used to indicate the potential for volatile and semivolatile organic compounds (VOC's and SVOC's), better data is provided by direct VOC and SVOC analyses performed on the waste material. In these analyses, the only compound detected above method detection limits was naphthalene (420 mg/kg). This level is above the TNRCC (1996c) guidance levels (389 mg/kg) for LPST sites; the TNRCC guidance level is not a standard but, rather, a total level used to indicate the need for TCLP testing. A TCLP test was performed on the waste materials and no VOC's or SVOC'S were detected in the TCLP leachate above method detection limits. In addition, no organic constituents were detected in ground-water samples from the onsite monitoring wells.

Chloride

Remediation of at least some of the chloride-impacted waste or soil may be justified to restrict chloride leaching to ground water and to allow vegetative growth at the site. Elevated chloride levels inhibit vegetation and can degrade surface water and ground water via runoff and leaching. 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 under Rule 3.8. Chloride levels in much of the waste-disposal area preclude land spreading or dilution burial of the waste materials.

The mean chloride concentration in the waste materials was 13,098 mg/kg. In comparison, the mean chloride concentration in surface soils was 842 mg/kg, but the two highest readings (5080 and 5081: 6,793 and 3,511 mg/kg, respectively) also exceeded the recommended level (3,000 mg/kg). Mean chloride concentration in soils below the waste material was 5,773 mg/kg (s.d. ± 1860 mg/kg). Determining whether the salinity of soil beneath the waste package reflects leaching from the waste, movement of saltwater from the pits during site operation, or natural salinity was beyond the scope of this study.

Metals

Although several metals were detected in site wastes, and some were detected above levels found at the background sampling location, none were detected above TNRCC cleanup levels for residential soils (TNRCC, 1998) or regulatory limits for waste disposal in an MSW facility. Barium, chromium, and mercury were detected in soils below the waste materials (mean barium: 235 mg/kg; mean chromium: 19 mg/kg; and mean mercury: 0.038 mg/kg). None of these metals was detected above regulatory limits, and the mean concentrations were similar to concentrations found in the waste materials and other onsite soils.

6.2.2 Waste Pits

No remediation is proposed to address the eight waste pits located between the site road and the east boundary of the Roeling Vacuum site. The waste pits appear to have been used for storage and disposal of drilling muds. Waste characteristics of the pit indicated low concentrations of hydrocarbons, metals, and chloride. In addition, leachability of these pit wastes as indicated by a TCLP test was negligible. In the eight waste pits, the estimated quantity of drilling-mud wastes is approximately 950 yd^3; their area is approximately 0.6 acres. Heavy vegetation surrounds the pits, which did not pose a physical hazard during the site investigation and supported foot traffic. No free fluids were observed in the pits.

TPH levels of the pit contents were below cleanup guidance levels. The mean TPH level of the pit wastes was 0.35 percent, ranging from 0.1 to 0.76 percent. Chloride levels, with one exception, were also below regulatory guidance. The mean chloride concentration in the waste pits was 1220 mg/kg (17 mg/kg minimum, 3,192 mg/kg maximum). Vegetation has not been inhibited near the one pit where the chloride level (3,192 mg/kg) was above regulatory guidance (3,000 mg/kg).

Of the RCRA 8 metals, only barium and chromium were detected above method detection limits in the waste pits. Barium levels are below regulatory guidance. Chromium concentrations in four pits were above TNRCC guidance levels that trigger TCLP testing for disposal purposes but were below residential cleanup levels (TNRCC, 1998). Both barium and chromium leached only slightly from the waste, significantly below regulatory guidance for disposal of nonhazardous wastes (TNRCC, 1996b).

6.2.3 Site Soils

Surface soils at the site do not require remediation and may be useful as cover soil during remediation activities. Oil and gas disposal activities may have slightly impacted surface soils outside of the waste-disposal area, mostly via runoff. Only slight TPH levels were detected in

some surface soil samples (maximum: 0.39 mg/kg), well below the RRC 1-percent guidance level. Chlorides at the surface were low (23 mg/kg) at MW-3 but averaged approximately 1,200 mg/kg across the site. Many areas of the site are heavily vegetated, indicating that surface chloride levels are not interfering with growth in all places.

No occurrences of metals were high enough or extensive enough to necessitate separate remediation of surface soils; all measurements were less than TNRCC residential cleanup levels (TNRCC, 1998) and disposal limits for an MSW facility.

6.2.4. Site Ponds

No treatment or remediation of the pond water or sediment is recommended because no regulatory limits were exceeded. TPH in pond water was less than 0.4 mg/L, less than the TNRCC limit (5 mg/L). The highest chloride concentrations in fluids were found in the north pond (260 mg/L), slightly above the EPA secondary MCL (250 mg/L) but less than the TNRCC secondary MCL (300 mg/L) for chloride. No dissolved metals were detected in pond water above MCL's or action levels.

TPH was less than 1 percent in all pond sediments. The highest chloride concentration in the sediments was 500 mg/kg. All RCRA 8 metals in sediments were below the TNRCC's regulatory guidance for total metals for LPST sites (TNRCC, 1996c), with the exception of lead. The lead concentration in the north pond sediments was 89 mg/kg, below the residential cleanup level of 500 mg/kg (TNRCC, 1998). Judging from the metals and chloride concentrations in water and sediments, the north pond has most likely been influenced by runoff from the waste-disposal area and may be a former pit, according to measured sediment depths, analytical results, aerial photos, and observed site-drainage patterns.

6.2.5 Ground Water

Although there were constituents in local wells that might be related to the site, there were no instances where regulatory limits were exceeded. Remediation of onsite wastes to restrict leaching of salt to ground water would most likely reduce risk of future offsite water-quality impacts.

Organics

No remediation directed toward organic constituents or potential impact of organic constituents is considered necessary with respect to ground water. No VOC's or PAH's were detected in the three onsite wells. In one of the five offsite domestic wells, located upgradient of the site, fluoranthene and pyrene were detected at levels below TNRCC action levels. Fluoranthene and pyrene were not detected above method detection limits in the wastes onsite. No other VOC's or PAH's were detected in the five offsite wells. TPH levels in the waste materials are low and the only VOC detected in the waste material was naphthalene. No VOC's or SVOC's were detected in the TCLP analysis on the waste material. These findings suggest that potential for organic contaminants in ground water is small.

Chloride

Chloride concentrations in two onsite wells (360 and 710 mg/L) and one offsite domestic well (Rogers, 540 mg/L) exceeded EPA's secondary MCL for chloride (250 mg/L) and are above background concentrations. These values suggest that the site has had an influence on these wells. The tested values are less than reported by RRC in 1992. The onsite wells closest to the waste package tended to have the highest chloride concentrations. Local background chloride concentration in the ground water is given by one upgradient offsite domestic well (39 mg/L). A side-gradient offsite domestic well had a chloride concentration of 43 mg/L. The ground-water gradient at this site is very flat and might vary with seasonal changes in recharge or pumping.

Elevated chloride levels in soils (mean of 5,773 mg/kg) underlying the waste in the waste-disposal area suggest some impact from saltwater, although a natural source has not been excluded. Chloride concentration in the waste is high (average of 13,098 mg/kg and maximum of 42,000 mg/kg) and generally increased toward the base of the waste mass. Judging from this existing chloride source, continued chloride impact to the ground water is possible.

EPA's secondary MCL for chloride (250 mg/L) is considered a recommended and reasonable goal, not an enforceable Federal regulation. Secondary MCL's consider taste, odor, color, and certain other nonaesthetic factors in ground water (U.S. EPA, 1996a). A general-guideline threshold between fresh and brackish water is 1,000 mg/L total dissolved solids (TDS) (Freeze and Cherry, 1979). This level was exceeded in two offsite domestic wells and one onsite well, indicating that the ground water can no longer be classified as fresh water.

Metals

No RCRA 8 metals were found dissolved in ground water above MCL's. Arsenic, barium, chromium, and mercury were detected in the onsite monitoring wells below EPA primary MCL's. Arsenic, barium, chromium, lead, mercury, selenium, and silver were detected in various combinations in five offsite wells, the most frequent and highest detections being in the Rogers and Simmons wells. Resampling showed that chromium and lead were below detection limit (<0.005 mg/L) and that reported lead values were susceptible to sampling or laboratory error (Texas Department of Health, 1997; see app. B). All metals detected in the offsite domestic wells were below EPA primary MCL's.

Our data suggest that metals have had no, or only a minor, impact on ground water at and near the site, whereas concentrations remain below MCL's. Possible sources of dissolved metals in ground water include infiltration from the ponds, surface infiltration from the site, leaching from the waste, or background metals in soil. Ground-water remediation is not triggered by reported

dissolved-metal concentrations because none of the dissolved metals exceeded EPA's primary or secondary MCL's.

The pattern of detected constituents, including chloride, in the Rogers and Simmons wells and previous data from the RRC on the Rogers (previously Taggert) well, however, suggest that low levels of ground-water contamination have occurred. Limited further monitoring is needed to develop more information about the detected constituents, constituent sources, and any change (increasing or decreasing) in concentration over time.

6.3 Remedial Alternatives

At the Roeling Vacuum site, areas of possible concern include high-chloride waste materials onsite and elevated chlorides in ground-water samples. Available technologies exist to address concerns, and the specifics of these technologies are discussed later. To evaluate remedial alternatives appropriately, the purpose and goals of the remedial action must be defined. Possible remedial actions include a no-action alternative. Securing the site, performing limited surface remediation, and monitoring the site are parts of other alternatives. Removing sources of potential contamination and performing selective remedial activities are a third option, and complete site cleanup is a final alternative.

6.3.1 No-Action Alternative

The no-action alternative means taking no action to remediate the site and leaving the site in its present condition, natural processes controlling the fate of wastes and the rate of remediation. Continued monitoring of the site conditions, however, is usually adopted as part of, or a condition for, a no-action alternative. Under a no-action alternative, the waste-disposal area would continue to pose a physical hazard. The potential for additional ground-water impact would continue, although that impact could be monitored. In addition, no changes to site security would be provided beyond the recent addition of a fence and gate. Because of the potential for continued

environmental impact and the physical hazards associated with the waste-disposal area, the no-action alternative is not considered appropriate for the Roeling Vacuum site.

6.3.2 Secure Site with Limited Surface Remediation and Monitoring

Another alternative is to secure the site, perform limited surface remediation, and monitor ground water. At a minimum, site security would include a gate and fence (which have already been installed) to restrict vehicular access and signs posted to discourage trespassers. Limited surface remediation might include surface treatment of the barren areas to reduce the chloride level, placement of stabilizing cover on exposed waste areas within the disposal area, and ground-water monitoring. These steps would address immediate remedial concerns but would not permanently resolve those concerns.

Securing the site would reduce the risks of future dumping onsite, and the risk of unsuspecting persons being exposed to the physical hazard in the waste-disposal area would also be reduced. Limited surface remediation would include placing sufficient cover thickness over the exposed waste in the disposal area to minimize entrapment hazard associated with the soft wastes. In the barren areas, surface sediments would be treated with gypsum and mixed with clean soil as necessary to decrease the chloride concentrations to a level amenable to vegetation. No action would be taken with respect to the waste pits and washout ponds. Ground-water monitoring would be performed to detect potential impact from chlorides and metals or to confirm that additional ground-water impact is not occurring.

This alternative neither addresses the waste material as a possible ongoing source of contamination to ground water nor does it consider practical restrictions on future use of the property. Soil cover and surface soil treatment for chloride would address risks due to surface exposure and vegetation inhibitions but would not address the potential for continued leaching from subsurface wastes or underlying low-compressive-strength materials for uses other than foot traffic.

6.3.3 Secure Site, Remove Elevated Chloride Waste, Limited Surface Remediation, and Monitoring

This alternative involves securing the site, removing the elevated chloride waste from the central waste-disposal area, removing sediment from the north pond with elevated lead content, and monitoring ground water. This alternative addresses immediate risk concerns, sources of potential future contamination, and removes some practical restrictions on future use of the property. It does not seek to restore the site to its preexisting condition or render it suitable for any specific future use.

Site security (already completed) would prevent vehicular traffic and discourage further trash dumping and trespassing. The elevated-chloride waste from the central waste-disposal area would be excavated and treated or disposed of offsite. Removing this material would remove a source of ground-water contamination, reduce the physical hazards relating to this material, and eliminate the need for cover soil to be placed over this part of the waste mass.

Limited surface remediation would include surface treatment of any barren areas to reduce chloride levels and ground-water monitoring. By excavating and removing the source of potential future contamination, these steps would address immediate and future remedial concerns. This alternative would not restore the site to its preexisting condition.

No action would be taken with respect to the east and west washout ponds.

No action would be taken under this alternative with respect to ground-water remediation. Ground-water monitoring would be performed to confirm that no increase in impact is occurring as a result of time or the remediation process. Removal of source materials, however, may be sufficient to reduce future risk of contaminants in ground water.

6.3.4 Comprehensive Site Remediation

This alternative would include the just-mentioned actions (section 6.3.3), as well as removal, treatment and disposal of the remaining waste materials in the waste-disposal area and the waste pits, and backfill of these areas with clean soil. This would also include removal of fluids and

sediments in the ponds. Site regrading would be performed. Ground-water remediation to reduce metals concentrations and chlorides to their preexisting concentrations would be performed, or an alternate water source for residents would be provided as a reduced-cost alternative. The goal of this alternative would be to remove physical hazards and to reestablish, as feasible, site conditions similar to those before oil and gas disposal activities.

Because less extensive remedial actions would accomplish the goals of reducing site risks from chemical and physical hazards and preventing further contamination of ground water, this alternative is not recommended at this time. The more extensive remediation of this option is not justified because no evidence of constituents exceeding health-based standards was found.

6.3.5 Evaluated Remedial Alternatives

Options that were evaluated but considered not practicable at Roeling Vacuum include land treatment, dilution burial, soil flushing, solidification and stabilization, capping, subsurface containment techniques such as slurry walls or sheet piling, and trench drains. These alternatives are summarized in appendix E.

7.0 RECOMMENDATIONS

The RRC has secured the site with an improved fence and gate to prevent unauthorized access and dumping. No remediation of ground water is recommended at this time because current information indicates no exceedances of health-based criteria in onsite or offsite wells. Additional sampling of existing and new onsite monitoring wells, however, is needed to (a) address reported concerns about potential drinking-water impacts around the site and (b) determine whether remediation is justified to reduce the potential for ground-water impact associated with elevated chloride concentration in waste materials. If remediation is deemed necessary, elevated-chloride wastes could be removed from the central site area by excavation to prevent future impacts to ground water. Limited surface remediation might also be performed to mitigate the effects of salt

on surface vegetation, remove the entrapment hazard from soft waste materials, and deal with the lead content of the north-pond sediments. Additional monitoring wells can be phased in and positioned on the basis of interim monitoring results. Scheduling remediation work during the dry season would minimize logistical problems associated with surface water and expedite remedial activities.

7.1 Secure Site

Because of the potential for unauthorized and uncontrolled dumping, as well as public-safety hazards and risks posed by site conditions, access to the site should be restricted. Securing the site involves, at a minimum, placing a locked gate across the entrance road to prevent vehicle access to the site and posting signs to discourage trespassers. Occasional visits to the site would confirm that further dumping and trespassing have been discouraged or would indicate that additional security measures are necessary. This option has been implemented by RRC.

7.2 Ground-Water Monitoring

Monitoring is recommended to provide additional data as a basis for determining the cost effectiveness of remediation. The one-time measurement of waste, soil, and water constituents in this study supports the preliminary finding presented in this report that remediation of waste materials is not justified on the basis of exposure risk. Monitoring can provide the following information or confirmation of findings presented in this report:

- information on whether elevated levels of chloride in waste materials indicate the need for remediation of waste materials,
- an evaluation of specific remedial actions that might be needed to control potential migration pathways,

- a confirmation of the direction of ground-water flow near the site and an evaluation of seasonal and annual fluctuation in flow gradient that might affect movement of possible contaminants.

Monitoring should include new wells in addition to the three installed in this study.

Quarterly monitoring allows documentation of seasonal changes in ground-water gradients and provides a statistically significant number of points to determine change in chemistry data. Statistical tests such as a students t-test are used to document the significance of changes in water-quality data. Specific goals of the monitoring process, such as implementing a remedial action or ending the monitoring process, are based on the results of the tests.

At a minimum, three additional ground-water monitoring wells should be installed along the east boundary of the site. One well would monitor the uppermost water-bearing unit, the same unit in which MW-1, MW-2, and MW-3 are screened. A second ground-water well would be screened in the next-deeper water-bearing unit to confirm that cross contamination of the lower unit has not occurred. A third well should be installed in the uppermost water-bearing unit at an upgradient location that is sufficiently distant from the waste materials to prevent impact by the wastes. It will need to be an offsite well, and landowner permission will be needed before drilling. All six monitoring wells and selected offsite wells, such as the Rogers and Simmons wells, should be sampled quarterly for a period of at least 2 yr to provide enough data to form a scientific basis for concluding whether further action is appropriate. Ground-water elevation data should be collected during these monitoring events. Data from each monitoring event should be promptly reviewed in light of existing information, and adjustments in the monitoring program should be made if necessary. Because of the proximity of potential receptors, if a primary MCL is exceeded in an onsite ground-water monitoring well, additional steps should be taken. These additional steps may include, among others, resampling, increasing monitoring frequency, installing additional wells, performing additional ground-water testing on domestic wells, and providing an alternate drinking-water source.

7.3 Waste Pits and Washout Ponds—No Action

On the basis of the results of the site assessment, we recommend no action with respect to the waste pits or the washout ponds because none of them posed a notable environmental or physical concern. Other factors, such as standard site-closure procedures or potential future uses, may dictate that action be taken with respect to the waste pits or washout ponds. Discharge of the water from the washout ponds would be viable, if necessary, because the analyses satisfied EPA's drinking-water standards. A discharge permit and procedures to minimize erosion and sediment loading would be required. Alternatively, the washout-pond fluids could be used as a water-supply source during site remediation for dust control. After water has been discharged, the sediments could be excavated and placed in the waste-disposal area.

7.4 High-Chloride Wastes

Whether the waste having high chloride concentrations in the central part of the waste-disposal area should be excavated and removed for offsite disposal should be determined on the basis of additional, long-term monitoring data. This action would remove a source of chloride that has the potential for contamination of ground water. Removing the waste material in the disposal area would also remove the physical hazards relating to this material and eliminate any need for cover soil to be placed over the waste mass.

The volume of waste material in the central disposal area is estimated to be 12,000 yd^3. No RRC-permitted commercial disposal facility is listed in Liberty County. The elevated chlorides would prevent most land-treatment and disposal-pit facilities permitted in nearby counties from accepting this waste. An alternative is to dispose of the high-chloride wastes in an RRC-permitted salt cavern. A salt-cavern disposal facility is located within 160 mi of the site.

As an alternative to RRC-permitted facilities, the Roeling Vacuum waste may be considered for disposal at TNRCC-permitted facilities. Generally TPH is limited to 600 mg/kg for waste disposed in municipal solid waste (MSW) landfills; certain MSW landfills accept waste having

TPH of as much as 1,500 mg/kg (0.15 percent). Most waste material at the site tested below these levels. Certain TNRCC-permitted MSW facilities request specific special-waste approval from the TNRCC to accept RCRA-exempt wastes and nonhazardous oil-field wastes (NOW). Some MSW facilities in the Houston area, within 55 mi of the site, regularly request such special-waste approvals. Besides MSW facilities, TNRCC-permitted Class 1 nonhazardous waste-disposal facilities generally accept TPH levels greater than 1,500 mg/kg. Two Class 1 industrial disposal facilities are located within 75 mi of the Roeling Vacuum site.

7.5 Surface Remediation

To reduce chloride concentrations to a level amenable to vegetation and establishment of acceptable surface-completion grades, it might be reasonable to consider remediating the surface of the barren areas by means of gypsum. Such action would be driven by land-use issues more than by health and environmental risks. This treatment would cover exposed waste sufficiently to reduce potential physical hazards and to encourage vegetative regrowth. The desired surface character of the site after remedial activities should be considered because site activities have influenced the entire surface character of the site. The site has been inactive in recent years, however, allowing some vegetation, and possibly wetlands, to establish. These wetlands may restrict the areas that can be disturbed during the remediation process.

If removal of waste materials from the waste-disposal area becomes necessary, on the basis of further monitoring data, an open excavation as much as 13 ft in depth might exist (12,000 yd^3). Soils may be taken from the irregular area between the washout pond and pits and placed in the excavation. Sediments from the north pond (as much as 6,800 yd^3) could also be evaluated for placement in this excavation, with an initial liner of clay soil and final cover of clean soil.

The quantity of available soil onsite is thought to be insufficient for complete backfill of the excavation. A precise determination of soil quantities requires site-specific topography, which was beyond the scope of this work, but may be appropriate before implementation of remedial actions.

One alternative is to import offsite soils to correct this soil deficiency and allow for complete backfill of the excavation. The disadvantage to this alternative is the cost of the imported soils.

Another alternative would be to place pond sediments in the excavation, cover with available site soils, and leave a partial excavation in place. The soils in the excavation should be placed in a controlled manner and rough graded. This alternative avoids the purchase of offsite backfill and may be appropriate if wetlands are determined to be present onsite. If wetlands are present and site remedial activities require disturbance of the wetlands, the partial excavation may be a mechanism to allow for reestablishment of those wetlands upon site completion.

7.6 Limitations of Remedial Approach

These remediation alternatives address immediate risk concerns and sources of potential future contamination; they remove some practical restrictions on future use of the property. These actions do not restore the site to its preexisting condition or render it suitable for any future use. They are intended to be conservatively protective of human health because of the active current- and future-risk pathways that exist at the site. The site assessment did not indicate any particular constituent at a concentration that would trigger a more aggressive remedial action, but it did indicate environmental impact to the site surface and subsurface soils, surface water, and ground water. A conservative, site-specific risk assessment indicated potential risk levels slightly above guidelines for soil ingestion and dust inhalation and ground-water exposure. Because of the proximity of human receptors to this site, their current and future use of ground water, and the potential for adults and children to incur increased risk from site waste materials and ground water, a conservative approach is recommended, particularly until a larger base of ground-water data can be collected.

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