Remedial Investigation and Feasibility Study

Roeder Avenue Landfill
Bellingham, Washington

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ThermoRetec Project No.: PORTB-03809-710

Prepared for:

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Bellingham, Washington 98225

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1 Introduction

This document summarizes the results of a Remedial Investigation and Feasibility Study (RI/FS) performed by ThermoRetec for the Roeder Avenue Landfill site (Landfill) in Bellingham. This RI/FS is being performed jointly on behalf of the Port of Bellingham and the City of Bellingham (City) to determine what remedial measures are required under the Model Toxics Control Act (MTCA) for cleanup of the Landfill. Review of the RI/FS is being provided by Ecology under the Voluntary Cleanup Program.

1.1 Site Description and Ownership

Figure 1-1 shows the location of the Roeder Avenue Landfill. The Landfill is located within Bellingham's Central Waterfront area, between the I&J Street Waterway and the Whatcom Waterway.

The landfill was constructed in 1965 in compliance with Army Corps of Engineers and City of Bellingham permits, and under lease agreements between the City of Bellingham and the area property owners. At the time the landfill was constructed, the landfill properties (excluding certain City of Bellingham right-of-ways) were owned by Georgia Pacific and the Port of Bellingham. Between 1965 and 1974 the landfill operated as the main disposal site for municipal refuse in the City. Municipal use of the site was terminated in 1974. Since that time, portions of the site have been acquired by Sanitary Services and by Puget Sound Energy. Current property ownership is summarized in Section 2.1, and Section 2.2 provides a detailed history of the Landfill and the surrounding properties.

1.2 Project Regulatory Context

The Landfill site has been evaluated by EPA, the Department of Ecology and the Whatcom County Department of Public Health (Health Department). No further actions have been required by EPA or the Health Department. Ecology remains the lead agency for site cleanup.

Ecology has identified the Landfill as a contaminated site subject to MTCA investigation and cleanup requirements. Ecology conducted a site hazard ranking in 1995. As a result of the site hazard assessment, Ecology concluded that further actions were necessary at the site, but the site was given a low priority ranking of 5 (on a scale of 1 to 5, with a rank of 1 indicating the highest priority sites). Ecology also issued a sampling report for the Landfill in 1996 (Ecology, 1996).

Ecology has issued early notice letters to Georgia Pacific, the City of Bellingham and Sanitary Services. To date, Ecology has not issued Potentially Liable Party (PLP) notices for the site, or initiated formal enforcement actions under MTCA.

The decision-making process for the Landfill and associated properties has been complicated by its central location, its multi-party ownership, and the proximity of the site to other contaminated properties. In response GP, the City and the Port have initiated coordinated actions at the site. These have included the Roeder Avenue Warehouse Feasibility Analysis (described in Section 2.3) and this RI/FS. Completion of the current RI/FS in advance of formal Ecology enforcement action addresses the following concerns:

- Timely investigation and resolution of any potential impacts of the Landfill to human health or the environment, through completion of site investigation and cleanup actions required under MTCA.

- Verification that the Landfill does not represent a potential source of sediment contamination for the Bellingham Bay area, as necessary to support coordinated sediment cleanup, source control and restoration actions being conducted under the Bellingham Bay Demonstration Pilot.

- Differentiation of Landfill and non-Landfill contaminants at neighboring properties with MTCA cleanup liabilities (including the Olivine site, the Chevron site and the Colony Wharf site) as necessary to facilitate cleanup decision-making at these higher-ranked MTCA cleanup sites.

- Definition of cleanup requirements for the Landfill site, including required use restrictions or institutional controls that must be incorporated into area-wide land use planning.

The RI/FS was initiated in 1998 after completion of a Scoping Memorandum (RETEC, 1998a) and a project Work Plan (RETEC, 1998b). The Work Plan included a public participation plan. Ecology has provided technical assistance and oversight during the RI/FS project under Ecology's Voluntary Cleanup Program.

After finalization of the RI/FS, final cleanup actions for the Landfill are expected to be conducted pursuant to a Cleanup Action Plan and Consent Decree. The development of these documents will be completed after Ecology and public review of this RI/FS document.

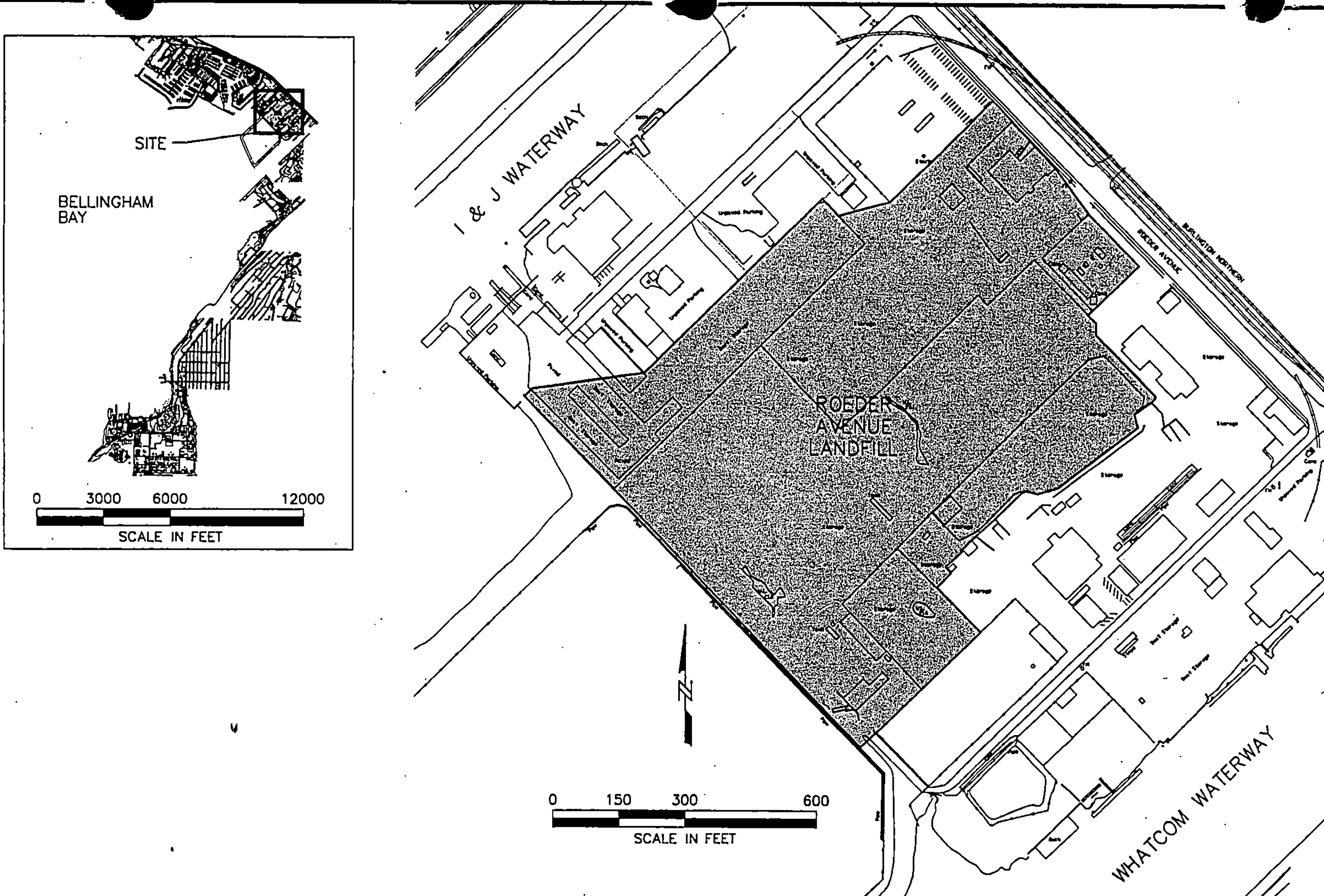
1.3 Previous Project Reports

The objectives and methods for the RI/FS were defined in the Work Plan (RETEC, 1998b) submitted previously to Ecology. The results of the RI/FS are being communicated to Ecology in a series of Progress Memoranda and in this RI/FS report.

The first Progress Memorandum for the project (ThermoRetec, 1999) was submitted to Ecology in June of 1999. That memorandum was used to communicate information regarding well installations at the site, the results of a tidal study and hydrogeologic testing performed in November of 1998 and the results of the first quarter of groundwater monitoring conducted in February of 1999. That document also explained how Ecology comments on the Work Plan were incorporated into the RI/FS process, and finalized the monitoring plan for subsequent quarters of groundwater monitoring.

The Second Progress Memorandum (ThermoRetec, 2000) for the project was submitted in March of 2000. That memorandum presented the final results of site groundwater monitoring, and identified the methods for groundwater modeling to be conducted as part of the RI/FS.

Coordinated Land Use Planning was conducted by the Port in parallel with this RI/FS. That work was funded under an EPA Brownfields grant and was performed by Makers during 1999 and 2000. That planning included extensive public comment and participation. The findings of the planning effort have been summarized in Section 5 of this RI/FS document.



ROEDER AVENUE LANDFILL RI/FS PORTB-03809-710			SITE LOCATION MAP
DATE: 06/01/01	DRWN: N.S.	FILE: 3809s203	FIGURE 1-1

Section 2

2 Site Background

This section provides site history and background information relevant to the scope and objectives of the RI/FS. The objectives and methods of the RI/FS are then described in Section 3.

2.1 Site Features

Figures 1-1 and 2-1 show the location of the Landfill with respect to the surface waters of Bellingham Bay and the adjacent upland properties. Characteristics of the Landfill and the adjacent areas are described below.

Ownership

Figure 2-1 shows current parcel boundaries as specified during a 1998 Record of Survey (Steele, 1998). The location of the Landfill refuse is shown based on the results of Warehouse Pre-Design Testing (RETEC, 1997).

The Landfill area as shown in Figure 2-1 represents approximately 21.4 acres. Current land ownership for the Landfill area is shown in Table 2-1.

Table 2-1 Property Ownership within the Landfill Boundary

Owner	Landfill Acreage	Percent of Total Landfill
City of Bellingham	0.5	2%
Puget Sound Energy	0.9	4%
Port of Bellingham	2.3	11%
Sanitary Services	4.2	20%
Georgia Pacific	13.5	63%
Total Landfill Area	21.4	100%

Properties located adjacent to the Landfill include those within the Colony Wharf site, the Olivine site, the Chevron site, as well as City streets and right-of-ways (see Figure 2-1).

Ownership changes during performance of the RI/FS have been minimal, and ownership of the Landfill itself has not been impacted. In 1999, Georgia Pacific acquired a small section of land from the B. C. Investments. The adjusted property boundary is shown in Figure 2-1. This change did not affect the distribution of Landfill ownership. Also during 1999 the Port of Bellingham acquired the Golden property located to the southeast of the Landfill (see Figure 2-1).

Adjacent Contaminated Sites

Four sites adjacent to the Landfill were listed on Ecology's Confirmed and Suspected Contaminated Sites List at the time the RI/FS was initiated. These sites include the Hawley's Hilton Terminal, Olivine, Colony Wharf (a.k.a., Bellingham Marine Industries or BMI) and Chevron Terminal sites. Ecology has issued a No Further Action Letter for the Hawley's Hilton Terminal site. The other sites have been placed on Ecology's Hazardous Sites List. The Olivine, Colony Wharf/BMI and Chevron sites have been given priority rankings of 3, 4 and 2, respectively (on a scale of 1 to 5, with a ranking of 1 indicating the highest cleanup priority).

Based on the groundwater gradients reported in studies prior to the RI/FS (Figure 2-2), groundwater from the Landfill was known to flow toward the I&J and Whatcom Waterways. As a result, the scope of the RI/FS included focused testing to assess the presence and extent of Landfill associated-contaminant migration onto or across these adjacent sites. Section 2.2 below includes a history of site uses and investigation and cleanup actions at each of these properties.

Zoning and Land Use

The properties along C-street and the main properties comprising the Landfill are zoned for industrial uses. This zoning is consistent with the City's Shoreline Master Plan and with historic, existing and reasonably forseeable land use within the area. The properties along Hilton Avenue are currently zoned for commercial uses. The findings of recent Land Use planning efforts for both groups of properties are summarized in Section 5. None of the properties within the Central Waterfront area are currently zoned for residential uses. No future residential uses are currently anticipated.

Site Topography

A topographic survey and utility locate was performed in 1997 and 1998 (Steele, 1998) on behalf of the Port. The results of that survey were presented in the RI/FS Work Plan.

The measured ground surface elevations within the Landfill boundary at the time the RI/FS was initiated ranged from 14 to over 40 feet above Mean Lower Low Water (MLLW). As described in Section 2.2, the Landfill was initially constructed to a grade of 15 feet MLLW, consistent with the average elevation for the surrounding industrial properties along C-street and along Hilton Avenue. The portion of the Landfill owned by the Port of Bellingham along Hilton Avenue remains at approximately this elevation.

The GP-owned portion of the Landfill was completed at a final refuse elevation of 20 feet MLLW. The Landfill was then covered with 2 feet of soil cover as part of Landfill closure. Much of the Landfill surface is consistent with this elevation, averaging roughly 22 feet above MLLW.

A crest in the center of the Landfill had an elevation of up to 29 feet MLLW prior to subsequent grading, capping and development by GP as part of the Warehouse project. Cover soils in this area included dredged sediments, bark, limestone and gravel which had been placed on site by GP subsequent to the 1974 Landfill closure.

In the eastern corner of the Landfill, adjacent to the PSE electrical substation was a large pile of soil. These clean soils were obtained from a previous Chestnut Street realignment project. The soils were stockpiled on site by G.P. for later reuse. The stockpile extended from elevation 26 feet to approximately 40 feet MLLW. These soils were reused during completion of the Warehouse project.

Shoreline Features

During preparation of this Work Plan, RETEC conducted an inspection of shoreline conditions along the I&J and Whatcom Waterways. This inspection was performed to identify factors which could influence the direction or flow rate for groundwater in the Landfill area (e.g., sheet pile bulkheads can significantly retard or divert the flow of groundwater in comparison to more-permeable armored soil slopes).

Descriptions of observed shoreline features are shown in Figure 2-2. Also shown in the figure are bathymetric contours for the existing sediments (Hart Crowser, 1997) and Corps-authorized project depths for the I&J and Whatcom Waterways.

Current shoreline conditions consist of a mix of bulkheads and armored slopes. Excluding the G.P. stabilization basin (GP Lagoon -- approximately 1,000 feet along the Laurel street alignment), the total shoreline between the head of the I&J Waterway and Roeder Avenue has a length of 2,930 feet. Observed shoreline conditions (0 to +15 feet MLLW) are summarized in Table 2-2.

Shoreline features of the project area were incorporated into the groundwater modeling activities performed during the RI/FS. This incorporation is described in Section 6 of this report.

Development Features

Figures 2-1 through 2-3 show the locations of existing buildings and paved surfaces. Prior to completion of the Warehouse project by GP, the vast majority of the Landfill surface consisted of ungraded soil or gravel cover. Buildings and paved areas comprised less than 10 percent of the total area.

Table 2-2 Observed Shoreline Features

Shoreline Types	Observed Locations	Total Estimated Length
Unprotected Soil Slope	Chevron (Damaged bulkhead)	60 feet
Armored Slope (Armor Stone, or Concrete Rubble)	Olivine Site (Bulkhead Gap) Port (Bornstein's Seafoods) Portions of Colony Wharf Site	30 90 540
Armored Slope with Beach	Laurel Street at Hawley's Hilton Laurel Street along Chevron	270 300
Wooden Bulkhead (Well Maintained)	Olivine Site Port (Bornstein's Seafoods)	280 320
Wooden Bulkhead (Poorly Maintained)	Chevron Site	160
Concrete or Steel Sheetpile Bulkhead	Colony Wharf Site Hawley's at Hilton	480 400
G.P. Aerated Stabilization Basin	Laurel Street alignment **	1,000
Total CWRP Area		3,930 feet

Notes:

** The shoreline lengths were estimated for the area between the head of the I&J Waterway and the head of the Whatcom Waterway at Roeder Avenue. The shoreline at the heads of the two Waterways was excluded in the length calculations. For the stabilization basin, only the length along the Laurel street alignment was included.

Buildings initially located on the Landfill included the GP compressor building (part of the GP wastewater treatment system), a GP Salvage Building, the Sanitary Services building and the Puget Sound Energy Substation. The Sanitary Services building and the GP compressor building are pile-supported structures.

Small paved areas of the Landfill were initially located adjacent to the buildings owned by GP and Sanitary Services. Some asphalt paving was located in the western corner of the Landfill, within the Hawley's Hilton Terminal site. The Hawley's paved areas were paved for use as boat storage. An additional asphalt-paved area is located adjacent to the GP stabilization basin. This area was paved as part of GP drainage improvements in this area.

As described in Section 5, GP completed construction of a 250,000 square foot Warehouse over a portion of the landfill (Figure 2-1). The building is a pile-supported structure. GP coordinated with the Department of Ecology during the building design process, including provisions for soil capping, gas collection and site drainage. Because of the site geologic conditions (i.e., lack of a hydrogeologic confining layer between the Landfill refuse and the underlying layer of permeable soils) the foundation piles installed as part of the Warehouse project were determined to pose no risk of exacerbation of site conditions. Surrounding areas that were paved as part of the Warehouse project are shown in Figure 2-1. Together, the Warehouse project resulted in capping and infiltration control of approximately 60 percent of the GP property, or 40 percent of the total Landfill refuse area.

Access to the majority of the Landfill is controlled by permanent site fencing. The fencing includes sections owned by the Port, Sanitary Services, G.P., Puget Sound Energy, Chevron and Colony Wharf (BMI). Fence locations that existed prior to the RI/FS are shown on Figures 2-1 and 2-2. Fence locations on the GP property were modified during the Warehouse project.

Utilities

Utilities in the vicinity of the Landfill were documented in the RI/FS Work Plan. Few underground utilities were identified within the Landfill, but a significant network of utilities exists at the adjacent properties. In some circumstances, utility corridors can act as preferential flow pathways for the flow of groundwater. Utility locations and depths were reviewed to determine which utility locations could be of potential significance to groundwater flow patterns. Utilities identified in the 1997 survey included the following:

- Sanitary sewer lines, pump stations and force mains (City)
- Storm drains and catch basins (City and private)
- C-street outfall tunnel (City)
- Abandoned F-street stormwater outfall (City)
- Underground and overhead electric service (Puget Sound Energy and private)
- Overhead telephone and electric service
- Underground fiber-optics (Starcom and US West)
- Natural gas lines
- Water lines for the GP Lagoon
- Water supply lines
- Steam lines (BMI and Colony Wharf)

The potential significance of area underground utilities to groundwater flow patterns was evaluated during groundwater modeling efforts as described in Section 6 of this report. These utilities were determined to have little or no affect on groundwater gradients and discharge patterns relevant to the RI/FS and MTCA remedy selection.

2.2 Site History

The history of the Landfill was described in the Warehouse Feasibility Analysis (RETEC, 1996) and in the RI/FS Work Plan. That history is briefly revisited below. The history of adjacent sites are summarized below where relevant to interpretation of potential groundwater contaminants and source areas adjacent to the Landfill.

As a result of the previous environmental and geotechnical studies at the Landfill and at these adjacent properties, the entire Central Waterfront area has been extensively investigated.

Figure 2-2 shows the locations of previous test pits, soil borings and groundwater monitoring wells which were installed during previous environmental and geotechnical investigations at the Landfill and at adjacent properties.

Regional History

The pre-settlement shoreline in the vicinity of the Landfill was located north and east of Roeder Avenue. The original shoreline location, as approximated from Department of Natural Resources maps from 1907 is shown on Figure 2-1.

Original development within the Landfill area consisted of lumber mills located on pilings above the tidelands. Infill development of the C-street and Hilton Avenue areas began in earnest circa 1910 with the initial dredging of the Whatcom Waterway. Fill areas were created by sidecasting the dredged sediments behind bulkheads constructed along the edges of the waterway. Much of the current C-street land mass was initially created in this way.

The soil area located between C-street and the Landfill was filled in subsequent projects during the 1940s and 1950s. Additional fill projects added to the area along Hilton Avenue in the 1960s.

While the I&J Waterway has been platted on DNR harbor maps since at least 1891, the first recorded dredging of the waterway was performed in 1947 when the Navy dredged a channel to a depth of 15 feet below MLLW to provide access to a Naval Reserve facility. The current federal channel of the I&J Waterway was not authorized until 1965. That channel was initially dredged in 1966. According to the Corps of Engineers dredging history records, neither the waterway nor the berth areas were dredged between 1966 and the first maintenance dredge in 1992.

Landfill Operation & Closure

The Roeder Avenue Landfill was constructed in 1965 to serve as a municipal landfill for the City of Bellingham. The Landfill was placed on tidelands located between the C-Street and Hilton Avenue infill development areas.

Permitting and Operation

In 1965 G.P. was the primary owner of the lands to be filled. The City and G.P. signed an agreement granting the City permission to conduct the fill. G.P. retained the right under the agreement to use the Landfill for G.P. wastes during its operation. The Landfill also involved Port-owned properties along Hilton Avenue which were provided for use under a lease agreement between the Port and the City's contractor, Sanitary Services.

Properties currently owned by Puget Sound Energy and Sanitary Services, as well as portions of F-Street and G-Street were also filled. The properties within the Colony Wharf and Chevron sites were not.

As a condition of the Army Corps of Engineers permit under which the Landfill was constructed, a berm was constructed across the gap between the C-Street and Hilton Avenue areas. The berm was used to contain the refuse during Landfill operation. The tideflat area enclosed by the berm was subsequently filled with municipal solid wastes and GP wastes between 1965 and 1974.

The original height of the fill was to be terminated at 15 feet above mean lower low water (MLLW). However, the facility was filled earlier than had been anticipated by the City. In response, the City obtained permission from GP to raise the permitted final height to 22 feet above MLLW. GP granted this request, and additional fill was placed in the facility.

The Landfill operation contract required placement of 2 feet of soil cover over the refuse upon Landfill closure. The final height at which municipal refuse was placed was 20 feet above MLLW in most of the Landfill, with soil cover being applied between elevations 20 and 22 feet above MLLW.

During Pre-Design Testing conducted in 1997, RETEC confirmed that municipal wastes are largely restricted to elevations below 20 feet above MLLW. The soils between elevations of 22 and 29 feet in the northern portion of the Landfill were determined to contain additional materials placed on the Landfill by G.P. subsequent to the Landfill closure.

Waste Volumes

During the Warehouse Feasibility Analysis, the total volumes of waste within the Landfill were estimated by RETEC to be between 340,000 and 470,000 cubic yards. Based on available information, approximately half of this volume consisted of municipal solid wastes. The balance consisted of wood waste from the G.P. mill operations. During its 1987 site investigation, the EPA noted that no hazardous materials from the G.P. mill operations had been reportedly disposed of in the Landfill.

After termination of Landfill activities, the Landfill area was used by GP for log storage. Between 1974 and 1996, GP placed additional materials on top of the Landfill. These materials included dredged sediments from the GP lagoon construction area, log yard soils and wood waste, soil fill from the Chestnut Street construction project, and other materials including spent limestone. The total volume of these non-refuse materials was estimated by RETEC during the Warehouse Pre-Design Testing (RETEC, 1997) to be 90,000 cubic yards. The Chestnut Street soils were estimated by RETEC to account for 20,000 cubic yards of this total. Army Corps permit records from construction of the GP biotreatment lagoon indicated that the volume of dredged sediments from the lagoon area which was placed on the Landfill was 35,000 cubic yards.

Leachate Seepage

The construction of the GP Lagoon was initiated in 1978 immediately offshore of the Laurel street dike. Construction of the GP Lagoon required that a stormwater outfall previously located along the F-Street alignment be rerouted. GP notified the City of this need during the Environmental Impact Statement process for the basin. After obtaining permission from the City, GP proceeded to weld shut the tidal gate at the end of the outfall. GP notified the City in October of 1978 that this had been completed.

Shortly thereafter, leachate from the Landfill seeped out of the slope of the Landfill and onto Port properties along Hilton Avenue. This occurred on the properties of the Olivine site. Port and Ecology correspondence from June and September of 1980 indicate that the leachate discharged to stormwater lines that ultimately drained to the I&J waterway.

In 1980, EPA received an anonymous complaint about the discharge of "black odorous" water to the waterway. EPA inspected the site and sampled the leachate. EPA inspection notes reported the volume to be 5 gallons per minute. The results of the leachate sampling were summarized in the Warehouse Feasibility Study (RETEC, 1996). The data indicated elevated levels of chromium and some other metals.

The City subsequently conducted utility improvements in the F-street area to correct the leachate discharge problem. These improvements included rerouting of area stormwater drains, and plugging of a storm drain that formerly discharged into the Landfill area. There have been no reports since these corrections of leachate discharge from the Landfill to surface waters.

Other than for storage of logs and limestone by G.P., the majority of the Landfill area received little use between1980 and the mid 1990s. The portions owned by Sanitary Services have been developed for operation of a solid waste transfer station and truck shop. The Puget Sound Energy property was developed in the 1970s for the operation of an electrical substation.

In 1994 the Port, the City and G.P. began evaluating the potential for redevelopment of the Central Waterfront Area including the Landfill. This process led to the initiation of the Warehouse Feasibility Analysis which was conducted under an EPA Brownfields Pilot as described below in Section 2.3. That process culminated in the construction of the GP Warehouse shown in Figure 2-1.

History of Adjacent Properties

The history of adjacent properties was evaluated using previous environmental reports and historical resources including Sanborn fire insurance maps, historical Port maps and files, old newspaper clippings and other resources.

Olivine Site

The Olivine site was originally used for operation of a lumber mill. Earliest activities at the site included construction of a saw mill on the site. The mill operated between 1892 and the early 1900s as the Lottie saw mill. By 1904, as recorded in Sanborn Maps, the mill was operated as the Whatcom Falls Mill Company which manufactured shingles and planed lumber. No petroleum product use has been defined for the early mill operations. Wood refuse was used as fuel according to the Sanborn maps. The mill was constructed on pilings over the tideflats.

Later aerial photographs show continued operation of the Whatcom Falls Mill Company after soil fills were constructed along Hilton Avenue.. The Whatcom Falls mill Company terminated operations by 1944, based on a Sanborn map of that date. The Port of Bellingham purchased the properties along Hilton Avenue in 1944 from SeaFirst Bank. The Olivine site properties were included in that acquisition.

Between the 1940s and the 1980s, the U.S. Naval Reserve operated a training facility in between the Olivine site and Roeder Avenue. A separate lumber mill operated at the head of the I&J Waterway between 1950 and the early 1960s. This mill was operated by Bayshore Lumber and then by H&H Products under separate leases from the Port of Bellingham.

In 1963, the Olivine Corporation initially leased a portion of the site. The main activity conducted by Olivine Corporation was the manufacturing of foundry sands and refractory materials for incinerators. Ores were imported to the site by truck and by barge. Olivine ore consists of a complex of silica, magnesium and iron. The manufacturing process conducted at the site consisted of crushing and grinding the ores into various grades, drying them and packing them in large bags for shipment. The products were generally shipped by truck or rail.

The Olivine Corporation's lease was terminated in July of 1992. Buildings and equipment were removed from the site in 1993.

Environmental testing was performed at the Olivine site in 1994 (Landau, 1994) and 1995 (Harding Lawson, 1995) by the Coast Guard. The Coast Guard was considering lease of the site at that time from the Port. Groundwater testing performed at that time indicated low levels of barium, chromium, mercury and zinc in site groundwater. The water samples were described as turbid in the sampling report. Other contaminants, including petroleum, volatile organics, semivolatile organics and PCBs were not detected in groundwater.

An underground storage tank was removed from the Olivine site in 1998 by the Port of Bellingham (Pinner, 1998). Diesel contamination was detected in soils and in excavation pit water at that time. The tank installation date was not known, but it is believed to have been used as part of the Olivine Corporation operations at the site.

Ecology has added the Olivine site to the hazardous sites list and has given the site a MTCA priority ranking of 3 (on a scale of 1 to 5). The Port has initiated an RI/FS for the site, with technical assistance and oversight provided by Ecology under the Voluntary Cleanup Program. That RI/FS is scheduled for completion during 2001.

Colony Wharf Site

The Colony Wharf site is currently the location of both Colony Wharf and Bellingham Marine Industries (see Figure 2-1). The site has been used for a variety of industrial activities since the early 1900s. Historical land uses are described in a Phase 1 Environmental Assessment report prepared for the site (GeoEngineers, 1990). These reported uses included the following:

- sales of building products (coal, lime, cement, plaster, brick & tile)
- former steel casting company foundry operations
- truck garage
- manufacture of cement products
- boat repair and maintenance
- machine shops and welding
- fish and seafood distribution
- electrical equipment manufacturing, sales and repair

Subsequent to completion of the Phase 1 Assessment, sampling of soils and groundwater were performed (GeoEngineers, 1992a, GeoEngineers, 1992b). That sampling detected elevated concentrations of petroleum, benzene, cyanide, chromium and other contaminants in site groundwater. The sources of petroleum and benzene were assumed to be associated with former underground storage tanks located at the site, and possibly with contamination from the adjacent Chevron site. Elevated concentrations of chromium and cyanide were attributed by GeoEngineers to the adjacent Roeder Avenue Landfill.

No cleanup actions other than UST removals have been performed at the Colony wharf site to date. The site has been added to Ecology's Hazardous Sites List and has been given a priority ranking of 4.

Chevron Site

The Chevron Site was operated as a bulk petroleum terminal from 1913 through 1987 (AGI, 1993). Petroleum was received from tankers or barges at docks along the Whatcom Waterway or by rail car. The products were stored on site in above-ground storage tanks and were then distributed by rail or truck, or were used to fuel ships. The facility was originally owned by Standard Oil. The facility became the Chevron terminal after the separation of Chevron from the other Standard Oil companies.

Two tank farms were located on site, one on either side of C-street. The tank farm on the Whatcom Waterway side was the oldest of the two. A warehouse building was constructed for storage and shipment of drummed products.

Rail car loading facilities were located along the southeast side of the warehouse. The rail spur on which these facilities were located has been removed. Two truck-loading racks were located northeast of the warehouse, and a third was located across C-street, northeast of the second tank farm.

Operation of the Chevron terminal ceased in 1987. The tank farm was subsequently demolished and most above-ground structures were removed. The first environmental investigations at the site were initiated in 1986 after a 4,800 gallon diesel fuel spill in the northeast tank farm. Subsequent investigations indicated the presence of soil and groundwater contamination beneath the facility, including within the other tank farm area.

Chevron has conducted several remediation activities at the site as part of an independent remedial action under MTCA. Activities conducted to date include the excavation and on-site biotreatment of soils from the old tank farm, the removal of all of the storage tanks and some of the underground and above-ground piping, the recovery of free-phase hydrocarbons and the evaluation of treatment alternatives for residual soil and groundwater contamination.

A wooden bulkhead used to contain soils along the Whatcom Waterway is in a state of poor disrepair (see Figure 2-2). Portions of the bulkhead have collapsed. Absorbent booms have been used to control seepage of petroleum sheen from the shoreline into the Whatcom Waterway. Product thicknesses in the shoreline recovery wells have decreased over time and active product recovery efforts have been terminated except for occasional placement of absorbents in wells where sheen is noted. Residual product remains in the former northern tank farm.

2.3 Previous Landfill Investigations

The scope of this RI/FS builds on the information generated during previous environmental and geotechnical investigations at the Landfill and in the vicinity. Figure 2-2 shows the locations of test pits, soil borings and monitoring wells from these previous investigations.

The findings of previous investigations were reviewed with Ecology during the RI/FS Scoping and Work Plan development process. A synopsis of those prior activities is provided below.

Previous Environmental Studies

Prior to initiation of the Warehouse Feasibility Analysis, the Landfill had been evaluated by EPA, Ecology and the Whatcom County Department of Health.

EPA Site Investigation

The Landfill was reviewed by EPA for inclusion on the National Priority List for Superfund Cleanup. Ecology & Environment (EPA's contractor) concluded after a preliminary site inspection conducted in 1987 that there were no records indicating the disposal of hazardous materials at the site. Ecology and Environment recommended no further action at the site at that time under CERCLA.

Ecology Site Investigation and Ranking

The Department of Ecology conducted a preliminary site inspection in 1994 and 1995. That inspection included the installation of 4 groundwater monitoring wells along the Hilton-Avenue side of the Landfill. These wells were installed to a depth of 17 feet below ground surface, within the shallow sand zone adjacent to the Landfill.

The groundwater data collected by Ecology were summarized in a sampling report (Ecology, 1996). The groundwater data indicated the presence of low levels of heavy metals including chromium. After completing the groundwater sampling effort, Ecology performed a hazard ranking for the Landfill. The site was ranked as a "5," indicating a need for further investigation and cleanup actions, but with a low priority ranking relative to other MTCA sites.

Department of Health Site Survey

Ecology forwarded their groundwater sampling data to the Whatcom County Department of Health. The Health Department performed an independent evaluation of the Landfill at that time. The Department concluded in their 1996 report the following: "Although this site has the potential to impact public health, it is not of immediate concern because of the lack of a current completed exposure pathway. Should further environmental data indicate that human health is, or soon will be impacted, and/or if there is increased community concern, a more in-depth assessment may be conducted." No additional evaluations have been performed for the Landfill by the Department of Health since that time.

Warehouse Feasibility Study and Pre-Design Testing

In 1996, the Port of Bellingham was awarded a Brownfields grant from the EPA. The grant was used for a Pilot Project to evaluate the potential for cleanup and redevelopment of the Central Waterfront Area, including the Landfill. The Warehouse Feasibility Analysis (RETEC, 1996) and Pre-Design Testing Report (RETEC, 1997) were performed under this grant.

During the Warehouse Feasibility Analysis, a summary of available environmental and geotechnical data was compiled. These data were used to develop conceptual design recommendations for construction of buildings and infrastructure on the Landfill. An analysis of economic factors was also performed. The conclusion of the study was that a properly designed development action could be performed safely and economically on the Landfill. Furthermore, such development could be integrated with the Landfill cleanup actions to maximize the efficiency of environmental cleanup.

Pre-Design Testing was performed during 1997 to fill critical design gaps for the design and construction of the warehouse project. Testing included the following elements:

- Geotechnical investigations at multiple locations within the Landfill to evaluate deep soil properties and determine foundation requirements for the warehouse

- Test pit investigations to verify the boundaries of the Landfill refuse and assess the characteristics of the soil cover

- Installation and monitoring of four gas probes within the Landfill refuse to assess the characteristics and quantity of gasses generated in the Landfill. These gas probes were completed as dual purpose monitoring wells so that they could also be used to monitor groundwater quality.

- Use of temporary piezometers to evaluate the depth to groundwater within the Landfill for use in design of Landfill cap and building foundations. A preliminary piezometric map and evaluation of tidal influences within the Landfill refuse layer was also performed.

The results of Pre-Design testing generally confirmed the assumptions made during the Warehouse Feasibility Analysis. However, changes were made to the recommended foundation piling lengths and to the site grading and capping assumptions. The gas probes installed during Pre-Design Testing were later used during development of the RI/FS Work Plan to assess Landfill groundwater quality as described in Section 2.4 below.

Additional design studies were performed by GP during 1998 and 1999 prior to their construction of the Warehouse. These studies were summarized in a Golder Associates report (Golder, 1999). The final design for the Warehouse project included the construction of a passive venting system beneath the Warehouse building, management of precipitation runoff generated from the building roof and paved surfaces, and detailed recommendations regarding foundation piles and other geotechnical considerations. GP provided copies of the design report and related information to Ecology and obtained technical review and assistance from Ecology under the VCP.

2.4 Work Plan Sampling and Area-Wide Data Review

As part of the Work Plan development process, available groundwater contaminant data from previous investigations were compiled and were reviewed by RETEC. The data included groundwater contaminant concentrations as reported in the following investigations:

- Olivine Site Investigations (Harding Lawson, 1995)
- Ecology sampling of wells along Hilton Avenue (Ecology, 1996)
- Groundwater Sampling at the Colony Wharf property (GeoEngineers 1992a and 1992b)
- Groundwater sampling at the Chevron Site (AGRA, 1993, Pacific Environmental Group, 1998)

In addition, groundwater samples were collected by RETEC during July of 1998 from the four landfill gas probes installed during Warehouse Project Pre-Design Testing. Those groundwater samples were analyzed for a broad range of constituents including volatile organics, heavy metals, cyanide, semivolatile organics and petroleum hydrocarbons. The Landfill groundwater data were then reviewed in conjunction with the groundwater data from previous investigations. This review was conducted within the context of MTCA cleanup levels and other applicable relevant and appropriate requirements (ARARs) that could ultimately drive cleanup decisions at the site.

The data were used to develop, in coordination with Ecology, the groundwater investigation program for use during the RI/FS. The final groundwater monitoring program is described in Section 3 and the results of groundwater testing are defined in Section 4. The following paragraphs revisit the regulatory factors evaluated and the findings of the data review on which the RI/FS sampling program was developed.

Analysis of Potentially Applicable Cleanup Standards

At most upland MTCA sites, groundwater cleanup levels are established using Method A, B or C cleanup levels. These values are based on the assumption that groundwater at the site constitutes a current or potential future source of drinking water. However, at the Roeder Avenue Landfill site and within the Central Waterfront Area as a whole, the groundwater does not constitute a source of drinking water as defined under MTCA. The main factor on which this conclusion is based is that the presence of the Landfill effectively prohibits use of the groundwater for drinking water production, now or in the future. Under Washington's water supply regulations (WAC 173-160-205) groundwater supply wells may not be installed within 1,000 feet of a sanitary Landfill. All portions of the Central Waterfront Area are within 1,000 feet of the Roeder Avenue Landfill, effectively prohibiting by law the use of the groundwater as a drinking water source.

Under MTCA, cleanup levels for groundwater must be protective of other media. Based on work conducted at the Chevron, Colony Wharf and Olivine sites, as well as information collected during Warehouse Pre-Design testing and this RI/FS, groundwater in the vicinity of the Landfill has been shown to discharge to surface waters of Bellingham Bay. As a result, the cleanup levels derived for the Roeder Avenue Landfill must be sufficiently protective to prevent degradation of surface water quality in the Bay. The location at which surface water cleanup levels must be met under MTCA requirements is defined as the "point-of-exposure".

The point-of-exposure for the Landfill area is where groundwater from the Landfill discharges into the sediment bioactive zone beneath Bellingham Bay. Because MTCA does not permit the use of a mixing zone *within* the surface water in evaluating compliance with surface water cleanup levels (WAC 173-340-730(6)), surface water cleanup levels must be met by the groundwater discharging into the base of the sediment bioactive zone. Previous studies (Hart Crowser, 1997) have demonstrated that the bioactive zone consists of the top 12 centimeters of marine sediments. The point-of-exposure is therefore specifically the groundwater discharging into the base of the 12-centimeter bioactive zone of marine sediments beneath Bellingham Bay.

Cleanup levels applicable to groundwater discharging at the point-of-exposure include ambient water quality criteria (AWQC as promulgated in WAC 173-201A-040 and 40 CFR 131.36) as well as MTCA Method B surface water criteria (WAC 173-340-730). These criteria were tabulated in the Work Plan, and are included in this RI/FS in Table 4-6 and in the groundwater data tables in Appendix B. Criteria were developed from each of the following:

- Washington State surface water criteria for the protection of aquatic life as established in WAC 173-201A-040 (chronic exposure to marine organisms)

- Federal Ambient Water Quality Criteria (AWQC) for continuous exposure to salt water organisms (40 CFR 131.36 - 7-1-97 Edition)
- Model Toxics Control Act (MTCA) Method B Criteria for surface water exposure
- Federal AWQC for protection of human health through consumption of organisms only (40 CFR 131.36 - 7-1-97 Edition)

Data evaluations conducted during the Work Plan development process and as part of the RI/FS have used the most stringent of these criteria. During the Work Plan development process, the MTCA Method A groundwater cleanup level was used in the analysis of groundwater data and applicable regulations. At the initiation of the RI/FS, section WAC 173-340-720(2) of the MTCA regulations defined the Method A groundwater cleanup standard as 1.0 mg/L for all petroleum fractions. Subsequent amendments to the MTCA regulations have modified the Method A cleanup levels for petroleum (WAC 173-340-900; Table 720-1). For diesel-range organics, the only petroleum mixture detected in landfill groundwater samples, the amended regulations stipulate a Method A cleanup level of 0.5 mg/L. After review of available aquatic toxicity data for diesel-range petroleum hydrocarbons, the amended Method A value for diesel-range hydrocarbons has been adopted for use during the RI/FS.

Federal and state water quality criteria have not yet identified ambient water quality criteria for petroleum mixtures. A total oil and grease concentration of 10 mg/L has been used for many years in the regulation of point-source surface water discharges. However, this criterion may not be protective for all petroleum hydrocarbon mixtures. Recent literature surveys (Markarian, 1994) for the toxicity of diesel fuel oils to invertebrates, fish and algae have identified median concentration criteria of 2.35 to 4.3 mg/L. Recent studies have focused on additional exposure scenarios and have yielded lower toxicity thresholds in some instances. A number of recent studies (Carls, 1999; Carls, 2000; Heintz, 1999) have documented lower toxicity thresholds for fish eggs or embryos than to adult fish. These studies have yielded total PAH toxicity values (EC50s) of 18 to 34 ug/L in tests with weathered crude oils. Assuming that the PAH constituents are responsible for the toxic effects (this is subject to debate -- see Neff et al, 2000), and based on a 5 percent typical PAH composition in diesel fuels (Millner and Nye, 1992) and similar TPAH/TPH ratios observed during the RI/FS (see data tables in Appendix B), these values suggest that TPH concentrations of between 0.36 to 0.68 mg/L would be protective for these exposure scenarios. Other experimenters (Little et al, 2000) have focused on toxicity of petroleum-associated PAH in the presence of ultraviolet light and have detected toxicity of diesel-range petroleum at concentrations between 0.51 and 2.84 mg/L. Finally, other researchers (Croce and Stagg, 1997) have detected additive sublethal toxicity of petroleum and other compounds for TPH concentrations of 2 mg/L. After review of available toxicological data, a site-specific screening level of 0.5 mg/L has been adopted for use during the RI/FS. A higher cleanup level is likely appropriate, but would be subject to additional verification testing. The site-specific screening level of 0.5 mg/L will be used as a cleanup level for groundwater discharging to the point-of-exposure unless other site-specific data are collected to demonstrate the protectiveness of a higher value. The 0.5 mg/L screening level is consistent with the MTCA Method A groundwater cleanup level, and ensures that aesthetic characteristics of surface waters are not adversely impacted (required under WAC 173-201A).

MTCA provides for comparison of cleanup levels to natural background levels. In the amended MTCA regulations (Ecology, February 2001) natural background levels are discussed in WAC 173-340-720(7)(c). That section states that cleanup levels shall not be set below the natural background concentrations. In cases where metals criteria specified above are lower than natural background concentrations of metals in sea water, ARARs were established at a concentration equal to the natural background concentration. Natural background concentrations for several inorganic parameters in uncontaminated seawater were obtained from Davis (1977). For arsenic, natural background concentrations of 0.005 to .015 mg/L are common in western Washington groundwater. The MTCA Method A cleanup level for arsenic (0.005 mg/L -- based on natural background concentrations) was adopted for use during the RI/FS).

Two additional regulatory considerations applicable to the protection of surface water quality have been incorporated into the scope of the RI/FS. The first is the prevention of sediment contamination as a result of groundwater contaminant discharges. The analysis of sediment source control issues requires quantitative groundwater analysis and was incorporated into the contaminant fate and transport analyses conducted during the RI/FS (Section 7). The second additional regulatory consideration is the establishment of a groundwater point of compliance. Point of compliance issues applicable to sites such as the Landfill that are near but not abutting surface water are specifically defined in the amended MTCA regulations under WAC 173-340-730(8)(d)(ii). Point of compliance issues are discussed further in Sections 6 and 7 of this document.

Findings of Landfill Well Sampling Data

During Pre-Design Testing for the Roeder Avenue Warehouse project, four monitoring wells were installed within the refuse layer of the Landfill. In July of 1998, these wells were sampled for a broad suite of contaminants and geochemical parameters.

The results of contaminant analyses for the refuse wells were compared to potentially applicable surface water cleanup levels as described above. Table 2-3 summarizes the maximum detected concentrations of contaminants from the Landfill wells. For each of these contaminants, the range of concentrations detected in the Landfill refuse is shown, along with the range of concentrations demonstrated at the adjacent Olivine, Colony Wharf and Chevron properties.

- Arsenic, lead, mercury, copper, nickel and cyanide were detected at concentrations between two and six times the applicable reference values for surface water.

- Total chromium concentrations ranged up to 10.1 mg/L in the Landfill wells. Applicable surface water cleanup levels are 0.05 mg/L for Cr^{+6} and 162 mg/L for Cr^{+3}. Landfill well testing confirmed that the chromium was present as the less-toxic Cr^{+3}. No exceedences of the Cr^{+3} cleanup levels were noted. Concentrations of chromium have been shown to be elevated within the Landfill refuse and in several immediately adjacent locations on the Colony Wharf and Olivine parcels (Figure 2-3). Chromium was retained as a contaminant of concern for the RI/FS, and extensive chromium speciation data were collected during the RI/FS for both the off-Landfill and Landfill areas.

- Diesel-range petroleum was detected in some of the wells at a concentration in excess of the MTCA Method A cleanup levels. Diesel hydrocarbons were detected both within the Landfill and at the adjacent Colony Wharf and Chevron properties. Diesel concentration data were not available for the Olivine property at the time of Work Plan preparation. Relative to the concentrations measured at the Chevron (25 mg/L) and Colony Wharf properties (8 mg/L), the diesel concentrations measured in the Landfill wells (non-detect to 2.4 mg/L) were relatively low. Diesel was retained as a contaminant of concern for the Landfill, with the recognition that additional off-Landfill sources of petroleum contamination exist at the Colony-Wharf and Chevron sites.

- No semivolatile organics were detected above the reference values other than bis(2-ethylhexyl)phthalate. This compound was detected above the reference values in one of the four samples. After discussion with Ecology, semivolatile organics testing was incorporated into the RI/FS sampling and analysis program.

- No volatile organic compounds were detected above the surface water criteria. However, Ecology requested that some sampling be performed for these compounds as part of the RI/FS testing. That sampling was performed as described in Section 3.

Analysis of Groundwater Data from Other Sites

The data review identified several contaminants that had been detected previously on adjacent properties, but that were either not detected in the Landfill wells or were detected at much lower concentrations. These other contaminants included benzene, barium, zinc, gasoline hydrocarbons and N-Nitroso-Di-N-Propylamine.

Gasoline hydrocarbons were not detected in the Landfill wells. In contrast, at the Colony Wharf and Chevron properties gasoline concentrations of over 10 mg/L have been measured. Elevated benzene concentrations were also noted at the Colony Wharf and Chevron sites. The gasoline and benzene concentrations are attributable to past hydrocarbon releases at these two properties.

N-Nitroso-Di-N-Propylamine were also elevated at the Colony Wharf site. The potential source of N-Nitroso-Di-N-Propylamine, which was detected just above the method detection limit, was not defined in the Colony Wharf site documents.

At the Olivine property, two metals were detected above surface water cleanup levels, including barium and zinc. Because barium concentrations were not tested in the Landfill wells, barium testing was included in initial sampling for the RI/FS, to verify that the barium concentrations were not derived from the Landfill refuse. Zinc was included in the RI/FS testing program.

Geochemical Parameters

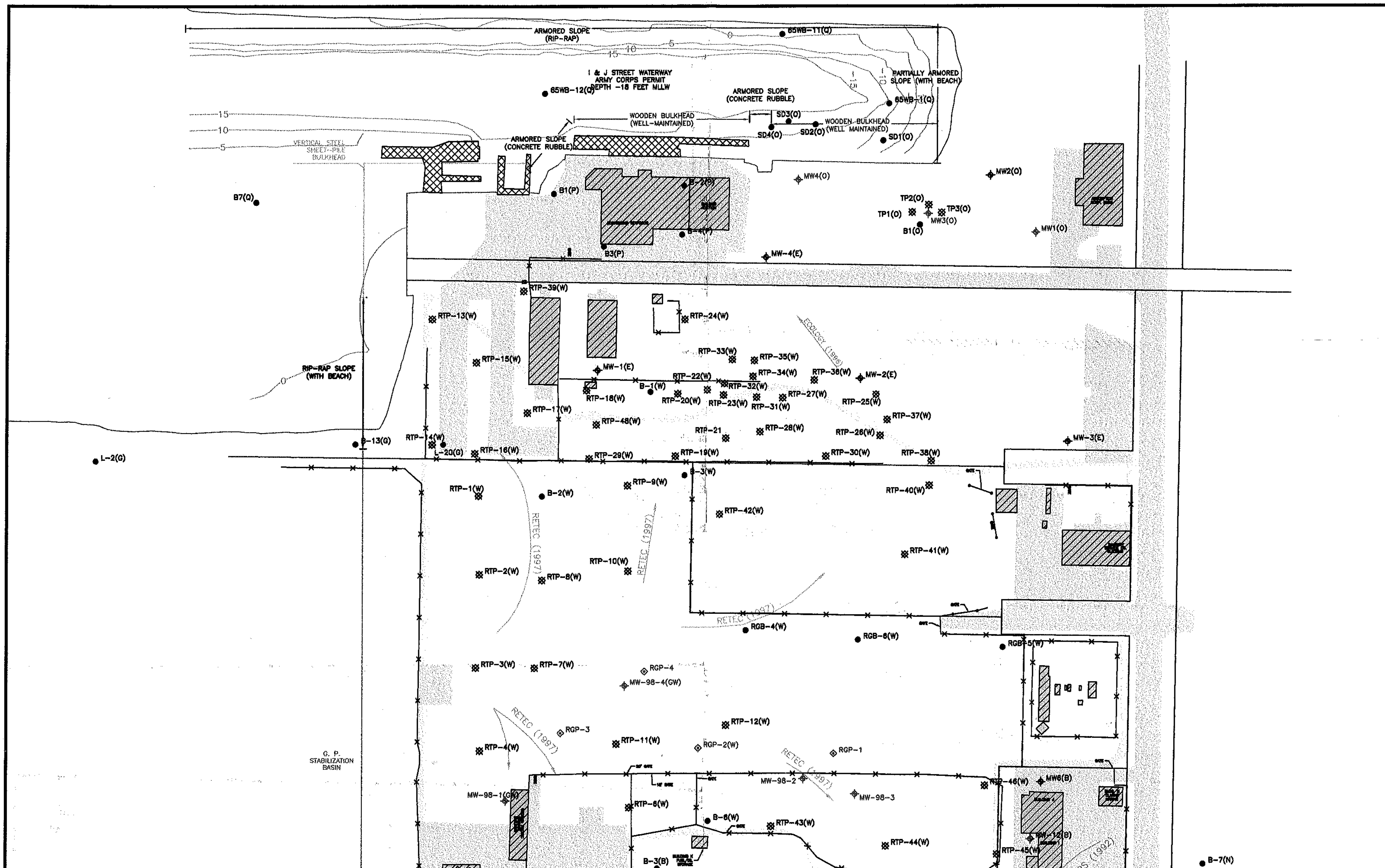
The availability and quality of geochemical monitoring data for the Landfill area was extremely limited prior to initiation of the RI/FS. For the most part, the previously available data were limited to testing for groundwater pH and electrical conductivity.

Limited geochemical monitoring data were collected as part of the Landfill well sampling conducted by RETEC during development of the project Work Plan. The results of that testing indicated the presence of reducing conditions, with low redox potential and the presence of elevated levels of dissolved manganese and iron. Additional geochemical testing was performed as part of the Landfill RI/FS.

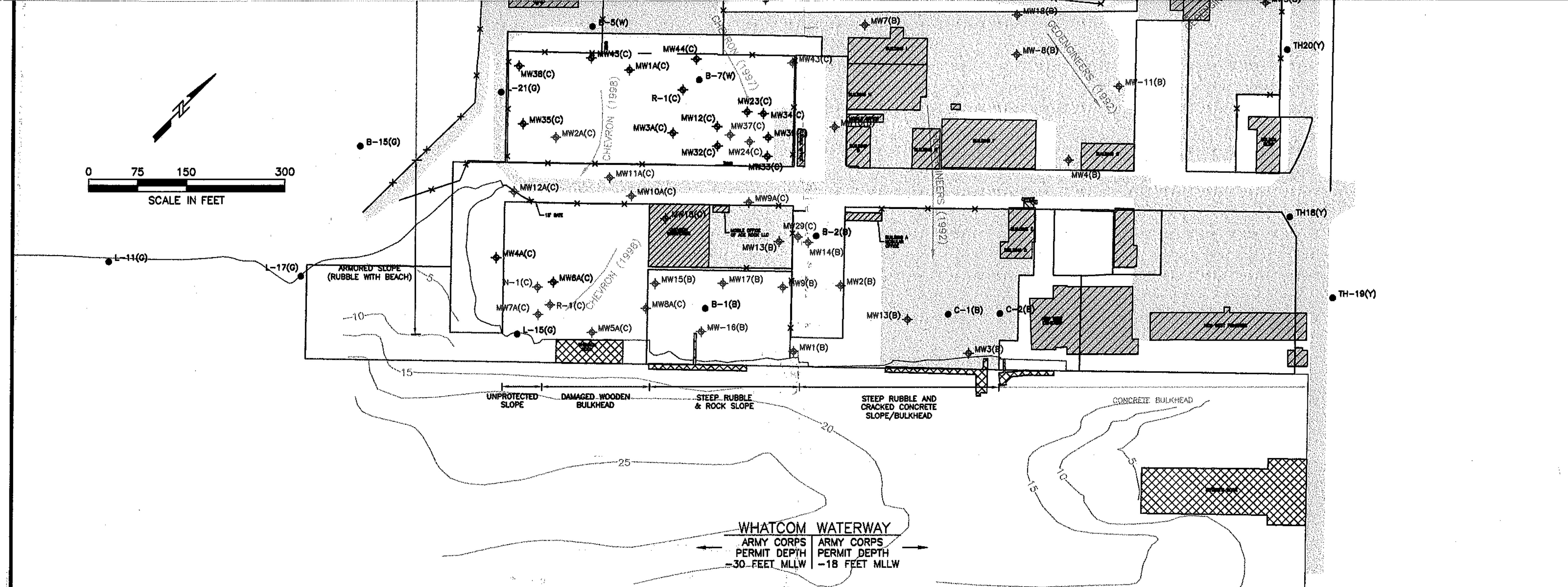
Landfill Gas

Previous testing data for landfill gas (predominantly methane) was available from work conducted as part of the Warehouse project. Pre-Design Testing performed in 1997 included testing of the four gas probes installed by RETEC. Gas sampling indicated the presence of significant gas production in one of the four wells, but little or no gas production in the other wells.

During subsequent design activities G.P.'s consultant, Golder & Associates, conducted additional methane tests within the Landfill. These results confirmed the presence of methane in the Landfill area. Golder used the sampling results in the design of the final gas collection and venting system for the Warehouse building.



ARMORED SLOPE (RIP-RAP)
65WB-11(Q)
I & J STREET WATERWAY ARMY CORPS PERMIT DEPTH -18 FEET MLLW
65WB-12(Q)
ARMORED SLOPE (CONCRETE RUBBLE)
PARTIALLY ARMORED SLOPE (WITH BEACH)
65WB-1(Q)
WOODEN BULKHEAD (WELL-MAINTAINED)
SD3(O)
SD4(O)
SD2(O)
WOODEN BULKHEAD (WELL MAINTAINED)
SD1(O)
VERTICAL STEEL SHEET-PILE BULKHEAD
ARMORED SLOPE (CONCRETE RUBBLE)
B7(Q)
B1(P)
B-2(P)
B3(P)
MW4(O)
MW2(O)
TP2(O)
TP1(O)
TP3(O)
MW3(O)
B1(O)
MW1(O)
MW-4(E)
RTP-39(W)
RTP-13(W)
RTP-24(W)
ECOLOGY (1996)
RTP-15(W)
RTP-33(W)
RTP-35(W)
RIP-RAP SLOPE (WITH BEACH)
MW-1(E)
RTP-22(W)
RTP-34(W)
RTP-36(W)
MW-2(E)
B-1(W)
RTP-32(W)
RTP-18(W)
RTP-20(W)
RTP-23(W)
RTP-31(W)
RTP-27(W)
RTP-25(W)
RTP-17(W)
RTP-48(W)
RTP-37(W)
RTP-21
RTP-28(W)
RTP-26(W)
B-13(G)
RTP-14(W)
MW-3(E)
L-2(G)
L-20(G)
RTP-16(W)
RTP-29(W)
RTP-19(W)
RTP-30(W)
RTP-38(W)
B-3(W)
RTP-1(W)
B-2(W)
RTP-9(W)
RTP-40(W)
RTP-42(W)
RETEC (1997)
RTP-41(W)
RTP-10(W)
RTP-2(W)
RTP-8(W)
RETEC (1997)
RGB-4(W)
RGB-6(W)
RGB-5(W)
RTP-3(W)
RTP-7(W)
RGP-4
MW-98-4(GW)
RETEC (1997)
RGP-3
RTP-12(W)
RTP-11(W)
RGP-2(W)
RGP-1
RTP-4(W)
G. P. STABILIZATION BASIN
RETEC (1997)
MW-98-2
RTP-46(W)
MW6(B)
MW-98-1(GW)
MW-98-3
RTP-6(W)
B-6(W)
RTP-43(W)
MW-12(B)
RTP-44(W)
RTP-45(W)
B-3(B)
B-7(N)



KEY TO PREVIOUS INVESTIGATIONS

B	BELLINGHAM MARINE INDUSTRIES
C	CHEVRON
N	BURLINGTON NORTHERN
E	DEPT. OF ECOLOGY
G	GEORGIA PACIFIC
Y	CITY OF BELLINGHAM
O	OLIVINE (PORT)
Q	SQUALICUM (PORT)
S	BORNSTEIN (PORT)
W	ROEDER AVENUE WAREHOUSE FEASABILITY ANALYSIS AND PRE-DESIGN TESTING
GW	GEORGIA PACIFIC WAREHOUSE DESIGN INVESTIGATIONS

DOCKS OR PIERS

EXISTING BUILDINGS

PAVED AREAS

EXISTING SHORELINE

PROPERTY BOUNDARIES

LANDFILL BOUNDARY

RETEC (1997) — GROUNDWATER GRADIENTS REPORTED IN PREVIOUS INVESTIGATIONS

MW-2(B) — EXISTING WELLS

MW-1A(C) — LOCATIONS OF WELLS THAT WERE NOT USED DURING THE RI/FS OR OF WELLS WHICH HAVE BEEN ABANDONED

RGP-1 — TEST PITS FROM PREVIOUS INVESTIGATIONS

B-1(B) — SOIL BORINGS FROM PREVIOUS INVESTIGATIONS

25 — BATHYMETRY (FEET BELOW MLLW PER WHATCOM WATERWAY 1997 RI REPORT)

CONCRETE — CONCRETE OR STEEL SHEETPILE BULKHEAD

WOODEN — WOODEN BULKHEAD

UNPROTECTED — UNPROTECTED SLOPE OR DAMAGED WOODEN BULKHEAD

UNPROTECTED — ARMORED SLOPE WITHOUT BEACH

WITH BEACH — ARMORED SLOPE WITH BEACH

G.P. BASIN — G.P. STABILIZATION BASIN

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ROEDER AVENUE LANDFILL RI/FS

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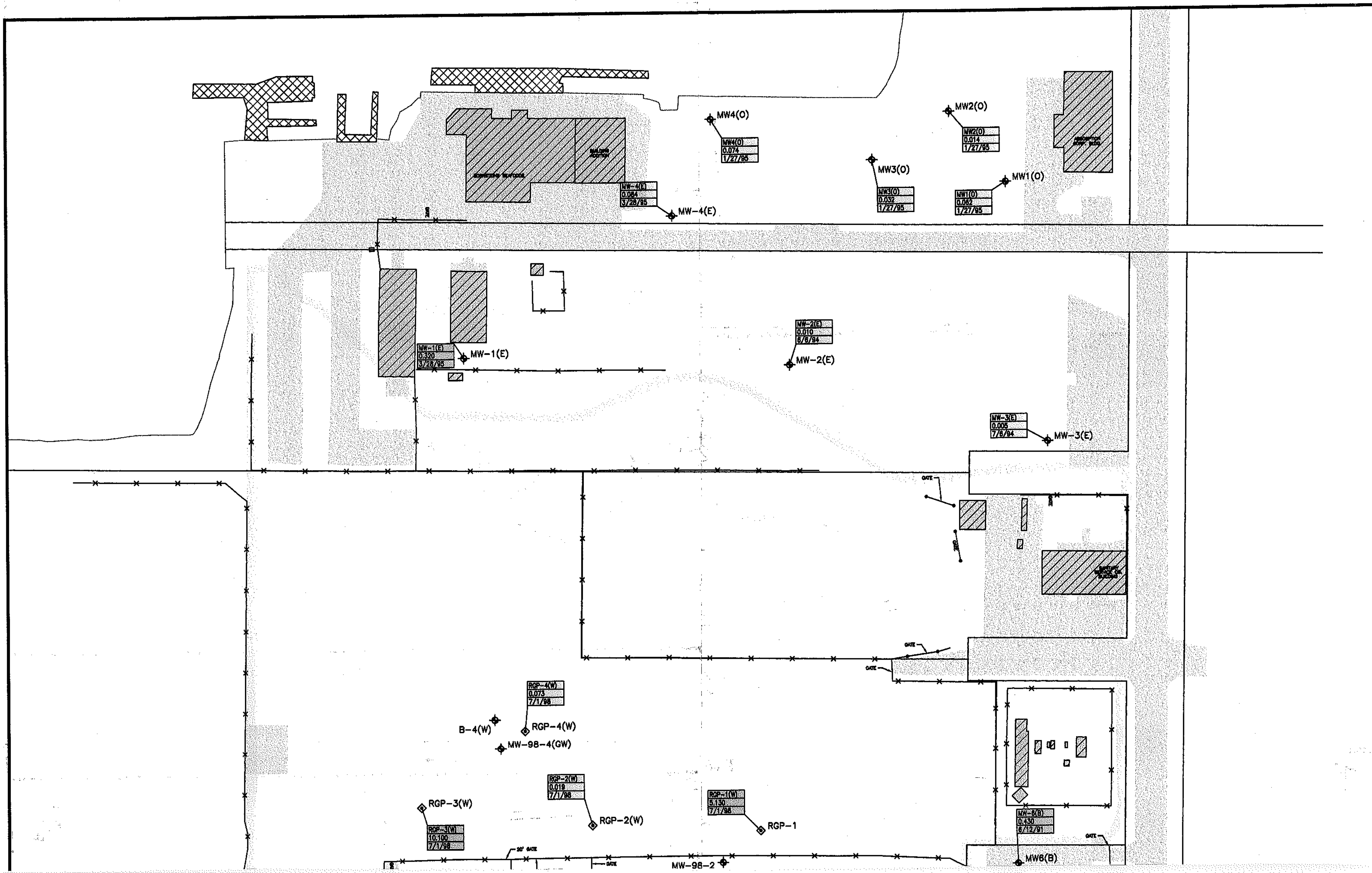
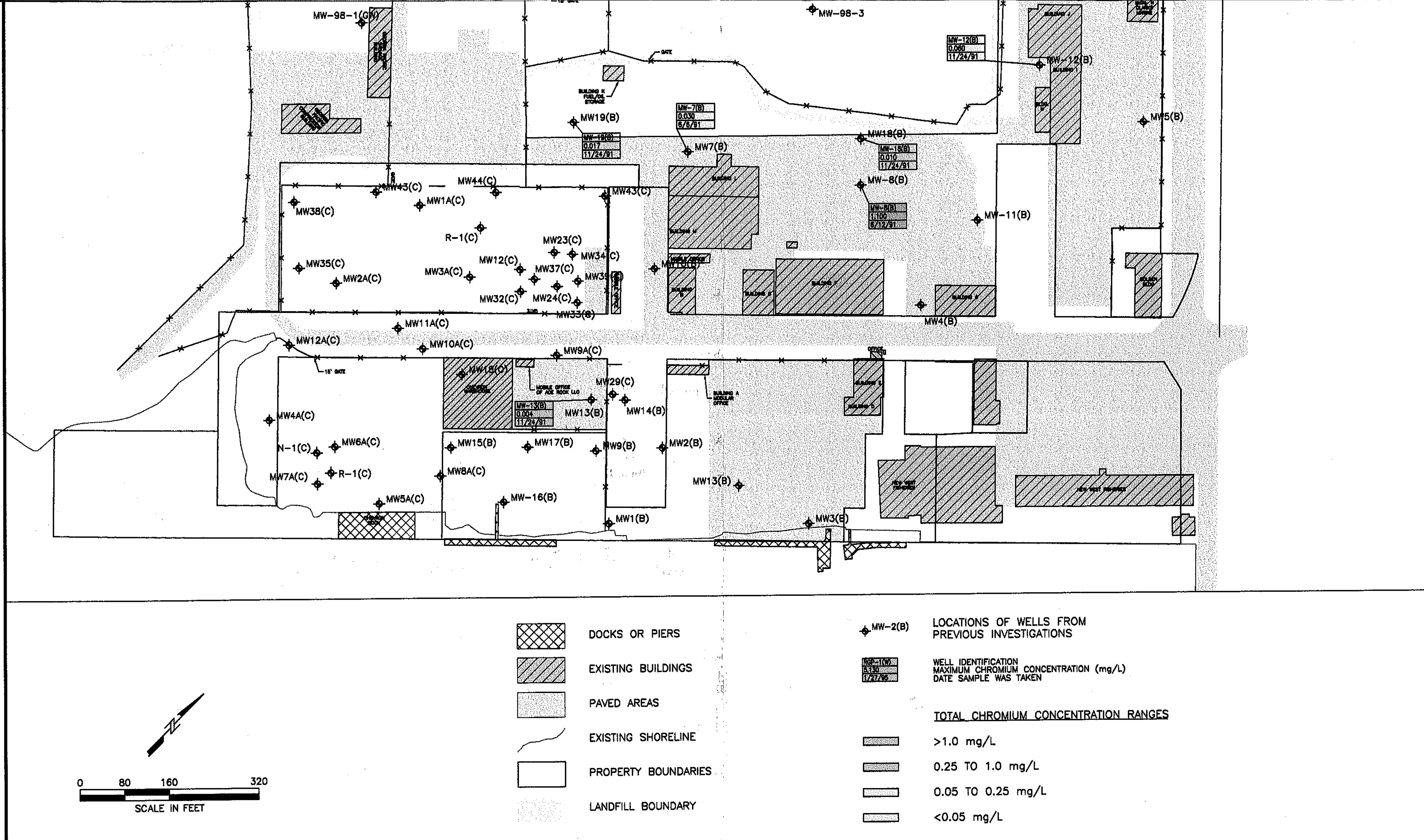
PREVIOUS INVESTIGATION DATA SHORELINE FEATURES AND AREA BATHYMETRY

FIGURE 2-2



MW4(O)
MW4(O)
0.074
1/27/95
MW2(O)
MW2(O)
0.014
1/27/95
MW3(O)
MW3(O)
0.032
1/27/95
MW1(O)
MW1(O)
0.062
1/27/95
MW-4(E)
0.064
3/28/95
MW-4(E)
MW-1(E)
0.320
3/28/95
MW-1(E)
MW-2(E)
0.010
6/6/94
MW-2(E)
MW-3(E)
0.005
7/6/94
MW-3(E)
GATE
GATE
GATE
GATE
GATE
RGP-4(W)
0.073
7/1/98
B-4(W)
RGP-4(W)
MW-98-4(GW)
RGP-2(W)
0.019
7/1/98
RGP-3(W)
RGP-2(W)
RGP-1(W)
5.130
7/1/98
RGP-1
RGP-3(W)
10.100
7/1/98
MW-6(B)
0.430
6/12/91
20' GATE
GATE
MW-98-2
MW6(B)



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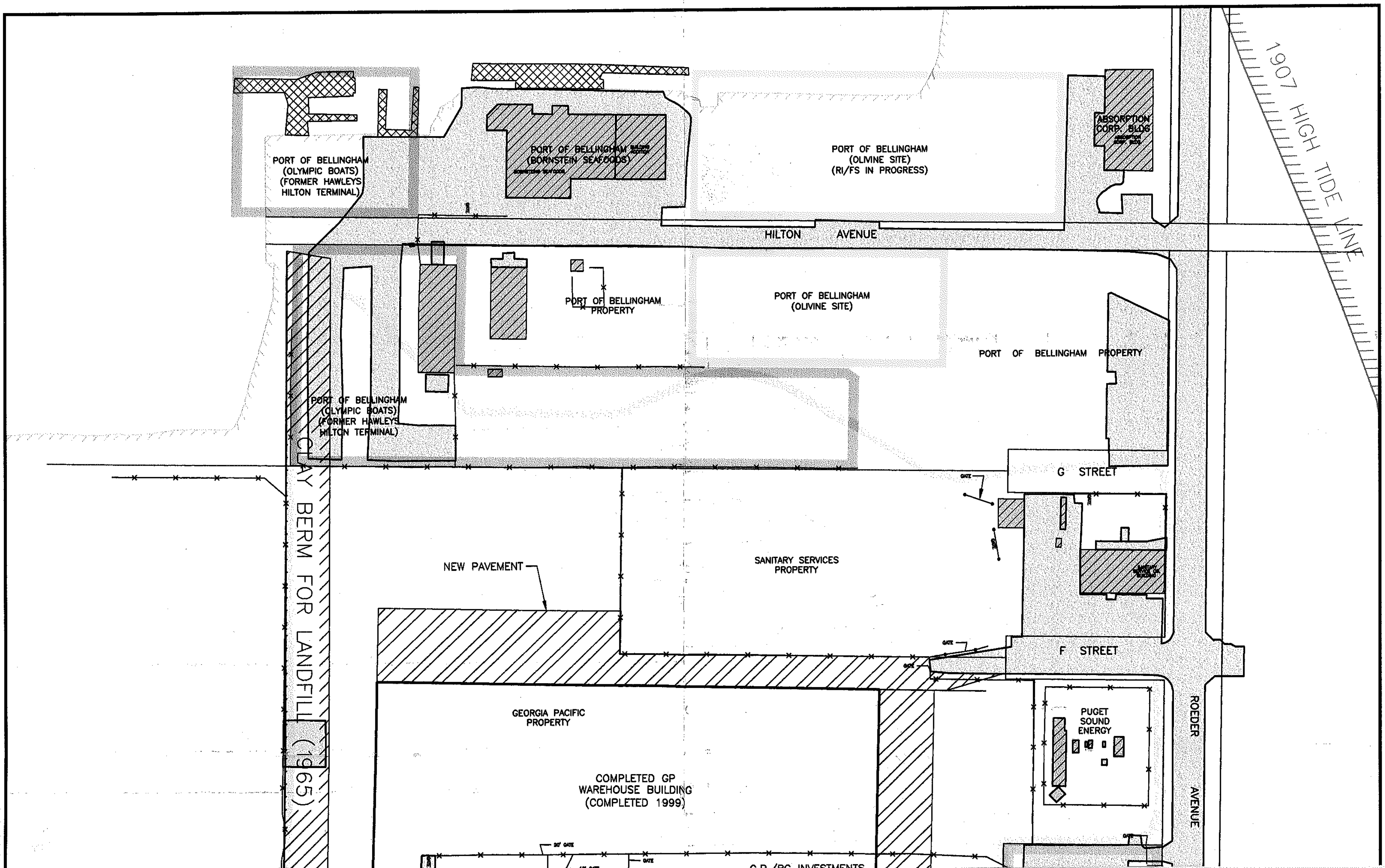
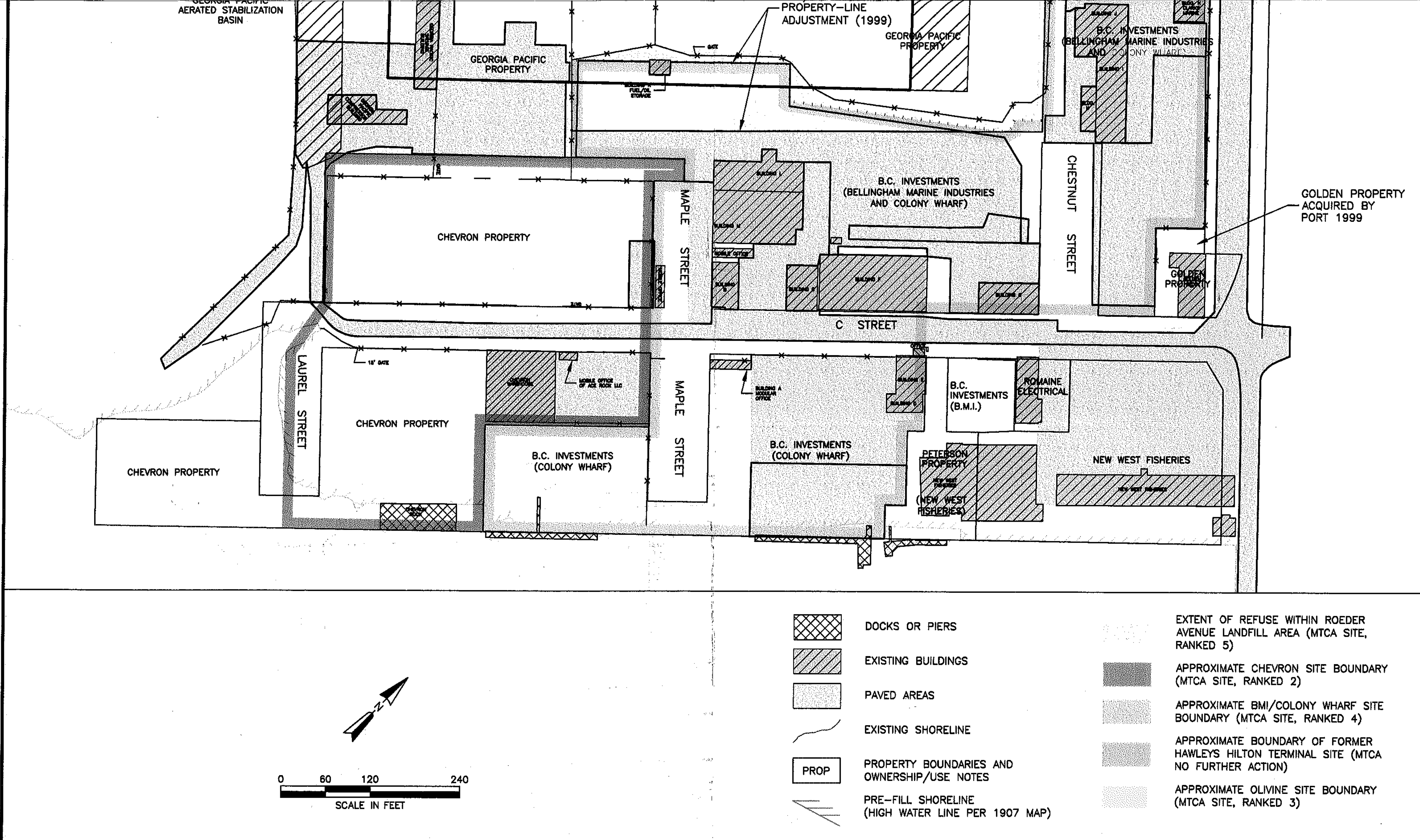
MAXIMUM REPORTED CHROMIUM CONCENTRATIONS IN SITE WELLS FROM PREVIOUS INVESTIGATIONS

FIGURE 2-3



1907 HIGH TIDE LINE
PORT OF BELLINGHAM (OLYMPIC BOATS) (FORMER HAWLEYS HILTON TERMINAL)
PORT OF BELLINGHAM (BORNSTEIN SEAFOODS)
PORT OF BELLINGHAM (OLIVINE SITE) (RI/FS IN PROGRESS)
ABSORPTION CORP. BLDG
HILTON AVENUE
PORT OF BELLINGHAM PROPERTY
PORT OF BELLINGHAM (OLIVINE SITE)
PORT OF BELLINGHAM PROPERTY
PORT OF BELLINGHAM (OLYMPIC BOATS) (FORMER HAWLEYS HILTON TERMINAL)
CLAY BERM FOR LANDFILL (1965)
G STREET
NEW PAVEMENT
SANITARY SERVICES PROPERTY
F STREET
GEORGIA PACIFIC PROPERTY
PUGET SOUND ENERGY
COMPLETED GP WAREHOUSE BUILDING (COMPLETED 1999)
ROEDER AVENUE



ThermoRetec

ROEDER AVENUE LANDFILL RI/FS

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SUMMARY OF AREA LAND USE AND OWNERSHIP

FIGURE 2-1

Table 2-3. Comparison of Initial Landfill Well Data and Data with Prior Data from Adjacent Sites

Groundwater Contaminant	Surface Water Reference Values	Max. Detected Concentration: RETEC Sampling of Landfill Refuse Wells Total	RETEC Sampling of Landfill Refuse Wells Dissolved	Ecology Data for Wells Along Hilton Avenue Total	Ecology Data for Wells Along Hilton Avenue Dissolved	Harding Lawson Data for Olivine Site Wells Total	Harding Lawson Data for Olivine Site Wells Dissolved	GeoEngineers Data for Colony Wharf Wells Total	GeoEngineers Data for Colony Wharf Wells Dissolved	Available Data for Chevron Site Wells Total	Available Data for Chevron Site Wells Dissolved
HEAVY METALS											
Arsenic	0.005	**0.016**	**0.014**	nd	---	nd	---	0.046	---	---	---
Barium	0.03	---	---	---	---	0.33	---	---	---	---	---
Chromium	162	9.78	10.1	0.32	---	0.076	---	1.1	---	---	---
Hexavalent Chrome	0.05	< 0.1	< 0.1	---	---	---	---	---	---	---	---
Copper	0.003	**0.005**	**0.004**	**0.014**	---	---	---	0.02	---	---	---
Lead	0.0081	**0.046**	**0.022**	0.0019 P	---	nd	---	0.0067	---	nd	---
Mercury	0.00005	**0.0001**	**0.0001**	**0.00007**	---	**0.00068**	---	nd	---	---	---
Nickel	0.0082	**0.01**	**0.02**	**0.011**	---	---	---	0.0073	---	---	---
Zinc	0.081	0.064	0.027	0.035	---	0.21	---	0.05	---	---	---
CYANIDES											
Total Cyanide	0.0028	**0.007**	---	---	---	---	---	0.43	---	---	---
PETROLEUM HYDROCARBONS											
Gasoline Range Hydrocarbons	0.8	< 1.2	---	---	---	---	---	10	---	10.4	---
Diesel Range Hydrocarbons	0.5	**2.4**	---	---	---	nd **	---	8	---	25	---
Motor Oil	0.5	< 0.5	---	---	---	---	---	---	---	6.2	---
TPH by EPA 418.1	0.5	---	---	---	---	---	---	4.2	---	---	
VOLATILE ORGANICS											
Benzene	0.043	0.0081	---	nd	---	nd	---	1.4	---	0.02	---
SEMIVOLATILE ORGANICS											
bis(2-Ethylhexyl)phthalate	0.00356	**0.0078** B	**0.0018** B	**0.0042**	---	---	---	---	---	---	---
N-Nitroso-Di-N-Propylamine	0.000819	< 0.002	< 0.002	nd	---	nd	---	0.0028	---	---	---

Notes:

All concentration data are reported as mg/L.
Values which represent the highest concentrations reported for the Landfill area have been underlined.
Values in excess of the listed reference value have been bolded.
---: This parameter not analyzed.
nd: Contaminant not detected.
**: At the Olivine site, diesel had not been detected in groundwater in 1998. However, recent testing performed during the Olivine RI/FS documented low levels of diesel in groundwater.
B: Contaminant detected at similar concentrations in the method blank or trip blank.
P: Compound detected above detection limit but below the quantitation limit.

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

3 Remedial Investigation Methods

The scope and methods for the RI/FS were presented in the RI/FS Work Plan (RETEC, 1998). Adjustments to the sampling and analysis schedule were made in the First Progress Memorandum (ThermoRetec, 1999). This section provides a summary of those methods.

3.1 Remedial Investigation Objectives

The objectives of the RI/FS were defined in the RI/FS Work Plan. of remediation systems in the event that such containment is not being achieved. Specific data requirements to be assessed during the RI/FS process include the following:

- Installation and development of additional groundwater wells and piezometers
- Performance of hydrologic testing including aquifer slug tests, preliminary well gauging and a tidal study
- Quarterly gauging and analytical sampling of selected wells and piezometers
- Definition of the rate and patterns of groundwater movement from the Landfill toward the surface waters of Bellingham Bay
- Collection of the information necessary to quantify the extent of groundwater mixing and flow-based attenuation that occurs in between the Landfill and the shoreline point-of-exposure
- Assessment of relevant biological and geochemical factors affecting the mobility and/or toxicity of the Landfill contaminants in groundwater, as necessary for assessing site conditions and porentially-required remedial actions
- Definition of groundwater cleanup levels and optimum points of compliance for the Landfill site, including prevention of cross-media contamination risks (e.g., sediment recontamination)
- Measurement of Landfill gas distribution in areas adjacent to the Landfill as necessary to estimate the lateral extent of potential impacts

3.2 Well and Piezometer Installation

Twenty-two monitoring wells were installed during October and November 1998 in accordance with the Work Plan (RETEC, 1998). The newly installed monitoring wells were installed to provide data on geochemical parameters, groundwater flow patterns, the influence of tidal fluctuations on groundwater elevations and chemistry, and concentrations of contaminants of concern at the site. These data are used to further characterize the site and to provide input data for groundwater flow and contaminant transport modeling described in the Work Plan.

The newly installed monitor wells are located along four transects described in the Work Plan. The transects and monitoring well locations are shown on Figure 3-1. These transects are located in areas of the shortest distance between the refuse layer and Bellingham Bay (Transects A and B), or in areas where elevated concentrations of chromium and other landfill contaminants have been noted in groundwater at adjacent sites (Transects C and D).

Monitor wells were installed to two discrete depth intervals classified as "shallow" and "deep" for the purpose of discussion. The depth intervals are screened to characterize hydraulic and groundwater chemistry variations with depth. Shallow wells are screened across the water table and the well screen is located in the refuse layer or soil fill depending on well location. Shallow well screens extend a few feet into the underlaying sand layer at some monitoring well locations. Deep wells screen a sand bed located across the entire site. Most deep well screen intervals extend 10 feet upward from the bottom of the sand bed. The 10-foot screen length is a variable percentage of the sand bed thickness, depending on the thickness of the sand bed at a given deep monitoring well location. A detailed discussion of site geology is presented in Section 4. Well construction details are provided in Appendix A.

The classification of shallow and deep monitoring wells applies to monitoring wells completed along transects A, B, and D. The classification is more difficult to apply to monitoring wells completed along transect C because both the soil fill and sand bed units are thinner northwest of the landfill along transect C (less than 10 feet thick) than along any of the other three transects. Monitoring wells completed along transect C screen both the sand bed and the overlying fill or refuse material and are not classified as shallow or deep.

3.2 Hydrologic Testing

Hydrogeologic site characterization data were collected using slug tests, tidal studies, and by contouring of measured groundwater elevations. Slug tests were conducted to provide point estimates of hydraulic conductivity at the site. Results of slug testing are described in Section 4 and slug test methodology is described in Appendix C.

Tidal studies were conducted to determine the effects of tidal fluctuations on groundwater flow elevations, flow patterns, and chemistry. An understanding of these tidal effects is an important consideration in planning a monitoring program and in interpreting results of the sampling. Tidal study results are described in Section 4 and tidal study methodologies and data are presented in Appendix C.

Groundwater elevation data were contoured to provide information on groundwater flow directions and gradient. Groundwater contour maps are presented in Section 4 along with a discussion of groundwater flow paths and gradients.

3.3 Analytical Testing

Seventeen monitor wells were sampled on February 9 and 10, 1999, in accordance with the Work Plan. The February sampling event is hereafter referred to as the first quarter 1999 sampling event. Locations of sampled wells are shown on Figure 3-1. All water samples were collected using low-flow procedures and analtyical methods described in the First Progress Memorandum. Analytical testing was performed by Analytical Resources Inc. (Seattle, Washington). All analytical results were validated, with raw analytical laboratory reports and data validation summaries presented in the First and Second Progress Memoranda.

3.4 Land Use Analysis

A land use analysis for the Landfill and adjacent properties was conducted by the Port of Bellingham in parallel with the Landfill RI/FS. That study was funded by an EPA Brownfields Grant. The scope of the analysis is summarized in Section 5 of this report.

3.5 Groundwater Flow Modeling

Groundwater flow modeling was performed using a 3-dimensional flow model. That model was developed in accordance with Ecology expectations. The modeling approach was presented in the Second Progress Memorandum. Section 6 of this report summarizes the detailed methods by which that modeling was performed.

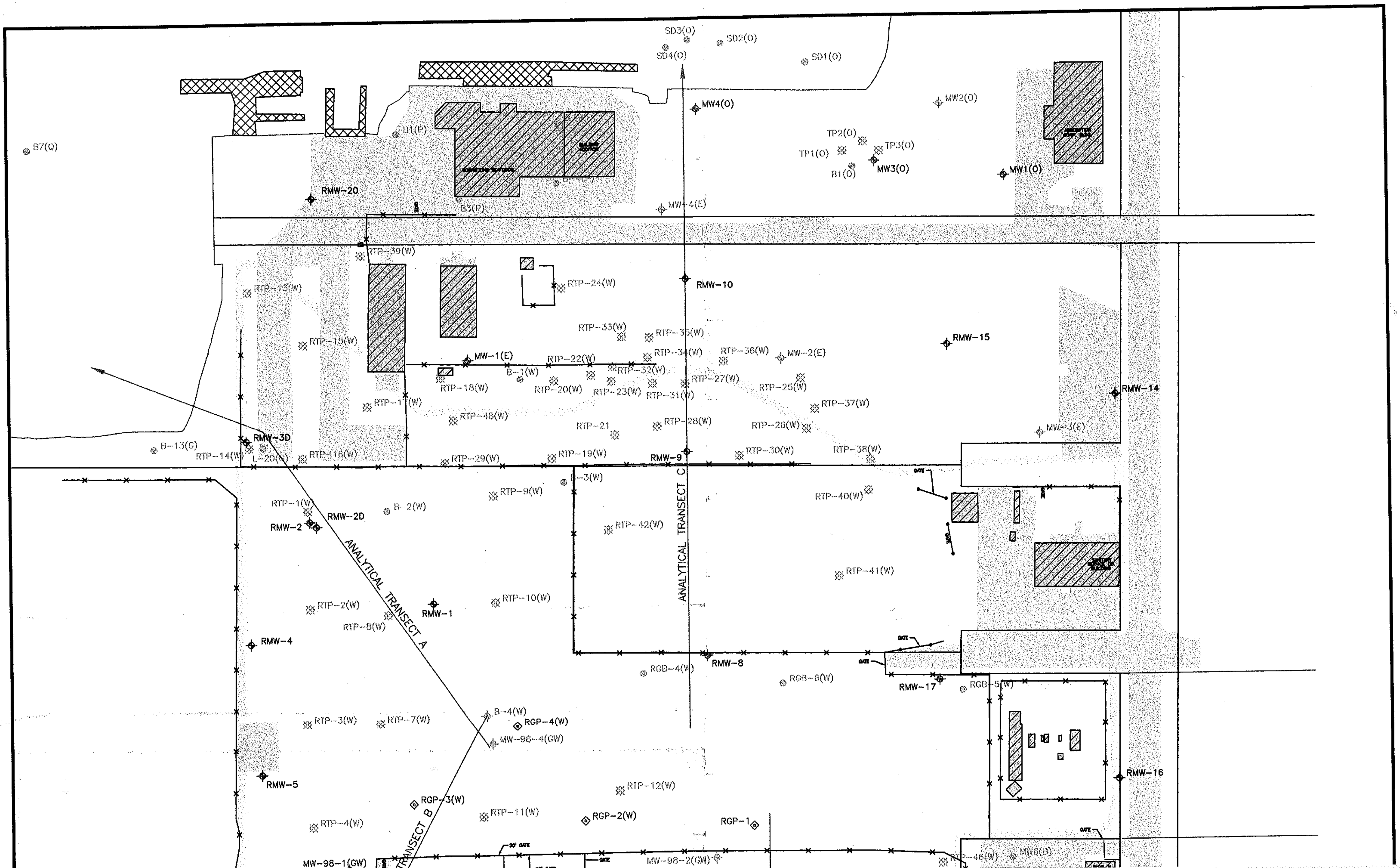
The groundwater flow model takes into account upland groundwater flow characteristics as well as the effects of idal influences occurring near the shoreline. Tidal influences at shorelines have been well defined in the literature including Jacob (1950), Ferris (1951), Carr and van der Kamp (1969), Yim and Mohsen (1992), and Farrell (1994) to name a few. The work by Farrell was used in the design of the slurry wall at the PSR Superfund site in Seattle, Washington. The work by Yim and Moshen has also been used on some relatively simple sites in the Puget Sound area. Both of these methods are 1-dimensional analyses that were not appropriate for the present project due to complexities of the the Roeder Avenue Landfill site area.

Tidal effects on flow and mass balance between tidal inflow and ambient groundwater flow were explicitly investigated in the modeling effort. Incorporating tidal effects explicitly in the modeling has not been done for most previous modeling efforts in the Puget Sound area. However, tidal effects were an integral part of the modeling effort for the PSR Superfund Site (Papadopulos & RETEC, 1997). Tidal effects are important when the concentration in groundwater discharge is estimated in the model analysis, since tidal inflow mixes with the ambient groundwater flow. In cases where the ambient groundwater flow is weak and the tide range is large, tidal inflows may be the dominant mechanism for transport, but at much lower concentrations than observed in the ambient groundwater.

The groundwater modeling results were used both to characterize existing site conditions, as well as to evaluate the benefits/limitations of remedial alternatives for the Landfill. Modeling methods and results are described in detail in Section 6.

3.6 Contaminant Fate & Transport Analysis

The final data analysis step for the remedial investigation was the evaluation of additional factors (other than groundwater flow and mixing) that impact contaminant fate and transport and that would impact the RI/FS decision-making process. This analysis was performed using the output from groundwater flow modeling and reliable information from scientific literature. The methods, results and conclusions of fate and trasnport modeling are described in Section 7 of this document.



SD3(O)
SD2(O)
SD4(O)
SD1(O)
MW4(O)
MW2(O)
B1(P)
B7(O)
TP2(O)
TP3(O)
TP1(O)
B1(O)
MW3(O)
MW1(O)
RMW-20
B3(P)
MW-4(E)
RTP-39(W)
RTP-24(W)
RMW-10
RTP-13(W)
RTP-33(W)
RTP-35(W)
RTP-15(W)
RTP-34(W)
RTP-36(W)
MW-2(E)
RMW-15
MW-1(E)
RTP-22(W)
B-1(W)
RTP-32(W)
RTP-18(W)
RTP-20(W)
RTP-23(W)
RTP-31(W)
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RMW-14
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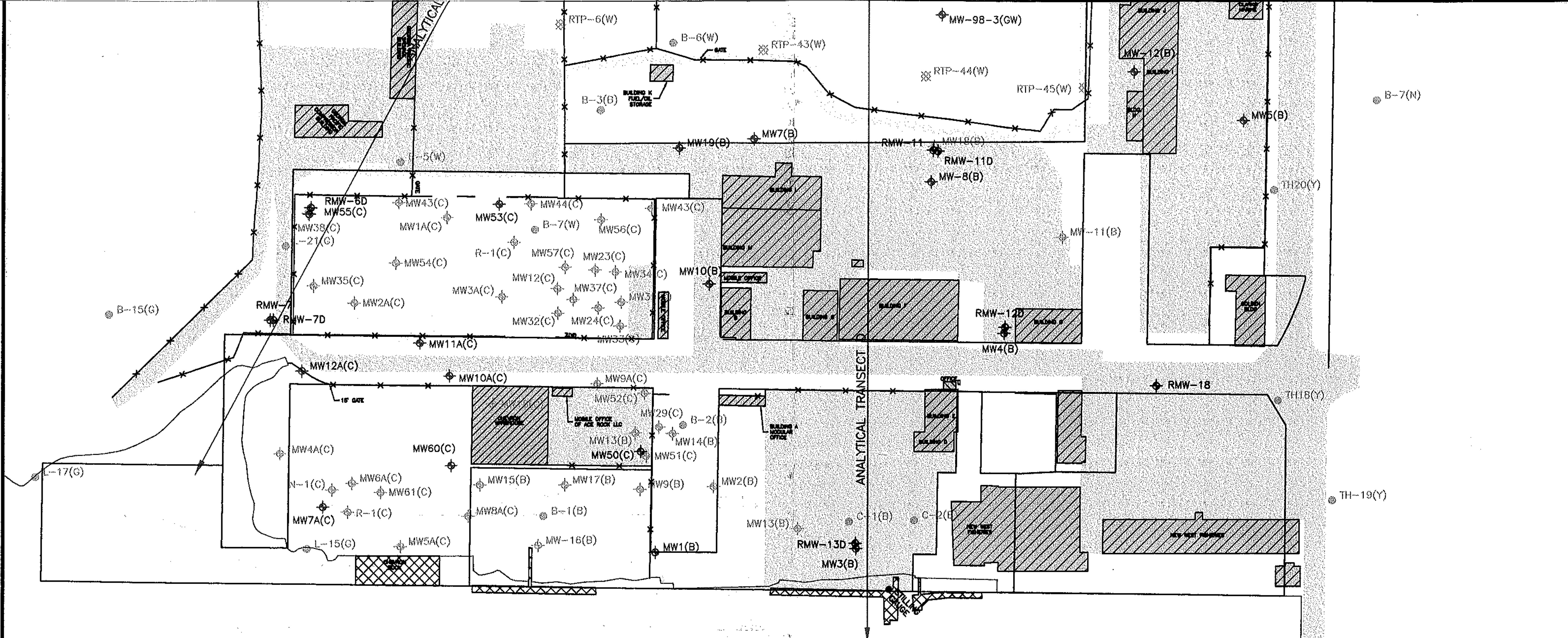
RTP-21
RTP-28(W)
RTP-26(W)
MW-3(E)
RMW-3D
B-13(G)
RTP-14(W)
L-20(E)
RTP-16(W)
RTP-29(W)
RTP-19(W)
RMW-9
RTP-30(W)
RTP-38(W)
B-3(W)
RTP-9(W)
RTP-40(W)
RTP-1(W)
B-2(W)
RMW-2D
RMW-2
RTP-42(W)
ANALYTICAL TRANSECT C
ANALYTICAL TRANSECT A
RTP-41(W)
RTP-2(W)
RMW-1
RTP-10(W)
RTP-8(W)
RMW-4
RMW-8
RGB-4(W)
RGB-6(W)
RMW-17
RGB-5(W)
B-4(W)
RGP-4(W)
RTP-3(W)
RTP-7(W)
MW-98-4(GW)
RMW-16
RMW-5
RTP-12(W)
RGP-3(W)
RTP-11(W)
RGP-2(W)
RGP-1
RTP-4(W)
TRANSECT B
MW-98-1(GW)
MW-98-2(GW)
RTP-46(W)
MW6(B)
GATE
20' GATE
18' GATE



KEY TO PREVIOUS INVESTIGATIONS

B	BELLINGHAM MARINE INDUSTRIES
C	CHEVRON
N	BURLINGTON NORTHERN
E	DEPT. OF ECOLOGY
G	GEORGIA PACIFIC
Y	CITY OF BELLINGHAM
O	OLIVINE (PORT)
Q	SQUALLICUM (PORT)
S	BORNSTEIN (PORT)
W	ROEDER AVENUE WAREHOUSE FEASABILITY ANALYSIS AND PRE-DESIGN TESTING
GW	GEORGIA PACIFIC WAREHOUSE DESIGN INVESTIGATIONS

TRANSECT A →	TIDAL STUDY TRANSECT
(symbol)	DOCKS OR PIERS
(symbol)	EXISTING BUILDINGS
(symbol)	PAVED AREAS
(symbol)	EXISTING SHORELINE
(symbol)	PROPERTY BOUNDARIES (SEE FIGURE 2-1 FOR OWNERSHIP NOTES)
(symbol)	LANDFILL BOUNDARY
RMW-6D	NEW WELL OR PIEZOMETER AT BASE OF SAND LAYER (BELOW WATER TABLE)
RMW-6	NEW WELL OR PIEZOMETER ACROSS WATER TABLE
MW-2(B)	EXISTING WELLS USED DURING RI/FS
MW-2(B)	LOCATIONS OF EXISTING WELLS WHICH WERE NOT BE USED DURING THE RI/FS OR OF WELLS WHICH HAVE BEEN ABANDONED
RTP-1	TEST PITS FROM PREVIOUS INVESTIGATIONS
B-1(B)	SOIL BORINGS FROM PREVIOUS INVESTIGATIONS

ThermoRetec

ROEDER AVENUE LANDFILL RI/FS

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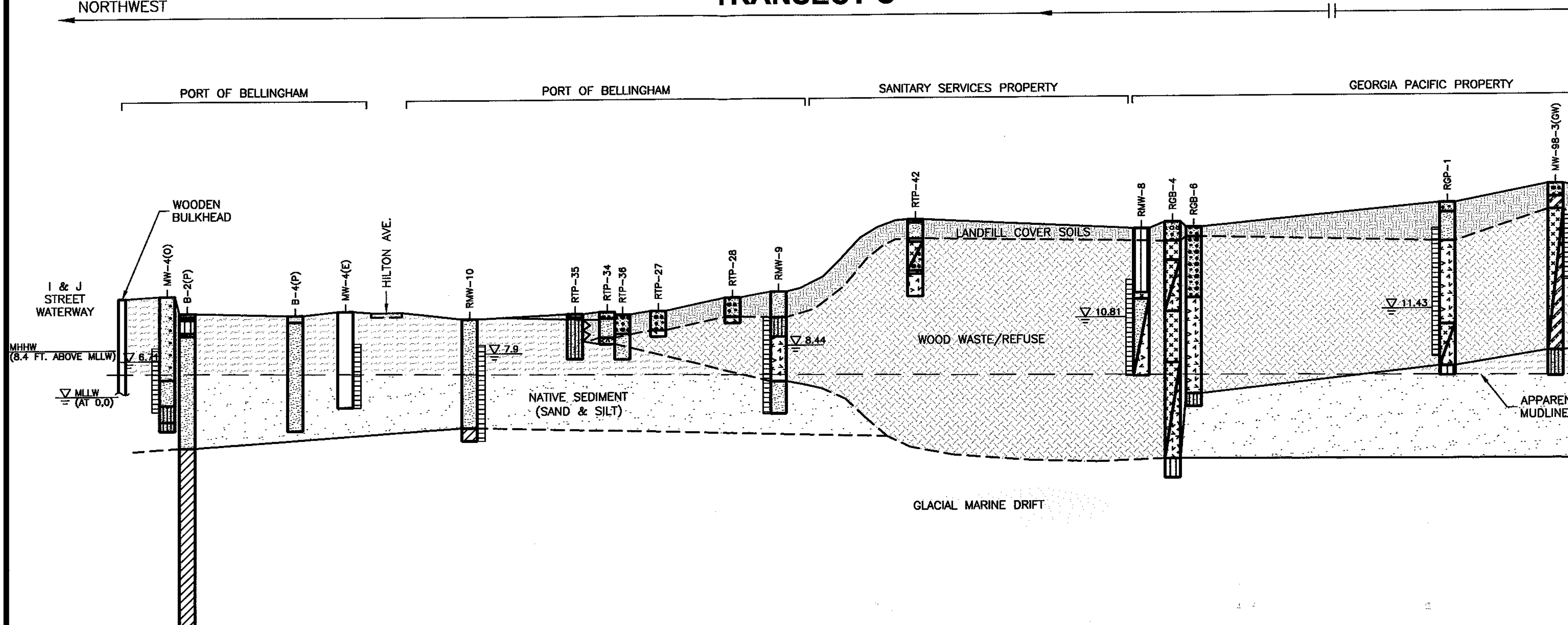
RI/FS WELL AND PIEZOMETER LOCATIONS

FIGURE 3-1

TRANSECT C

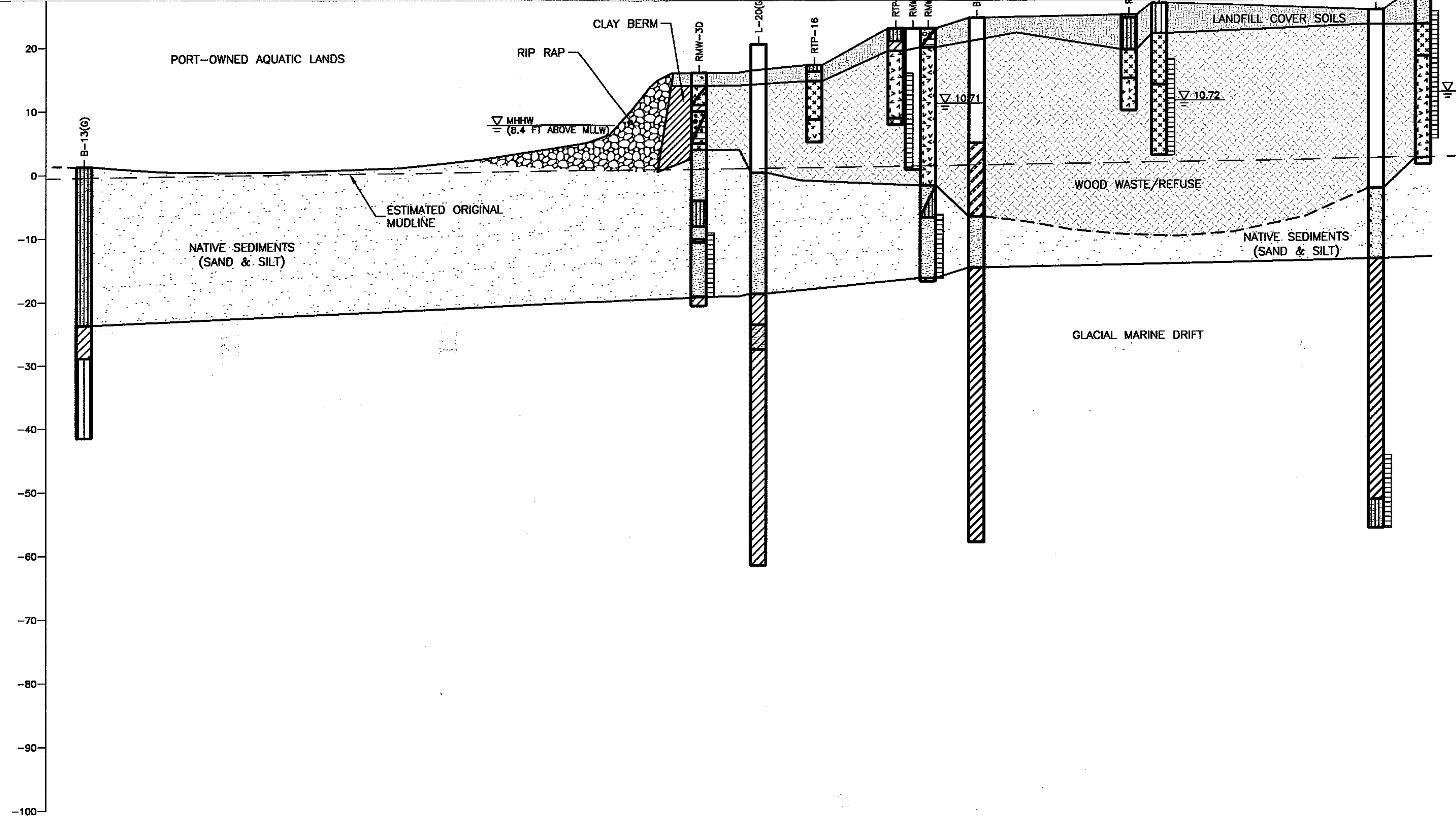


TRANSECT A

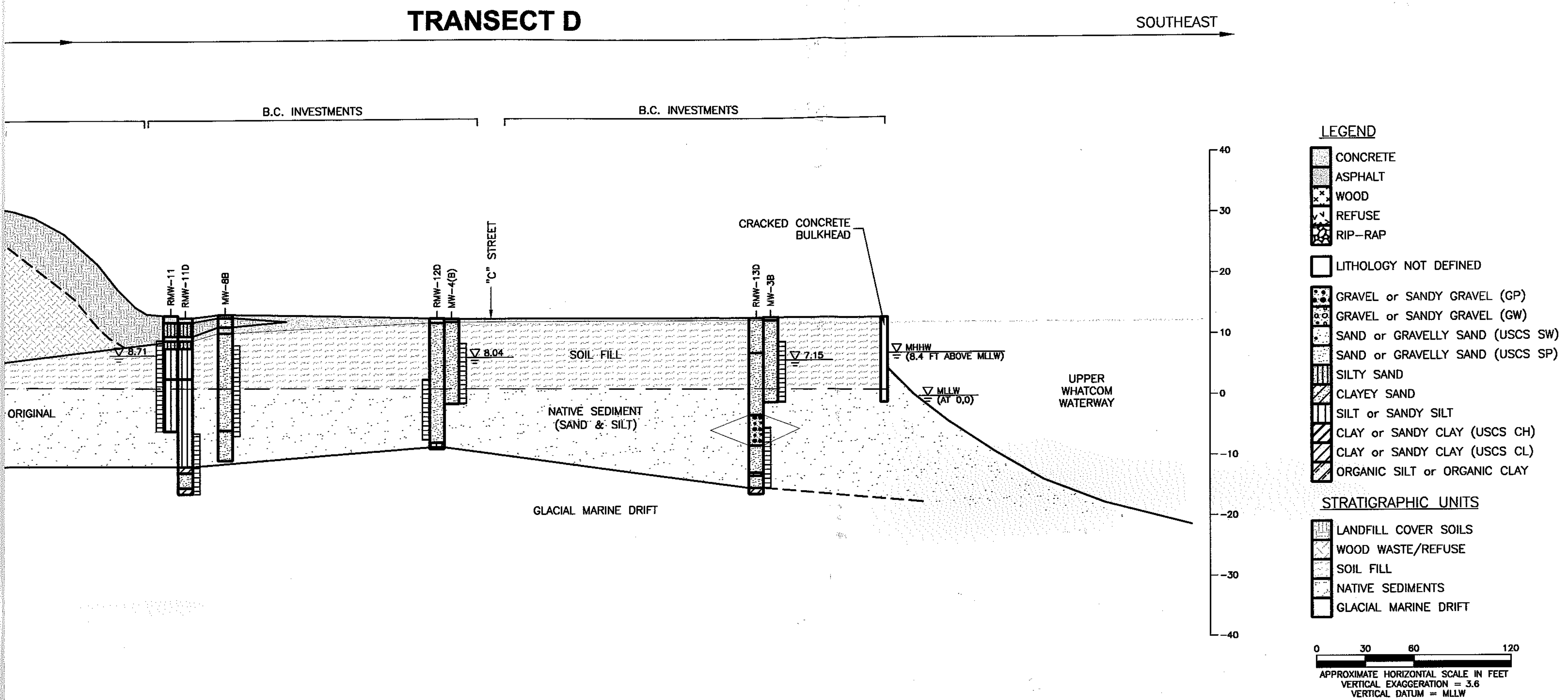
WEST — EAST

PORT OF BELLINGHAM — GEORGIA PACIFIC PROPERTY

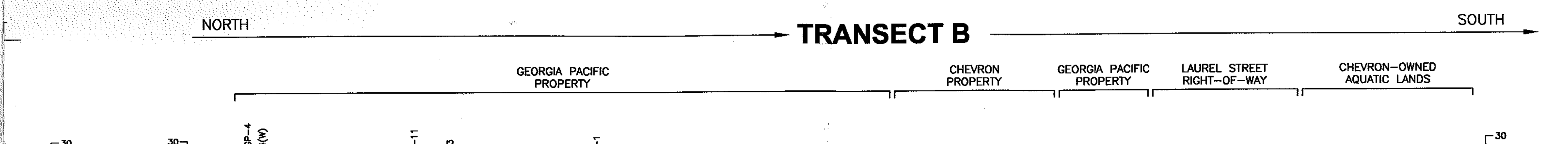
30

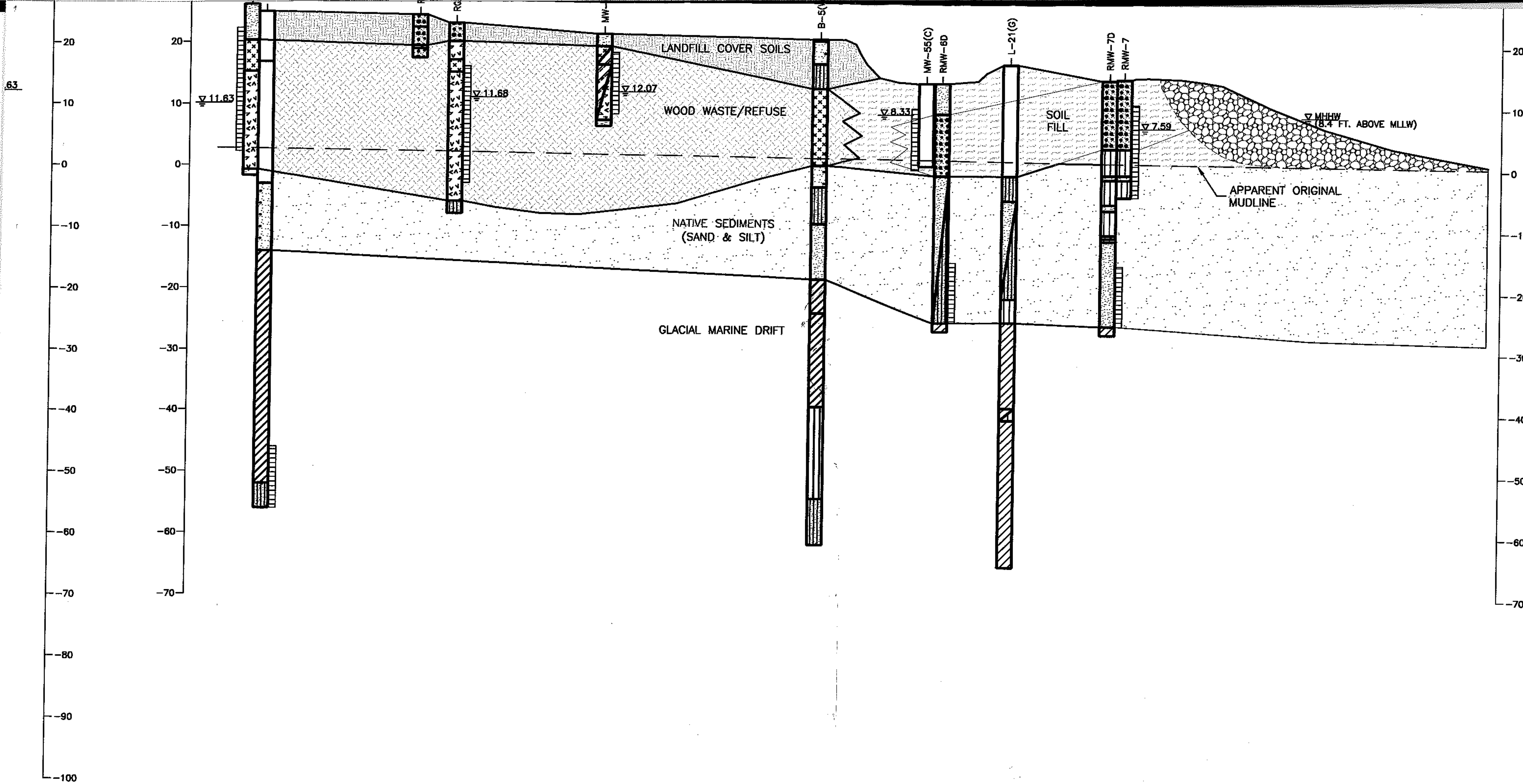


ThermoRetec



NOTE: MEAN SHALLOW GROUNDWATER ELEVATIONS SHOWN HERE ARE TAKEN FROM FIGURE 4-1 OF THE PROGRESS MEMO.





ROEDER AVENUE LANDFILL RI/FS

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GEOLOGIC CONDITIONS ALONG ANALYTICAL TRANSECTS A, B, C & D

FIGURE 3-2

4 Findings of Field Investigations

This section summarizes the results of field activities performed as part of the field investigation. Site geologic and hydrogeologic data are described, followed by groundwater analytical data. The groundwater analytical data are compared to surface water cleanup levels applicable to the point-of-exposure. Sections 6 and 7 subsequently present the groundwater modeling and fate and transport evaluations necessary to interpret overall site conditions.

4.1 Site Geology and Hydrogeology

The findings of geologic and hydrogeologic testing were summarized in the First and Second Progress Memoranda (ThermoRetec, 1999; ThermoRetec, 2000). Completed testing included the installation of groundwater wells in and around the landfill, completion of a tidal study, slug testing of area wells, and completion of quarterly well gauging in November of 1998, and February, April, August and November of 1999.

Site Geologic Characteristics

Figure 3-2 provides geologic cross-sections for the Landfill area. These cross sections were compiled from RI/FS investigation findings, as well as the results of previous studies performed or reviewed by ThermoRetec. From the new and existing data, a site geologic conceptual model was developed. That model defined the following primary geologic units:

- Landfill Cover Soils: These soils are located above the refuse unit and are generally not saturated. The cover soils have some effect on the chemistry of precipitation infiltrating into the landfill,with some increases in the pH of the infiltrating water through contact with limestone cobbles in localized areas.

- Refuse Unit: The refuse unit consists of the buried landfill refuse. The unit is highly permeable and is the source of contamination through leaching of contaminants.

- Soil Fill Unit: The soil fill unit is located north and south of the Landfill and extends from the Landfill to the waterways. This unit serves as the porous media in which some of the groundwater contaminant transport pathways occur.

- Sand Unit: The native sand unit is located across the entire site area, except where it has been locally removed by excavation of the Landfill depression. The primary groundwater contaminant transport pathways between the landfill and the waterways occur in the Sand Unit.

- Glacial Marine Drift: The Glacial Marine Drift is the bottom confining layer for groundwater flow at the site. The unit is fine grained and occurs beneath the entire area with a thickness of at least 90 feet.

velocities are presented to illustrate general trends at the site. Groundwater modeling work in Section 6 was based on actual head measurements.

Most horizontal groundwater flow gradients are in the range of 1 x 10^{-3} to 1 x 10^{-2}. In general, the seasonal variation of gradients along any particular flowpath is not greater than a factor of 2. This corresponds to a seasonal variation in groundwater flow velocities of a factor of 2 because gradients are directly proportional to flow velocities.

Groundwater data indicate the presence of vertical flow components in the Landfill and near shoreline areas along the Whatcom waterway (Table 4-4). Vertical flow components in the Landfill are the result of groundwater mounding. The vertical flow components near the shoreline appear to be associated with the partial bulkheads along the Whatcom Waterway.

Data collected from five rounds of water level measurements were adequate for the purposes of groundwater flow model calibration and verification as described in Section 6 of this memorandum.

4.2 Groundwater Contaminants and Geochemistry

Geochemical Observations

The First and Second Progress Memoranda (ThermoRetec, 1999; ThermoRetec, 2000) included detailed maps of measured geochemical parameters for the Landfill area. Copies of all collected geochemical data are attached to this RI/FS as part of Appendix B.

The groundwater geochemistry within and adjacent to the Landfill is characterized by highly-reducing conditions and a neutral to slightly acidic pH. Dissolved oxygen was consistently absent, except in certain areas outside of the landfill refuse and immediately adjacent to the shoreline.

Most significant, the groundwater geochemistry favors reduction of hexavalent chromium to the less mobile and less toxic trivalent form. Conditions favoring this transformation include low redox potential and the availability of reduced iron. Chemical testing performed during the RI/FS (see below) established that no detectable hexavalent chromium was present in the landfill area groundwater, even though concentrations of trivalent chromium were significantly elevated.

Trends in total dissolved solids and specific inorganic ions correlate well with electrical conductivity measurements. These trends all indicated elevated levels of total dissolved solids and electrical conductivity along the shorelines, particularly in deep groundwater wells. These data were presented in detail as part of the First and Second Progress Memoranda (ThermoRetec, 1999; ThermoRetec, 2000). The data demonstrate the presence of a "salt wedge" in the groundwater mixing zones along the shoreline. Groundwater modeling described in Section 6 included the effect of the salt wedge on the assessment of groundwater flow patterns.

Groundwater Contaminant Concentrations

Groundwater analytical sampling performed during this RI/FS has included preliminary landfill well sampling (July 1998) as well as four quarters of groundwater sampling (February, April, August, and November 1999). Copies of laboratory analytical reports and associated data validation reports were provided as part of the First and Second Progress Memoranda (ThermoRetec, 1999; ThermoRetec, 2000). Data tables containing all of the data collected during the RI/FS are attached as Appendix B.

Table 4-5 lists those contaminants that were detected in the Landfill at concentrations above surface water criteria (these criteria are applicable to the point-of-exposure). These compounds included six heavy metals, three semivolatile organics, weak-acid dissociable cyanide and diesel-range hydrocarbons. These eleven compounds represent the contaminants of concern (COC) for the RI/FS.

In reviewing the analytical data for groundwater contaminants, all detected values have been compared to the surface water cleanup levels and ARARs developed during the RI/FS Work Plan process (see discussion in Section 2.4 of this document). Table 4-6 lists the basis for selection of each surface water cleanup level. The table also provides the relevant MTCA cleanup level for application at sites where groundwater represents a potential source of drinking water. Potable groundwater uses in the Central Waterfront area are prohibited, such that these cleanup levels are not applicable to the Landfill site. These groundwater cleanup levels are provided for informational purposes only.

Figure 4-2 summarizes all cases (excluding data with QA/QC problems) in which Landfill contaminants-of-concern were detected above surface water cleanup levels applicable to the point-of-exposure. These data are shown for areas both on and off of the Landfill. Because the cleanup levels used in this evaluation are only applicable to the point-of-exposure (groundwater discharging to the sediment bioactive zone) the highlighted values in Figure 4-2 do not necessarily represent exceedances of site cleanup levels. As described in the Work Plan, site compliance with MTCA criteria is appropriately assessed after the incorporation of groundwater flow and contaminant fate & transport information. These analyses are described in Section 6 and 7 of this document and quantify the relationship between upland contaminant concentrations and those in the point-of-exposure for each area of the site. Conclusions regarding the compliance of site conditions with MTCA cleanup levels and ARARs are then presented and used in the development of cleanup alternatives for the Landfill.

Figure 4-3 summarizes the distribution of total organic carbon and total chromium throughout the project area. These compounds are characteristically elevated in Landfill groundwater and provide indicators of leachate distribution in the areas between the Landfill and the shoreline.

Contaminant Concentrations in Landfill Groundwater

To assist in the analysis of contaminant distribution, the groundwater data for wells within the Landfill refuse were pooled and used to calculate average contaminant concentrations within Landfill groundwater. Wells and data sets included in this analysis are listed in Table 4-7. The statistical output for each of the contaminants of concern is provided in Table 4-8.

Note that under MTCA data can be represented by either averages or upper confidence limits. The use of averages (mean) is appropriate for evaluation of carcinogenic compounds or for compounds posing a chronic toxicity risk. By contrast, an upper confidence limit (UCL) is stipulated under MTCA for non-carcinogenic compounds where the cleanup level is based on an acute toxicity exposure hazard. Included in Table 4-6 are the statistical methods appropriate to each compound. In Table 4-8, both averages and upper confidence limits were calculated for each compound. The more appropriate of the two measurements is highlighted for each compound.

One use of the data in Table 4-8 is to evaluate the potential regulatory compliance status of a hypothetical direct-discharge scenario for Landfill groundwater. A discharge scenario of this type could be triggered if groundwater was extracted and discharged into a storm drain as part of construction activities (e.g., dewatering for utility installations). Under this direct discharge scenario, eight of the Landfill contaminants would be expected to exceed applicable surface water cleanup levels. Specific conclusions for these eight compounds are summarized as follows:

- **1,4-Dichlorobenzene:** Based on the available data, 1,4-dichlorobenzene would exceed MTCA criteria under a direct discharge scenario. This semivolatile organic compound was detected in 12 out of 20 samples analyzed. Of the detected samples, 8 exceeded surface water criteria. The arithmetic mean concentration was just slightly above the surface water criteria, with a mean concentration approximately 1.1 times the MTCA Method B surface water cleanup level. If calculated using the 95% UCL, the exceedance ratio is 1.6 times the cleanup level.

- **Pentachlorophenol:** Based on the available data, pentachlorophenol (PCP) could exceed MTCA criteria under a direct discharge scenario. This semivolatile organic compound was detected in only 2 out of 20 samples analyzed. However, both of those detections were well above the surface water criteria. Both of these detections were in well RGP-3 which was located within the footprint of the Warehouse project. Due to the impacts of the two RGP-3 sample results, the arithmetic mean concentration exceeds the surface water criteria, with a mean concentration equal to about 11 times the MTCA Method B surface water cleanup level. If calculated using the 95% UCL, the exceedance ratio is 25 times. As discussed in Section 7, the lack of PCP detections in groundwater from any other wells, including the wells located in between RGP-3 and the shoreline indicates that the PCP is isolated in occurrence and that the contamination is not migrating. Factors that appear to be controlling potential migration of PCP are discussed in Section 7.

- **Diesel-Range Hydrocarbons:** Based on the available data, diesel-range hydrocarbons would be expected to slightly exceed MTCA criteria under a direct discharge scenario. Diesel-range hydrocarbons were detected in 15 of 19 samples analyzed. Of these detections, ten samples contained exceedances of the MTCA Method A cleanup level (0.5 mg/L) as amended by Ecology in February of 2001. The arithmetic mean concentration was approximately 1.1 mg/L, above the MTCA Method A cleanup level by a factor of approximately 2.2. If calculated using the 95% UCL, the exceedance ratio is 3.2 times.

- **WAD Cyanide:** Based on the available data, WAD cyanide would be expected to exceed surface water criteria under a direct-discharge scenario. WAD cyanide was detected in only 3 of 14 samples analyzed. The concentrations measured in the three samples with detectable cyanide exceeded the surface water criteria. The arithmetic mean concentration was calculated as 1.7 times the state water quality criterion. If calculated using the 95% UCL, the exceedance ratio is 3.1 times. Use of the mean concentration is appropriate, because state water quality criteria (WAC 173-201A) use the mean concentration in evaluating regulatory compliance.

- **Arsenic:** Based on the available data, arsenic would be expected to exceed applicable criteria under a direct-discharge scenario. Arsenic was detected in 15 out of 19 samples analyzed. Four of the detected samples exceeded the natural background concentration for groundwater of 0.005 mg/L. These four detected values ranged between 0.008 and 0.034 mg/L. Three of the four concentrations were measured in areas beneath the footprint of the Warehouse project. The fourth value was measured in well RMW-9, but this was an isolated detection (one exceedance out of five sampling events). The arithmetic mean concentration for arsenic was 0.0054, just above the MTCA Method A cleanup level for arsenic in groundwater. That cleanup level was established by Ecology based on estimated natural background concentrations for groundwater in Washington state. If calculated using the 95% UCL, the exceedance ratio is 1.8 times, but use of the mean concentration is more appropriate for arsenic which is a suspected carcinogen.

- **Lead:** Based on the available data, lead would be expected to exceed surface water criteria under a direct-discharge scenario. Lead was detected in 12 out of 19 samples analyzed. Six of the detected samples exceeded the surface water standard of 0.0081 mg/L. With the exception of well RGP-3 which was located within the Warehouse project footprint, no wells had multiple exceedences of the surface water criterion. The arithmetic mean concentration for lead was 1.8 times the surface water criterion. If calculated using the 95% UCL, the exceedance ratio is 3.5 times, but state water quality criteria (WAC 173-201A) use the mean concentration in evaluating regulatory compliance.

- **Mercury:** Based on the available data, mercury could potentially exceed the natural background concentration for marine surface waters under a direct-discharge scenario. Mercury was detected in only 2 of 19 samples analyzed, with both samples detected at the reporting limit of 0.0001 mg/L. The detected values were isolated, occurring in separate wells. The reported background mercury concentration in marine waters is 0.00005 mg/L (Davis, 1977) or half of the reporting limit used for groundwater sampling. If all non-detect samples are assumed to contain mercury at a concentration equal to one half of the reporting limit, the UCL concentration is estimated to exceed the background concentration by 1.4 times.

- **Zinc:** Based on the available data, zinc concentrations may exceed surface water criteria under a direct-discharge scenario. Zinc was detected in 18 out of 19 samples analyzed, but only four of the detected samples exceeded the surface water standard of 0.081 mg/L. Three of these four exceedences were noted in well RMW-9. The arithmetic mean concentration for zinc was equivalent to the surface water standard (exceedance ratio of 1.0 times). If calculated using the 95% UCL, the exceedance ratio is 1.68 times, but state water quality criteria use the mean concentration in evaluating regulatory compliance.

Mean concentrations for three of the Landfill COCs were on average below surface water cleanup levels and would therefore not be expected to exceed MTCA criteria during a direct discharge event. Conclusions for these compounds are summarized below:

- **Bis(2-ethylhexyl)phthalate:** Based on the available data, bis(2-ethylhexyl)phthalate would not exceed MTCA criteria under a direct discharge scenario. This semivolatile organic compound was detected in 8 out of 20 samples analyzed. But only two of the detected samples contained exceedances of surface water criteria. The arithmetic mean concentration was well below the surface water criteria, with a mean concentration equal to 0.43 times the MTCA Method B surface water cleanup level. If calculated using the 95% UCL, the exceedance ratio is 0.65 times, well below the criterion (the use of the mean concentration is more appropriate for bis(2-ethylhexyl)phthalate which is a suspected carcinogen). As discussed in Section 7, a lower cleanup level may be applicable to the point-of-exposure in order to protect against sediment quality exceedances. Based on partitioning calculations as described in Section 7, the final cleanup level for the point-of-exposure may be 0.0007 mg/L, or five times lower than the MTCA Method B surface water cleanup level. This cleanup level may or may not be applicable to direct-discharge scenarios for Landfill groundwater, depending on the volume, rate and type discharge.

- **Copper:** Based on the available data, copper concentrations would not be expected to exceed surface water criteria under a direct-discharge scenario. Copper was detected in only 5 of 19 samples analyzed. Four of these detected values exceeded the surface water criterion of 0.0031 mg/L. These exceedances were all isolated, with no individual well having two or more samples in excess of the criterion. The arithmetic mean concentration was below the surface water criteria, with a mean concentration equal to 0.85 times the state water quality criterion. If calculated using the 95% UCL, the exceedance ratio is 1.46 times the criterion, but state water quality rules (WAC 173-201A) use the mean concentration to evaluate regulatory compliance.

- **Nickel:** Based on the available data, nickel concentrations would not be expected to exceed surface water criteria under a direct-discharge scenario. Nickel was detected in only 2 of 19 samples analyzed. These two samples exceeded the surface water standard of 0.0082 mg/L. These two detected values were isolated, with no repeated exceedances in any Landfill wells. The arithmetic mean concentration was below the surface water criteria, with a mean concentration equal to 0.87 times the state water quality criterion. If calculated using the 95% UCL, the exceedance ratio is 1.31 times the criterion, but state water quality rules (WAC 173-201A) use the mean concentration to evaluate regulatory compliance.

Total chromium and total organic carbon were both included in the statistical analysis as potential indicators for landfill leachate in area groundwater. However, neither constituent exceeded any sort of surface water cleanup level applicable to the site. The statistical analyses were performed for informational purposes only.

- **Total Chromium:** The MTCA Method B surface water cleanup level for total chromium is 162 mg/L. The detected landfill concentrations of total chromium ranged between non-detect and 9.78 mg/L, with total chromium detected in 17 of 19 samples analyzed. Hexavalent chromium was never detected in any of the landfill wells sampled. The arithmetic mean concentration for total chromium in the landfill wells was 1.62 mg/L, with a 95% UCL of 2.83 mg/L. These concentrations between 50 and 100 times lower than the cleanup level applicable to trivalent chromium at the point of exposure.

- **Total Organic Carbon:** There is no surface water standard for total organic carbon. The detected landfill concentrations of total organic carbon ranged between 16 to 520 mg/L, with total organic carbon detected in all samples analyzed. The arithmetic mean concentration for total organic carbon was 121 mg/L, with a 95% UCL of 200 mg/L.

Based on the data collected during the RI/FS, direct discharge of Landfill leachate to surface waters would not be compliant with MTCA requirements. Average concentrations of eight contaminants would likely exceed applicable surface water criteria. For six of the contaminants, average exceedances would be less than a factor of two. Petroleum concentrations would exceed the criteria by 3.2 times (assuming use of the UCL for compliance evaluation and continued use of the conservative 0.5 mg/L Method A cleanup level for diesel-range hydrocarbons. For pentachlorophenol, the average exceedance could be significantly greater, because the direct-discharge of Landfill groundwater would not be attenuated by the natural processes occurring in area groundwater between the Landfill and the shoreline (see Section 7).

Remedial action objectives for the site must include provisions necessary to prevent direct discharge of landfill leachate to surface waters. Section 8 defines alternatives by which such discharge can be prevented.

Contaminant Concentrations in Groundwater Along Hilton Avenue

Table 4-9 summarizes the analytical data collected from the groundwater monitoring wells located between the landfill and the I&J Waterway. The first of the two wells, RMW-10, was located adjacent to Hilton Avenue, approximately 113 feet downgradient from the landfill refuse boundary. The second well, MW-4(O), is located near the I&J Waterway shoreline, and was initially installed as part of environmental investigations at the Olivine site. Each of these two wells was analyzed for groundwater contaminants during four consecutive quarterly sampling events.

Both of the Hilton Avenue wells contained elevated concentrations of total chromium and total organic carbon. These parameters are generally indicative of the presence of Landfill leachate in area groundwater. The concentration of total chromium was approximately three times higher in RMW-10 (located closest to the Landfill) than in the shoreline well, MW-4(O). However, both concentrations were significantly lower than typical Landfill area groundwater (e.g., arithmetic mean total chromium concentrations in Hilton Avenue wells RMW-10 and MW-4(O) were 15 and 44 times lower than in the Landfill groundwater). Neither TOC nor chromium concentrations exceeded any applicable surface water criteria along Hilton Avenue.

Of the eleven landfill contaminants of concern, most compounds were either not detected or were detected at concentrations below the surface water standards applicable to the point-of-exposure. Only three compounds -- bis(2-ethylhexyl)phthalate, nickel and zinc were detected one or more times above surface water standards. Of these, only two exceeded surface water standards using the compliance measurement basis defined in Table 4-6.

Bis(2-ethylhexyl)phthalate was detected once in RMW-10 and twice in MW-4(O). The detected concentration exceeded MTCA Method B surface water cleanup levels once in each well. Based on the available data, average concentrations in the wells were below surface water criteria. If the surface water cleanup level for phthalate is adjusted downward to provide additional protection against sediment recontamination (see Section 7), the exceedance ratios for the two Hilton Avenue wells are 2.6 and 3.0, respectively.

Nickel was detected only once in RMW-10, and not at all in well MW-4(O). Nickel is a confirmed Landfill contaminant, and was detected in the well closest to the Landfill refuse. It is reasonable that this detection is associated with the Landfill. Based on the available data, average concentrations of nickel are below surface water criteria in RMW-10, and not detectable in MW-4(O).

Zinc was detected in both of the Hilton Avenue wells. It was detected four times in RMW-10, closest to the landfill, but did not exceed surface water criteria in any of these measurements. In MW-4(O) zinc was detected twice, including one detection significantly above the surface water criterion. This resulted in an estimated average exceedance ratio of 1.68X in this well. Due to the heterogeneity of the groundwater sampling data for zinc at these wells, it is not clear whether the elevated zinc concentrations at MW-4(O) are the result of sampling and analysis artifacts, an off-Landfill source associated with the Olivine site, or migration of Landfill area groundwater. For the contaminant fate and transport evaluations conducted as part of the RI/FS, the elevated zinc concentrations were treated as Landfill-related.

Contaminant Concentrations in Groundwater At the Foot of Hilton Avenue

Wells located at the foot of Hilton Avenue include RMW-2D and RMW-3D (see Figure 4-2). Data for these wells are summarized in Table 4-10.

Well RMW-2D is located within the Landfill footprint, but the screen interval is below the refuse layer. Concentrations of total chromium (average 0.098 mg/L) indicate the presence of Landfill leachate, but at levels 16 times lower than typical Landfill leachate concentrations (compare Table 4-10 values with those in Table 4-8) and over 8 times lower than the concentrations measured in paired shallow well RMW-2 (see Appendix B). The relatively low chromium in this well despite its close proximity (less than 5 feet vertically) to the Landfill refuse is explained by the "lagoon effect" as described in Section 6. As a result of this effect, the main source of groundwater in the vicinity of RMW-2D is predicted to be recharge from the lagoon, rather than downward migration of leachate from the Landfill refuse located above the well screen interval.

Well RMW-3D is located beneath the clay landfill berm. This well is also within the lagoon affect area but is located closest to the shoreline. Concentrations of total organic carbon and total chromium concentrations are very similar to those measured in well RMW-2D.

Of the available analytical data, no contaminants were detected above surface water criteria in well RMW-2D. In well RMW-3D, the only exceedances of surface water criteria were cyanide and zinc. Each contaminant was detected above surface water criteria once. The resulting exceedance ratios were calculated to be 1.04 for cyanide, and 0.37 for zinc. Both ratios are well below 1.0X if flow-based attenuation between the well and the point of exposure are taken into account (see Sections 6 and 7).

Contaminant Concentrations in Groundwater Along C-Street

Three pairs of groundwater monitoring wells between the landfill perimeter and the shoreline of the Whatcom Waterway were monitored as part of the RI/FS. The first well pair (RMW-11 and RMW-11D) is located near the current property line between Georgia Pacific and BC Investments. The second (MW-4(B) and RMW-12D) and third pairs (MW-3(B) and RMW-13D) are located on the BC Investments property at increasing distances from the landfill. All three well pairs include shallow and deep wells. Analytical data collected from these three well pairs are summarized in Tables 4-11, 4-12 and 4-13, respectively.

Concentrations of total chromium and total organic carbon vary from relatively high concentrations typical of Landfill area groundwater at wells RMW-11/RMW-11D to much lower concentrations at the Whatcom Waterway shoreline. The concentration trends for these leachate indicators are generally consistent with the predictions of the contaminant fate and transport predictions described in Sections 6 and 7.

Leachate migration is projected by the groundwater modeling output (Section 6) to be greatest in the deeper groundwater layers. The higher degree of attenuation in the shallow groundwater is caused by meteoric recharge and the resultant dilution of leachate with non-landfill waters. Consistent with this trend, the total chromium concentration declines more rapidly in the shallow wells, dropping from 0.580 mg/L, to 0.015 between RMW-11 and MW-4(B). In the corresponding deep wells, the concentrations of total chrome are higher initially in RMW-11D (0.949 mg/L) and drop less abruptly with distance from the landfill (total chromium concentration of 0.257 mg/L at RMW-12D, and then to 0.105 mg/L at

RMW-13D). Concentration trends in this area for total organic carbon are similar to those of chromium.

Seven of the eleven Landfill contaminants of concern were detected one or more times above the surface water ARARs in well RMW-11, located adjacent to the Landfill. Contaminants with exceedance ratios greater than 1.0X in this well included copper, lead, mercury, cyanide and copper. Far fewer ARAR exceedences were noted in the deep well at this location, RMW-11D. Only cyanide was detected above ARARs in this deep well. That compound was detected above ARAR concentrations in 3 out of 5 samples analyzed.

The trends in copper concentrations suggest a non-Landfill contaminant source located on the BC Investments property. Copper was never detected above ARAR concentrations in any of the deep wells in this area. In contrast, the compound was detected above ARARs multiple times in wells RMW-11 and MW-3(B). In well MW-3(B) the average copper concentration was 6.8 times the corresponding surface water ARAR, and copper was detected above the ARAR in all four of the samples analyzed. These results are generally consistent with the results of previous analytical testing performed at the BC Investments property (GeoEngineers 1992a, GeoEngineers 1992b). Those data indicated multiple detections of elevated copper concentrations in groundwater at the BC Investments/Colony Wharf site. Possible site-specific sources include non-refuse fill soils used at the property, former foundry activities, and bottom paints from boat maintenance activities performed at the property.

Concentrations of cyanide were detected above ARARs one or more times in each of the six wells. The average concentrations were slightly higher in the deep wells compared to the shallow wells, suggesting a possible Landfill source for the contamination. Calculated exceedance ratios for the C-street wells ranged from 1.0 to 1.5.

Elevated lead concentrations were noted above ARARs only in a single sample collected from RMW-11. The presence of lead at this location is consistent with a potential Landfill source for the contamination.

Mercury was detected twice above ARAR concentrations. Both detections were in shallow soils, one sample from RMW-11 and one sample from MW-3(B). Due to the infrequent nature of these detections, the source of the mercury could not be reliably determined. The lack of mercury detections in the deep wells along C-street suggest a non-Landfill source. However, pending additional data, it is assumed for purposes of the RI/FS that the elevated mercury concentrations in the C-street area are Landfill associated.

Contaminant Concentrations in Groundwater at the Foot of C-Street

Two pairs of RI/FS groundwater monitoring wells were located at the foot of C-street. One pair (MW-55(C) and RMW-6D) was located near the GP/Chevron property line. The second well pair (RMW-7 and RMW-7D) was installed on GP-owned property at the end of the C-street right-of-way. Analytical data collected from these three well pairs are summarized in Table 4-14.

Flow modeling for the area at the foot of C-street indicated a strong lagoon effect, with significant subsurface groundwater recharge from the lagoon area (see Section 6).The influence of the lagoon effect is evident in the distribution of total chromium and total organic carbon. Based on the proximity of wells MW-55(C) and RMW-6D to the landfill refuse (less than 50 feet) the concentrations of these leachate indicator constituents would be expected to be similar to those observed at wells RMW-11 and/or RMW-11D (also located about 50 feet from the landfill refuse). Instead, the total chromium concentrations at well MW-55(C) are almost 12 times lower than those in RMW-11, and the chromium concentrations in RMW-6D are about 7 times lower than those in RMW-11D (compare Tables 4-14 and 4-11).

Virtually no chromium was detected in wells RMW-7 and RMW-7D, consistent with the lagoon effect. In the absence of this effect, the concentrations of total chromium in the wells would be expected to be similar to those at well pair MW-4(B) / RMW-12D (see Table 4-12). Rather, the total chromium concentrations are much lower in well RMW-7 than in MW-4(B), and chromium was not detected at all in well RMW-7D.

In the two wells located adjacent to the landfill (MW-55(C) and RMW-6D), only two contaminants were detected above ARARs. These included arsenic and cyanide. Arsenic was detected in both the shallow and the deep well, and was measured above the natural background concentration of 0.005 mg/L in all shallow samples analyzed. In the shallow well the concentrations were substantially elevated (average exceedance ratio of 6.8X). In the deep well, the concentrations were detected above background in only 2 of 3 samples analyzed, and the average concentration was only 1.2X above background. The vertical distribution of the arsenic is the reverse of that for total chromium (which is higher in the deep well than in the shallow). The arsenic distribution strongly suggests a site-specific contamination source for arsenic at the Chevron site, with some additional contribution by the Landfill. In the two shoreline wells (RMW-7 and RMW-7D) the mean arsenic concentration was below natural background concentrations for groundwater.

Cyanide was detected above ARAR concentrations only once at the Foot of Hilton Avenue. Cyanide was detected in one of three samples analyzed from RMW-6(D). It is possible that the cyanide represents a Landfill-associated contaminant, because cyanide has been detected in the other areas adjacent to the Landfill, including both the C-street and Hilton Avenue areas. The mean cyanide exceedance ratio for well RMW-6(D) was calculated to be 1.8X.Cyanide was below ARAR concentrations in all other wells at the foot of Hilton including the two shoreline wells.

Copper was not detected in either wells MW-55(C) or RMW-6D located adjacent to the Landfill. However, copper concentrations in shallow well RMW-7 were elevated, with four out of four measurements exceeding the surface water ARAR, and an average exceedance ratio of 1.9. The distribution of the contamination (present in shallow groundwater rather than deep, and not detected adjacent to the Landfill) suggest a non-Landfill source of the contamination at or near the Chevron property.

Zinc was detected above surface water ARARs one time in well RMW-7. But average zinc concentrations were below ARAR concentrations in all four of the wells at the Foot of Hilton.

Sporadic detections of bis(2-ethylhexyl)phthalate were noted in the two deep wells (RMW-6D and RMW-7D). The compound was detected once in each well. The calculated average concentration for this compound was well below the Method B cleanup level in RMW-6(D). The average concentration was approximately 1.4 times the more stringent sediment source control value. In well RMW-7(D) the average concentrations of bis(2-ethylhexyl)phthalate were also below the MTCA Method B cleanup level, but higher than the more stringent sediment source control value. Given the sporadic detection of this compound, the high frequency of sampling and analysis artifacts for this compound at low levels and the observation that both detections (RMW-6D and RMW-7D) occurred during the same sampling event, it is likely that the phthalate detections are the results of sampling and analysis artifacts rather than migration of Landfill area groundwater.

4.3 Distribution of Landfill Gas

Testing data for Landfill gas (principally methane) are summarized in Table 4-15. Those data include a screening survey for elevated methane concentrations in water table monitoring wells located along the C-street and Hilton Avenue sides of the Landfill.

Methane concentrations were evaluated by measuring the combustible gases present in the headspace of the monitoring well at each location. These data are reported as a percentage of the lower explosive limit (LEL). Simultaneous measurements were also performed using a photo-ionization detector to differentiate methane-associated gases from other possible volatile organic compound vapors. Methane was detectable only by the LEL meter used, but not by the PID. The presence of methane is indicated by a high reading on the LEL, without a corresponding high reading on the PID. In contrast, a gasoline hydrocarbon or solvent vapor would produce an elevated reading on both instruments.

Readings for oxygen, carbon monoxide and hydrogen sulfide are also provided in Table 4-15. Methane accumulations typically displace oxygen, resulting in readings well below typical atmospheric oxygen values (20.5 to 20.9 percent). Carbon monoxide and hydrogen sulfide can both be produced in landfills as part of the refuse decomposition process.

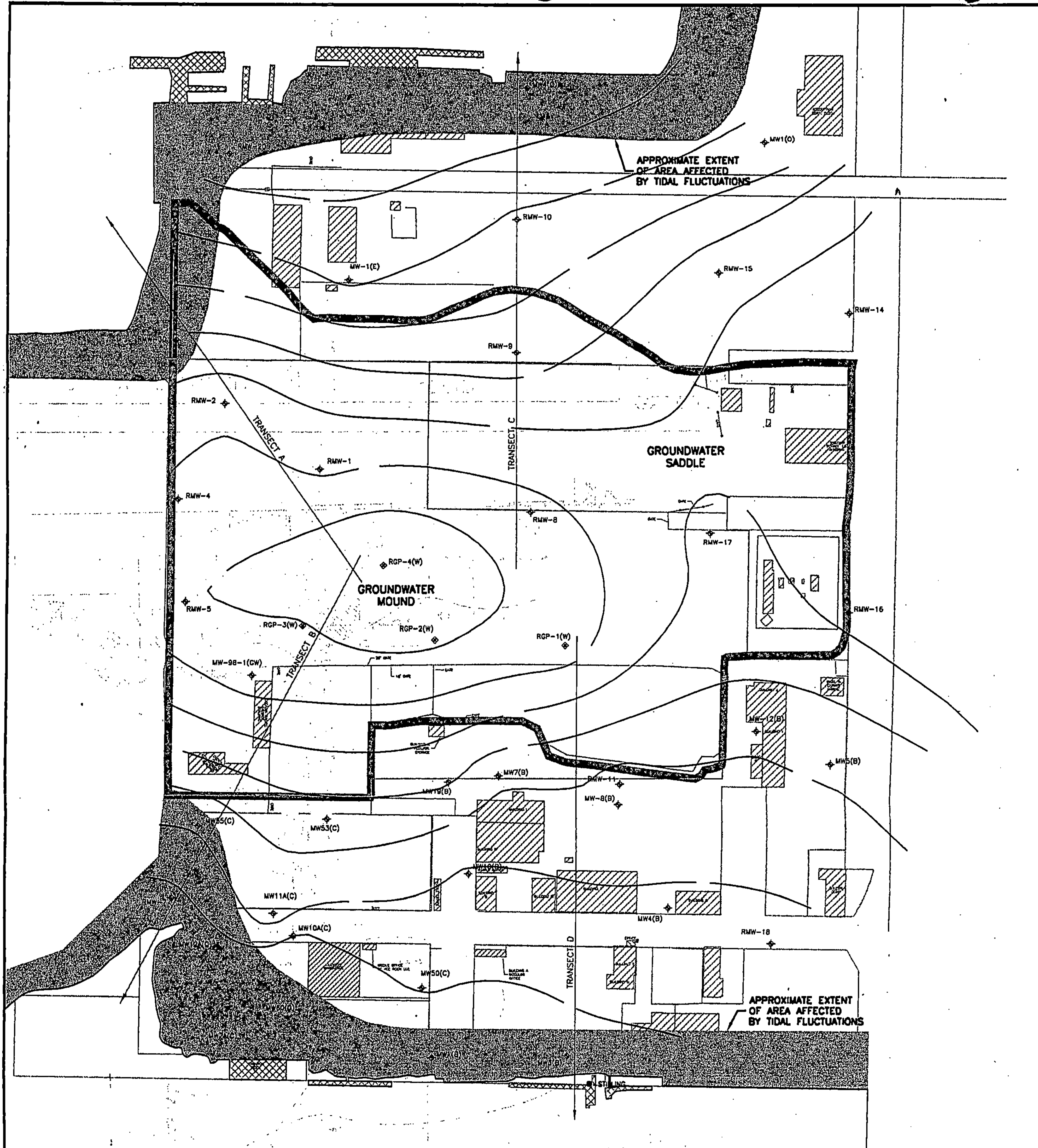
Headspace readings from each of the wells were screened by comparison to regulatory reference values. A combustible gas limit of 10% of the LEL is defined as the maximum cleanup level for any vapor-phase contamination under the recent MTCA amendments (see WAC 173-340-750). Worker safety regulations promulgated by the Occupational Safety and Health Administration (OSHA) also establish permissible exposure limits (PEL) for carbon monoxide and hydrogen sulfide. Both the MTCA cleanup levels and the OSHA standards apply to areas where human exposure is possible. Such areas include buildings, enclosed utility vaults and other structures in which persons could potentially be exposed to harmful atmospheres. The monitoring wells used for the landfill gas measurements as part of the RI/FS are not such spaces, but were tested as indicators of the distribution of landfill gas and the potential of the gas to accumulate in enclosed spaces. Therefore, while the presence of elevated gas levels in the monitoring well headspace does not indicate an exceedance of MTCA cleanup levels or OSHA standards, it does provide an indication of where such violations could potentially occur and where further evaluation and/or corrective actions are appropriate under MTCA.

The results of Landfill as testing confirmed the presence of methane, hydrogen sulfide and carbon monoxide in wells located within the Landfill refuse. These findings are consistent with earlier testing performed as part of the Warehouse project. Methane concentrations in some wells both on and off of the Landfill exceeded 100% of the LEL.

Elevated levels of hydrogen sulfide and carbon monoxide, as well as depressed levels of oxygen were noted in those wells that had elevated methane concentrations (Table 4-15). These findings are consistent with a Landfill source for the detected methane. Other methane sources (e.g., leakage from natural gas piping) would not produce elevated carbon monoxide and hydrogen sulfide concentrations, whereas these compounds are commonly associated with landfill gas.

The migration of the Landfill gas was greater in the C-street area southeast of the Landfill than in the Hilton Avenue area northwest of the Landfill. In the C-street area methane gas concentrations in excess of 10% of the LEL were noted to distances of nearly 200 feet from the Landfill refuse perimeter. In contrast, along the Hilton Avenue side of the Landfill, no gas concentrations above 10% of the LEL were noted in wells as close as 60 and 90 feet to the Landfill refuse boundary.

The differences in Landfill gas migration along the C-street and Hilton Avenue may result from two or more factors. First, the Landfill refuse layer is thinner along the Hilton Avenue refuse boundary than along the C-street refuse boundary. The additional thickness along the C-street boundary means that there is a greater quantity of refuse present and as a result an increased potential for methane production. Second, the relative extent of paving and capping is greater along C-street than along Hilton Avenue. In the Hilton Avenue area, paving is limited to small portions of the Hawley's Hilton, GP Warehouse yard and Sanitary Services properties. Along the C-street side of the Landfill, paving and/or buildings cover much greater portions of the GP, and BC Investments properties (see Figure 2-1). The unpaved/uncapped areas along Hilton Avenue provide a mechanism for gas accumulations to dissipate rather than accumulating and migrating laterally. Development actions at the Sanitary Services, GP or Port of Bellingham properties could increase paving/capping in these areas and change the patterns of landfill gas migration.



SHALLOW WELL LEGEND

Symbol	Description
	MEASURED GROUNDWATER ELEVATION IN FEET MLLW
RMW-6D	NEW WELL OR PIEZOMETER AT BASE OF SAND LAYER (BELOW WATER TABLE)
RMW-6	NEW WELL OR PIEZOMETER ACROSS WATER TABLE
MW-2(B)	EXISTING WELLS USED DURING RI/FS
RGP-4(W)	GAS PROBE INSTALLED DURING WAREHOUSE FEASABILITY INVESTIGATION

LEGEND

- GROUNDWATER CONTOUR IN FEET MLLW (DASHED WHERE INFERRED)
- DOCKS OR PIERS
- EXISTING BUILDINGS
- EXISTING SHORELINE
- PROPERTY BOUNDARIES
- LANDFILL REFUSE BOUNDARY (MTCA SITE BOUNDARY NOT DETERMINED)

KEY TO PREVIOUS INVESTIGATIONS

B	BELLINGHAM MARINE INDUSTRIES
C	CHEVRON
N	BURLINGTON NORTHERN
E	DEPT. OF ECOLOGY
G	GEORGIA PACIFIC
Y	CITY OF BELLINGHAM
O	OLIVINE (PORT)
Q	SQUALICUM (PORT)
S	BORNSTEIN (PORT)
W	ROEDER AVENUE WAREHOUSE FEASABILITY ANALYSIS AND PRE-DESIGN TESTING
GW	GEORGIA PACIFIC WAREHOUSE DESIGN INVESTIGATIONS

N

0 90 180 360
SCALE IN FEET

ThermoRetec

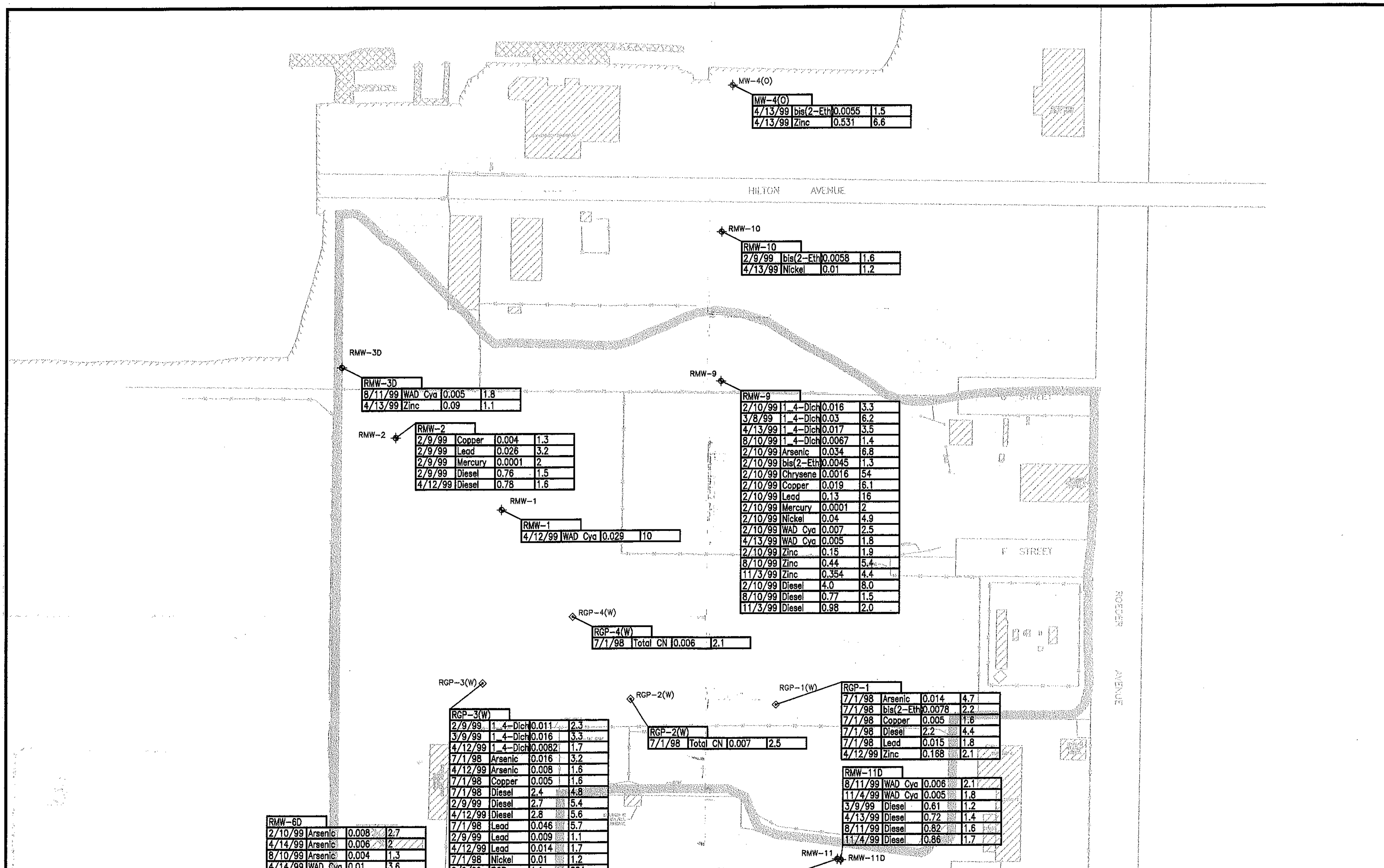
ROEDER AVENUE LANDFILL RI/FS

PORTB-03809-710

DATE: 06/01/01 | DRWN: N.S. | FILE: 3809S208

GENERALIZED SUMMARY OF SITE GROUNDWATER FEATURES

FIGURE 4-1



MW-4(O)			
4/13/99	bis(2-Eth	0.0055	1.5
4/13/99	Zinc	0.531	6.6

RMW-10			
2/9/99	bis(2-Eth	0.0058	1.6
4/13/99	Nickel	0.01	1.2

RMW-3D			
8/11/99	WAD Cya	0.005	1.8
4/13/99	Zinc	0.09	1.1

RMW-2			
2/9/99	Copper	0.004	1.3
2/9/99	Lead	0.026	3.2
2/9/99	Mercury	0.0001	2
2/9/99	Diesel	0.76	1.5
4/12/99	Diesel	0.78	1.6

RMW-1			
4/12/99	WAD Cya	0.029	10

RMW-9			
2/10/99	1_4-Dich	0.016	3.3
3/8/99	1_4-Dich	0.03	6.2
4/13/99	1_4-Dich	0.017	3.5
8/10/99	1_4-Dich	0.0067	1.4
2/10/99	Arsenic	0.034	6.8
2/10/99	bis(2-Eth	0.0045	1.3
2/10/99	Chrysene	0.0016	54
2/10/99	Copper	0.019	6.1
2/10/99	Lead	0.13	16
2/10/99	Mercury	0.0001	2
2/10/99	Nickel	0.04	4.9
2/10/99	WAD Cya	0.007	2.5
4/13/99	WAD Cya	0.005	1.8
2/10/99	Zinc	0.15	1.9
8/10/99	Zinc	0.44	5.4
11/3/99	Zinc	0.354	4.4
2/10/99	Diesel	4.0	8.0
8/10/99	Diesel	0.77	1.5
11/3/99	Diesel	0.98	2.0

RGP-4(W)			
7/1/98	Total CN	0.006	2.1

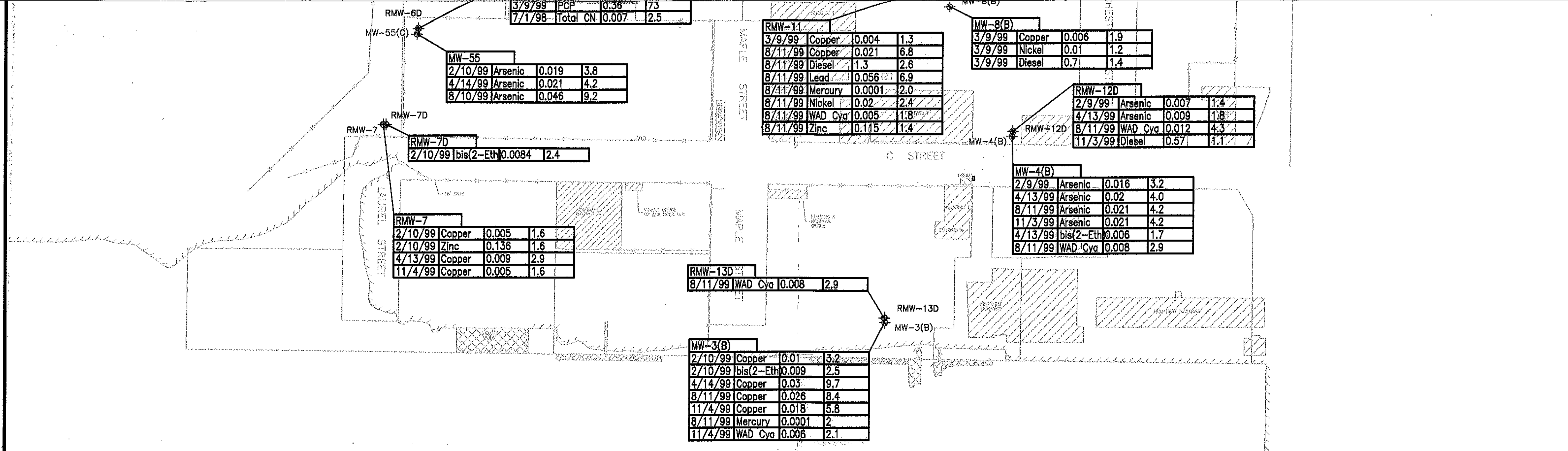
RGP-3(W)			
2/9/99	1_4-Dich	0.011	2.3
3/9/99	1_4-Dich	0.016	3.3
4/12/99	1_4-Dich	0.0082	1.7
7/1/98	Arsenic	0.016	3.2
4/12/99	Arsenic	0.008	1.6
7/1/98	Copper	0.005	1.6
7/1/98	Diesel	2.4	4.8
2/9/99	Diesel	2.7	5.4
4/12/99	Diesel	2.8	5.6
7/1/98	Lead	0.046	5.7
2/9/99	Lead	0.009	1.1
4/12/99	Lead	0.014	1.7
7/1/98	Nickel	0.01	1.2
2/9/99	PCP	1.1	224

RGP-2(W)			
7/1/98	Total CN	0.007	2.5

RGP-1			
7/1/98	Arsenic	0.014	4.7
7/1/98	bis(2-Eth	0.0078	2.2
7/1/98	Copper	0.005	1.6
7/1/98	Diesel	2.2	4.4
7/1/98	Lead	0.015	1.8
4/12/99	Zinc	0.168	2.1

RMW-11D			
8/11/99	WAD Cya	0.006	2.1
11/4/99	WAD Cya	0.005	1.8
3/9/99	Diesel	0.61	1.2
4/13/99	Diesel	0.72	1.4
8/11/99	Diesel	0.82	1.6
11/4/99	Diesel	0.86	1.7

RMW-6D			
2/10/99	Arsenic	0.008	2.7
4/14/99	Arsenic	0.006	2
8/10/99	Arsenic	0.004	1.3
4/14/99	WAD Cya	0.01	3.6



DOCKS OR PIERS

EXISTING BUILDINGS

EXISTING SHORELINE

PROPERTY BOUNDARIES

LANDFILL BOUNDARY

RMW-6D — NEW DEEP WELL OR PIEZOMETER AT BASE OF SAND LAYER (BELOW WATER TABLE)

RMW-6 — NEW SHALLOW WELL OR PIEZOMETER ACROSS WATER TABLE

MW-2(B) — EXISTING WELLS USED DURING RI/FS

NOTE: EXCEEDANCE OF ARAR CONCENTRATIONS IN MONITORING WELL DOES NOT NECESSARILY INDICATE EXCEEDANCE OF MTCA CLEANUP LEVELS OR ARARS AT THE POINT OF EXPOSURE.

MW-3(B)

Date	Param	Conc	Exc. Fac.
2/10/99	Copper	0.01	3.2
4/14/99	Copper	0.03	9.7
2/10/99	bis(2-Eth)	9	2.5

\# OF TIMES CONC. EXCEEDS ARAR

CONCENTRATION (mg/L)

CHEMICAL PARAMETER

ABBREVIATED CHEMICAL NAMES
1_4-Dichl = 1,4-Dichlorobenzene
bis(2-Eth) = bis(2-Ethylhexyl)phthalate
WAD Cya = WAD Cyanide

70 0 140
1"=140'

ThermoRetec

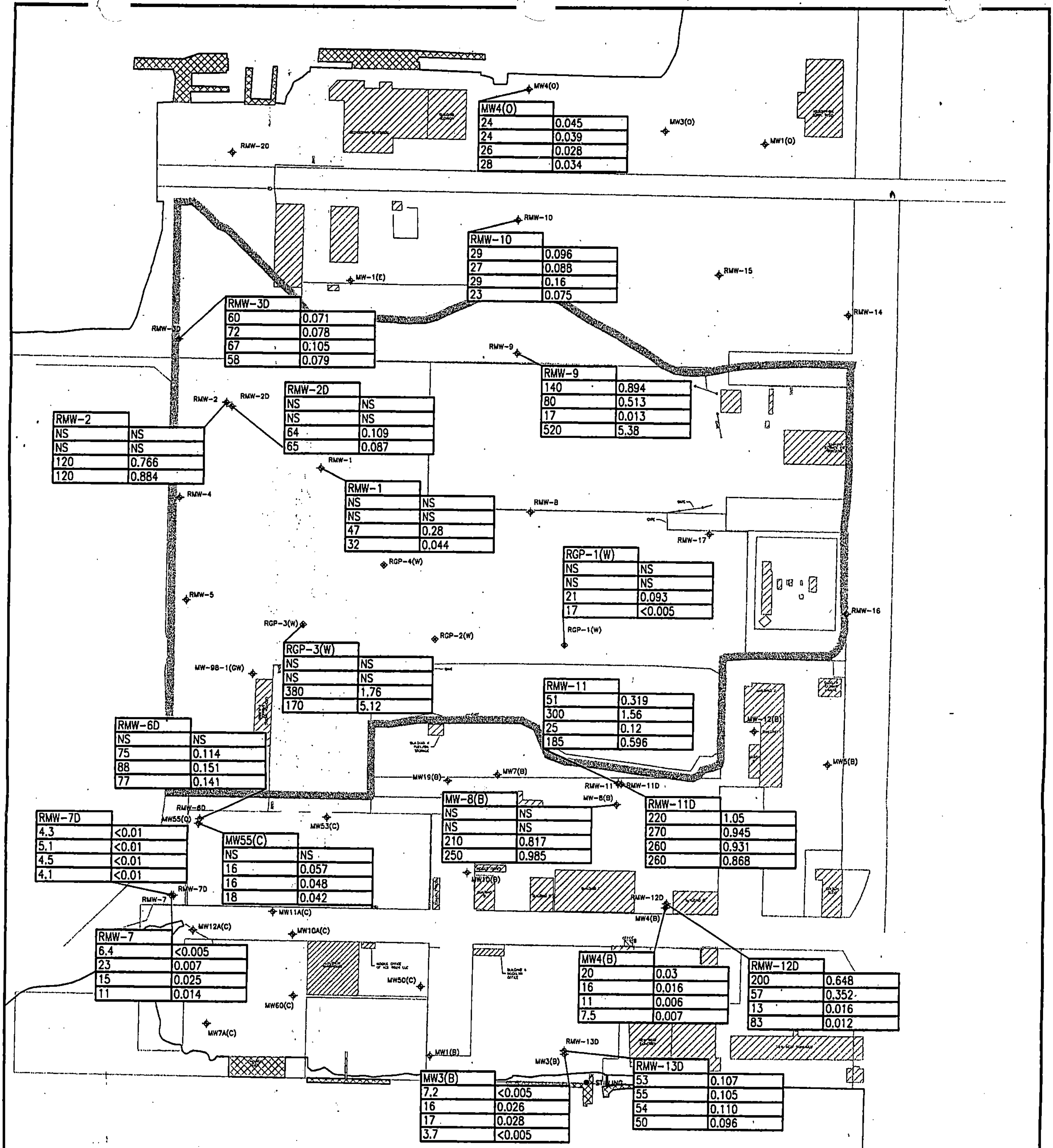
ROEDER AVENUE LANDFILL RI/FS

PORTB-03809-710

EXCEEDANCES OF SURFACE WATER ARARs IN SITE GROUNDWATER

DATE: 06/02/01 | DRWN: N.S. | FILE: 3809S210

FIGURE 4-2



MW4(O)	
24	0.045
24	0.039
26	0.028
28	0.034

RMW-10	
29	0.096
27	0.088
29	0.16
23	0.075

RMW-3D	
60	0.071
72	0.078
67	0.105
58	0.079

RMW-9	
140	0.894
80	0.513
17	0.013
520	5.38

RMW-2D	
NS	NS
NS	NS
64	0.109
65	0.087

RMW-2	
NS	NS
NS	NS
120	0.766
120	0.884

RMW-1	
NS	NS
NS	NS
47	0.28
32	0.044

RGP-1(W)	
NS	NS
NS	NS
21	0.093
17	<0.005

RGP-3(W)	
NS	NS
NS	NS
380	1.76
170	5.12

RMW-11	
51	0.319
300	1.56
25	0.12
185	0.596

RMW-6D	
NS	NS
75	0.114
88	0.151
77	0.141

RMW-7D	
4.3	<0.01
5.1	<0.01
4.5	<0.01
4.1	<0.01

MW55(C)	
NS	NS
16	0.057
16	0.048
18	0.042

MW-8(B)	
NS	NS
NS	NS
210	0.817
250	0.985

RMW-11D	
220	1.05
270	0.945
260	0.931
260	0.868

RMW-7	
6.4	<0.005
23	0.007
15	0.025
11	0.014

MW4(B)	
20	0.03
16	0.016
11	0.006
7.5	0.007

RMW-12D	
200	0.648
57	0.352
13	0.016
83	0.012

MW3(B)	
7.2	<0.005
16	0.026
17	0.028
3.7	<0.005

RMW-13D	
53	0.107
55	0.105
54	0.110
50	0.096

SHALLOW WELL LEGEND

- RMW-6D — NEW WELL OR PIEZOMETER AT BASE OF SAND LAYER (BELOW WATER TABLE)
- RMW-6 — NEW WELL OR PIEZOMETER ACROSS WATER TABLE
- MW-2(B) — EXISTING WELLS USED DURING RI/FS
- RGP-4(W) — GAS PROBE INSTALLED DURING WAREHOUSE FEASABILITY INVESTIGATION

LEGEND

- DOCKS OR PIERS
- EXISTING BUILDINGS
- EXISTING SHORELINE
- PROPERTY BOUNDARIES
- LANDFILL REFUSE BOUNDARY (MTCA SITE BOUNDARY NOT DETERMINED)

WELL NUMBER	
4th QUARTER	4th QUARTER
3rd QUARTER	3rd QUARTER
2nd QUARTER	2nd QUARTER
1st QUARTER	1st QUARTER
TOTAL ORGANIC CARBON	TOTAL CHROMIUM

CONCENTRATIONS GIVEN IN mg/L.
NS = NOT SAMPLED

0 90 180 360
SCALE IN FEET

ThermoRetec

ROEDER AVENUE LANDFILL RI/FS

PORTB-3809-710

DATE: 06/02/01 | DRWN: N.S. | FILE: 3809S209

TOTAL ORGANIC CARBON AND TOTAL CHROMIUM CONCENTRATIONS

FIGURE 4-3

Table 4-1 Monitoring Well Tidal Efficiency

Tidal Study Round 1						
Well Location	Minimum Elevation (MLLW)	Maximum Elevation (MLLW)	Net Fluctuation (feet)	Tidal Efficiency (%)	Tide Cycle	Lag Time (hrs:min)
Transect A						
RMW-2	NA	NA	NA	NA	High Low	NT
RMW-2D	NA	NA	NA	NA	High Low	NT
RMW-3D	7.52	9.23	1.71	20.66	High Low	0:40 0:40
Transect B						
RMW-7	5.96	8.83	2.87	26.54	High Low	0:30 1:30
RMW-7D	4.7	8.54	3.84	43.75	High Low	0:50 0:50
RMW-6D	8.24	9.89	1.65	19.79	High Low	2:10 2:00
MW-55(C)	NA	NA	NA	NA	High Low	NT
Transect C						
MW-3B	7.10	8.02	0.92	9.68	High Low	1:00 1:00
RMW-10	NA	NA	NA	NA	High Low	NT
MW-4(O)	6.27	8.45	2.18	24.98	High Low	0:30 0:40
Transect D						
RMW-13D	4.88	8.47	3.59	41.27	High Low	0:30 0:30
Tidal Stilling Gauge/ Staff Gauge						
Stilling Gauge	1	9.39	8.39	100	NA	NA
Other Wells for Piezometric Monitoring						
MW-3(O)	7.53	8.17	0.64	8.69	High Low	2:20 2:30
MW-1E	NA	NA	NA	NA	High Low	NT

NOTES:
NA - Not Applicable. Tidal efficiency is zero or too small to be calculated from data.
NT - No lag time trend was observed in data for these wells.

Table 4-1 (Cont'd)

Tidal Study Round 2						
Well Location	**Minimum Elevation (MLLW)**	**Maximum Elevation (MLLW)**	**Net Fluctuation (feet)**	**Tidal Efficiency (%)**	**Tide Cycle**	**Lag Time (hrs:min)**
Tidal Stilling Gauge/Staff Gauge						
Stilling Gauge	-0.28	8.62	8.9	100	NA	NA
Other Wells for Piezometric Monitoring						
MW-12A(C)	7.04	8.36	1.32	1.04	High Low	1:05 1:35
MW-7A(C)	6.72	8.64	1.92	8.80	High Low	0:50 2:15
MW-50(C)	7.58	7.96	0.38	1.72	High Low	NT
MW-53(C)	NA	NA	NA	NA	High Low	NT
MW-60(C)	5.88	8.20	2.32	22.85	High Low	0:45 0:40
MW-10A(C)	7.63	7.94	0.31	3.16	High Low	NT
MW-11A	NA	NA	NA	NA	High Low	NT
MW-1B	4.63	8.05	3.42	32.17	High Low	1:45 1:30
MW-10B	NA	NA	NA	NA	High Low	NT
MW-12B	NA	NA	NA	NA	High Low	NT

NOTES:

NA - Not Applicable. Tidal efficiency is zero or too small to be calculated from data.
NT - No lag time trend was observed in data for these wells.

Table 4-1 (Cont'd)

Preliminary Gauging	
Well	**Tidal Efficiency (%)**
MW-4(B)	NA
MW-5(B)	NA
MW-7(B)	NA
MW-8(B)	NA
MW-19(B)	NA
MW-1(O)	NA
MW-98-1(GW)	NA
RGP-1(W)	NA
RGP-2(W0	NA
RGP-3(W)	NA
RGP-4(W)	NA
RMW-1	NA
RMW-4	NA
RMW-5	NA
RMW-8	NA
RMW-9	NA
RMW-11	NA
RMW-11D	NA
RMW-12D	NA
RMW-14	NA
RMW-15	NA
RMW-16	NA
RMW-17	NA
RMW-18	NA
RMW-20	NA

NOTES:
NA - Not Applicable. Tidal efficiency is zero or too small to be calculated from data.

Table 4-2 Monitor Well Hydraulic Conductivity Values

Well	Slug Test Hydraulic Conductivity (ft/d)		Tidal Study Hydraulic Conductivity (ft/d)	Geologic Unit
	Injection	Withdrawal		
Transect A-Shallow				
RMW-1	Not tested	<28	Not applicable	Refuse
RMW-2	Not tested	16	Not applicable	Refuse
Transect A-Deep				
RMW-2D	21	21	Not applicable	Sand
RMW-3D	Not tested	40	Not applicable	Sand
Transect B - Shallow				
MW-55(C)	Not tested	65	Not applicable	Sand and Soil Fill
RMW-7	Not tested	71	Not applicable	Sand and Soil Fill
Transect B - Deep				
RMW-6D	Not tested	6.2	Not applicable	Sand
RMW-7D	4.8	Not tested	187	Sand
Transect C - Shallow				
RMW-10	Not tested	42	Not applicable	Sand and Soil Fill
RMW-8	Not tested	74	Not applicable	Refuse
RMW-9	Not tested	62	Not applicable	Refuse
MW-4(O)	Not tested	85	482	Sand and Soil Fill
Transect D -Shallow				
RMW-11	Not tested	<28	Not applicable	Sand and Soil Fill
MW-3(B)	Not tested	156	207	Sand and Soil Fill
MW-4(B)	Not tested	91	Not applicable	Sand and Soil Fill
MW-8(B)	Not tested	45	Not applicable	Sand and Soil Fill
Transect D - Deep				
RMW-13D	34	34	567	Sand
RMW-11D	Not tested	19	Not applicable	Sand
RMW-12D	Not tested	59	Not applicable	Sand
Other				
MW-60(C)	Not tested	Not tested	1,474	Sand and Soil Fill
RMW-4	Not tested	91	Not applicable	Sand and Refuse
RMW-5	Not tested	397	Not applicable	Refuse
RMW-14	Not tested	68	Not applicable	Sand and Glacial Marine Drift
RMW-15	Not tested	65	Not applicable	Sand and Soil Fill
RMW-16	Not tested	68	Not applicable	Sand and Refuse
RMW-17	Not tested	28	Not applicable	Refuse
RMW-18	Not tested	68	Not applicable	Sand and Soil Fill

Notes:

Conductivity estimates obtained from tidal study values are expected to represent the high range for the geologic unit. As discussed in the text, the tidal study calculations for conductivity require specific yield for the geologic units to be assumed based on literature data and soil type.

Table 4-3 Summary of Average Groundwater Gradients and Velocities

Transect Location	Measurement Period	Measured Gradients (ft/ft)		Estimated Flow Velocities (ft/day) [4]	
		Landfill Mound to Shoreline [1]	Landfill Edge to Shoreline [2]	Landfill Mound to Shoreline [1]	Landfill Edge to Shoreline [2]
Transect A (Deep Wells)		RMW-2D / RMW-3D		RMW-2D / RMW-3D	
(Beneath Landfill Berm, Toward I&J Waterway)	*Wet Season*				
	Feb-99	0.0115	--[3]	0.7	--[3]
	Apr-99	0.0153	--[3]	1.0	--[3]
	Dry Season				
	Nov-98	0.0094	--[3]	0.6	--[3]
	Aug-99	--	--	--[3]	--[3]
	Nov-99	--	--	--[3]	--[3]
Transect B		RGP-4 / RMW-7	MW-55(C) / RMW-7	RGP-4 / RMW-7	MW-55(C) / RMW-7
(Across Chevron, Toward Whatcom Waterway)	*Wet Season*				
	Feb-99	0.0126	0.0134	3.1	3.3
	Apr-99	0.0133	0.0102	3.3	2.5
	Dry Season				
	Nov-98	0.0058	0.0059	1.4	1.4
	Aug-99	--	0.0107	--	2.6
	Nov-99	--	--	--	--
Transect B (Deep Wells)			RMW-6D / RMW-7D		RMW-6D / RMW-7D
(Across Chevron, Toward Whatcom Waterway)	*Wet Season*				
	Feb-99	--[5]	0.012	--[5]	0.8
	Apr-99	--[5]	0.023	--[5]	1.5
	Dry Season				
	Nov-98	--[5]	0.017	--[5]	1.1
	Aug-99	--[5]	0.022	--[5]	1.4
	Nov-99	--[5]	--	--[5]	--
Transect C		RMW-8 / MW-4(O)	RMW-10 / MW-4(O)	RMW-8 / MW-4(O)	RMW-10 / MW-4(O)
(Across Olivine Site, Toward I&J Waterway)	*Wet Season*				
	Feb-99	0.0087	0.0113	2.1	2.8
	Apr-99	0.0095	0.0123	2.4	3.0
	Dry Season				
	Nov-98	0.0054	0.0050	1.3	1.2
	Aug-99	--	0.0068	--	1.7
	Nov-99	--	0.0063	--	1.5
Transect D		RGP-1 / MW-3(B)	RMW-11 / MW-3(B)	RGP-1 / MW-3(B)	RMW-11 / MW-3(B)
(Across BMI, Toward Whatcom Waterway)	*Wet Season*				
	Feb-99	--	--	--	--
	Apr-99	0.0108	0.0052	2.7	1.3
	Dry Season				
	Nov-98	0.0058	0.0033	1.4	0.8
	Aug-99	--	0.0040	--	1.0
	Nov-99	--	0.0047	--	1.2
Transect D (Deep Wells)			RMW-11D / RMW-13D		RMW-11D / RMW-13D
(Across BMI, Toward Whatcom Waterway)	*Wet Season*				
	Feb-99	--[5]	--	--[5]	--
	Apr-99	--[5]	0.0084	--[5]	0.5
	Dry Season				
	Nov-98	--[5]	0.0047	--[5]	0.3
	Aug-99	--[5]	0.0070	--[5]	0.4
	Nov-99	--[5]	0.0063	--[5]	0.4

Notes:

These gradients are presented for comparative purposes only. Actual groundwater flow velocities and travel times will be determined using the completed groundwater model. In this table the term "shoreline" is used to reference the well closest to the shoreline, not the point of actual groundwater discharge.

--: Some gradients could not be calculated due to well abandonment as anticipated in the RI/FS Work Plan.

1. These gradients & velocities are calculated between the approximate center of the Landfill mound and the well closest to the shoreline.
2. These gradients are calculated between the edge of the Landfill and the monitoring well closest to the shoreline. These gradients are anticipated to determine flow velocity and travel times between the edge of the Landfill and the shoreline.
3. Monitoring well RMW-3D is located along the Landfill Berm (edge of Landfill), near the shoreline.
4. Flow velocities have been calculated assuming a porosity of 0.3, and assuming hydraulic conductivities of 74 feet per day for the refuse and soil fill units and of 19 feet per day for the native sand unit. Final velocities will be determined using the findings of groundwater modeling.
5. No deep wells are present within the Landfill area along transects B and D.

Table 4-4 Paired Monitoring Well Water Level Elevations & Gradients

Well Pair	Date	Relative Well Depth S = Shallow D = Deep	Water Level Elevation (ft. above MLLW)	Water Level Elevation Difference (ft)	Gradient Direction
Transect A -- Within Landfill (RMW-2 / RMW-2D)					
RMW-2 RMW-2D	Nov-98	S D	10.71 9.43	1.28	Down
RMW-2 RMW-2D	Feb-99	S D	14.30 11.96	2.34	Down
RMW-2 RMW-2D	Apr-99	S D	13.33 10.98	2.35	Down
Transect B -- Edge of Landfill (MW-55(C) / RMW-6D)					
MW-55(C) RMW-6D	Nov-98	S D	8.33 8.65	-0.32	Up
MW-55(C) RMW-6D	Feb-99	S D	10.27 10.13	0.14	Down
MW-55(C) RMW-6D	Apr-99	S D	8.51 9.11	-0.60	Up
MW-55(C) RMW-6D	Aug-99	S D	9.16 8.69	0.47	Down
Transect B -- Shoreline Area (RMW-7 / RMW-7D)					
RMW-7 RMW-7D	Nov-98	S D	7.54 6.35	1.19	Down
RMW-7 RMW-7D	Feb-99	S D	8.46 8.49	-0.03	Up
RMW-7 RMW-7D	Apr-99	S D	7.13 5.99	1.14	Down
RMW-7 RMW-7D	Aug-99	S D	7.71 5.70	2.01	Down
RMW-7 RMW-7D	Nov-99	S D	7.71 6.26	1.45	Down
Transect D -- Edge of Landfill (RMW-11 / RMW-11D)					
RMW-11 RMW-11D	Nov-98	S D	8.71 8.72	-0.01	Up
RMW-11 RMW-11D	Apr-99	S D	10.27 10.28	-0.01	Up
RMW-11 RMW-11D	Aug-99	S D	9.42 9.46	-0.04	Up
RMW-11 RMW-11D	Nov-99	S D	9.85 9.77	0.08	Down
Transect D -- Intermediate Location (MW-4(B) / RMW-12D)					
MW-4(B) RMW-12D	Nov-98	S D	8.04 8.04	0	--
MW-4(B) RMW-12D	Feb-99	S D	9.57 9.57	0	--
MW-4(B) RMW-12D	Apr-99	S D	9.43 9.41	0.02	Down
MW-4(B) RMW-12D	Aug-99	S D	8.37 8.39	-0.02	Up
MW-4(B) RMW-12D	Nov-99	S D	8.39 8.65	-0.26	Up
Transect D -- Shoreline Area (MW-3(B) / RMW-13D)					
MW-3(B) RMW-13D	Nov-98	S D	7.15 6.46	0.69	Down
MW-3(B) RMW-13D	Feb-99	S D	8.54 7.65	0.89	Down
MW-3(B) RMW-13D	Apr-99	S D	7.77 6.27	1.50	Down
MW-3(B) RMW-13D	Aug-99	S D	7.51 6.12	1.39	Down
MW-3(B) RMW-13D	Nov-99	S D	7.60 6.75	0.85	Down

Table 4-5 Revised Landfill COC List

Contaminants of Concern	Maximum Exceedance Ratio				
	Landfill Wells	I&J Waterway Shoreline		Whatcom Waterway Shoreline	
		Transect A	Transect C	Transect B	Transect D
Arsenic	**6.8**	< 1	< 1	< 1	< 1
Copper	**6.1**	< 1	< 1	**2.9** [1]	**9.7** [1]
Lead	**16**	< 1	< 1	< 1	< 1
Mercury	**2.0**	< 1	< 1	< 1	**2.0**
Nickel	**4.9**	< 1	< 1	< 1	< 1
Zinc	**5.4**	**1.1**	**6.6** [4]	**1.6**	< 1
WAD Cyanide	**10**	**1.8**	< 1	< 1	**2.9**
Diesel Hydrocarbons	**8.0**	< 1	< 1	< 1 [2]	< 1
Pentachlorophenol	**224** [3]	< 1	< 1	< 1	< 1
Bis(2-ethylhexyl)phthalate	**1.3**	< 1	**1.5**	**2.4**	< 1
1,4-Dichlorobenzene	**6.2**	< 1	< 1	< 1	< 1

Notes:

1. Elevated copper concentrations along the shoreline at Transect D appear to be attributable to non-Landfill contaminant sources on the BMI property. Elevated copper and arsenic concentrations have also be detected at the Chevron property in shallow groundwater.
2. Additional sources of petroleum hydrocarbon contamination are known to exist at the Chevron site. Areas along the Whatcom Waterway with existing contamination attributable to Chevron sources are not included in this value.
3. Pentachlorophenol was detected in only one well out of the 22 that were monitored during the RI/FS. The exceedence factor shown here is representative of only this one well (RGP-3)
4. Zinc was detected above ARARs at the location in only one of four sampling events. Zinc was not detected above ARARs at RMW-10, located in between the shoreline and the Landfill boundary.

Table 4-6. Surface Water Criteria and Statistical Methods for Evaluating Compliance

Contaminant	Controlling Surface Water Standard (Applicable to Point of Exposure) [1]		MTCA Criteria for Potable Groundwater (Not Applicable per WAC 173-160-205)[4]		Appropriate Basis for Compliance Monitoring	Compliance Monitoring Notes
	Basis for Criteria	Concentration (mg/L)	Basis for Criteria	Concentration (mg/L)		
Semivolatile Organics						
1,4-Dichlorobenzene	Method B Surface Water	0.00486	Method B Groundwater	0.00182	Mean	Carcinogen -- Use mean to assess compliance.
Bis(2-Ethylhexyl)phthalate	Method B Surface Water	0.00356	Method B Groundwater	0.00625	Mean	Carcinogen -- Use mean to assess compliance.
	Sediment Source Control	0.00070 [5]				
PCP	Method B Surface Water	0.00491	Method B Groundwater	0.000729	Mean	Carcinogen -- Use mean to assess compliance.
Petroleum Hydrocarbons						
Diesel	MTCA Method A and Most Stringent Toxicity Data	0.5 [2]	MTCA Method A Groundwater	0.5	UCL	UCL appropriate for evaluation of potential acute effects to ecological receptors.
Conventionals						
WAD Cyanide	WAC 173-201A	0.0028	Method B Groundwater	0.32	Mean	Compliance evaluated using mean concentration. For point sources, the one-hour average is not to be exceeded more than once every three years on average.
Heavy Metals						
Arsenic	Natural background	0.005 [3]	Natural background	0.005 to 0.015 [3]	Mean	Carcinogen -- Use mean to assess compliance.
Copper	WAC 173-201A	0.0031	Method B Groundwater	0.592	Mean	Compliance evaluated using mean concentration. For point sources, the monthly average is not to be exceeded more than once per three years on average.
Lead	WAC 173-201A	0.0081	Method A Groundwater	0.005	Mean	Compliance evaluated using mean concentration. For point sources, the monthly average is not to be exceeded more than once per three years on average.
Mercury	Natural background	0.00005	Method B Groundwater	0.0048	UCL	Non-carcinogen -- use 95% UCL and statistical tests to assess compliance
Nickel	WAC 173-201A	0.0082	Method B Groundwater	0.32	Mean	Compliance evaluated using mean concentration. For point sources, the monthly average is not to be exceeded more than once per three years on average.
Zinc	WAC 173-201A	0.081	Method B Groundwater	4.8	Mean	Compliance evaluated using mean concentration. For point sources, the monthly average is not to be exceeded more than once per three years on average.

Notes:

1. Surface water criteria are applicable only at the Point of Exposure. However, concentrations in groundwater must be protective of surface water.Attenuation factors determined during the remedial investigation (see Sections 6 and 7) may be used to determine groundwater concentrations that will prevent exceedance of surface water criteria at the point of exposure.
2. The MTCA regulations and ARAR do not provide a surface water standard for diesel-range petroleum hydrocarbons. As described in Section 2.4 the use of the 0.5 mg/L MTCA Method A cleanup level for diesel was selected for use as a screening level in the RI/FS after review of aquatic toxicity test data for petroleum hydrocarbons. See Section 2.4 for the scientific basis for this screening level and for a discussion of what actions could be conducted if the development of a less stringent site-specific standard is desired.
3. Arsenic is naturally-occuring in Washington state groundwater at concentrations typically between 0.005 and 0.015 mg/L. Criteria applied to groundwater discharging at the Point of Exposure should be adjusted to between 0.005 and 0.015 mg/L to account for natural background influences.
4. These groundwater cleanup levels specified under MTCA for use where groundwater is a potential current or future source of drinking water are not applicable to the Landfill site, but are provided here for reference. In most cases the surface water standard is equal to or more stringent than the corresponding drinking-water based groundwater standard.
5. Sediment source control calculations (Section 7) suggest that the surface water cleanup level for bis(2-ethylhexyl)phthalate as applied to groundwater discharging into the point of exposure may need to be reduced by 5X to prevent sediment recontamination. Both the surface water cleanup level and the sediment source control value are shown here. The influences of soil/water partitioning on the attenuation of phthalates between the Landfill and the point of exposure are discussed in Section 7.

Table 4-7. Landfill Wells Included in Statistical Analysis of Landfill Groundwater

	RI/FS Work Plan Sampling Jul-98	1st Quarter Sampling Feb-99	1st Quarter Resampling Mar-99	2nd Quarter Sampling Apr-99	3rd Quarter Sampling Aug-99	4th Quarter Sampling Nov-99	Total All Events
Semivolatile Organics							
RGP-1:	1	2		1			4
RGP-2:	1						1
RGP-3:	1	1	1	1			4
RGP-4:	1						1
RMW-1:		1		1			2
RMW-2:		1		1			2
RMW-9:		1		2	1	1	6
				Total All Refuse Wells			**20**
Heavy Metals							
RGP-1:	1	2		1			4
RGP-2:	2						2
RGP-3:	1	1		1			3
RGP-4:	1						1
RMW-1:		1		1			2
RMW-2:		1		1			2
RMW-9:		1		2	1	1	5
				Total All Refuse Wells			**19**
Petroleum Hydrocarbons							
RGP-1:	1	2		1			4
RGP-2:	2						2
RGP-3:	1	1		1			3
RGP-4:	1						1
RMW-1:		1		1			2
RMW-2:		1		1			2
RMW-9:		1		2	1	1	5
				Total All Refuse Wells			**19**
WAD Cyanide							
RGP-1:	1*	2		1			3
RGP-2:	2*						0
RGP-3:	1*	1		1			2
RGP-4:	1*						0
RMW-1:		1		1			2
RMW-2:		1		1			2
RMW-9:		1		2	1	1	5
				Total All Refuse Wells			**14**

Notes:

Duplicate anlayses are indicated by a "2" in the column for the specific sampling event.

* Initial cyanide measurements collected during July of 1998 were performed using the "total cyanide analysis protocol, rather than the WAD cyanide sampling protocol. These analyses were not included in the statistical analysis of landfill leachate, because the total cyanide test tends to overestimate the cyanide concentration measureable using the WAD cyanide testing protocol.

Table 4-8. Statistical Analysis of Landfill Groundwater Data -- Direct Discharge Scenario

Groundwater Parameter	ARAR Value	Number of Samples	Number of Detections	Number of ARAR Exceedances	% of Samples with ARAR Exceedances	Minimum Value (inlcuding DL)	Maximum Value (inlcuding DL)	Maximum Exceed. Ratio	Non-Detects = One-half the Reporting Limit: Arithmetic Mean	Geometric Mean	Mean as 95% UCL	Mean Exceedance Ratios[2] (Ar. Mean)	(95% UCL)
Contaminants Above ARARs													
1,4-Dichlorobenzene (ug/L)	4.86	20	12	8	40.0%	1	18	3.7	5.30	2.26	7.92	**1.09**	1.63
Arsenic	0.005	19	15	4	21.1%	0.001	0.034	6.8	0.0054	0.0028	0.0091	**1.1**	1.8
Diesel Range Hydrocarbons	0.5	19	15	10	52.6%	0.25	4	8.0	1.08	0.62	1.60	2.17	**3.20**
Lead	0.0081	19	12	6	31.6%	0.001	0.13	16.0	0.0144	0.0034	0.0280	**1.8**	3.5
Mercury	0.00005	19	2	2	10.5%	0.0001	0.0002	4.0	0.00006	0.00006	0.00007	1.21	**1.40**
Pentachlorophenol (ug/L)	4.91	20	2	2	10.0%	5	640	130.3	52.8	4.2	123.2	**10.7**	25.1
Weak Acid Dissoc. Cyanide	0.0028	14	3	3	21.4%	0.004	0.029	10.4	0.0049	0.0038	0.0086	**1.7**	3.1
Zinc	0.081	19	18	4	21.1%	0.004	0.44	5.4	0.081	0.033	0.136	**1.00**	1.68
Contaminants Below ARARs													
Bis(2-Ethylhexyl)phthalate (ug/L)	3.56	20	8	2	10.0%	1	7.8	2.2	1.52	0.96	2.33	**0.43**	0.65
Bis(2-Ethylhexyl)phthalate (ug/L)	0.70 [1]	20	8	8	40.0%	1	7.8	11.1	1.52	0.96	2.33	**2.17**	3.33
Copper	0.0031	19	5	4	21.1%	0.002	0.019	6.1	0.0026	0.0016	0.0045	**0.85**	1.46
Nickel	0.0082	19	2	2	10.5%	0.01	0.04	4.9	0.0071	0.0058	0.0107	**0.87**	1.31
Leachate Indicators													
Total Chromium	162	19	17	0	0.0%	0.005	9.78	0.1	1.62	0.19	2.84	**0.01**	0.02
Total Organic Carbon	—	14	14	na	na	16	520	na	121.2	62.4	200.5	na	na

Note:

UCL: Upper confidence limit

Contaminant concentrations are shown in units of mg/L unless otherwise indicated. Semivolatile organics are shown in units of micrograms per liter.

See Table 4-7 for a summary of analytical data included in statistical analysis of landfill groundwater quality. See Table 4-6 for a description of the cleanup levels.

1. Based on the results of sediment source control analyses performed as described in Section 7, the surface water ARAR for bis(2-ethylhexyl)phthalate may need to be reduced by a factor of 5X (from 3.56 to 0.71 ug/L) in order to be protective of marine sediment concentrations. Statistical calculations are shown both for the surface water ARAR (MTCA Method B Surface water cleanup level) and for the lower sediment source-control value.
2. The exceedance ratio is a direct comparison of the mean or UCL groundwater concentrations with the surface water cleanup level or ARAR defined in Section 2.4 and Table 4-6 for the point-of-exposure. A ratio equal to or less than 1.0 indicates that the mean or UCL concentration at the specified montoring locations would be protective of surface water receptors if this water discharged without attenuation into the point-of-exposure.

Table 4-9. Statistical Analysis of Groundwater Data -- Hilton Avenue

Wel Parameter	ARAR Value	Number of Samples	Number of Detections	Number of ARAR Exceedences	% of Samples with ARAR Exceedences	Minimum Value (inlcuding DL)	Maximum Value (inlcuding DL)	Maximum Exceed. Ratio	Non-Detects = One-half the Reporting Limit: Arithmetic Mean	Geometric Mean	Mean as 95% UCL	Well Exceedance Ratios[2] (Ar. Mean)	(95% UCL)
Well RMW-10 Analytical Data													
Contaminants Above ARARs in Leachate													
1,4-Dichlorobenzene (ug/L)	4.86	4	0	0	0.0%	1	1	nd	0.500	0.500	nd	nd	nd
Arsenic	0.005	4	2	0	0.0%	0.001	0.001	0.2	0.0008	0.0007	0.0010	0.15	0.21
Diesel Range Hydrocarbons	0.5	4	1	0	0.0%	0.25	0.25	0.5	0.156	0.149	0.217	0.31	0.43
Lead	0.0081	4	0	0	0.0%	0.001	0.001	nd	0.0005	0.0005	nd	nd	nd
Mercury	0.00005	4	0	0	0.0%	0.0001	0.0002	nd	0.0001	0.0001	nd	nd	nd
Pentachlorophenol (ug/L)	4.91	4	0	0	0.0%	5	5	nd	2.50	2.50	nd	nd	nd
Weak Acid Dissoc. Cyanide	0.0028	4	0	0	0.0%	0.005	0.005	nd	0.0025	0.0025	nd	nd	nd
Zinc	0.081	4	4	0	0.0%	0.006	0.008	0.1	0.0068	0.0067	0.0077	0.08	0.09
Contaminants Below ARARs in Leachate													
Bis(2-Ethylhexyl)phthalate (ug/L)	3.56	4	1	1	25.0%	1	5.8	1.6	1.83	0.92	4.42	0.51	1.24
Bis(2-Ethylhexyl)phthalate (ug/L)	0.70 [1]	4	1	1	25.0%	1	5.8	8.3	1.83	0.92	4.42	2.61	6.32
Copper	0.0031	4	0	0	0.0%	0.002	0.002	nd	0.0010	0.0010	nd	nd	nd
Nickel	0.0082	4	1	1	25.0%	0.01	0.01	1.2	0.0063	0.0059	0.0087	0.8	1.1
Leachate Indicators													
Total Chromium	162	4	4	0	0.0%	0.075	0.16	0.0	0.105	0.100	0.142	0.00065	0.00088
Total Organic Carbon	—	4	4	0	0.0%	23	29	na	27.00	26.88	29.77	na	na
Well MW-4(O) Analytical Data													
Contaminants Above ARARs in Leachate													
1,4-Dichlorobenzene (ug/L)	4.86	4	0	0	0.0%	1	1	nd	0.5000	0.5000	nd	nd	nd
Arsenic	0.005	4	0	0	0.0%	0.001	0.001	nd	0.0005	0.0005	nd	nd	nd
Diesel Range Hydrocarbons	0.5	4	0	0	0.0%	0.25	0.25	nd	0.1250	0.1250	nd	nd	nd
Lead	0.0081	4	0	0	0.0%	0.001	0.001	nd	0.0005	0.0005	nd	nd	nd
Mercury	0.00005	4	0	0	0.0%	0.0001	0.0002	nd	0.0001	0.0001	nd	nd	nd
Pentachlorophenol (ug/L)	4.91	4	0	0	0.0%	5	5	nd	2.5000	2.5000	nd	nd	nd
Weak Acid Dissoc. Cyanide	0.0028	4	0	0	0.0%	0.005	0.005	nd	0.0025	0.0025	nd	nd	nd
Zinc	0.081	4	2	1	25.0%	0.004	0.531	6.6	0.1360	0.0126	0.3941	1.68	4.87
Contaminants Below ARARs in Leachate													
Bis(2-Ethylhexyl)phthalate (ug/L)	3.56	4	2	1	25.0%	1	5.5	1.5	2.1250	1.2878	4.4363	0.60	1.25
Bis(2-Ethylhexyl)phthalate (ug/L)	0.70 [1]	4	2	2	50.0%	1	5.5	7.9	2.1250	1.2878	4.4363	3.04	6.34
Copper	0.0031	4	0	0	0.0%	0.002	0.002	nd	0.0010	0.0010	nd	nd	nd
Nickel	0.0082	4	0	0	0.0%	0.01	0.01	nd	0.0050	0.0050	nd	nd	nd
Leachate Indicators													
Total Chromium	162	4	4	0	0.0%	0.028	0.045	0.0	0.0365	0.0360	0.0436	0.00023	0.00027
Total Organic Carbon	—	4	4	0	0.0%	24	28	na	25.5000	25.4471	25.5600	na	na

Note:

UCL: Upper confidence limit

Contaminant concentrations are shown in units of mg/L unless otherwise indicated. Semivolatile organics are shown in units of micrograms per liter.

See Appendix B for raw analytical data included in statistical analysis. See Table 4-6 for a description of the cleanup levels.

1. Based on the results of sediment source control analyses performed as described in Section 7, the surface water ARAR for bis(2-ethylhexyl)phthalate may need to be reduced by a factor of 5X (from 3.56 to 0.71 ug/L) be protective of marine sediment concentrations. Statistical calculations are shown both for the surface water ARAR (MTCA Method B Surface water cleanup level) and for the lower sediment source-control value.
2. The exceedance ratio is a direct comparison of the mean or UCL groundwater concentrations with the surface water cleanup level or ARAR defined in Section 2.4 and Table 4-6 for the point-of-exposure. A ratio equal or less than 1.0 indicates that the mean or UCL concentration at the specified montoring locations would be protective of surface water receptors if this water discharged without attenuation into the point-of-exposure.

Table 4-10. Statistical Analysis of Groundwater Data -- Foot of Hilton

Wel Parameter	ARAR Value	Number of Samples	Number of Detections	Number of ARAR Exceedences	% of Samples with ARAR Exceedences	Minimum Value (inlcuding DL)	Maximum Value (inlcuding DL)	Maximum Exceed. Ratio	Non-Detects = One-half the Reporting Limit				
									Arithmetic Mean	Geometric Mean	Mean as 95% UCL	Exceedance Ratios[2] (Ar. Mean)	(95% UCL)
Well RMW-2D Analytical Data													
Contaminants Above ARARs in Leachate													
1,4-Dichlorobenzene (ug/L)	4.86	2	0	0	0.0%	1	1	nd	0.5000	0.5000	nd	nd	nd
Arsenic	0.005	2	2	0	0.0%	0.002	0.002	0.4	0.0020	0.0020	0.0020	**0.40**	0.40
Diesel Range Hydrocarbons	0.5	2	0	0	0.0%	0.25	0.25	nd	0.1250	0.1250	nd	nd	nd
Lead	0.0081	2	0	0	0.0%	0.001	0.001	nd	0.0005	0.0005	nd	nd	nd
Mercury	0.00005	2	0	0	0.0%	0.0001	0.0001	nd	0.0001	0.0001	nd	nd	nd
Pentachlorophenol (ug/L)	4.91	2	0	0	0.0%	5	5	nd	2.5000	2.5000	nd	nd	nd
Weak Acid Dissoc. Cyanide	0.0028	2	0	0	0.0%	0.005	0.005	nd	0.0025	0.0025	nd	nd	nd
Zinc	0.081	2	1	0	0.0%	0.004	0.007	0.1	0.0045	0.0037	0.0094	**0.06**	0.1
Contaminants Below ARARs in Leachate													
Bis(2-Ethylhexyl)phthalate (ug/L)	3.56	2	0	0	0.0%	1	1	nd	0.5000	0.5000	nd	nd	nd
Bis(2-Ethylhexyl)phthalate (ug/L)	0.70 [1]	2	0	0	0.0%	1	1	nd	0.5000	0.5000	nd	nd	nd
Copper	0.0031	2	0	0	0.0%	0.002	0.002	nd	0.0010	0.0010	nd	nd	nd
Nickel	0.0082	2	0	0	0.0%	0.01	0.01	nd	0.0050	0.0050	nd	nd	nd
Leachate Indicators													
Total Chromium	162	2	2	0	0.0%	0.087	0.109	0.0	0.098	0.097	0.120	**0.00060**	0.00074
Total Organic Carbon	—	2	2	0	0.0%	64	65	na	64.50	64.50	65.48	na	na
Well RMW-3D Analytical Data													
Contaminants Above ARARs in Leachate													
1,4-Dichlorobenzene (ug/L)	4.86	4	0	0	0.0%	1	1	nd	0.5000	0.5000	nd	nd	nd
Arsenic	0.005	4	3	0	0.0%	0.001	0.001	0.2	0.0009	0.0008	0.0011	**0.18**	0.22
Diesel Range Hydrocarbons	0.5	4	0	0	0.0%	0.25	0.25	nd	0.1250	0.1250	nd	nd	nd
Lead	0.0081	4	0	0	0.0%	0.001	0.001	nd	0.0005	0.0005	nd	nd	nd
Mercury	0.00005	4	0	0	0.0%	0.0001	0.0002	nd	0.0001	0.0001	nd	nd	nd
Pentachlorophenol (ug/L)	4.91	4	0	0	0.0%	5	5	nd	2.5000	2.5000	nd	nd	nd
Weak Acid Dissoc. Cyanide	0.0028	5	1	1	20.0%	0.004	0.005	1.8	0.0029	0.0027	0.0039	**1.04**	1.41
Zinc	0.081	4	3	1	25.0%	0.006	0.09	1.1	0.0300	0.0149	0.0695	**0.37**	0.86
Contaminants Below ARARs in Leachate													
Bis(2-Ethylhexyl)phthalate (ug/L)	3.56	4	2	0	0.0%	1	3.3	0.9	1.4250	1.0367	2.7186	**0.40**	0.76
Bis(2-Ethylhexyl)phthalate (ug/L)	0.70 [1]	4	2	2	50.0%	1	3.3	4.7	1.4250	1.0367	2.7186	**2.04**	3.88
Copper	0.0031	4	0	0	0.0%	0.002	0.002	nd	0.0010	0.0010	nd	nd	nd
Nickel	0.0082	4	0	0	0.0%	0.01	0.01	nd	0.0050	0.0050	nd	nd	nd
Leachate Indicators													
Total Chromium	162	4	4	0	0.0%	0.071	0.105	0.0	0.0833	0.0823	0.0979	**0.00051**	0.00060
Total Organic Carbon	—	4	4	0	0.0%	58	72	na	64.2500	64.0098	70.5694	na	na

Note:

Contaminant concentrations are shown in units of mg/L unless otherwise indicated. Semivolatile organics are shown in units of micrograms per liter.
See Appendix B for raw analytical data included in statistical analysis. See Table 4-6 for a description of the cleanup levels.

1. Based on the results of sediment source control analyses performed as described in Section 7, the surface water ARAR for bis(2-ethylhexyl)phthalate may need to be reduced by a factor of 5X (from 3.56 to 0.71 ug/L) be protective of marine sediment concentrations. Statistical calculations are shown both for the surface water ARAR (MTCA Method B Surface water cleanup level) and for the lower sediment source-control value.
2. The exceedance ratio is a direct comparison of the mean or UCL groundwater concentrations with the surface water cleanup level or ARAR defined in Section 2.4 and Table 4-6 for the point-of-exposure. A ratio equal or less than 1.0 indicates that the mean or UCL concentration at the specified montoring locations would be protective of surface water receptors if this water discharged without attenuation into the point-of-exposure.

Table 4-[illegible] Statistical Analysis of Groundwater Data – C-Street Landfill Property Boundary Areas

Wel Parameter	ARAR Value	Number of Samples	Number of Detections	Number of ARAR Exceedences	% of Samples with ARAR Exceedences	Minimum Value (inlcuding DL)	Maximum Value (inlcuding DL)	Maximum Exceed. Ratio	Non-Detects = One-half the Reporting Limit: Arithmetic Mean	Geometric Mean	Mean as 95% UCL	Exceedance Ratios[2] (Ar. Mean)	(95% UCL)
Well RMW-11 Analytical Data													
Contaminants Above ARARs in Leachate													
1,4-Dichlorobenzene (ug/L)	4.86	4	0	0	0.0%	1	1	nd	0.5000	0.5000	nd	nd	nd
Arsenic	0.005	6	6	0	0.0%	0.002	0.004	0.8	0.0035	0.0034	0.0042	0.7	0.8
Diesel Range Hydrocarbons	0.5	5	5	1	20.0%	0.36	1.3	2.6	0.5820	0.5078	0.9347	1.2	1.9
Lead	0.0081	6	5	1	16.7%	0.001	0.056	6.9	0.0126	0.0045	0.0297	1.6	3.7
Mercury	0.00005	5	1	1	20.0%	0.0001	0.0002	4.0	0.00007	0.00007	0.00009	1.4	1.9
Pentachlorophenol (ug/L)	4.91	4	0	0	0.0%	5	5	nd	2.5000	2.5000	nd	nd	nd
Weak Acid Dissoc. Cyanide	0.0028	6	1	1	16.7%	0.004	0.005	1.8	0.0028	0.0027	0.0037	1.0	1.3
Zinc	0.081	6	4	1	16.7%	0.006	0.115	1.4	0.0283	0.0127	0.0628	0.3	0.8
Contaminants Below ARARs in Leachate													
Bis(2-Ethylhexyl)phthalate (ug/L)	3.56	4	0	0	0.0%	1	1	nd	0.5000	0.5000	nd	nd	nd
Bis(2-Ethylhexyl)phthalate (ug/L)	0.70 [1]	4	0	0	0.0%	1	1	nd	0.5000	0.5000	nd	nd	nd
Copper	0.0031	6	3	2	33.3%	0.002	0.021	6.8	0.0052	0.0025	0.0115	1.7	3.7
Nickel	0.0082	6	1	1	16.7%	0.01	0.02	2.4	0.0075	0.0063	0.0124	0.9	1.5
Leachate Indicators													
Total Chromium	162	5	5	0	0.0%	0.12	1.56	0.0	0.5824	0.4078	1.0839	0.0036	0.0067
Total Organic Carbon	—	5	5	0	0.0%	25	300	na	121.8000	81.7403	223.8863	na	na
Well RMW-11D Analytical Data													
Contaminants Above ARARs in Leachate													
1,4-Dichlorobenzene (ug/L)	4.86	3	0	0	0.0%	1	1	nd	0.5000	0.5000	nd	nd	nd
Arsenic	0.005	4	4	0	0.0%	0.002	0.003	0.6	0.0028	0.0027	0.0032	0.55	0.65
Diesel Range Hydrocarbons	0.5	4	4	4	100.0%	0.61	0.86	1.7	0.7525	0.7460	0.8620	1.51	1.72
Lead	0.0081	4	2	0	0.0%	0.001	0.005	0.6	0.0025	0.0015	0.0048	0.31	0.59
Mercury	0.00005	4	0	0	0.0%	0.0001	0.0002	nd	0.0001	0.0001	nd	nd	nd
Pentachlorophenol (ug/L)	4.91	3	0	0	0.0%	5	5	nd	2.5000	2.5000	nd	nd	nd
Weak Acid Dissoc. Cyanide	0.0028	5	3	3	60.0%	0.005	0.006	2.1	0.0042	0.0039	0.0056	1.5	2.0
Zinc	0.081	4	4	0	0.0%	0.005	0.013	0.2	0.0095	0.0088	0.0135	0.12	0.17
Contaminants Below ARARs in Leachate													
Bis(2-Ethylhexyl)phthalate (ug/L)	3.56	3	0	0	0.0%	1	1	nd	0.5000	0.5000	nd	nd	nd
Bis(2-Ethylhexyl)phthalate (ug/L)	0.70 [1]	3	0	0	0.0%	1	1	nd	0.5000	0.5000	nd	nd	nd
Copper	0.0031	4	0	0	0.0%	0.002	0.002	nd	0.0010	0.0010	nd	nd	nd
Nickel	0.0082	4	0	0	0.0%	0.01	0.01	nd	0.0050	0.0050	nd	nd	nd
Leachate Indicators													
Total Chromium	162	4	4	0	0.0%	0.868	1.05	0.0	0.9485	0.9463	1.0225	0.0059	0.0063
Total Organic Carbon	—	4	4	0	0.0%	220	270	na	252.5000	251.7290	274.2297	na	na

Note:

Contaminant concentrations are shown in units of mg/L unless otherwise indicated. Semivolatile organics are shown in units of micrograms per liter.

See Appendix B for raw analytical data included in statistical analysis. See Table 4-6 for a description of the cleanup levels.

1. Based on the results of sediment source control analyses performed as described in Section 7, the surface water ARAR for bis(2-ethylhexyl)phthalate may need to be reduced by a factor of 5X (from 3.56 to 0.71 ug/L be protective of marine sediment concentrations. Statistical calculations are shown both for the surface water ARAR (MTCA Method B Surface water cleanup level) and for the lower sediment source-control value.
2. The exceedance ratio is a direct comparison of the mean or UCL groundwater concentrations with the surface water cleanup level or ARAR defined in Section 2.4 and Table 4-6 for the point-of-exposure. A ratio equa or less than 1.0 indicates that the mean or UCL concentration at the specified montoring locations would be protective of surface water receptors if this water discharged without attenuation into the point-of-exposure.

Table 4-12. Statistical Analysis of Groundwater Data – C-Street Alignment

Wel Parameter	ARAR Value	Number of Samples	Number of Detections	Number of ARAR Exceedences	% of Samples with ARAR Exceedences	Minimum Value (inlcuding DL)	Maximum Value (inlcuding DL)	Maximum Exceed. Ratio	Non-Detects = One-half the Reporting Limit: Arithmetic Mean	Geometric Mean	Mean as 95% UCL	Exceedance Ratios[2] (Ar. Mean)	(95% UCL)
Well MW-4(B) Analytical Data													
Contaminants Above ARARs in Leachate													
1,4-Dichlorobenzene (ug/L)	4.86	4	0	0	0.0%	1	1	nd	0.5000	0.5000	nd	nd	nd
Arsenic	0.005	4	4	4	100.0%	0.016	0.021	4.2	0.0195	0.0194	0.0218	3.9	4.4
Diesel Range Hydrocarbons	0.5	4	0	0	0.0%	0.25	0.25	nd	0.1250	0.1250	nd	nd	nd
Lead	0.0081	4	0	0	0.0%	0.001	0.001	nd	0.0005	0.0005	nd	nd	nd
Mercury	0.00005	4	0	0	0.0%	0.0001	0.0002	nd	0.0001	0.0001	nd	nd	nd
Pentachlorophenol (ug/L)	4.91	4	0	0	0.0%	5	5	nd	2.5000	2.5000	nd	nd	nd
Weak Acid Dissoc. Cyanide	0.0028	4	1	1	25.0%	0.005	0.008	2.9	0.0039	0.0033	0.0066	1.4	2.3
Zinc	0.081	4	4	0	0.0%	0.005	0.044	0.5	0.0170	0.0118	0.0348	0.21	0.43
Contaminants Below ARARs in Leachate													
Bis(2-Ethylhexyl)phthalate (ug/L)	3.56 [1]	4	2	1	25.0%	1	6	1.7	2.1000	1.2038	4.6816	0.59	1.32
Bis(2-Ethylhexyl)phthalate (ug/L)	0.70 [1]	4	2	2	50.0%	1	6	8.6	2.1000	1.2038	4.6816	3.00	6.69
Copper	0.0031	4	0	0	0.0%	0.002	0.002	nd	0.0010	0.0010	nd	nd	nd
Nickel	0.0082	4	0	0	0.0%	0.01	0.01	nd	0.0050	0.0050	nd	nd	nd
Leachate Indicators													
Total Chromium	162	4	4	0	0.0%	0.006	0.03	0.0	0.0148	0.0119	0.0256	0.00009	0.00016
Total Organic Carbon	—	4	4	0	0.0%	7.5	20	na	13.6250	12.7468	19.0130	na	na
Well RMW-12D Analytical Data													
Contaminants Above ARARs in Leachate													
1,4-Dichlorobenzene (ug/L)	4.86	4	0	0	0.0%	1	1	nd	0.5000	0.5000	nd	nd	nd
Arsenic	0.005	4	4	2	50.0%	0.001	0.009	1.8	0.0050	0.0037	0.0086	1.0	1.7
Diesel Range Hydrocarbons	0.5	4	2	1	25.0%	0.25	0.57	1.1	0.2900	0.2346	0.4982	0.58	1.00
Lead	0.0081	4	0	0	0.0%	0.001	0.001	nd	0.0005	0.0005	nd	nd	nd
Mercury	0.00005	4	0	0	0.0%	0.0001	0.0002	nd	0.0001	0.0001	nd	nd	nd
Pentachlorophenol (ug/L)	4.91	4	0	0	0.0%	5	5	nd	2.5000	2.5000	nd	nd	nd
Weak Acid Dissoc. Cyanide	0.0028	5	1	1	20.0%	0.004	0.012	4.3	0.0043	0.0033	0.0081	1.5	2.9
Zinc	0.081	4	3	0	0.0%	0.004	0.016	0.2	0.0073	0.0058	0.0131	0.09	0.16
Contaminants Below ARARs in Leachate													
Bis(2-Ethylhexyl)phthalate (ug/L)	3.56 [1]	4	1	0	0.0%	1	1.8	0.5	0.8250	0.6887	1.4620	0.23	0.41
Bis(2-Ethylhexyl)phthalate (ug/L)	0.70 [1]	4	1	1	25.0%	1	1.8	2.6	0.8250	0.6887	1.4620	1.18	2.09
Copper	0.0031	4	0	0	0.0%	0.002	0.002	nd	0.0010	0.0010	nd	nd	nd
Nickel	0.0082	4	0	0	0.0%	0.01	0.01	nd	0.0050	0.0050	nd	nd	nd
Leachate Indicators													
Total Chromium	162	4	4	0	0.0%	0.012	0.648	0.0	0.2570	0.0813	0.5564	0.0016	0.0034
Total Organic Carbon	—	4	4	0	0.0%	8.3	200	na	69.5750	33.3029	157.4536	na	na

Note:

Contaminant concentrations are shown in units of mg/L unless otherwise indicated. Semivolatile organics are shown in units of micrograms per liter.

See Appendix B for raw analytical data included in statistical analysis. See Table 4-6 for a description of the cleanup levels.

1. Based on the results of sediment source control analyses performed as described in Section 7, the surface water ARAR for bis(2-ethylhexyl)phthalate may need to be reduced by a factor of 5X (from 3.56 to 0.71 ug/L) be protective of marine sediment concentrations. Statistical calculations are shown both for the surface water ARAR (MTCA Method B Surface water cleanup level) and for the lower sediment source-control value.
2. The exceedance ratio is a direct comparison of the mean or UCL groundwater concentrations with the surface water cleanup level or ARAR defined in Section 2.4 and Table 4-6 for the point-of-exposure. A ratio equal or less than 1.0 indicates that the mean or UCL concentration at the specified montoring locations would be protective of surface water receptors if this water discharged without attenuation into the point-of-exposure.

Table 4-1[illegible]. [illegible]istical Analysis of Groundwater Data – Whatcom Waterway Nearshore Areas

Wel Parameter	ARAR Value	Number of Samples	Number of Detections	Number of ARAR Exceedences	% of Samples with ARAR Exceedences	Minimum Value (inlcuding DL)	Maximum Value (inlcuding DL)	Maximum Exceed. Ratio	Non-Detects = One-half the Reporting Limit: Arithmetic Mean	Geometric Mean	Mean as 95% UCL	Exceedance Ratios[2] (Ar. Mean)	(95% UCL)
Well MW-3(B) Analytical Data													
Contaminants Above ARARs in Leachate													
1,4-Dichlorobenzene (ug/L)	4.86	4	0	0	0.0%	1	1	nd	0.5000	0.5000	nd	nd	nd
Arsenic	0.005	4	2	0	0.0%	0.001	0.005	1.0	0.0020	0.0019	0.0027	0.4	0.5
Diesel Range Hydrocarbons	0.5	4	0	0	0.0%	0.25	0.25	nd	0.1250	0.1250	nd	nd	nd
Lead	0.0081	4	0	0	0.0%	0.001	0.005	nd	0.0010	0.0007	nd	nd	nd
Mercury	0.00005	4	1	1	25.0%	0.0001	0.0002	4.0	0.00008	0.00007	0.00010	1.5	2.1
Pentachlorophenol (ug/L)	4.91	4	0	0	0.0%	5	5	nd	2.5000	2.5000	nd	nd	nd
Weak Acid Dissoc. Cyanide	0.0028	4	1	1	25.0%	0.005	0.006	2.1	0.0034	0.0031	0.0051	1.2	1.8
Zinc	0.081	4	4	0	0.0%	0.012	0.047	0.6	0.0255	0.0221	0.0411	0.3	0.5
Contaminants Below ARARs in Leachate													
Bis(2-Ethylhexyl)phthalate (ug/L)	3.56	4	1	1	25.0%	1	9	2.5	2.6250	1.0299	6.7899	0.7	1.9
Bis(2-Ethylhexyl)phthalate (ug/L)	0.70 [1]	4	1	1	25.0%	1	9	12.9	2.6250	1.0299	6.7899	3.8	9.7
Copper	0.0031	4	4	4	100.0%	0.01	0.03	9.7	0.0210	0.0194	0.0297	6.8	9.6
Nickel	0.0082	4	0	0	0.0%	0.01	0.01	nd	0.0050	0.0050	nd	nd	nd
Leachate Indicators													
Total Chromium	162	4	2	0	0.0%	0.005	0.028	0.0	0.0148	0.0082	0.0286	0.0	0.0
Total Organic Carbon	—	4	4	0	0.0%	3.7	17	na	10.9750	9.2263	17.3944	na	na
Well RMW-13(D) Analytical Data													
Contaminants Above ARARs in Leachate													
1,4-Dichlorobenzene (ug/L)	4.86	4	0	0	0.0%	1	1	nd	0.5000	0.5000	nd	nd	nd
Arsenic	0.005	4	1	0	0.0%	0.001	0.002	0.4	0.0008	0.0007	0.0010	0.15	0.21
Diesel Range Hydrocarbons	0.5	4	1	0	0.0%	0.25	0.26	0.5	0.1588	0.1501	0.2249	0.32	0.45
Lead	0.0081	4	0	0	0.0%	0.001	0.001	nd	0.0005	0.0005	nd	nd	nd
Mercury	0.00005	4	0	0	0.0%	0.0001	0.0002	nd	0.0001	0.0001	nd	nd	nd
Pentachlorophenol (ug/L)	4.91	4	0	0	0.0%	5	5	nd	2.5000	2.5000	nd	nd	nd
Weak Acid Dissoc. Cyanide	0.0028	5	1	1	20.0%	0.004	0.008	2.9	0.0035	0.0030	0.0057	1.3	2.0
Zinc	0.081	4	3	0	0.0%	0.004	0.009	0.1	0.0058	0.0049	0.0090	0.07	0.11
Contaminants Below ARARs in Leachate													
Bis(2-Ethylhexyl)phthalate (ug/L)	3.56	4	1	0	0.0%	1	1.2	0.3	0.6750	0.6223	1.0180	0.2	0.3
Bis(2-Ethylhexyl)phthalate (ug/L)	0.70 [1]	4	1	1	25.0%	1	1.2	1.7	0.6750	0.6223	1.0180	1.0	1.5
Copper	0.0031	4	2	0	0.0%	0.002	0.002	0.6	0.0015	0.0014	0.0021	0.5	0.7
Nickel	0.0082	4	0	0	0.0%	0.01	0.01	nd	0.0050	0.0050	nd	nd	nd
Leachate Indicators													
Total Chromium	162	4	4	0	0.0%	0.096	0.11	0.0	0.1045	0.1044	0.1104	na	na
Total Organic Carbon	—	4	4	0	0.0%	50	55	na	53.0000	52.9664	55.1170	na	na

Note:

Contaminant concentrations are shown in units of mg/L unless otherwise indicated. Semivolatile organics are shown in units of micrograms per liter.

See Appendix B for raw analytical data included in statistical analysis. See Table 4-6 for a description of the cleanup levels.

1. Based on the results of sediment source control analyses performed as described in Section 7, the surface water ARAR for bis(2-ethylhexyl)phthalate may need to be reduced by a factor of 5X (from 3.56 to 0.71 ug/L) to be protective of marine sediment concentrations. Statistical calculations are shown both for the surface water ARAR (MTCA Method B Surface water cleanup level) and for the lower sediment source-control value.
2. The exceedance ratio is a direct comparison of the mean or UCL groundwater concentrations with the surface water cleanup level or ARAR defined in Section 2.4 and Table 4-6 for the point-of-exposure. A ratio equal to or less than 1.0 indicates that the mean or UCL concentration at the specified montoring locations would be protective of surface water receptors if this water discharged without attenuation into the point-of-exposure.

Table 4-[illegible]tistical Analysis of Groundwater Data – Foot of C-Street (Cont'd)

Well & Parameter	ARAR Value	Number of Samples	Number of Detections	Number of ARAR Exceedences	% of Samples with ARAR Exceedences	Minimum Value (inlcuding DL)	Maximum Value (inlcuding DL)	Maximum Exceed. Ratio	Non-Detects = One-half the Reporting Limit				
									Arithmetic Mean	Geometric Mean	Mean as 95% UCL	Exceedance Ratios[2] (Ar. Mean)	(95% UCL)
Well RMW-7 Analytical Data													
Contaminants Above ARARs in Leachate													
1,4-Dichlorobenzene (ug/L)	4.86	4	0	0	0.0%	1	1	nd	0.50	0.50	nd	nd	nd
Arsenic	0.005	4	3	0	0.0%	0.002	0.005	1.0	0.0029	0.0028	0.0037	0.6	0.7
Diesel Range Hydrocarbons	0.5	4	0	0	0.0%	0.25	0.25	nd	0.125	0.125	nd	nd	nd
Lead	0.0081	4	3	0	0.0%	0.001	0.005	0.6	0.0021	0.0020	0.0030	0.26	0.37
Mercury	0.00005	4	0	0	0.0%	0.0001	0.0002	nd	0.00006	0.00006	nd	nd	nd
Pentachlorophenol (ug/L)	4.91	4	0	0	0.0%	5	5	nd	2.50	2.50	nd	nd	nd
Weak Acid Dissoc. Cyanide	0.0028	4	0	0	0.0%	0.005	0.005	1.8	0.0025	0.0025	nd	nd	nd
Zinc	0.081	4	4	1	25.0%	0.008	0.136	1.7	0.0425	0.0202	0.1037	0.52	1.28
Contaminants Below ARARs in Leachate													
Bis(2-Ethylhexyl)phthalate (ug/L)	3.56	4	0	0	0.0%	1	1	nd	0.50	0.50	nd	nd	nd
Bis(2-Ethylhexyl)phthalate (ug/L)	0.70 [1]	4	0	0	0.0%	1	1	nd	0.50	0.50	nd	nd	nd
Copper	0.0031	4	4	4	100.0%	0.005	0.009	2.9	0.0060	0.0058	0.0080	1.9	2.6
Nickel	0.0082	4	0	0	0.0%	0.01	0.01	nd	0.0050	0.0050	nd	nd	nd
Leachate Indicators													
Total Chromium	162	4	3	0	0.0%	0.005	0.025	na	0.0121	0.0088	0.0217	0.00007	0.00013
Total Organic Carbon	—	4	4	0	0.0%	6.4	23	na	13.85	12.48	20.75	na	na
Well RMW-7D Analytical Data													
Contaminants Above ARARs in Leachate													
1,4-Dichlorobenzene (ug/L)	4.86	4	0	0	0.0%	1	1	nd	0.50	0.50	nd	nd	nd
Arsenic	0.005	4	2	0	0.0%	0.003	0.005	1.0	0.0033	0.0031	0.0044	0.7	0.9
Diesel Range Hydrocarbons	0.5	4	0	0	0.0%	0.25	0.25	nd	0.125	0.125	nd	nd	nd
Lead	0.0081	4	0	0	0.0%	0.001	0.005	nd	0.0010	0.0007	nd	nd	nd
Mercury	0.00005	4	0	0	0.0%	0.0001	0.0002	nd	0.0001	0.0001	nd	nd	nd
Pentachlorophenol (ug/L)	4.91	4	0	0	0.0%	5	5	nd	2.50	2.50	nd	nd	nd
Weak Acid Dissoc. Cyanide	0.0028	4	0	0	0.0%	0.005	0.005	nd	0.0025	0.0025	nd	nd	nd
Zinc	0.081	4	0	0	0.0%	0.008	0.01	nd	0.0043	0.0042	nd	nd	nd
Contaminants Below ARARs in Leachate													
Bis(2-Ethylhexyl)phthalate (ug/L)	3.56	4	1	1	25.0%	1	8.4	2.4	2.48	1.01	6.35	0.70	1.78
Bis(2-Ethylhexyl)phthalate (ug/L)	0.70 [1]	4	1	1	25.0%	1	8.4	12.0	2.48	1.01	6.35	3.54	9.07
Copper	0.0031	4	0	0	0.0%	0.004	0.004	nd	0.0020	0.0020	nd	nd	nd
Nickel	0.0082	4	0	0	0.0%	0.02	0.02	nd	0.0100	0.0100	nd	nd	nd
Leachate Indicators													
Total Chromium	162	4	0	0	0.0%	0.01	0.01	nd	0.0050	0.0050	nd	nd	nd
Total Organic Carbon	—	4	4	0	0.0%	4.1	5.1	na	4.50	4.48	4.92	na	na

Note:

Contaminant concentrations are shown in units of mg/L unless otherwise indicated. Semivolatile organics are shown in units of micrograms per liter.

See Appendix B for raw analytical data included in statistical analysis. See Table 4-6 for a description of the cleanup levels.

1. Based on the results of sediment source control analyses performed as described in Section 7, the surface water ARAR for bis(2-ethylhexyl)phthalate may need to be reduced by a factor of 5X (from 3.56 to 0.71 u be protective of marine sediment concentrations. Statistical calculations are shown both for the surface water ARAR (MTCA Method B Surface water cleanup level) and for the lower sediment source-control value
2. The exceedance ratio is a direct comparison of the mean or UCL groundwater concentrations with the surface water cleanup level or ARAR defined in Section 2.4 and Table 4-6 for the point-of-exposure. A ratio e or less than 1.0 indicates that the mean or UCL concentration at the specified montoring locations would be protective of surface water receptors if this water discharged without attenuation into the point-of-exposu

Table 4-14. Statistical Analysis of Groundwater Data -- Foot of C-Street

Well & Parameter	ARAR Value	Number of Samples	Number of Detections	Number of ARAR Exceedences	% of Samples with ARAR Exceedences	Minimum Value (inlcuding DL)	Maximum Value (inlcuding DL)	Maximum Exceed. Ratio	Non-Detects = One-half the Reporting Limit: Arithmetic Mean	Geometric Mean	Mean as 95% UCL	Exceedance Ratios[2] (Ar. Mean)	(95% UCL)
Well MW-55(C) Analytical Data													
Contaminants Above ARARs in Leachate													
1,4-Dichlorobenzene (ug/L)	4.86	4	0	0	0.0%	1	1	nd	0.500	0.500	nd	nd	nd
Arsenic	0.005	4	4	4	100.0%	0.019	0.046	9.2	0.033	0.030	0.0477	6.6	9.5
Diesel Range Hydrocarbons	0.5	4	4	0	0.0%	0.26	0.3	0.6	0.270	0.269	0.290	0.54	0.58
Lead	0.0081	4	0	0	0.0%	0.001	0.001	nd	0.0005	0.0005	nd	nd	nd
Mercury	0.00005	4	0	0	0.0%	0.0001	0.0002	nd	0.000063	0.000059	nd	nd	nd
Pentachlorophenol (ug/L)	4.91	4	0	0	0.0%	5	5	nd	2.50	2.50	nd	nd	nd
Weak Acid Dissoc. Cyanide	0.0028	4	0	0	0.0%	0.005	0.005	nd	0.0025	0.0025	nd	nd	nd
Zinc	0.081	4	4	0	0.0%	0.007	0.019	0.2	0.0105	0.0096	0.0161	0.13	0.20
Contaminants Below ARARs in Leachate													
Bis(2-Ethylhexyl)phthalate (ug/L)	3.56	4	0	0	0.0%	1	1	nd	0.50	0.50	nd	nd	nd
Bis(2-Ethylhexyl)phthalate (ug/L)	0.70 [1]	4	0	0	0.0%	1	1	nd	0.50	0.50	nd	nd	nd
Copper	0.0031	4	0	0	0.0%	0.002	0.002	nd	0.0010	0.0010	nd	nd	nd
Nickel	0.0082	4	0	0	0.0%	0.01	0.01	nd	0.0050	0.0050	nd	nd	nd
Leachate Indicators													
Total Chromium	162	4	4	0	0.0%	0.042	0.057	0.0	0.050	0.049	0.056	0.00031	0.00035
Total Organic Carbon	—	4	4	0	0.0%	16	18	na	16.75	16.73	17.69	na	na
Well RMW-6(D) Analytical Data													
Contaminants Above ARARs in Leachate													
1,4-Dichlorobenzene (ug/L)	4.86	3	0	0	0.0%	1	1	nd	0.50	0.50	nd	nd	nd
Arsenic	0.005	3	3	2	66.7%	0.004	0.008	1.6	0.0060	0.0058	0.0083	1.2	1.7
Diesel Range Hydrocarbons	0.5	3	0	0	0.0%	0.25	0.25	nd	0.125	0.125	nd	nd	nd
Lead	0.0081	3	0	0	0.0%	0.001	0.001	nd	0.00050	0.00050	nd	nd	nd
Mercury	0.00005	3	0	0	0.0%	0.0001	0.0002	nd	0.000067	0.000063	nd	nd	nd
Pentachlorophenol (ug/L)	4.91	3	0	0	0.0%	5	5	nd	2.50	2.50	nd	nd	nd
Weak Acid Dissoc. Cyanide	0.0028	3	1	1	33.3%	0.005	0.01	3.6	0.0050	0.0040	0.0099	1.8	3.5
Zinc	0.081	3	3	0	0.0%	0.006	0.007	0.1	0.0067	0.0066	0.0073	0.08	0.09
Contaminants Below ARARs in Leachate													
Bis(2-Ethylhexyl)phthalate (ug/L)	3.56	3	1	0	0.0%	1	2	0.6	1.00	0.79	1.98	0.28	0.56
Bis(2-Ethylhexyl)phthalate (ug/L)	0.70 [1]	3	1	1	33.3%	1	2	2.9	1.00	0.79	1.98	1.43	2.83
Copper	0.0031	3	0	0	0.0%	0.002	0.002	nd	0.0010	0.0010	nd	nd	nd
Nickel	0.0082	3	0	0	0.0%	0.01	0.01	nd	0.0050	0.0050	nd	nd	nd
Leachate Indicators													
Total Chromium	162	3	3	0	0.0%	0.114	0.151	0.0	0.135	0.134	0.157	0.00084	0.00097
Total Organic Carbon	—	3	3	0	0.0%	75	88	na	80.0	79.8	87.9	na	na

Note:

Contaminant concentrations are shown in units of mg/L unless otherwise indicated. Semivolatile organics are shown in units of micrograms per liter.

See Appendix B for raw analytical data included in statistical analysis. See Table 4-6 for a description of the cleanup levels.

1. Based on the results of sediment source control analyses performed as described in Section 7, the surface water ARAR for bis(2-ethylhexyl)phthalate may need to be reduced by a factor of 5X (from 3.56 to 0.71 u be protective of marine sediment concentrations. Statistical calculations are shown both for the surface water ARAR (MTCA Method B Surface water cleanup level) and for the lower sediment source-control value
2. The exceedance ratio is a direct comparison of the mean or UCL groundwater concentrations with the surface water cleanup level or ARAR defined in Section 2.4 and Table 4-6 for the point-of-exposure. A ratio e or less than 1.0 indicates that the mean or UCL concentration at the specified montoring locations would be protective of surface water receptors if this water discharged without attenuation into the point-of-exposu

Table 4-15 Summary of Landfill Gas Monitoring Data

Monitoring Location	Distance from Landfill Refuse (ft)	Sampling Time	LEL (%LEL)	PID (ppm)	O_2 (% by volume)	CO (ppm)	H_2S (ppm)	Comments
C-Street Area Monitoring Locations								
RMW-16	1	15:46	6		20.8	0	2	Well in good condition.
	(refuse encountered in soil boring)	15:46:30	81		17.4	0	5	
		15:47	229	1.2	10.4	241	16	
		15:49	4		1.7	219	28	
		15:50	9		1.4	177	28	
		15:51	13	2.1	1.4	149	28	
MW-12 (B)	60	13:12	293		19.8	150		Well in good condition.
		13:12:30	66	0	4.9	207	2	
		13:14	86		7.3	625	2	
		13:15	90		6.5	567	1	
		13:16	91		6.2	582		
		13:17	92	0	6.1	612		
MW-8 (B)	60	14:21	276		15.0	300	10	Well in good condition.
		14:21:30	93	0	6.1	250	29	H_2S odor
		14:23	119		8.8	400	21	
		14:24	138		9.6	383	17	
		14:25	147		10.2	304	14	
		14:26	157	0	11.0	417	11	
MW-5 (B)	192	12:50	273		18.5			Well in good condition.
		12:50:30	80		7.1	410		
		12:51	59	0	4.9	376		
		12:52	90		8.3	665		
		12:53	81		7.1	671		
		12:54	78		6.9	735		
		12:56	75	0	6.5	831		
MW-4 (B)	240	14:36	0		20.8	0	0	Well in good condition.
		14:37	2	5.1	18.3	1	0	
		14:39	3		15.8	2	0	
		14:40	3		15.8	1	0	
		14:41	3	5.1	15.8	1	0	
MW-10 (B)	240	14:00	0		12.2	0	0	Well in good condition.
		14:01	2	7.6	16.1	0	0	
		14:03	3		12.6	0	0	
		14:04	2		12.4	0	0	
		14:05	3	9.7	12.4	0	0	
RMW-18	330	12:25	2		18.5			Well in good condition.
		12:26	4		16.8			
		12:27	4		13.8			
		12:28	5		10.8			
		12:29	5		10.4			
		12:31	5	10.1	10.2			
Hilton Avenue Monitoring Locations								
RMW-9	1	16:46	337		18.8	100	5	Well in good condition.
	(refuse encountered in soil boring)	16:47	83	0	4.8	146	12	
		16:48	59		3.8	166	12	
		16:49	64		3.0	55	12	
		16:50	59	0	2.5	28	12	
MW-1 (E)	60	17:15	8	0	20.8	0	0	Well in good condition. 1" diameter.
		17:17	3	0	20.7	0	0	LEL/PID tubing lowered into well casing.
RMW-14	90	16:03	0		20.9	0	0	Well in good condition.
		16:04	2	13.5	19.5	0	0	
		16:06	3		16.8	1	0	
		16:07	3		16.7	0	0	
		16:08	3	11.0	16.7	0	0	
RMW-10	120	16:31	0		20.9	0	1	Well in good condition.
		16:32	3	7.4	20.0	0	0	
		16:34	2		20.4	0	0	
		16:35	1	5.8	20.4	0	0	
RMW-15	180	17:00	0		20.9	0	0	Well in good condition.
		17:01	0	30.3	20.9	0	0	
		17:02	0		20.8	0	0	
		17:03	0		20.8	0	0	
		17:04	0	24.3	20.8	0	0	
Regulatory Reference Values:			MTCA Limitation < 10%	na	na	OSHA PEL 50 ppm	OSHA PEL 20 ppm	Reference values would apply to air in breathing zone, not to well casing headspace. Values are used here for initial screening of site data.

Notes:
Sampling was conducted on April 20, 2001 using the procedures described in Section 3.

5 Results of Land Use Planning

Under MTCA regulations, land uses and facility characteristics must be taken into account when evaluating and selecting remedial alternatives. This section provides a summary of existing facility characteristics, including changes since the initiation of the RI/FS. The most significant of these changes has been the completion of the G.P. Warehouse project, located within the main portion of the landfill.

As part of the RI/FS process, the Port has also recently completed a land use evaluation, evaluating future development alternatives for the area. These evaluations were performed by Makers Consulting, under a Brownfields Grant from the U.S. EPA. The results of these evaluations are discussed in this section as they relate to the evaluation and selction of remedial alternatives under MTCA.

5.1 Completion of the Warehouse Project

The main change in area land use that has occurred since initiation of the RI/FS project has been the completion of the G.P. Warehouse. The location of the completed building is shown in Figure 2-1.

The Warehouse project was conducted as an independent action by Georgia Pacific, with technical assistance provided by Ecology under the Voluntary Cleanup Program. The activities of the Landfill RI/FS have been coordinated with the Warehouse project as described in the First and Second Progress Memoranda. The Warehouse project included completion of the following specific actions:

- Construction of 250,000 square-foot warehouse building
  - Building roof drains are connected to stormwater collection/conveyance system
  - Under-slab methane collection and venting system installed per G.P. project design report
  - Landfill settlement issues and impacts on building utilities addressed per project design report and building permits

- Landfill surface was regraded to enhance drainage

- The access road, and portions of the yard area were paved with asphalt

- The main yard areas and fire lanes have been provided with gravel cover

- Monitoring wells within the project footprint were abandoned

- Yard areas between the warehouse and the G.P. aeration stabilization basin were regraded to improve drainage

- The property boundary-line between Georgia Pacific and BC Investments was modified (moved toward C-street) as necessary to support project completion

Completion of the Warehouse project is estimated to have significantly reduced precipitation recharge of groundwater within the project footprint. This reduction includes complete removal of rainwater from the Warehouse building footprint and a net reduction of approximately 50 percent in the recharge from the balance of the Warehouse project area. A complete cap was not installed as part of the project, such that some recharge will continue to occur in gravel-covered areas. These characteristics have been incorporated into groundwater modeling efforts as described in Section 6 of this report. No changes were made as part of the Warehouse project to landfill areas owned by Sanitary Services or to Port-owned areas along Hilton Avenue.

5.2 Other Property Ownership and Land Use Changes

Current land ownership boundaries are shown in Figure 2-1. Specific changes to land ownership and/or lease activity since preparation of the RI/FS Work Plan in 1998 include the following:

- Acquisition of the Golden Property by the Port of Bellingham (southwest corner of Roeder Avenue and C-street).

- Modification of the G.P./B.C. investments property line as discussed in Section 5.1.

- Expansion of the Bornstein Seafoods building and yard area southwest of the Olivine site, with continued use of the Bornstein Seafoods lease property for seafood processing.

No changes in property ownership have occurred at the New West Fisheries or Chevron properties. Chevron continues to evaluate cleanup alternatives for its site as an indepedent action under the MTCA. Other than the boundary line adjustment with G.P. as part of the Warehouse project, no significant land use changes or cleanup actions have been performed at the B.C. Investments property.

The Port has initiated an RI/FS for the Olivine site. That RI/FS is being conducted with technical assistance provided by Ecology under the Voluntary Cleanup Program. The Port has also been evaluating redevelopment alternatives for that site along with adjacent vacant Hilton Avenue properties as part of area-wide land use planning (see below).

5.3 Results of Land Use Planning

Two sets of land use planning studies have been completed since production of the RI/FS Work Plan. These have included the following:

- City Center Master Plan (Sept. 1999). Completed by Winter & Company et al. For the City of Bellingham.

- Central Waterfront Redevelopment Plan (January 2000). Completed by Makers et al. For the Port of Bellingham.

Land use planning conducted by the City has focused on the properties to the east of Roeder Avenue and those largely to the south of Whatcom Creek. The 1999 Master Plan deferred planning efforts for the Central Waterfront Area to the Port of Bellingham.

The Port's recent land use planning effort was completed under a Brownfields Grant from the U.S. EPA. That study included an analysis of appropriate land uses for parcels within the Central Waterfront Area, including the Roeder Avenue landfill and adjacent properties. The study evaluated three land use alternatives as summarized below:

- **Current Development Trends:** Current land use trends include evolution from heavy industrial uses to light industrial uses. The parcel size, access characteristics and real estate and planning trends favor this transformation. These trends will favor addition of industrial/retail, wholesale showroom, or on-site assembly/sales business uses. Water-dependent uses would be maintained consistent with current shoreline plan. Some rezoning from heavy industrial to light industrial would be performed under this alternative.

- **Partial Mixed-Use Development:** This option focuses on mixed-use redevelopment, similar to actions taken by the Port on the north side of the I&J Street waterway. This option would include increased public access to shoreline areas and linkages to redevelopment activities at Squalicum marina and the City's downtown and Old Town areas. The main difference between this alternative and the first alternative is the incorporation of commercial, office and/or retail uses along the I&J Street waterway and along Roeder Avenue. Light industrial uses would be maintained along C-street and along the Landfill side of Hilton Avenue.

- **Aggressive Mixed-Use Redevelopment:** Under this scenario, the areas of light-industrial, office and retail mixed use development would be expanded to include portions of the properties along C-street and the properties between Hilton Avenue and the Landfill. B.C. The shoreline of the I&J Waterway could under this alternative include commercial, retail, office and potentially some urban residential (i.e., condominium or hotel) uses. This alternative would retain light industrial uses along the Whatcom Waterway and adjacent to the G.P. Warehouse property. This alternative is considered less likely due to zoning, economic and development factors.

The primary conclusion of the land use planning effort for the Central Waterfront was that future uses will likely be characterized by a mixture of light industrial, commercial, retail and water dependent uses. Redevelopment will tend to include water dependent uses associated with the nearby marina areas. Future rezoning to allow residential development is considered unlikely due to a variety of factors.

5.4 Conclusions

Relative to Landfill remediation planning, the important land use observations for the Central Waterfront area include the following:

- **Ownership Patterns:** Property ownership will likely consist of several mid-sized parcels of between 2 and 20 acres. The most likely areas for change in ownership exist in the non-landfill properties along the C-street (Chevron, B.C. Investments, New West Fisheries). However, at this time there is no firm schedule for a change in ownership of these properties. Owners of these properties have been included in notifications and project coordination during the RI/FS process.

- **Zoning and Land Uses:** Current zoning is restricted to heavy industrial uses along the Whatcom Waterway, and light-industrial and commercial/retail uses along the I&J Waterway. These uses are likely to predominate for the forseeable future. Public access will likely be incorporated into shoreline development projects consistent with City and Port planning efforts. Residential uses within the area are considered unlikely for the forseeable future.

- **Warehouse Impacts:** The Warehouse project has resulted in capping of a significant portion of the landfill. Though complete capping of the landfill was not performed, the Warehouse project has resulted in significant reductions to infiltration of precipitation into the landfill refuse. The design life for the warehouse building is greater than 30 years. The Warehouse has been incorporated into the groundwater modeling process in Section 6 as part of the site evaluation.

- **Other Development-Related Ground Cover and Infiltration Control:** Relative to groundwater impacts, commercial, retail and light industrial redevelopment will tend to result in development capping and an average of 50% or more reductions in infiltration for currently vacant parcels. Specific infiltration patterns will vary with the development action, with much greater infiltration reductions (approaching 100%) possible for certain industrial operations. An average infiltration reduction of 50% is considered conservative for defining future baseline conditions as part of environmental planning efforts. The potential impacts of these actions on groundwater flow and contaminant fate & transport have been assessed as part of the groundwater modeling effort as described in Section 6.

- **Project Coordination:** Investigation and cleanup actions are ongoing at the Olivine, Chevron and Colony Wharf (B.C. Investments) sites. Environmental planning for the Roeder Avenue Landfill should consider potential interactions with these cleanup sites, as well as with the integration of cleanup requirements with land uses and development characteristics.

6 Groundwater Flow Modeling

As described in the RI/FS Work Plan, a two-step modeling process has been used by ThermoRetec to evaluate site conditions and the need for active groundwater remediation.

In the first step of the modeling process, site geologic and hydrogeologic data were combined and used to develop a detailed groundwater flow model. The flow model incorporated the features of the site including multiple recharge sources, tidal conditions and complex geologic sequences. The flow model was then used to determine groundwater flow directions, quantities and the extent of mixing that occurs between landfill groundwater and other non-landfill groundwater prior to discharge into adjacent surface waters.

In the second step of the modeling process, groundwater flow model results were combined with site contaminant data to assess the fate and transport characteristics of specific Landfill contaminants. This step provides the information necessary to evaluate compliance of the site with MTCA cleanup levels applicable to site conditions.

Section 6 summarizes the methods, results and conclusions of the groundwater flow modeling work performed. Section 7 then discusses the results of the second step in the modeling process, the analysis of contaminant fate & transport.

6.1 Modeling Objectives

The primary objective of the groundwater flow modeling process was to develop a quantitative groundwater model that effectively replicates groundwater flow conditions within the project area and can be used to evaluate current conditions and remedial alternatives for the site. In order to meet this objective, the completed model must be able to quantify 1) groundwater flux and mixing ratios, 2) the effects of the GP warehouse project on groundwater flow patterns in the Landfill, and 3) the changes in groundwater flow patterns resulting from evaluated remedial alternatives. Specific outputs required from the flow model include the following:

- **Groundwater Flow Patterns and Velocities:** Groundwater flow velocities are the most important factor in groundwater contaminant transport because in most situations advection (mass transport due to groundwater movement) moves contaminants greater distances than dispersion (mass transport due to mechanical dispersion and molecular diffusion). Groundwater flow velocities are required when calculating contaminant travel times along a groundwater flow path.

- **Water Flux/Water Balance:** The water flux/water balance is a measure of the accuracy of the flow model with respect to total water flow volumes in the modeled area. Calculation of water flux in different areas or at groundwater sources and potential sinks is also important to the understanding of the overall groundwater flow system and in estimating contaminant mass transport across physical or other defined boundaries.

- **Specific Shoreline Conditions:** Conditions unique to shoreline areas are important because they may have an effect on the transport of dissolved contaminants in shoreline areas. For example salt wedges may affect the area where freshwater discharges to the more saline waters of Bellingham Bay. The groundwater flow model used in the RI/FS process simulates shoreline conditions in order to accurately predict contaminant fate & transport.

- **Groundwater Mixing and Attenuation Factors**: The model must accurately represent the patterns of groundwater flow and mixing that occurs between the landfill and the point of groundwater discharge. This mixing has a substantial influence on contaminant fate & transport. At the site, the mixing occurs due to both tidal and non-tidal influences. The model used for the RI/FS simulates both types of mixing as described in this Section.

- **Foundation for Contaminant Fate and Transport Evaluations:** The groundwater flow model serves as the foundation of contaminant fate and transport modeling. The flow model must be representative of site conditions so that results of contaminant transport modeling can be viewed with confidence.

The groundwater flow model used for the RI/FS meets all of the above-listed objectives. The specific process by which the flow model was developed is described in Section 6.2, below.

6.2 Groundwater Modeling Methods

Development of the Flow Model

The Second Progress Memorandum provided an overview of the methods to be used for groundwater modeling. As described in that Memorandum, a 3-dimensional model was selected for use on the project. A 3-dimensional model was selected over a simpler 2-dimensional approach for the following reasons:

- The 3-dimensional modeling approach was able to directly incorporate the differences across the project area in geologic units, shoreline conditions, recharge areas and contaminant source areas. Simulation of these differences, and of the interplay between them was not possible using a 2-dimensional modeling approach.

- The 3-dimensional model provided an ability to directly test assumptions regarding the site geologic conditions during model calibration. Because a 2-dimensional model would have been itself a gross simplification of site conditions, the calibration process would have represented a less rigorous test of geologic assumptions for the site.

- The greatest strength of the 3-dimensional modeling approach is its ability to directly test remedial alternatives and their impact on groundwater flow and contaminant fate & transport. The interplay between multiple remedial technologies or features could not be directly simulated with a 2-dimensional modeling approach.

Code Selection

Available modeling codes were reviewed in the Second Progress memorandum for potential applicability to the site and RI/FS objectives. Given the RI/FS flow model objectives and the complexities of the site SEAWAT, MODFLOW and MT3D were used to simulate groundwater flow and contaminant transport at the Roeder Avenue Landfill. A brief overview of each code follows:

- **MODFLOW and MT3D:** The code, MODFLOW, is the most widely used and defensible groundwater flow model code. MODFLOW was developed and is supported by the USGS as well as a number of private firms. MODFLOW is a fully three-dimensional finite difference model code that is flexible enough to simulate complex settings. Solute transport can be added to MODFLOW simulations using the MT3D solute transport code (Zheng, 1991). Revisions to this code were made in 1992, 1996 and 1998 to simulate more complex reactions and geologic settings. MT3D is the most widely used transport code and has had extensive peer review.

- **SEAWAT**: SEAWAT is a model code incorporating the MODFLOW and MT3D codes to simulate the flow of groundwater of variable density. A typical use of SEAWAT is to model seawater intrusion and groundwater flow at freshwater-seawater interfaces. Density contrasts in groundwater are due to total dissolved solids concentrations and not to a single dissolved solute. The SEAWAT model code has the advantages of the MODFLOW code in being flexible, easy to use, and defensible, but the effects of groundwater density can be simulated directly rather than as an equivalent freshwater head boundary.

The selected modeling code is capable of accurately representing subsurface characteristics of the Landfill area including freshwater-seawater interfaces, tidal fluctuations, three-dimensional groundwater flow, and variable stratigraphic thicknesses. In addition, technical support to resolve problems with model setup and execution was more accessible with the SEAWAT code than with any of the alternative codes discussed in the Second Progress Memorandum. Ecology provided concurrence on the selection of the modeling code for use during the project.

Model Grid and Layer Construction

A variable-spaced grid was used for the model with cell sizes ranging from 20 by 20 feet to approximately 20 by 100 feet. Figure 6-1 shows the grid pattern overlaid on the project area. The area bounded by the two waterways, the GP lagoon, and Roeder Avenue is covered by a 20- by 20-foot grid. The remainder of the model area is covered by a grid of variable dimensions as shown in Figure 6-1.

Five model layers were employed in the model. The use of five layers was required to accurately simulate the range of geologic and shoreline conditions present in the project area. The layers represent the Sand Unit, the Refuse/Soil Fill Unit, and various features of the GP lagoon construction and area bulkheads. The Landfill cover soils were not modeled because those soils occurs above the water table across the entire model area. The top of the glacial marine drift defines the bottom of the model grid.

Figure 6-2 summarizes the characteristics that were incorporated into each of the model layers. The figure shows the locations and depths of bulkheads incorporated into the model, boundaries between different geologic units, and the conductivity values assumed for each unit. The conductivity values were based on the empirical measurements collected during geologic and hydrogeologic testing at the site (see Section 4), as well as on the results of model calibration.

As shown in Figure 6-2, a stratigraphic unit may be represented by more than one model grid layer to improve the numerical accuracy of the model. For example, consider a sand unit 30 feet thick with groundwater flow patterns that contain vertical flow components. The vertical flow components would not be seen in the flow model results if the sand unit is represented by a single layer of model cells 30 feet thick. However, the vertical flow components would be apparent in the flow model results if the sand unit is represented by two or three model layers. Final model layer thicknesses range from 1 to just over 10 feet.

Boundary Conditions

Constant head boundaries were set on three sides of the model as shown on Figure 6-1. Two of the constant head boundaries represent the middle of the waterways on either side of the Landfill. Note that small portions of the model boundaries on the upland side of the two waterways are set to no flow. These boundaries represent the flow lines of groundwater flowing directly into the two waterways, and therefore no flow across the model boundaries is assumed to occur. The third constant head boundary represents the water levels in Bellingham Bay just seaward of the GP Lagoon.

The fourth boundary represents the upland side of the model. A portion of this boundary was set to a general head boundary to simulate groundwater flow into the model from upland areas. A general head boundary simulates groundwater flow from areas upland of Roeder Avenue without directly affecting model calculated head values.

Recharge, Sources, and Sinks

Average annual precipitation at the nearest station of record (located in Bellingham) is 36 inches per year. Figure 6-2 shows the assumptions made regarding annual recharge from precipitation. Modeled infiltration values ranged from zero (used to simulate buildings with roof drains) to 22 inches per year (used to simulate uncovered areas of the landfill). The only instance where a higher infiltration rate was used was for the Lagoon "overspray area" (see

Figure 6-2). Model calibration confirmed field observations that overspray from the foam control system used on the lagoon resulted in additional water recharge to this area. The final infiltration values used in the model were determined through model calibration.

Note that two different sets of infiltration scenarios were tested as part of the flow modeling. Each scenario is shown in Figure 6-2. The first scenario estimated infiltration rates using site conditions as they were in 1998. At that time, the majority of the Landfill was unpaved and poorly graded. The Warehouse had not been constructed. Similarly, the Chevron, Olivine and nearby sites were undeveloped. These conditions are subsequently referred to in this document as the "Pre-Warehouse" conditions.

The second modeling scenario incorporated the completed Warehouse building along with associated changes in the Warehouse project area. Based on pending redevelopment at the Olivine, Hilton Avenue and Chevron properties, these areas were modeled with a 50% reduction in infiltration over the Pre-Warehouse conditions. Modeled parameters for this second scenario are shown in Figure 6-2. These modeling conditions are subsequently referred to the "Development Baseline" conditions, because they simulate site conditions as they will occur if no additional active remedial measures are implemented as part of the Landfill cleanup.

The waterways, bay, and GP lagoon are represented by constant head cells. Equivalent freshwater constant heads in the waterway and bay cells were set to the 72 hour average tide in Bellingham Bay for the data calibration set, and to actual tide measurements for transient model runs. Constant head cells in the GP lagoon were set to a value of 20 feet above MLLW, consistent with lagoon design parameters.

Hydraulic sinks can be significant at some sites due to influences of utility corridors, pumping stations or other hydraulic influences on groundwater flow patterns. However, results of modeling accurately simulated site conditions without incorporating hydraulic sinks. No hydraulic sinks were incorporated into the final model for either the Pre-Warehouse or the Development Baseline modeling scenarios.

Hydraulic Parameters

Model layers were assigned initial hydraulic conductivity values based on literature values and values determined from slug testing as described in Section 4. Final hydraulic conductivity values of the model were adjusted during model calibration. The final conductivity values established during calibration are shown in Figure 6-2.

Storage coefficients vary layer by layer in the model. Layer 1 cells have storage coefficients of 0.25, representing unconfined conditions. Storage coefficients for layers 2 through 5 were set at 0.1, representing confined conditions. Storage coefficients are not used in steady state flow calculations or steady state flow model calibration. Storage coefficients in transient flow modeling were determined during transient flow model calibration. The magnitude in the variation of possible storage coefficient values and their effect on model results is small.

Site-specific information on horizontal anisotropy is not available. Horizontal isotropy ratios were set at 1 to 1. Vertical anisotropy in the Sand Unit was set at 10 to 1; that is, horizontal hydraulic conductivity was set 10 times greater than the vertical hydraulic conductivity. Vertical anisotropy in the Refuse Unit was set to 100 to 1 to reflect the layered nature of the material in the Refuse Unit. These anisotropy values are derived from model calibration runs.

Chemical Parameters

SEAWAT models the effects of variable water density on groundwater flow by running MODFLOW and MT3D in a quasi-simultaneous manner. The quasi-simultaneous execution of the two model codes is accomplished using a two-step process (simplified here for purpose of discussion). The first step is the generation of a groundwater density field by MT3D. In the second step MODFLOW calculates a head and flux distribution that account for the density field generated by MT3D. The process then returns to the first step with MT3D calculating a new groundwater density field based on the head flux distribution generated by MODFLOW.

The MT3D code uses a number of input values unique to contaminant transport models. One of these is salinity or total dissolved solid (TDS) concentrations.The transport portion of SEAWAT simulates the transport of TDS and uses TDS concentrations to calculate groundwater fluid density. SEAWAT and MT3D were used to establish Groundwater total dissolved solid (TDS) distributions for use with the model. These interfaces were generally similar to the TDS data collected during quarterly sampling.

Model Calibration

Model calibration is a measure of the degree to which flow model results simulate actual site conditions, especially with respect to groundwater head values. Model calibration can also be thought of as a process whereby model input values such as hydraulic parameters are optimized to minimize the difference between model-predicted heads and actual field-measured heads.

The difference between model-predicted heads and actual field-measured heads is called the residual. Model calibration is designed to minimize the residual at all chosen points where field-measured head data exist. The data set of field-measured head data is typically a set of water level measurements collected at a point in time or over a short period of a few days.

For the RI/FS flow model calibration process the set of field-measured head data consists of water levels measured in November 1998. This is an appropriate data set to use because the data provide complete coverage of the landfill area. In addition, 72-hour average head values were calculated for tidally-influenced monitor wells. These 72-hour values are close to average head values. Average head values are more representative of long term values in tidally-influenced wells than single measurements.

The model calibration process included two steps. First, model-predicted heads from initial model runs were compared with the November 1998 data. Input parameters were modified and model runs were executed until residuals were at acceptable values. Figure 6-3 compares the actual head data from November 1998 with the model-predicted heads for the Pre-Warehouse modeling scenario. The overall heads produced by the model are very similar to those empirically measured. Figure 6-4 shows a regression analysis comparing the predicted and measured values for the calibration data set. The R_2 value for the regression analysis was 0.94, indicating an acceptable model calibration.

The second step of the model calibration process involved calibrating storage coefficients used when simulating transient groundwater flow conditions. In the case of this model the transient groundwater flow conditions are the changing tides of Bellingham Bay and associated fluctuations of groundwater elevations in shoreline areas of the Roeder Landfill area. Storage coefficients were modified to reproduce the aquifer response at individual monitor wells during the first tidal study conducted between the 11th and the 16th of November, 1998.

Predicted versus actual tidal responses for shoreline area wells are provided on Figure 6-5 along with correlation coefficients and trend lines. Predicted responses correlate well with the timing and magnitude of actual water level changes in most wells. The absolute difference between actual and predicted water levels at any given time is small and is comparable to differences observed between actual and predicted heads in the steady state flow model.

Use of the Calibrated Model

Groundwater flow modeling was conducted to simulate both steady-state (average long-term groundwater flow patterns) and transient (tidally-influenced) conditions. Steady state flow modeling was conducted to simulate long-term, average head distribution and the resulting flow field beneath the landfill and adjacent areas between the landfill and the waterway shorelines. Steady state head distributions were also used as input data for transient flow modeling.

Steady-State Head Distributions

Two types of steady state head distributions were derived from the flow modeling. The first type of head distribution was obtained assuming that all water in the landfill area was freshwater (non-saline), and of constant density. The freshwater steady state head distributions were simulated using the MODFLOW groundwater modeling flow program.

The second type of steady-state head distribution was derived using the SEAWAT groundwater flow and chemical transport program. As described above, the SEAWAT program is capable of modeling the flow of groundwater with variable density. The variations in density are due to differences in salinity. A common application of SEAWAT is to sites where freshwater and saline water mix, such as at the Roeder Avenue Landfill.

Both types of steady state head distributions were obtained to determine the effect of density variations on the groundwater flow field. The effects of density variations on the overall pattern of groundwater flow are subtle. As expected, modeling of variable density groundwater flow increased equivalent freshwater heads compared to heads derived from constant density flow simulations, mainly in the nearshore areas. However, the increase in heads was small relative to the total head predicted in any particular cell. In the Pre-Warehouse model conditions, the increase in nearshore area heads varied from a maximum of about 0.1 feet in layer 1 (shallowest) of the model to a maximum of about 0.38 feet in layer 5 (deepest) of the model. The pattern of greater head increases with depth is expected because equivalent freshwater heads in saline water increase with depth.

Landfill Water Balance Calculations

Recharge of water into the landfill footprint was determined directly from the steady-state model. Net flow of water across a flow field boundary (e.g., flow of precipitation into Layer 1 through the top of the model, or flow of water laterally from the lagoon into Layers 1-5 of the model located within the Landfill footprint) was output by MODFLOW directly. The results of the water balance calculations are discussed in Sections 6.3 and 6.4 below.

Particle Tracking

Groundwater particle tracks were obtained from the steady-state model. These provide a visual representation of groundwater and solute transport paths in the Roeder Avenue Landfill area.

Particle tracking was performed using a set of 21 separate starting locations. Locations used for the analysis included RI/FS monitoring well locations as well as additional locations at proposed monitor well locations.

The particle tracking model PATH3D was used to calculate transport pathways. This model is compatible with MODFLOW and uses flow fields and heads generated by MODFLOW to calculate particle pathways. All particle pathways represent steady state flow conditions. The particle tracking was performed using a theoretical solute with a retardation factor of eleven. This retardation factor was selected to provide a conservative (i.e., low) estimate of contaminant retardation that may occur due to soil/water partitioning. Of the organic landfill contaminants of concern, the ones with the least tendency to adsorb to soil and organic carbon are 1,4-dichlorobenzene and pentachlorophenol. A retardation factor of eleven is approximately half of the retardation factors that would be calculated for these compounds for groundwater in the presence of aquifer solids containing an average total organic carbon content of 0.5 percent and no biodegradation. Because the other compounds have higher tendencies to adsorb to soil particles and because the TOC content of both the Landfill refuse and the waterway sediments is greater than 0.5 percent, the retardation factor used in the modeling effort is conservative (i.e., will tend to overestimate contaminant migration risks). The use of a conservatively low retardation factor for the particle tracking step was performed to provide a base on which contaminant-specific transport evaluations could be conducted. Actual contaminant migration patterns will tend to be higher and vary from contaminant to contaminant as discussed in Section 7.

Analysis of Potential Contaminant Migration

In constructing the groundwater model grid, areas known to contain refuse were specifically assigned to the refuse unit. This allowed these cells to be established as non-depleting source areas for simulation of contaminant transport. Contaminant transport runs were conducted using the following sequence:

- Initial Conditions: MODFLOW and SEAWAT were used to establish flow fields and heads for the initial site conditions (Pre-Warehouse conditions).

- Source concentrations were established for all landfill cells at a non-depleting value of 100 concentration units. Non-landfill cells were established with initial concentrations of 0. Solute particles were given a retardation factor of 11, and a zero degradation rate. This simulated the potential migration of landfill contaminants from the refuse material with minimal retardation.

- Consecutive MT3D runs were then conducted for a period equivalent to 35 years. During this period, the model simulated groundwater flows and solute transport for the entire model area. During these runs, the model was operated such that any water infiltrating vertically or migrating laterally into the landfill refuse was assumed to become impacted with the landfill contaminants, resulting in an applied concentration value of 100 concentration units. Water leaving the landfill then mixes with other waters, resulting in reductions in modeled concentrations in relation to the amount of mixing that occurs.

- At the end of the first 35 years (simulating year 2000), two scenarios were tested. The first was simply a continuation of the Pre-Warehouse conditions for another 35 years. This scenario simulated conditions anticipated in 2035 if the GP Warehouse had not been constructed and if additional development activities in the Central Waterfront Area were not implemented. This additional 35 year run of the Pre-Warehouse scenario was conducted to verify stabilization of solute concentrations in the modeling output, and to provide the ability to directly compare Pre-Warehouse and Development Baseline output. For the Development Baseline scenario, new flow fields and heads were established to simulate completion of the Warehouse project and other anticipated development. These values were then used with the output from the year-2000 Pre-Warehouse scenario runs as the starting conditions. The Development Baseline conditions were established based on the parameters defined in Figure 6-2. The Development Baseline scenario was run for an additional 35-year period, simulating the period between year 2000 and Year 2035. Year 2035 was selected as an appropriate termination point for the flow modeling based on 1) consistency with typical remedial evaluation time-frames of at least 30 years, and 2) the assymptotic stabilization of model output for solute concentrations.

Assessment of Conditions at Specific Locations

The Year 2035 results from the solute transport model were used directly to quantify maximum potential Landfill contaminant concentrations throughout the project area. Model output for solute concentrations was analyzed using the following methods:

- **Point-of-Exposure Concentrations**: As described in Section 2.4, MTCA requires that surface water cleanup levels be met by groundwater discharging into the point-of-exposure. For the Roeder Avenue Landfill, the point-of-exposure specifically represents the 12 centimeter thick sediment bioactive zone beneath Bellingham Bay. For modeling purposes, the point-of-exposure was conservatively estimated using the Layer 2 model cells located beneath Layer 1 bay cells. The minimum thickness of the Layer 2 cells was set at 30 centimeters (1 foot). This minimum thickness ensures that the model output conservatively represents the water quality discharging into the 12 centimeter layer. The model output involves a degree of averaging within each cell. Use of a Layer 2 cell thickness of 12 centimeters would have produced estimates of the groundwater quality in the middle of the bioactive zone (i.e., at 6 cm depths). Use of a 1-foot thickness provides an estimate of water quality just beneath the bioactive zone. This is more consistent with MTCA regulations which prohibit the use of dilution zones within surface waters in evaluating compliance of groundwater discharges with surface water standards. For most model areas, the model-predicted concentrations are read directly from the Layer 2 model output for those cells located past the water line (i.e., beneath the Bay). Each point-of-exposure cell contains a discrete concentration estimate. The values can be directly compared to model groundwater contaminant concentrations for the Landfill. For example, a concentration value of 10 at a point-of-exposure cell indicates that the long-term predicted concentration of Landfill contaminants in that cell is expected to be one tenth of that in the Landfill (Landfill source cells have concentrations of 100 units). The only Layer 1 cells used directly in evaluating model output are the intertidal cells located at the foot of Hilton Avenue. The concentration output in these cells is read directly as with the Layer 2 point-of-exposure cells.

- **Upland Well Concentrations**: For locations within the upland portions of the project area, the solute concentrations vary vertically across the model layers. This effect was observed both within the groundwater modeling output as well as in groundwater contaminant data empirically collected during the RI activities. Model-predicted concentration values for specific wells were read directly from the model cells. Where the screened portion of the groundwater well being analyzed intersected multiple model layers, the concentrations were integrated based on predicted transmissivity of the well. Specifically, concentrations in each cell intersected by the well screen were given a relative weighting factor based on the length of screen within each model layer and the conductivity of that layer. The weighting factors were then multiplied by the concentration within each cell and the resultant concentrations summed for a total predicted well concentration. This value simulates predicted water quality for groundwater extracted or sampled from that well, and is directly comparable to empirical measurements of groundwater quality collected from site wells during the RI field activities.

Calculation of Flow-Based Attenuation Factors

The final step in data analysis from the solute transport model was to quantify the attenuation of groundwater contaminants predicted under the model assumptions. Because these predictions are based on theoretical contaminants with little retardation (i.e., retardation factor of 11), and because contaminant degradation and geochemical immobilization were not incorporated into this step, the results provide a conservative estimate of contaminant attenuation (i.e., results will tend to overestimate contaminant migration risks). The attenuation factors were calculated directly from the model output as follows:

- **Gross Attenuation Factors (GAF)**: The most direct estimate of contaminant attenuation was calculated directly and is referred to as the "Gross Attenuation Factor" or GAF. These Gross Attenuation Factors represent the ratio between solute concentration in the Landfill groundwater and that predicted for a given point-of-exposure cell. These Gross Attenuation Factors are expressed in model concentration units (Landfill groundwater is always expressed as 100 concentration units). Therefore, if a point-of-exposure cell has a predicted concentration of 5 units, the GAF for this cell is 20, meaning that landfill leachate is reduced by dilution/attenuation to 1/20th of its original concentration prior to discharging to the point-of-exposure cells beneath Bellingham Bay. The Gross Attenuation Factors vary throughout the model due to differences in groundwater flow and mixing. Areas with low Gross Attenuation Factors are those with the greatest potential for discharge of Landfill contaminants to surface waters in excess of applicable criteria.

- **Area-Specific Attenuation Factors (ASF):** In addition to the Gross Attenuation Factors described above, the model output can be used to quantify the amount of flow-based attenuation that occurs between any intermediate upland location and the shoreline. In intermediate upland locations located downgradient form the landfill, the leachate concentrations will be typically less than 100 concentration units. The area-specific attenuation factor represents the ratio between the predicted concentration at one of these intermediate locations, and the predicted concentration at the appropriate downgradient point-of-exposure cell (where that groundwater will ultimately discharge). Particle tracking analyses are used to select the appropriate point-of-exposure cells for this calculation. For example, take a hypothetical upland cell with a leachate concentration of 50. If groundwater from that cell discharges at a point-of-exposure cell with a concentration of 5, the resultant Area-Specific Attenuation Factor is 10. This means that the concentration of leachate contaminants will be reduced by dilution/attenuation to 1/10th of the concentration measured at the intermediate point, prior to discharge at the point-of-exposure. Area-Specific Attenuation Factors (ASF) are important, because they provide a basis for correlating empirical groundwater quality data from non-landfill areas to point-of-exposure concentrations.

The GAF and ASF values for the Pre-Warehouse and Development Baseline scenarios are described in Sections 6.3 and 6.4 below. The level of conservatism inherent in these calculated values is discussed in Section 6.5 and also as part of Section 7.

Because the attenuation factors are specific both to site locations and to the assumptions used for the modeling scenario, any changes in modeling assumptions (e.g., precipitation rates within the landfill area) have an impact on solute transport and hence the calculated attenuation factors. Providing a method for quantifying these effects was one objective of the RI/FS groundwater modeling effort. As part of the feasibility study evaluations, the effects of various remedial alternatives on groundwater attenuation factors was evaluated. These measures tended to reduce the flux of both Landfill groundwater and its associated contaminants toward the shoreline, resulting in increases in both GAF and ASF values. The results of modeling conducted for each of the remedial alternatives are described in Section 9 of this document and were used in the evaluation of remedial alternatives.

6.3 Modeling of Pre-Warehouse Conditions

Results of Pre-Warehouse groundwater flow and solute transport modeling are described in this section. Results from the Development Baseline scenario are presented separately in Section 6.4. For each modeling scenario, the steady state flow simulation results presented are generated from the SEAWAT program. Use of heads from the SEAWAT program is slightly more realistic than the use of heads from MODFLOW, because SEAWAT takes into account the influences of nearshore salinity effects on groundwater flow.

Groundwater Flow Patterns

Groundwater Heads

Figure 6-3 shows model-generated heads for layer 1 from the Pre-Warehouse scenario. Those heads are compared in Figure 6-3 to both of the empirically measured heads from November 1998, and also to the model-predicted heads from the Development Baseline scenario discussed in Section 6.4. The Pre-Warehouse heads shown in Figure 6-3 represent a late dry / early wet season head distribution prior to GP Warehouse construction. Layer 1 is the shallowest layer and is similar to the heads water elevations measured during RI investigations at the site. Key groundwater features of the project area were simulated by the model, including the groundwater mound or ridge extending from the GP biotreatment lagoon toward Roeder Avenue, a groundwater saddle located in the vicinity of Roeder Avenue, and groundwater flow toward both waterways from central portions of the landfill.

An important feature of the modeled head distribution is the apex of the groundwater ridge, adjacent to the lagoon. The head of this ridge is created by increased recharge in the area of the ridge head. Modeled recharge distribution is shown on Figure 6-2. Increased recharge in this area represents the combined affect of precipitation, overspray from the lagoon, and potential spillage from leachate water handling activities. The model output (Table 6-1) indicates a cumulative recharge rate of about 860 cubic feet (6,500 gallons) per day from these sources. This is equivalent to a precipitation rate of about 4 inches per year if applied over the entire landfill area. This additional volume represents 17 percent of the total landfill recharge for the Pre-Warehouse scenario.

Modeled head distributions in layers 2 through 5 were similar to the distribution in layer 1 but less amplified. The output of the completed model indicated that some water from the GP biotreatment lagoon flows under the landfill berm and mixes with groundwater beneath the landfill refuse. Model predicted flow from the lagoon to the area within the landfill footprint is about 2,400 cubic feet (17,900 gallons) per day (see Table 6-1). This is equivalent to a precipitation rate of about 11 inches per year if applied over the entire landfill area. While much of this flow migrates to areas not containing landfill refuse (i.e., in many areas the water flows *beneath* the Landfill refuse, not necessarily *through* the Landfill refuse), the flow does have a substantial impact on area-wide groundwater flow patterns and Landfill contaminant fate and transport behavior. For the Pre-Warehouse modeling scenario, recharge from the GP lagoon flow is about 31 percent of the total flow of water into the landfill footprint from all sources, including precipitation recharge.

Aquifer properties beneath the lagoon were modified during model calibration to test the effects of Lagoon leakage on the groundwater flow system. Model calibration results show that some recharge from the Lagoon to the landfill is required to maintain heads within the landfill footprint. Zero recharge from the lagoon resulted in the flow model significantly under-predicting Landfill groundwater heads. The landfill heads could not be maintained by reasonable recharge values from overspray and precipitation alone, especially in the bottom model layers.

Particle Tracking

Groundwater particle tracks were developed from the model to provide a visual representation of groundwater solute transport paths in the Roeder Avenue Landfill area. Using the model, transport paths can be calculated between any model cell and the shoreline. Figure 6-6 provides a set of pathlines developed using RI/FS well locations and additional selected locations. The pathline analysis for the Pre-Warehouse modeling scenario is shown at the left side of the figure. Pathways at these locations were calculated to facilitate the interpretation of groundwater contaminant data (see discussions in Section 4.2 and Section 7).

Pathways are shown in plan view on Figure 6-6 for all five model layers combined. Particle tracks near the lagoon curve away from the lagoon because of the influence of Lagoon flow and overspray on groundwater flow patterns. These particle tracks provide a graphic illustration of a "Lagoon Shadow Effect" on each side of the GP lagoon (compare pathlines in Figure 6-6 with simplified representation in Figure 6-7). In these areas Lagoon groundwater represents the majority of discharging groundwater, and Landfill leachate is diverted laterally to other discharge areas. The Lagoon Shadow effect was consistent with groundwater quality data collected during the RI/FS. These data are discussed in Sections 4.2 and Section 7 of this report.

Landfill Water Balance

Pre-Development water balance volumes are summarized in Table 6-1. These calculated volumes represent the predicted recharge rates for water derived from four different sources. These recharge sources include the following:

- **Lagoon Flow:** Sub-surface groundwater flow from the lagoon to the landfill footprint

- **Cross-Roeder Flow:** Sub-surface groundwater flow from the upland side of Roeder Avenue to the landfill footprint

- **Overspray:** The combined volume of infiltration derived from overspray and water handling activities in the "overspray area" areas shown on Figure 6-2.

- **Precipitation:** Natural meteoric precipitation (rainfall, snowmelt, etc.) occurring within the landfill footprint.

Previous water balance estimates conducted as part of the Warehouse Feasibility Study (RETEC, 1996) predicted meteoric recharge rates of 3,800 cubic feet per day, and groundwater outflow from the Landfill of 5,100 cubic feet per day respectively. The model-calculated values for these same parameters are 4,160 (precipitation recharge) and 7,657 (outflow) cubic feet per day. The meteoric recharge values from 1996 and the present study are very similar to each other. But the outflow values from the model are significantly greater than those from 1996. This difference (between the 1996 estimates and the current model-derived value) is due mostly to the Lagoon effect and Lagoon overspray. Water flow volumes from these two sources could not be reliably estimated prior to groundwater flow modeling, and were greater than had been anticipated in the 1996 estimates.

As shown in Table 6-1, water inflow into the landfill from sources other than natural precipitation is an important component of the total volume of water entering the landfill. The flow of groundwater from beneath the biotreatment lagoon to the landfill (about 2,400 cubic feet per day) comprised 31 percent of the total volume of water entering the landfill, prior to completion of the Warehouse project.

Model-calculated landfill recharge due to overspray and leachate handling activities is 860 cubic feet of water per day or about 17 percent of the total Pre-Warehouse recharge volume.

The volume of flow into the landfill from across Roeder Avenue is small compared to the volume of subsurface flow from the lagoon. The flow rates calculated for groundwater flowing across Roeder Avenue into the landfill were about 250 cubic feet per day. This represented only 3 percent of the total recharge of water into the landfill under the Pre-Warehouse modeling scenario.

Summary of Groundwater Flow Patterns

Figure 6-7 provides a simplified representation of groundwater flow patterns as determined through the modeling process. The figure shows the relationship between vertical and horizontal groundwater flow, as well as the effects of tidal influences in shoreline areas.

Flow-Based Attenuation of Landfill Groundwater

The solute transport model was run for 35 years using the Pre-Warehouse modeling conditions. This simulates the period 1965 to 2000 when the landfill was operated and closed, and prior to recent development of the GP Warehouse on top of the landfill. This simulation was generally representative of site conditions during this period, with the exception of the G.P. Lagoon as noted below.

The model was established using the Lagoon as an existing condition during the entire 35-year period. In actuality, the lagoon was not completed until approximately 1978. This means that the early groundwater discharge patterns between the Landfill and the Bay in the current vicinity of the Lagoon were not directly simulated for the early period (1965 to 1978). During this early period, discharge of groundwater may have occurred beneath the landfill berm to surface waters formerly located in the area of the GP Lagoon. After construction of the lagoon, this flow was terminated due to the Lagoon Effect described above. Because the flow patterns in this early period were transient, direct simulation of this flow was not considered critical to model representativeness as it relates to existing and future site conditions.

Findings of Landfill Groundwater Contaminant Tracing Study

Figure 6-8 shows an example of model concentration output. This particular figure shows Year 2035 estimated solute concentrations for the Development Baseline Scenario. Similar output was produced for the Pre-Warehouse Scenario as well as each of the remedial alternatives evaluated in Section 9. Figure 6-8 shows the model grid and shoreline. Estimated concentrations can be read directly for each of the Layer 2 cells in the figure. Appendix D contains model output from Layers 1, 3, 4 and 5 of this same modeling scenario. These distributions reflect the influence of groundwater flow and site features on leachate transport. Refer to Figure 6-7 for a representation of the main groundwater flow patters. The main observed features include the following:

- **Dilution by Meteoric Recharge:** As Landfill groundwater migrates laterally toward the waterway shorelines leachate concentrations are attenuated more in the shallow model layers (1 & 2) than in the deeper layers (e.g., layers 4 & 5). This attenuation effect in the shallow model layers is caused by mixing of landfill groundwater with meteoric recharge. The precipitation mixes with and dilutes the concentration of leachate. Relatively little of this mixing occurs at depth, resulting in greater lateral migration of landfill leachate in these deeper layers. This pattern was observed in the actual sampling data from the Landfill (see Section 4.2 and Section 7).

- **Nearshore Upwelling and Bulkhead Effects:** A vertical convergence of leachate was noted in several areas of the model. In areas of partially-penetrating bulkheads, shallow groundwater (typically in layers 1 and/or 2) is forced downward by the presence of a shoreline bulkhead. This water then mixes with deeper groundwater. Once past the effect of the bulkheads, the groundwater begins to migrate vertically upward into shallower layers. This vertical migration is mainly caused by the saline-freshwater interface that forces fresh water progressively upward until it reaches the point-of-exposure cell (generally layer 2 cell) at the base of the waterway. Model results show that Landfill constituents do not migrate more than 2 or 3 cells into the waterways (40 to 60 feet) while moving upward, and that the majority of leachate discharges in the first row of cells (20 feet) within the waterways.

- **Tidal Mixing & Dilution:** The effects of tidal mixing and dilution are concentrated in the last few cells prior to discharge at the point-of-exposure. Generally, the groundwater mixes as it moves from deeper to shallower model layers. The tidal mixing effect can be seen by comparing model-predicted concentrations in model cells from each of the layers (see Figure 6-8 and Appendix D for data from the Development Baseline Scenario).

- **Lagoon Shadow and Cross-Roeder Effects:** Lateral flow of water into the landfill footprint occurs both at the GP Lagoon and along Roeder Avenue. This lateral flow has two effects. First, the flow of Landfill groundwater is affected in both areas. Near the lagoon, a shadow effect is observed (see Figure 6-7), and along Roeder, extensive mixing with non-landfill groundwater occurs along either side of the landfill. The second effect of lateral groundwater flow is to cause a convergence of leachate in the deeper model layers as the leachate migrates toward the two waterways. This creates narrow areas of relatively undiluted leachate in deeper model layers, extending from the landfill toward the shorelines (see figures in Appendix D). These areas remain relatively undiluted until reaching the shoreline areas where upwelling and tidal mixing occurs.

- **Hilton Avenue Discharge Patterns:** Along Hilton Avenue, discharge patterns are influenced by the presence of a bulkhead in the northwest corner of the project area. Flow patterns to the south of this bulkhead include flow underneath the landfill berm, with upwelling in the intertidal and subtidal beach areas. The highest leachate concentrations of all point of exposure cells are observed in these beach areas. To the east of the Hilton bulkhead, the flow involves discharge beneath the wooden bulkhead and into the I&J Waterway.

Calculation of Contaminant Attenuation Factors

Using the methods described in Section 6.2, two sets of flow-based attenuation factors were calculated for the Pre-Warehouse scenario. These include the Gross Attenuation Factors (GAF) and also the Area-Specific Attenuation Factors (ASF). The results of these calculations are shown in Figure 6-9. Table 6-2 through 6-4 provide an example of how these calculations are performed using the Development Baseline scenario data.

As shown in Figure 6-9, gross attenuation factors vary significantly around the perimeter of the Landfill. In areas where leachate discharge occurs without extensive dilution, the attenuation factors are the lowest. Areas with the lowest attenuation factors include the following:

- **Foot of Hilton:** The beach area at the foot of Hilton Avenue has the lowest gross attenuation factor of any point-of-exposure cell in the model. The gross attenuation factor for the cells in this area are as low as 3.2 for the Pre-Warehouse scenario. Due to the topography of this area, the point-of-exposure cells in this area are present in Layer 1 of the model. The low attenuation factors are caused by the short pathlines between the Landfill refuse and the point-of-exposure cells, and the upwelling of landfill leachate from underneath the landfill berm. The area of elevated contaminant concentrations is relatively narrow, constrained on the south side by the Lagoon Effect and on the north side by sheetpiling along the I&J waterway.

- **Gap in I&J Bulkhead:** There is a gap in the bulkhead along the I&J waterway between the Olivine site and the Bornstein Seafoods lease area. The 3-dimensional characteristics of the gap produce the second lowest gross attenuation factor for the model. For the Landfill area discharging through this bulkhead gap, the gross attenuation factor for the Pre-Warehouse conditions is just over 5X. This factor is significantly about half of the GAF for other areas along Hilton Avenue side of the Landfill.

- **I&J Waterway Bulkheads:** The majority of point-of-exposure cells along the I&J Waterway have gross attenuation factors of greater 9X to 10X or greater. Higher factors are present in the areas peripheral to the main Landfill attenuation zone, including the area at the head of the waterway and also along the sheet-pile bulkhead at the northwest corner of the project area.

- **Whatcom Waterway Shoreline:** The gross attenuation factors at the head of the Whatcom Waterway and in the lagoon shadow are high due to the influences of non-landfill groundwater on leachate dilution and attenuation. Gross attenuation factors in these areas are all greater than 20. In contrast, the area near Maple street has lower factors due to upwelling of leachate from the deep model layers. Gross attenuation factors in this area range from a low of 11X to 20 or more.

Area-Specific Attenuation Factors are shown in Table 6-9 for selected model areas. The ASF patterns are similar to those for the GAF.

6.4 Modeling of Development Baseline Conditions

Site Development Assumptions

The Development Baseline model scenario simulates the completion of the GP Warehouse project and the anticipated redevelopment of other area properties. The scenario simulates site development which has occurred or will occur in the absence of specific site remediation requirements. Modeling assumptions for this scenario are based on the GP Warehouse plans and the results of area-wide land use planning (Section 5).

Modeling assumptions used for the Development Baseline scenario are summarized in Figure 4-2. The Georgia Pacific warehouse is simulated in the flow model by assigning a recharge value of zero to Layer 1 cells within the footprint of the warehouse. A recharge value of zero is reasonable given that the warehouse is a fully enclosed building with an efficient rainwater collection system. Stormwater management routes roof water directly to the GP Lagoon without the opportunity for infiltration into the Landfill surface. Areas adjacent to the warehouse were assigned a recharge value half that of unpaved areas. This simulates the range of paved, and non-paved conditions existing in the area, and the incomplete capture of precipitation and stormwater from these paved areas.

In simulating future conditions on the Landfill and in adjacent areas, pending redevelopment actions at the Olivine, Sanitary Services and Chevron properties were incorporated. The recharge assumptions used were conservative, and consistent with land use planning efforts as described in Section 5. Recharge rates in areas proposed for redevelopment were established at 50 percent of the rates used for uncovered areas. This is a conservative estimate of recharge rates assuming that no extraordinary measures are taken as part of site redevelopment to minimize infiltration. Greater reductions in infiltration rates would be expected for heavy industrial land uses, intensive urban development, or environmental capping scenarios.

Groundwater Flow Patterns

The reductions in meteoric recharge results in significant changes to groundwater heads and flow paterns for the Development Baseline scenario. These effects include reduced groundwater flow toward both waterways, a lowering of the groundwater mound in the middle of the landfill, and increases in the amount of mixing and flow-based attenuation of leachate between the landfill boundary and the point of exposure.

Groundwater Heads

In the Development Baseline scenario the groundwater mound in the center of the landfill is reduced in height by as much as 2.7 feet compared to the Pre-Warehouse scenario. This change in model-predicted head is shown in Figure 6-3.

Groundwater flow toward both waterways is reduced as reflected in the position of the 7, 8 and 9 foot contours. These contours are located further inland than equivalent contours in the pre-development flow simulations, indicative of decreased groundwater flow volumes toward the waterways because the gradients are lower. Upland head values of 7 feet and lower are less affected by development conditions due to the proximity of these head values to the waterways.

In the Development Baseline scenario, the groundwater saddle along Roeder Avenue is more pronounced and located further within the landfill compared to the Pre-Warehouse simulation. This effect results from decreases in meteoric recharge within the Landfill and slight increases in groundwater flow across Roeder Avenue and from the Lagoon.

Because of the lower heads in the Landfill, the groundwater gradient between the center of the Landfill and adjacent waterways is reduced. The flux of water through the Landfill refuse is reduced, as is the total volume of saturated landfill material. These factors combine to reduce the flux of Landfill groundwater and associated contaminants under the Development Baseline scenario. Because the Warehouse is located along the Whatcom Waterway side of the Landfill, the reductions in contaminant flux are greatest along the Whatcom Waterway shoreline.

Particle Tracking

Figure 6-6 shows the changes in pathlines that are predicted under the Development Baseline scenario in comparison to the Pre-Warehouse scenario. The changes in pathlines are generally small. The main effect on particle pathlines is caused by the increase in Lagoon and cross-Roeder groundwater flow. This results in a slight expansion of the Lagoon shadow and a concentration of flow along the Maple Street axis toward both the Whatcom Waterway and I&J Waterway shorelines. This pinching effect significantly increases attenuation in peripheral areas, but results in only moderate improvements in attenuation for areas along the Maple Street axis.

Landfill Water Balance

Table 6-1 summarizes the change in landfill water balance for the Development Baseline scenario.

The most important effect of development on the landfill water balance is a reduction in meteoric recharge by 60 percent. However, secondary effects associated with the increased Lagoon and cross-Roeder flow offset some of this reduction, resulting in an overall 28 percent reduction in the quantity of water entering the landfill footprint. Groundwater flow from the GP Lagoon toward the Landfill increased 23 percent from about 2,400 to just over 2,900 cubic feet per day. Flow from the lagoon as a percentage of the total flow into the Landfill footprint increased from 31 to 53 percent of the total recharge volume.

Ground water flow from across Roeder Avenue into the Landfill increased significantly from 249 to 714 cubic feet per day. The increase in flow from across Roeder Avenue is 465 cubic feet per day, similar in total quantity to the increase in flow from the Lagoon.

Recharge from overspray decreased from over 800 cubic feet per day to less than 200 cubic feet per day. The decrease is caused by the reduced infiltration in areas previously exposed to overspray. A small portion of the Landfill area between the warehouse and the clay berm receives overspray in the Development Baseline model. This area is shown on Figure 4-2.

Flow-Based Attenuation of Landfill Groundwater

Findings of Landfill Groundwater Contaminant Tracing Study

Model calculated leachate distributions for the Development Baseline scenario are presented in Figure 6-8 (Layer 2) and in Appendix D (Layers 1, 3, 4 and 5). These distributions show the effect of Warehouse and development features on transport of Landfill groundwater. The distribution of Landfill groundwater is similar to that observed with the Pre-Warehouse scenario. Observed changes in distribution included the following:

- **Increased Lagoon and Roeder Effects:** The influence of Lagoon Effect and cross-Roeder flow was more pronounced in the Development Baseline scenario than in the Pre-Warehouse scenario. These effects produced greater mixing in areas near Roeder and near the Lagoon. Landfill groundwater migration was more focused along the Maple street axis and at the foot of Hilton Avenue.

- **Reduction in Off-Landfill Concentrations:** In most off-Landfill areas of the model grid, predicted concentrations of Landfill constituents in groundwater were reduced in the Development Baseline model. The extent of reduction varied with model Layer and location. These results confirm that the reductions in overall recharge and groundwater flux produce a corresponding reduction in the migration of Landfill constituents toward the waterways.

Calculation of Contaminant Attenuation Factors

The changes in attenuation factors between the Pre-Warehouse scenario and the Development Baseline scenario are shown in Figure 6-9.The attenuation factors increased in most areas, indicating increased mixing and flow-based attenuation of Landfill contaminants prior to discharge into the point-of-exposure cells. The main changes are as follows:

- **Foot of Hilton:** The beach area at the foot of Hilton Avenue continues to show the lowest Gross Attenuation Factor of any point-of-exposure cell in the model. The GAF in this area improves slightly from 3.2X to just over 3.6X. As in the Pre-Warehouse modeling scenario, this area is relatively narrow, constrained on the south side by the Lagoon Effect and on the north side by sheetpiling along the I&J waterway.

- **Gap in I&J Bulkhead:** The gap in the bulkhead along the I&J waterway between the Olivine site and the Bornstein Seafoods lease area continues to exhibit the second lowest attenuation factors for the project area. The Gross Attenuation Factor for groundwater discharging through this area increases slightly from 5X to 6X. The Area-Specific Attenuation Factors in this area show a corresponding increase (see Figure 6-9). The extent of improvement in attenuation in this area is limited by the extent of Landfill areas without full infiltration control along the Hilton Avenue side of the Landfill, and also the "pinching" effect of the cross-Roeder flow and the Lagoon flow that tends to concentrate the discharge of residual Landfill groundwater along the Maple Street axis.

- **I&J Waterway Bulkhead Areas:** The attenuation factors along the other areas of the I&J Waterway increase significantly due to the reductions in Landfill groundwater heads and the flux of Landfill groundwater toward the waterway. Changes in attenuation factors are shown in Figure 6-9.

- **Whatcom Waterway Shoreline:** The attenuation factors along the C-Street side of the Landfill increase near Roeder Avenue and near the Lagoon. Near the Maple street axis, the factors don't change significantly because the reductions in total groundwater and contaminant flux toward the waterway are offset in this area by the "pinching" of the Landfill groundwater along the Maple Street axis. Gross attenuation factors along the Maple Street axis remain at 13 and above.

Evaluation of Worst-Case Attenuated Discharge Scenario

Table 6-5 presents the results of a worst-case analysis of attenuated groundwater discharge. This analysis was conducted using 1) average Landfill groundwater quality data from Table 4-8 and the Gross Attenuation Factors from Figure 6-9. The results provide a direct comparison between predicted point-of-exposure concentrations and the applicable surface water criteria. These results are presented using the exceedance ratio format where a ratio of 1.0 or below indicates a protective concentration in the point-of-exposure.

As shown in Table 6-5, the flow-based attenuation documented under the Development Baseline scenario produces point-of-exposure concentrations for most contaminants of concern that are below applicable surface water standards. Compared to the Landfill area groundwater which had exceedance ratios greater than 1.0 for eight compounds. Additionally, bis(2-ethylhexyl)phthalate had an exceedance ration greater than 1.0 when the more stringent sediment source control value was used as the applicable cleanup standard.

In contrast to the Landfill area groundwater, the flow-based attenuation results in exceedance ratios in excess of 1.0 only for pentachlorophenol. All other compounds are predicted by the model to be below applicable surface water criteria at the point-of-exposure. Biological and geochemical factors that may influence the attenuation of pentachlorophenol are discussed further in Section 7 of this report.

6.5 Preliminary Testing of Additional Scenarios

In addition to the Pre-Warehouse and Development Baseline scenarios described in the preceding sections, ThermoRetec conducted two additional sets of simulations to evaluate factors that could change the conclusions of groundwater and solute transport modeling. The two additional evaluations were conducted to assess potential additive interactions of Landfill contaminants in the C-street area, and to evaluate implications of potential changes to GP Lagoon characteristics.

Interactions with Non-Landfill Contaminants

Most of the Landfill contaminants of concern are common industrial contaminants. In the case of copper, elevated copper levels have been detected in groundwater at the BC Investments/Colony Wharf site.

Due to the relatively low average copper concentrations in the Landfill area groundwater and the extent of flow-based attenuation occurring between the Landfill and the shoreline, the copper concentrations at the point-of-exposure and attributable to the Landfill are predicted to be less than 0.07 times the applicable surface water standard. However, as part of the RI/FS process Ecology requested that an evaluation be conducted to ascertain whether this contribution of Landfill copper to the Colony Wharf site area might significantly exacerbate the existing conditions there.

To test the potential additive effects of the Colony Wharf site copper and the Landfill-associated copper, a simulation was conducted in which Layer 1 cells within the Colony Wharf site were established as non-depleting contaminant source cells. Layer 1 cells were established as the source given the likely release scenarios for copper at the Colony wharf site (i.e.., placement of copper-containing fill materials or releases of copper-containing materials to surface soils through spills of paint or foundry wastes).

Source concentrations were based on measured copper concentrations at the Landfill and Colony Wharf sites. The average copper concentration in well MW-3B has been measured at 6.8 times the applicable surface water standard (see Table 4-13). In contrast, Landfill groundwater concentrations of copper average only 0.85 times the surface water standard. Source concentrations for the Layer 1 Colony Wharf cells and the Landfill refuse cells were established at 700 and 100 concentration units, respectively. The model simulation was then conducted using the Development Baseline scenario, with model runs of 35 years. A corresponding run was conducted without the Landfill as a source.

The addition of the Colony Wharf source area to the modeling scenario did cause an increase in point-of-exposure copper concentrations from 0.07 to 0.16 times the surface water standard. Results of modeling indicate that the interaction of Landfill-associated copper with the site-specific conditions at the Colony Wharf site does not pose a significant threat to surface water quality under an attenuated discharge scenario. Copies of the modeling output are included with other modeling data in Appendix D.

Impacts of Changes to GP Lagoon Conditions

A second set of evaluations was conducted to qualitatively evaluate the impacts of potential changes to the GP Lagoon operation and/or characteristics. Since initiation of the RI/FS, GP has closed its pulp manufacturing operations in Bellingham. The GP tissue mill remains active and the Lagoon remains in operation for treatment of facility wastewater. However, it is possible that the operation or characteristics of the GP Lagoon will change as a result of the pulp mill closure and the resulting reduction in facility wastewater generation and treatment needs.

The range of changes to the Lagoon characteristics or operation could potentially include 1) no change, 2) partial closure of the Lagoon with portions converted to upland use by infill, 3) partial closure of the Lagoon with portions converted to in-water use by modification and containment dike breaching/removal/relocation, 4) complete closure with conversion to upland use by infill, or 5) complete closure with conversion to open water use. Of these alternatives, the most significant change relative to the Landfill groundwater flow regime would be the full closure and conversion to open-water uses. Under this scenario the water elevations within the Lagoon would be reduced and would become identical to those in the Bay, inflow from the Lagoon to the Landfill would cease, and outflow of groundwater toward the Lagoon would occur under tidally-influenced conditions. Each of the other alternatives would represent intermediate changes between the Development Baseline modeling scenario and this hypothetical scenario.

A limited evaluation was conducted in which the Lagoon was assumed to be converted to open-water uses. The accumulated bottom sediments within the Lagoon were assumed to be removed to the original grade (-12 feet MLLW). The water elevations within the Lagoon were set equal to those in the Bay, including normal tidal influences. Point-of-exposure cells were established within the Lagoon using the same 1-foot thicknesses simulated in other portions of the model. Salinity effects were incorporated as described in Section 6.2, and then the groundwater flow and solute transport models were run to evaluate the influence of groundwater gradient changes on point-of-exposure concentrations of Landfill contaminants.

Under the Lagoon closure scenario, the groundwater saddle (Figure 4-1) disappears and groundwater flows outward from the Landfill in all directions toward the Bay, including toward the Lagoon area. Groundwater upwelling from underneath the Laurel street clay berm occurs within a tidally-influenced area. The mixing associated with this tidal activity results in gross attenuation factors of over 10X. In Lagoon closure simulations conducted in parallel with the elements of the Preferred Remedial Alternative (see Section 9) the closure of the Lagoon tended to improve the effectiveness of the alternative.

6.6 Flow Modeling Uncertainty Analysis

A degree of uncertainty is inherent in any model. Sources of uncertainty include the quantity and quality of empirical data for the physical system the model is meant to simulate, the limitations of the modeling code, the adequacy of calibration, and the selection of model test input parameters such as the temporal and spatial distribution of recharge. In developing the groundwater model for application to the Roeder Avenue Landfill RI/FS, the overall uncertainty of the model has been minimized through the use of extensive and corroborating empirical data and through the use of a robust and extensively tested modeling code. In defining input parameters, those which produce a conservative (i.e., high) estimate of contaminant mobility have been selected where the parameters are not tightly constrained by empirical measurements. Factors with a significant impact on the overall results of groundwater flow and solute transport modeling are described below:

- **Site Geologic Characteristics:** The uncertainties regarding the physical system represented by the model were minimized by the extensive data available for the Landfill and vicinity. Data incorporated into the geologic model for the site included over 80 soil borings (including both shallow and deep borings), over 50 monitoring wells, and over 50 test pits. The information from these sources was cross-referenced with the extensive historical information available for the Landfill and vicinity. As a result, the refuse boundaries, the characteristics of the fill soils and the presence, depth and characteristics of deep confining layers are all known with a high degree of certainty.

- **Site Hydrogeologic Data:** Hydrogeologic data important for the modeling effort include the groundwater gradients, the conductivity values for the various soil units, and the effects of shoreline conditions, tidal influences and salinity gradients on hydraulic properties. The quality of groundwater gradient information was ensured through 1) the availability of prior gradient data to assist in placing RI/FS monitoring wells and piezometers, and 2) the extensive number of wells and piezometers included in the RI/FS investigation effort. Tidal influences were directly quantified, both to ensure that gradient information was not adversely impacted by tidal artifacts, as well as to obtain additional data useful to the groundwater modeling effort. Aquifer conductivity values were analyzed using aquifer slug tests, cross-checked against the conductivity values determined from the tidal study data. The dual data collection effort for conductivity values ensures the quality of this important data set. Finally, the shoreline features and salinity gradients present in the site area were directly evaluated during the RI/FS. These factors were directly incorporated into the groundwater flow model construction. Physical parameters for shoreline bulkheads, buildings, pavement and the GP Lagoon characteristics were developed based on available project design documents or direct inspection.

- **Choice of Modeling Code:** In selecting a modeling code, careful consideration was given to the objectives of the modeling effort, the complexities of the site area and the quality of the available codes. The model codes selected for use on the project (MODFLOW, MT3D, SEAWAT) represent the best available science for achieving the modeling objectives. Modeling code selection was approved by Ecology.

- **Simulation of Point-of-Exposure Areas:** The critical output of the solute transport modeling is the estimation of maximum point-of-exposure concentrations of Landfill contaminants after taking into account flow-based attenuation processes. In setting up the point-of-exposure cells, care was taken to match model design with regulatory requirements. The grid for Layer 2 of the model simulates a 1-foot thickness of soil/sediment beneath the Bay. The use of the 1 foot interval ensures that the groundwater quality entering the 12 cm bioactive zone is not underestimated due to the mathematical averaging that would occur if a thinner point-of-exposure cell thickness was selected. The point-of-exposure cell thicknesses are maintained uniformly to ensure consistency of the model output with regulatory requirements.

- **Local Data for Meteoric Recharge Rates:** Recharge rates associated with meteoric recharge (e.g., precipitation) were based on the average annual precipitation in Bellingham. That value was reported as 36 inches per year based on local meteorological data. Initial meteoric recharge values in the model were established at 22 inches per year, or 60 percent of this local average value. Some annual variations in precipitation will occur, but long-term patterns will not be affected by these short-term effects. Seasonal variations have limited effects on solute transport conclusions given the long time-periods (70 years) involved in the modeling process.

- **Multiple Model Calibration Steps:** The accuracy of groundwater model calibration was enhanced through the use of transient model runs as part of the calibration step. These runs verified that the model could accurately reproduce not just the long-term groundwater head distribution, but also the short-term effects of tides acting on the shoreline areas of the model. This additional calibration step provides greater certainty than typically available with groundwater modeling efforts.

- **Incorporation of Salinity Effects:** The modeling code selected for the project allowed salinity impacts on groundwater flow to be directly simulated. The saline conditions result in a more concentrated groundwater discharge, occurring in an area closer to the shoreline than when simulated without incorporating salinity effects. This produces a higher estimate of point-of-exposure concentrations than would be produced otherwise.

- **Use of Non-Depleting Source Cells:** In modeling the transport of solutes from the Landfill to the shoreline, the source cells were simulated as "non-depleting" sources. For long-term simulations this provides a conservatively high estimate of contaminant transport potential. Weathering and natural geochemical processes that have been documented to occur in landfills will tend to reduce actual flux of contaminants. As a result, the model-predicted solute transport should be greater than that observed during long-term monitoring.

- **Use of Conservatively Low Retardation Factors:** The retardation factors used during flow modeling were established at a value at least two-fold lower (producing a conservatively high estimate of contaminant mobility) than the most mobile of the site contaminants. Further, no degradation or geochemical immobilization was incorporated into this step of the analysis. This baseline estimate of retardation can then be adjusted on a contaminant-specific basis as appropriate to the available data.

- **Use of Long-Term Asymptotic Output:** The modeling periods conducted were run for periods of 70 years to ensure that the modeling output used for site decision-making was based on true steady-state conditions. The stability of the output was verified by comparing the results of modeling at multiple time steps.

Based on the foregoing considerations, ThermoRetec concludes that the groundwater flow model is suitable for site decision-making. Any differences between predicted and actual observed contaminant transport will tend to err on the side of conservatism, providing an additional degree of protection for human health and the environment.

With respect to individual contaminants with known and documented biodegradation and/or geochemical processes that tend to reduce contaminant mobility, the flow-based attenuation factors described in this section should be adjusted to take into account these process. Biological and geochemical processes are described in more detail in Section 7 of this report. For other contaminants, the attenuation factors from this Section can be used conservatively.

6.7 Conclusions of Groundwater Flow Modeling

The following conclusions were drawn from the results of groundwater flow modeling, in conjunction with the groundwater analytical data reviewed in Section 4.2:

- **Range of Attenuation Factors:** The results of groundwater flow modeling demonstrate that even without taking into account contaminant degradation or geochemical immobilization, flow-based attenuation of Landfill constituents can be significant. Gross attenuation factors determined for the site range from 3.2X to over 20X.

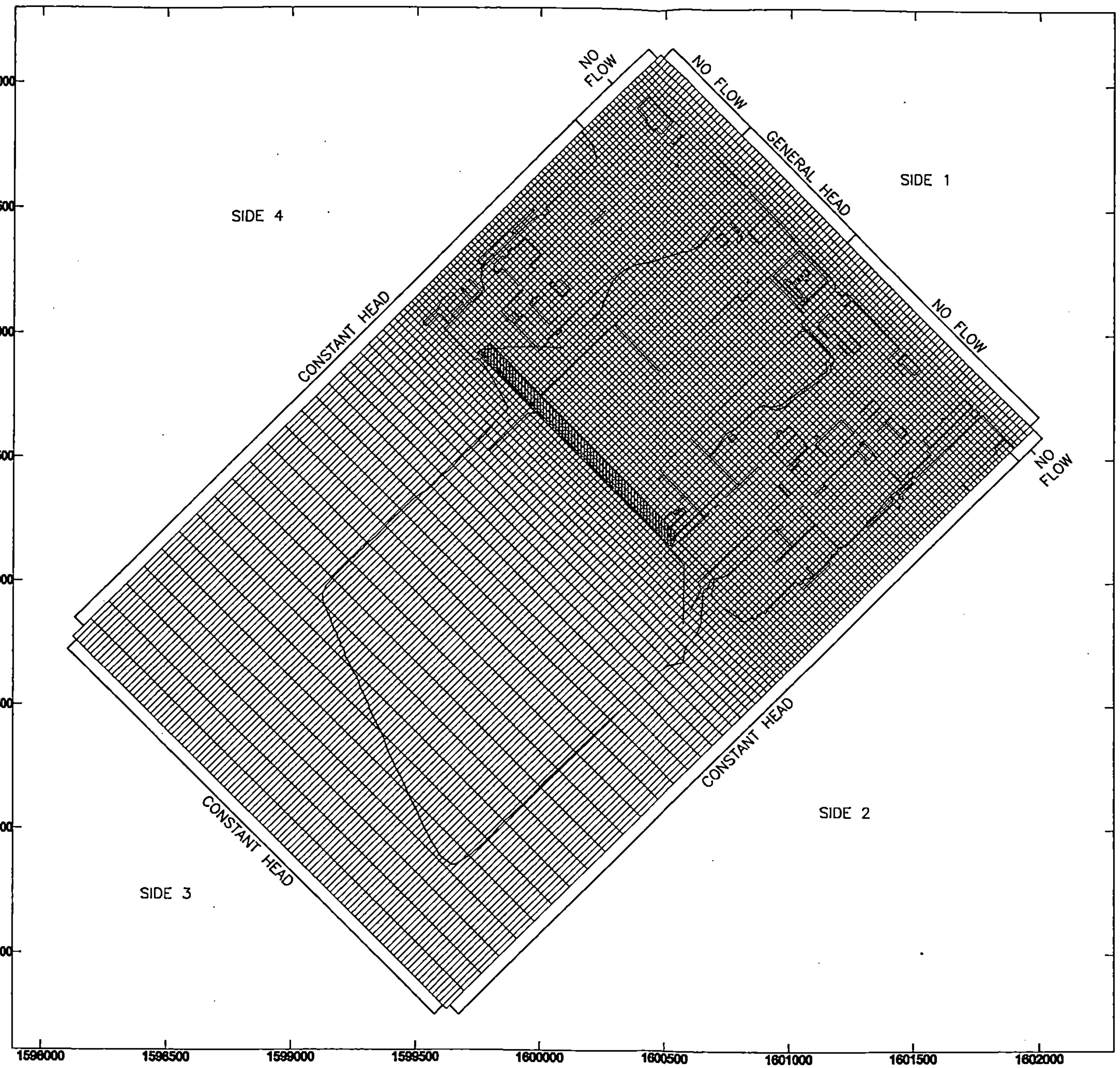
- **Landfill Groundwater Distribution:** Based on the use of total chromium and total organic carbon as indicator constituents, the patterns of leachate migration are similar to those predicted by the flow and solute transport models. The main differences between the predicted and observed distributions is that the leachate distribution is less than the predicted distribution. This difference is due to the conservatism of the flow modeling assumptions, as well as to geochemical and biological factors that limit the migration of Landfill groundwater constituents.

- **Evidence of Natural Biodegradation:** The migration of organic compounds was less than predicted by the flow model in the absence of contaminant degradation. For example, the compound 1,4-dichlorobenzene was commonly detected in landfill leachate, but has not been detected in any of the off-landfill samples. The fact that this compound is not colocated with the landfill leachate suggests the influence of biological degradation. Pentachlorophenol was also not detected in any of the off-landfill wells, also suggesting these influences on PCP transport.

- **Effects of Site Development:** The development of the Landfill site and adjacent properties has a beneficial effect on Landfill contaminant fate and transport. The reductions in infiltration result in reductions in predicted contaminant transport. However, as the extent of the cap increases and approaches 100 percent, changes in groundwater heads result in increases in other sources of groundwater recharge (e.g., cross-Roeder flow). This situation produces a case of diminishing returns for site capping.

- **Interactions with Non-Landfill Contaminants:** Elevated concentrations of copper were detected in shallow groundwater at the BC Investments property. The distribution and concentrations of the contamination indicate that these impacts are associated with non-Landfill contamination sources. Additional groundwater modeling evaluations were performed to specifically assess the relationship between the Landfill and non-Landfill copper. These additional evaluations indicated that the contributions of the Landfill copper concentrations do not significantly contribute to point-of-exposure concentrations. Potential geochemical immobilization of copper in between the Landfill and the shoreline would further reduce this potential contribution.

- **Effects of Lagoon Modifications:** The GP Lagoon is currently a source of groundwater recharge in the Landfill. Modifications to the Lagoon by conversion to upland or open water uses would reduce or eliminate this recharge. These effects would tend to further reduce the migration potential for Landfill contaminants in groundwater.



NOTE: SIDE 1 BOUNDARY CONDITIONS FOR LAYERS 2, 3, AND 4 ARE PARTIAL GENERAL HEAD. SIDE 2, 3, AND 4 BOUNDARY CONDITIONS FOR LAYERS 2, 3, AND 4 ARE NO FLOW.

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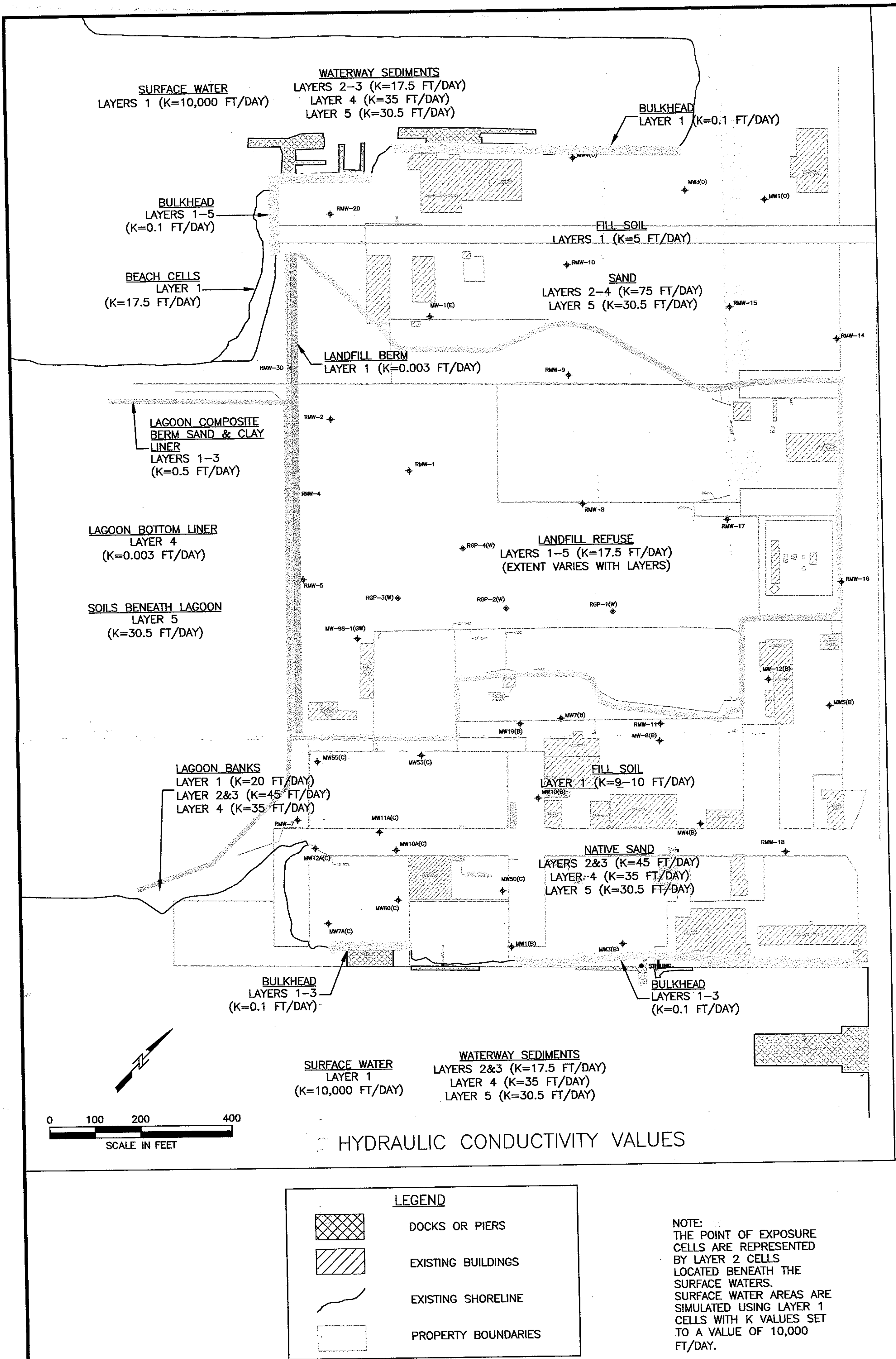
ROEDER AVENUE LANDFILL RI/FS

PORTB-03809-710

DATE: 06/02/01 | DRWN: N.S. | FILE: 3809S211

GROUNDWATER FLOW MODEL GRID AND BOUNDARIES FOR TOP MODEL LAYER

FIGURE 6-1



HYDRAULIC CONDUCTIVITY VALUES

NOTE:
THE POINT OF EXPOSURE CELLS ARE REPRESENTED BY LAYER 2 CELLS LOCATED BENEATH THE SURFACE WATERS.
SURFACE WATER AREAS ARE SIMULATED USING LAYER 1 CELLS WITH K VALUES SET TO A VALUE OF 10,000 FT/DAY.

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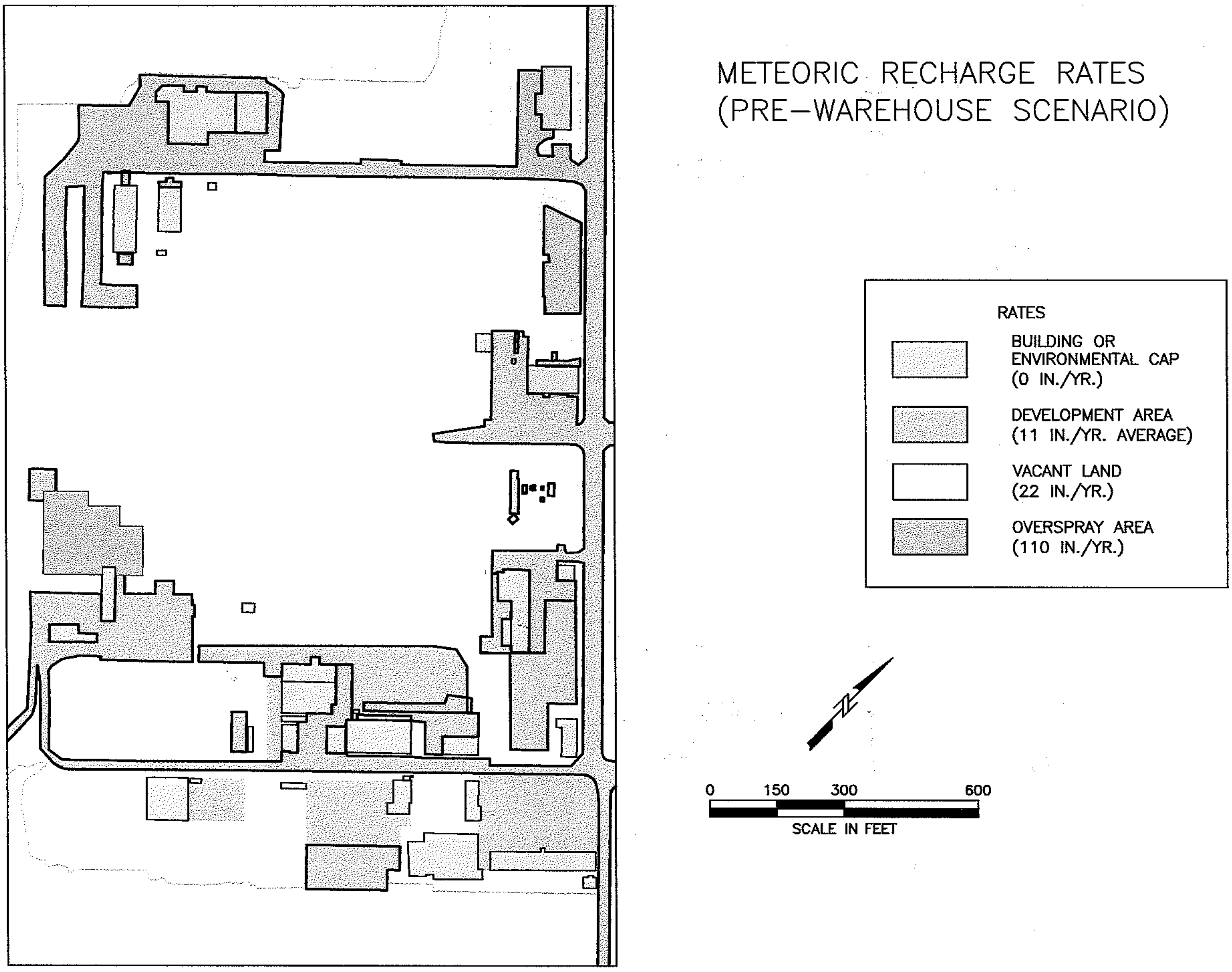
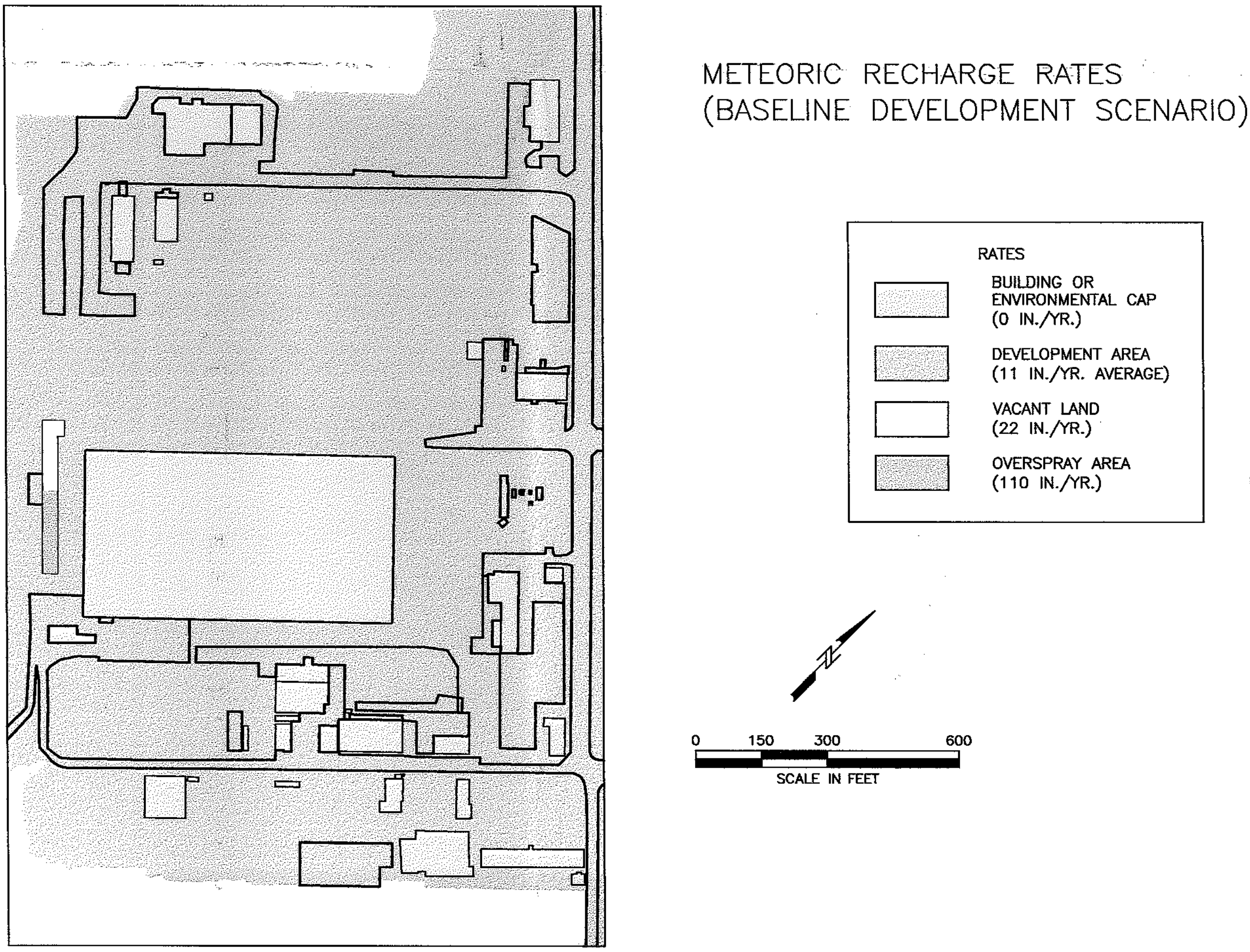




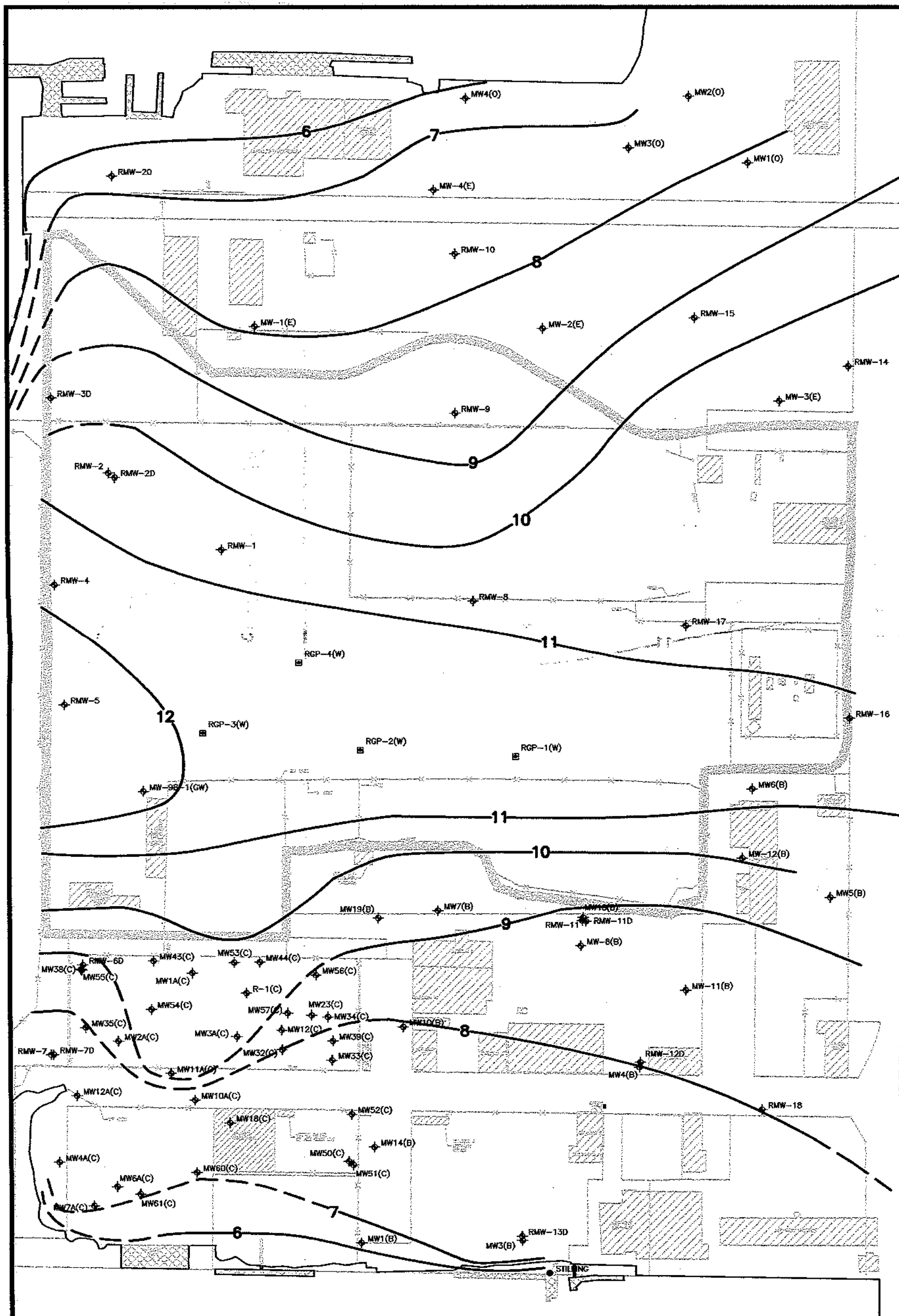
ROEDER AVENUE LANDFILL RI/FS

PORTB-03809-710

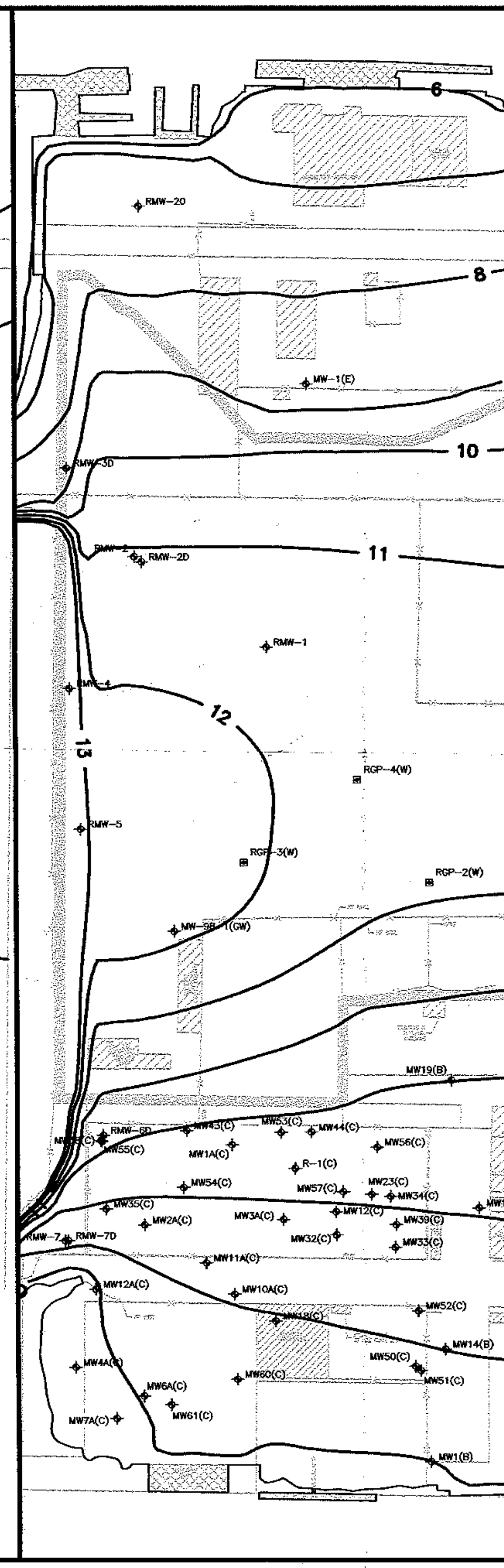
SITE FEATURES INCORPORATED INTO THE GROUNDWATER MODEL

DATE: 06/02/01 | DRWN: N.S. | FILE: 3809S212

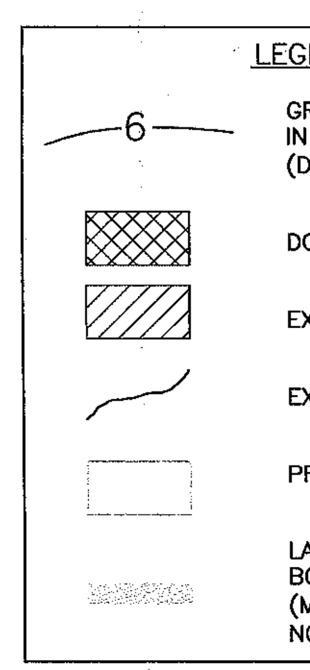
FIGURE 6-2



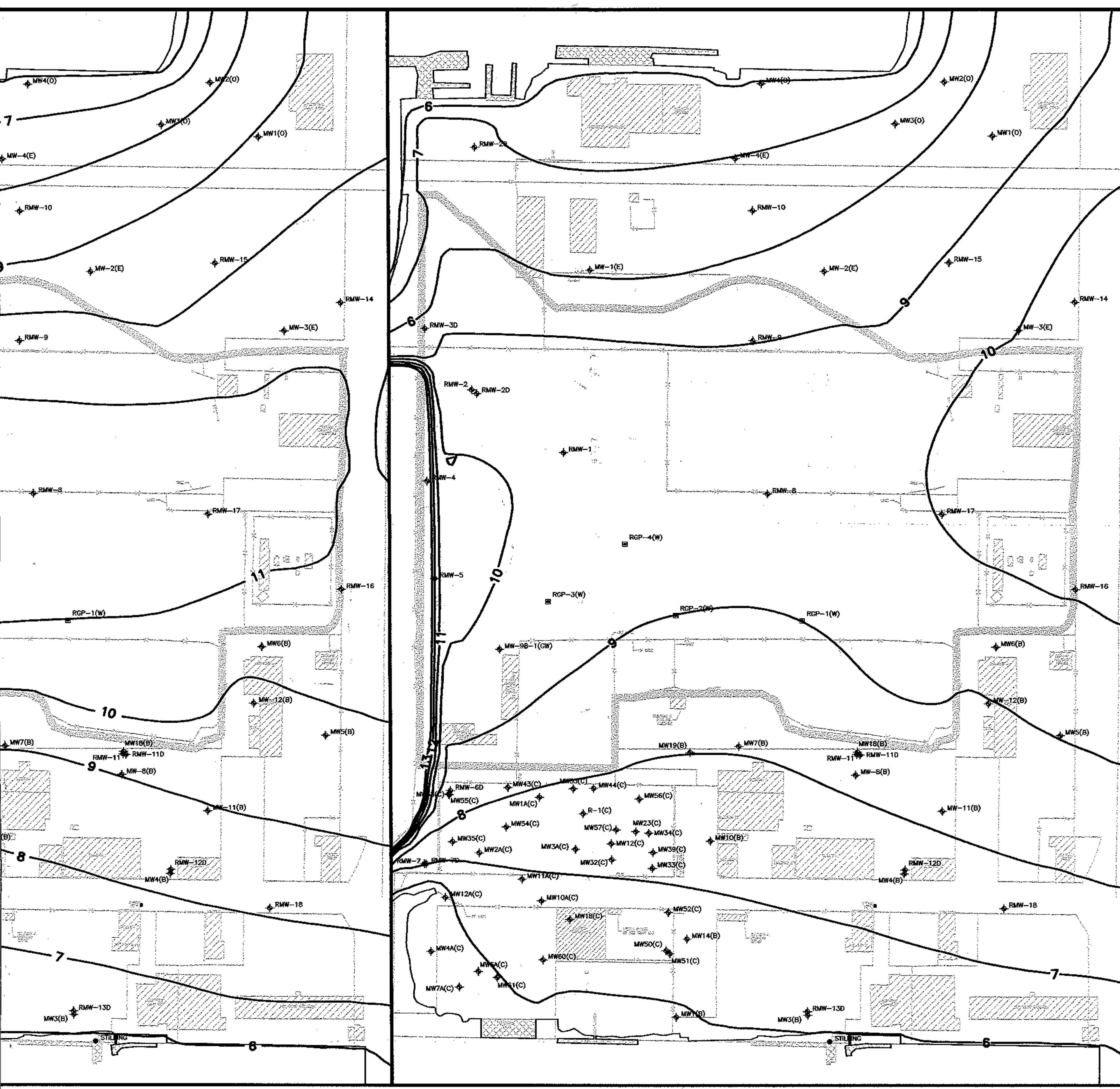
MEASURED GROUNDWATER ELEVATIONS
FROM NOVEMBER 1998
(FIGURE 4-1, FIRST PROGRESS MEMO)



MODEL PREDICTED
PRE-WAREHO



ThermoRetec



HEADS (LAYER 1)
USE SCENARIO

MODEL PREDICTED HEADS (LAYER 1)
DEVELOPMENT BASELINE SCENARIO

ND

UNDWATER CONTOUR
FEET MLLW
SHED WHERE INFERRED)

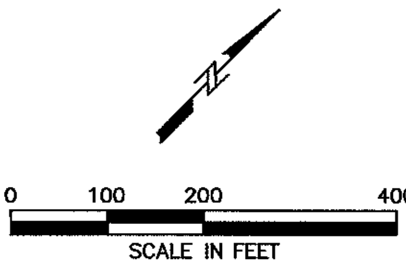
KS OR PIERS

STING BUILDINGS

STING SHORELINE

PERTY BOUNDARIES

DFILL REFUSE
NDARY
CA SITE BOUNDARY
DETERMINED)



ROEDER AVENUE LANDFILL RI/FS			MEASURED VERSUS PREDICTED GROUNDWATER HEADS FROM FLOW MODEL
PORTB-03809-710			
DATE: 06/02/01	DRWN: N.S.	FILE: 3809s144	FIGURE 6-3

Figure 6-4. Groundwater Model Calibration Data

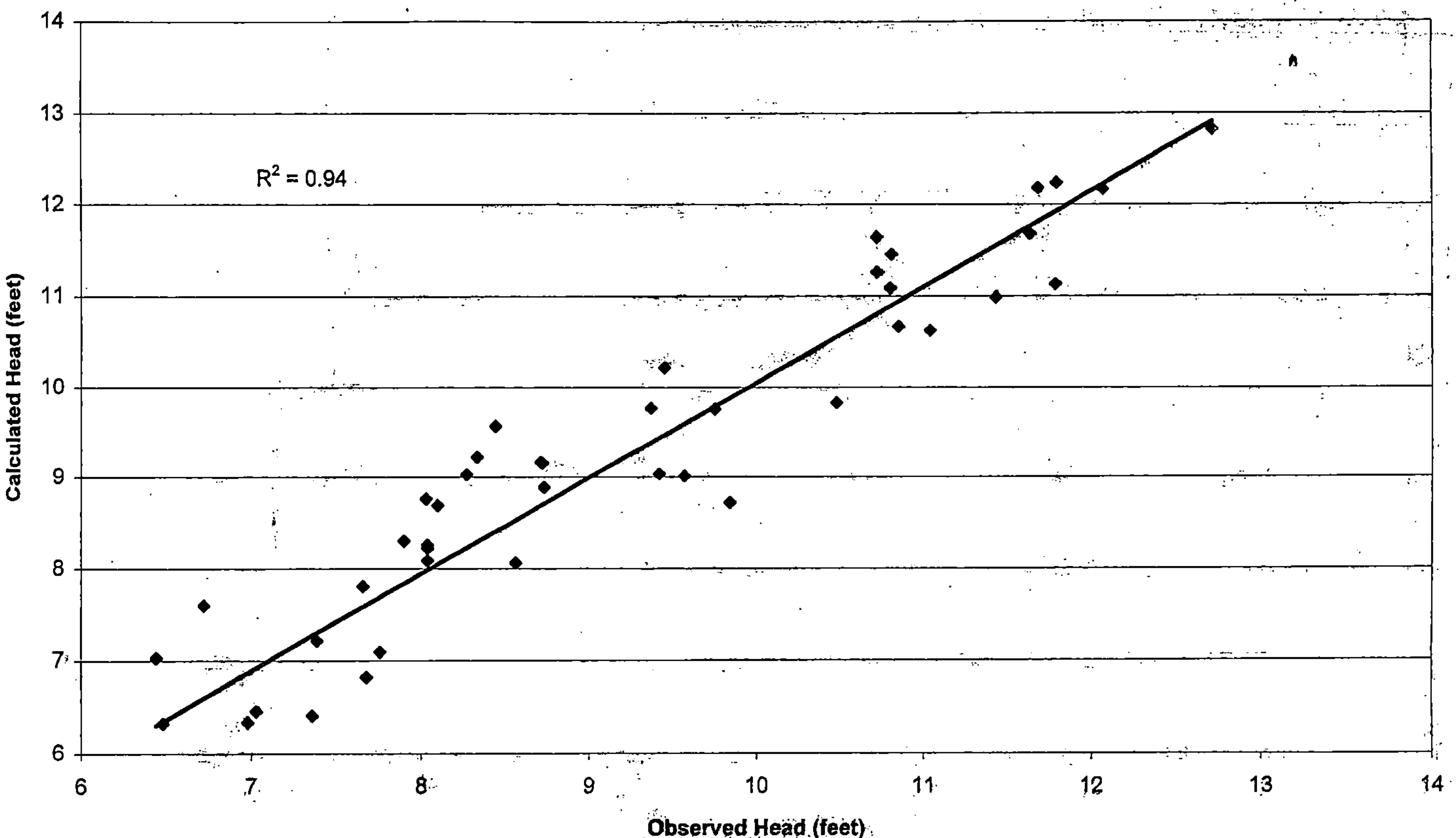
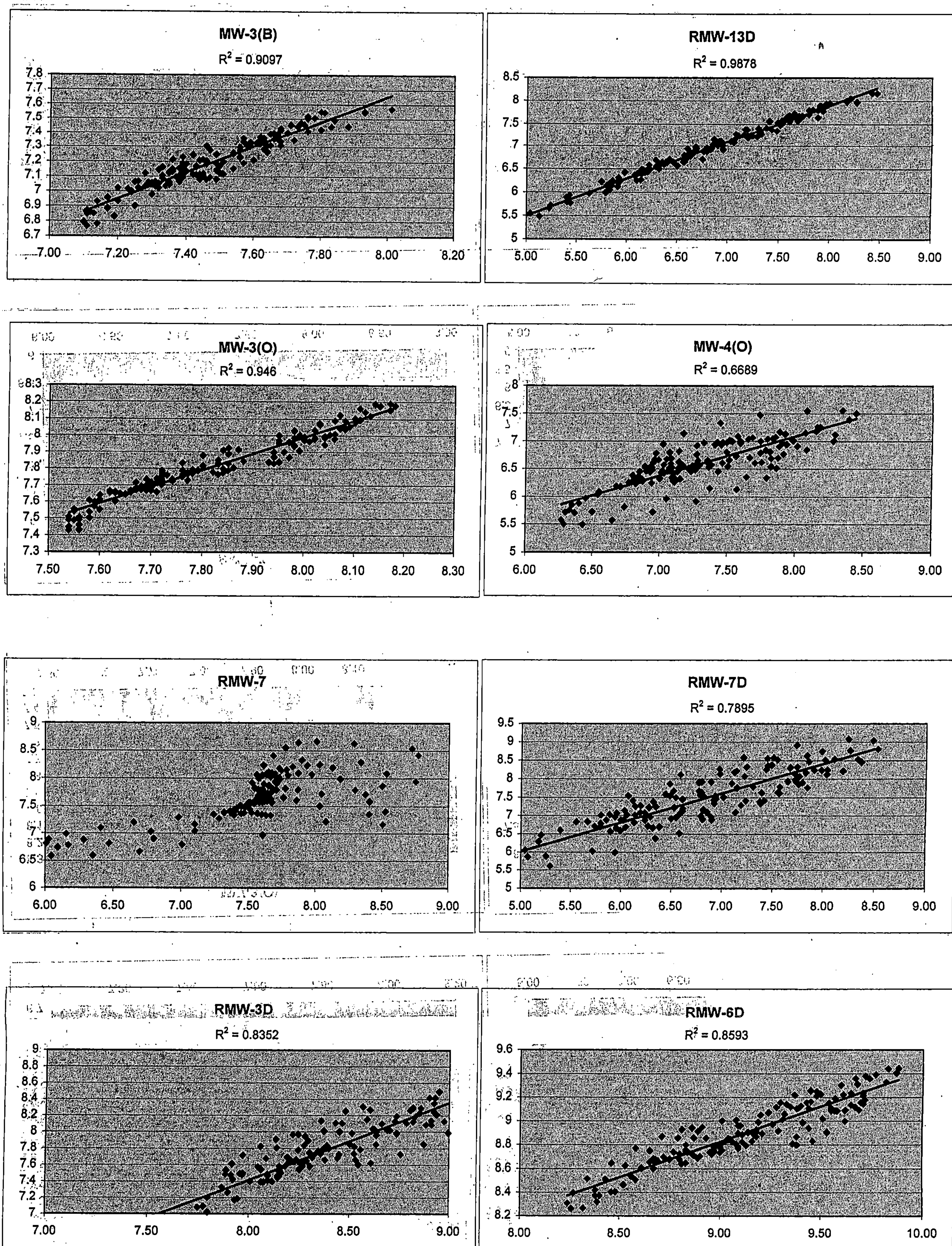


Figure 6-5. Transient Model Calibration Data for Selected Monitoring Wells



MODELED SHORELINE

MODEL–PREDICTED "LEACHATE" CONCENTRATION CONTOURS FOR LAYER 2 CELLS (90)

LAYER 2 MODEL GRID AND PREDICTED "LEACHATE" CONCENTRATION (0.00)

NOTE: SEE APPENDICES … MODEL LAYER OU…

50 0

1"=100'

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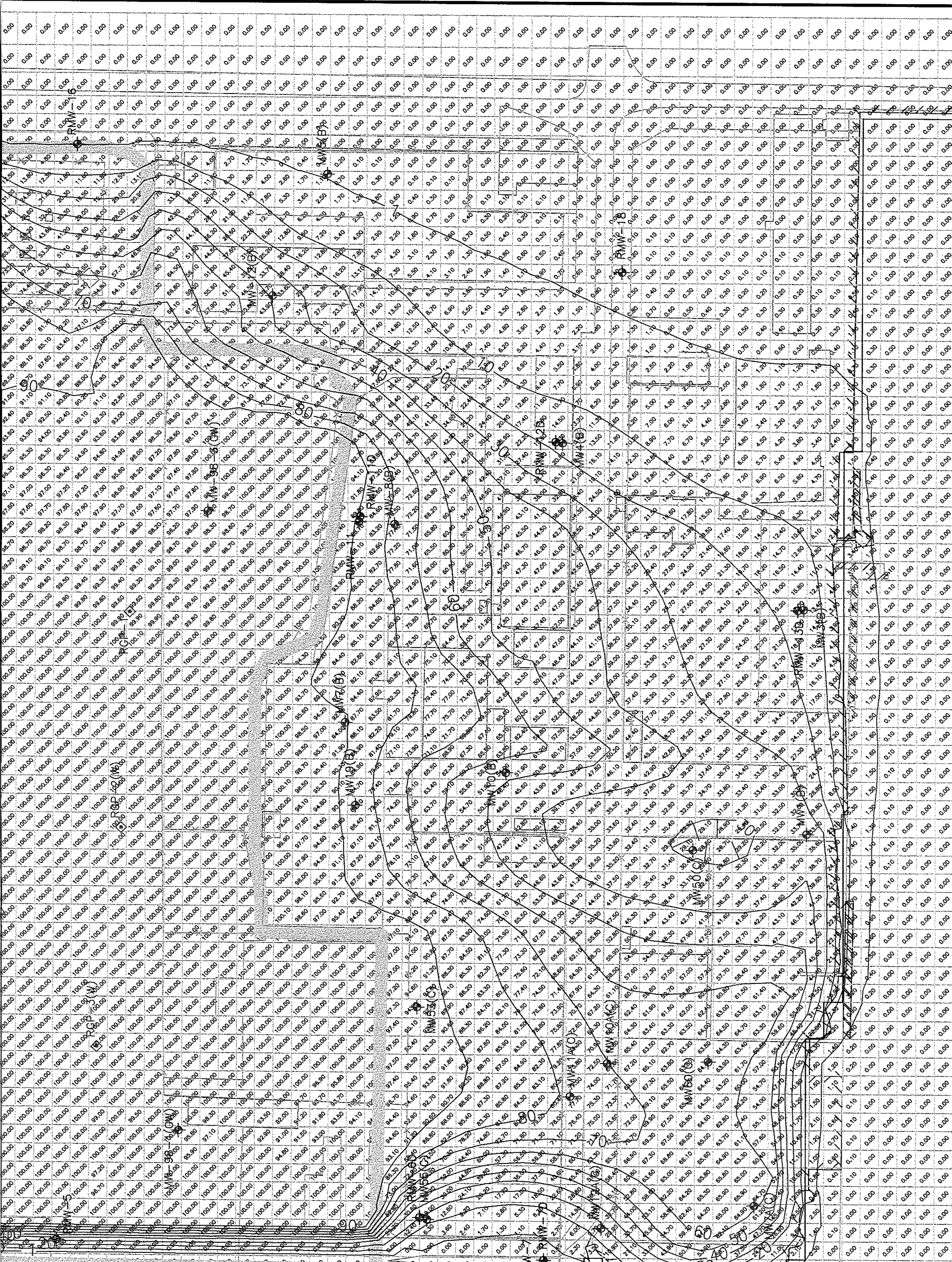


FOR ADDITIONAL
TPUT

100

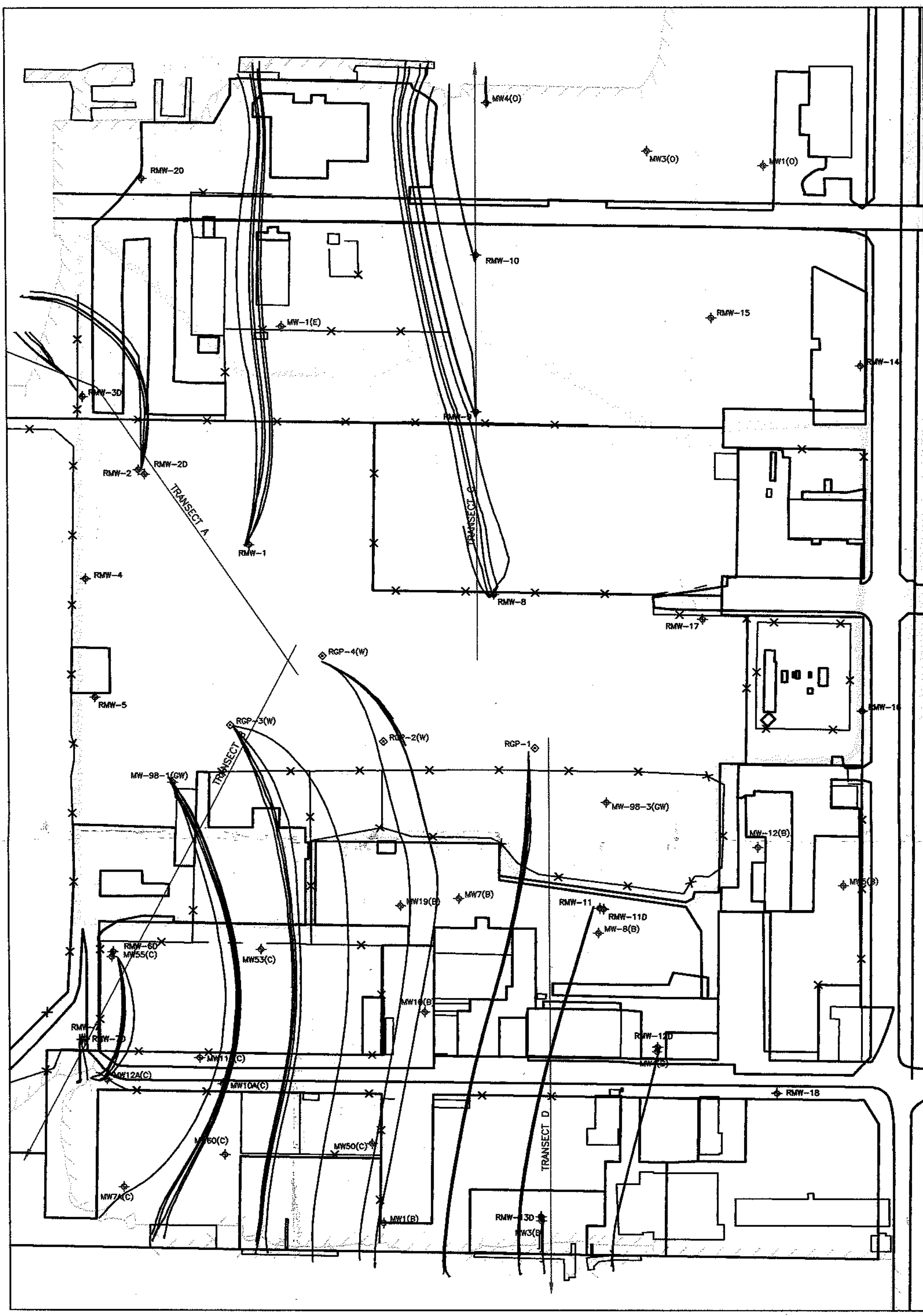
ROEDER AVENUE LANDFILL RI/FS

PORTB-03809-710

DATE: 12/15/00 | DRWN: N.S. | FILE: 3809s126

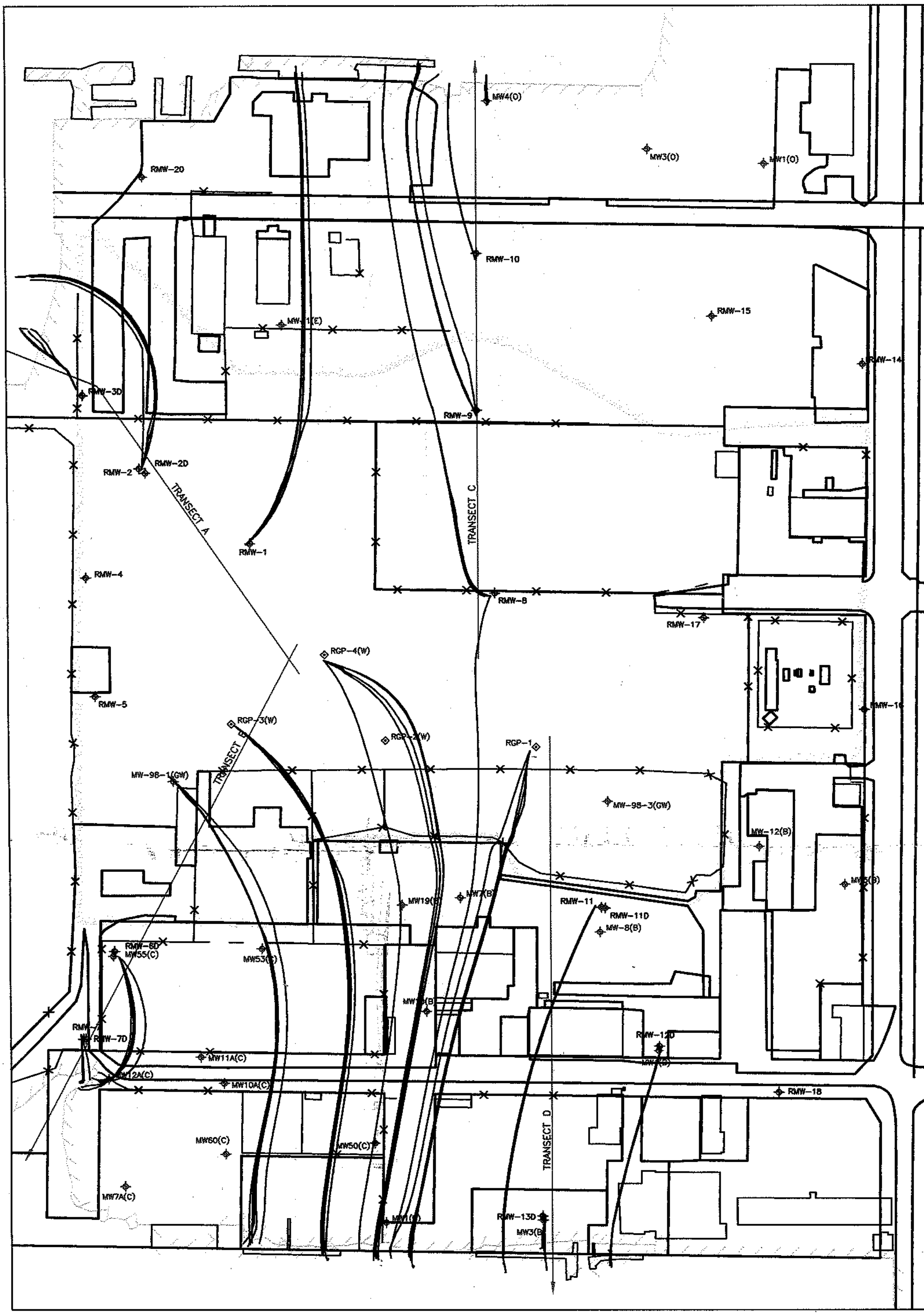
DEVELOPMENT BASELINE SCENARIO
YEAR 2035 CONCENTRATIONS
LAYER 2

FIGURE 6-8

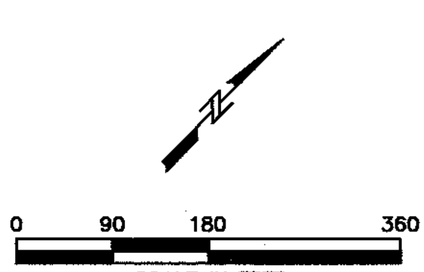


PATHLINE OUTPUT FOR
PRE-WAREHOUSE SCENARIO

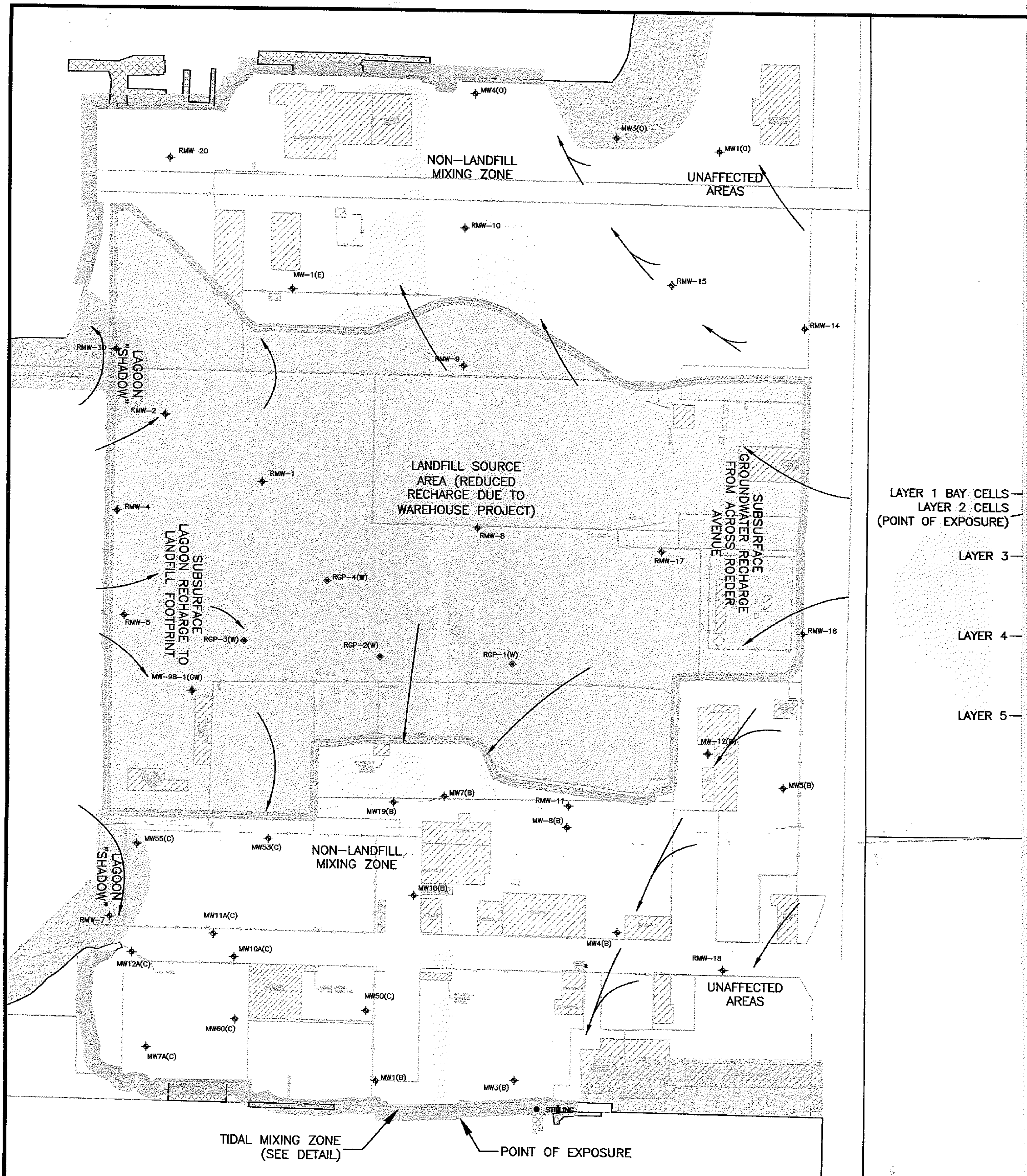
ThermoRetec



PATHLINE OUTPUT FOR
DEVELOPMENT BASELINE SCENARIO



ROEDER AVENUE LANDFILL RI/FS PORTB-03809-710			RESULTS OF PARTICLE TRACKING ANALYSIS
DATE: 06/02/01	DRWN: N.S.	FILE: 3809S215	FIGURE 6-6



SHALLOW WELL LEGEND

Symbol	Description
	MEASURED GROUNDWATER ELEVATION IN FEET MLLW
RMW-6D	NEW WELL OR PIEZOMETER AT BASE OF SAND LAYER (BELOW WATER TABLE)
RMW-6	NEW WELL OR PIEZOMETER ACROSS WATER TABLE
MW-2(B)	EXISTING WELLS USED DURING RI/FS
RGP-4(W)	GAS PROBE INSTALLED DURING WAREHOUSE FEASABILITY INVESTIGATION

LEGEND

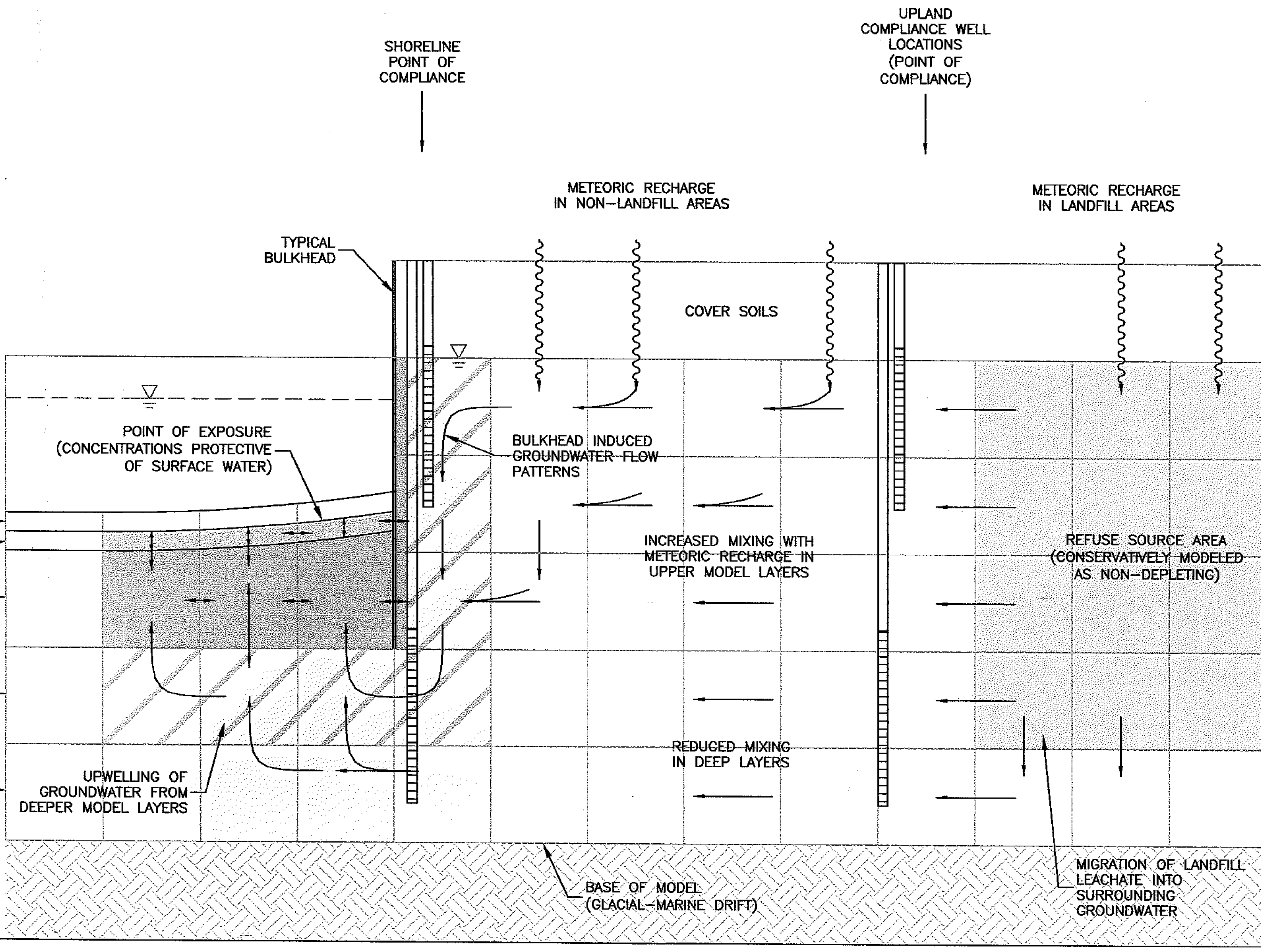
- DOCKS OR PIERS
- EXISTING BUILDINGS
- EXISTING SHORELINE
- PROPERTY BOUNDARIES
- LANDFILL REFUSE BOUNDARY (MTCA SITE BOUNDARY NOT DETERMINED)

KEY TO PREVIOUS INVESTIGATIONS

Code	Investigation
B	BELLINGHAM MARINE INDUSTRIES
C	CHEVRON
N	BURLINGTON NORTHERN
E	DEPT. OF ECOLOGY
G	GEORGIA PACIFIC
Y	CITY OF BELLINGHAM
O	OLIVINE (PORT)
Q	SQUALICUM (PORT)
S	BORNSTEIN (PORT)
W	ROEDER AVENUE WAREHOUSE FEASABILITY ANALYSIS AND PRE-DESIGN TESTING
GW	GEORGIA PACIFIC WAREHOUSE DESIGN INVESTIGATIONS

0 90 180 3
SCALE IN FEET

ThermoRetec



POINT OF EXPOSURE
MTCA REQUIRES THAT GROUNDWATER DISCHARGES INTO SURFACE WATER COMPLY WITH SURFACE WATER STANDARDS AT THE POINT OF DISCHARGE INTO SURFACE WATER. THE MODEL CONSERVATIVELY QUANTIFIES POTENTIAL LEACHATE CONCENTRATIONS IN WATERS BELOW THE MUDLINE (i.e., SIMULATES WATER DISCHARGING INTO SEDIMENT BIOACTIVE ZONE)

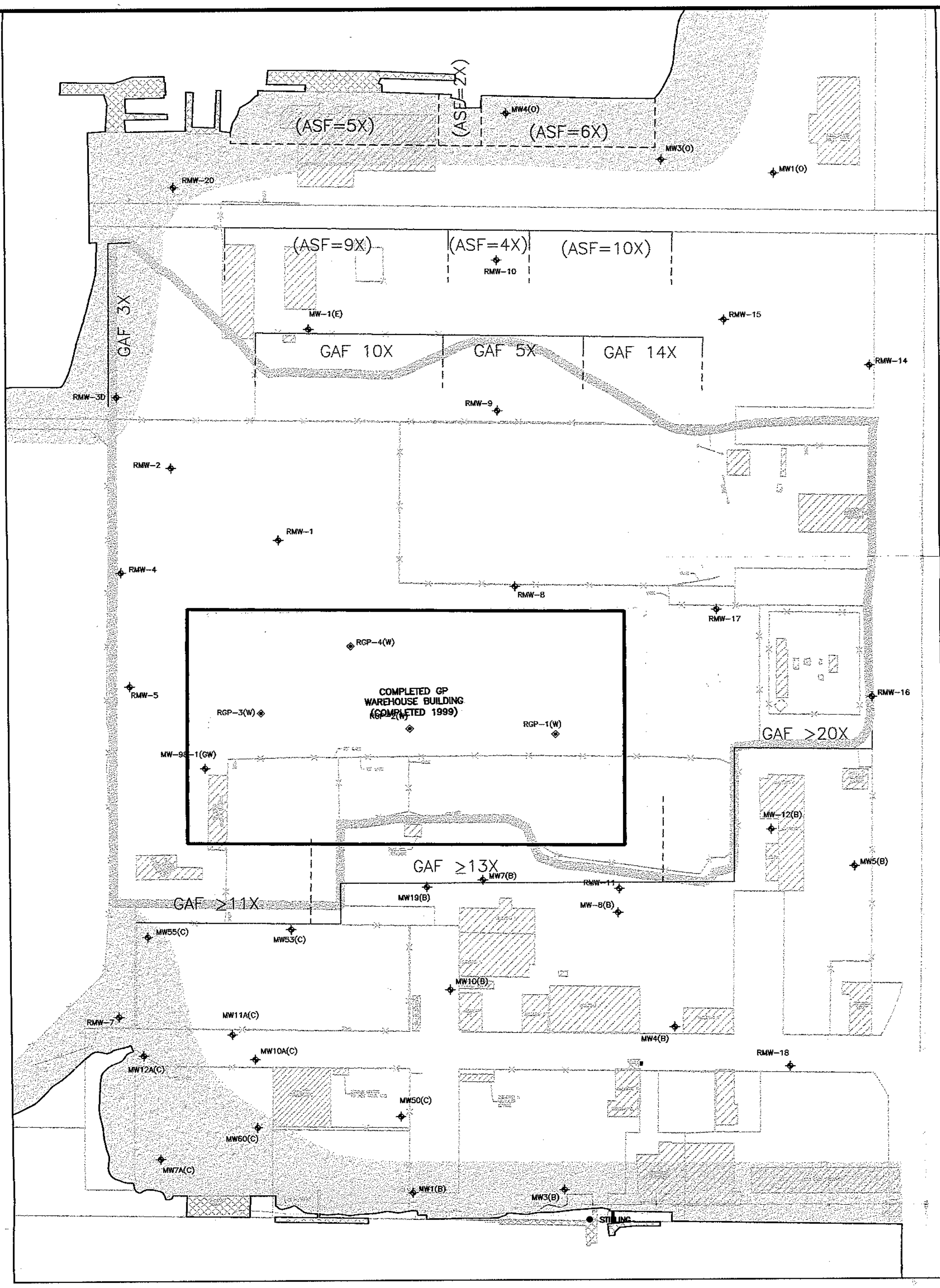
TIDAL MIXING ZONE (PRIMARY)
MOST TIDALLY-INFLUENCED MIXING OCCURS WITHIN THE FIRST FEW MODEL CELLS FROM THE BAY.

TIDAL MIXING ZONE (SECONDARY)
SOME TIDALLY-INFLUENCED MIXING OCCURS AT GREATER DISTANCE FROM THE BAY, BUT THE EFFECT ATTENUATES RAPIDLY WITH DISTANCE.

NON-LANDFILL MIXING ZONE
LANDFILL LEACHATE MIXES WITH METEORIC RECHARGE AND NON-LANDFILL GROUNDWATERS. THE EXTENT OF MIXING VARIES.

NOTE:
ALL LEACHATE MIGRATION ESTIMATES WERE PERFORMED UNDER WORST-CASE SCENARIOS, ASSUMING THAT NO BIODEGRADATION OR GEOCHEMICAL ATTENUATION IS OCCURRING. SEE SECTION 7 FOR A DISCUSSION OF THESE FACTORS. LANDFILL IS UNIFORM SOURCE.

ROEDER AVENUE LANDFILL RI/FS PORTB-03809-710			SIMPLIFIED REPRESENTATION OF GROUNDWATER MODEL
DATE: 06/02/01	DRWN: N.S.	FILE: 3809S213	FIGURE 6-7



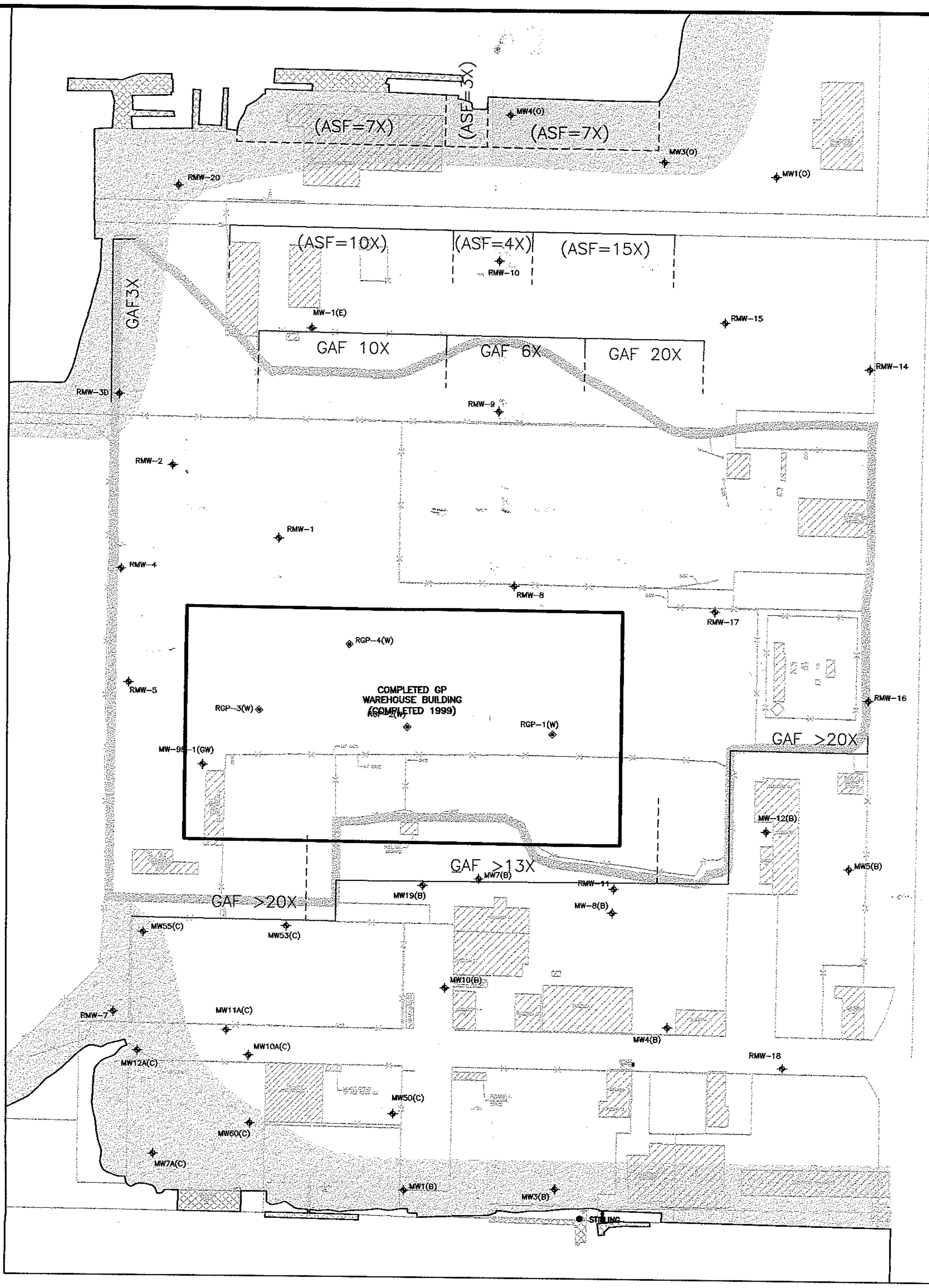
PRE-WARHOUSE CONDITION

SHALLOW WELL LEGEND

MW-2(B)	WELLS USED DURING RI/FS
RGP-4(W)	GAS PROBE INSTALLED DURING WAREHOUSE FEASABILITY INVESTIGATION

L
D
E
E
P
L B (I N
GAF 5X G F.
(ASF=4X) A A

ThermoRetec



DEVELOPMENT BASELINE SCENARIO

GEND

CKS OR PIERS

ISTING BUILDINGS

ISTING SHORELINE

OPERTY BOUNDARIES

NDFILL REFUSE
UNDARY

TCA SITE BOUNDARY
T DETERMINED)

OSS ATTENUATION
CTOR

EA–SPECIFIC
TENUATION FACTOR

NOTES:

1) SEE SECTION 6 FOR A DISCUSSION OF ATTENUATION FACTORS.
2) GAF: GROSS ATTENUATION FACTOR (CUMULATIVE FLOW–BASED ATTENUATION OCCURING BETWEEN LANDFILL AND POINT OF EXPOSURE).
3) ASF: AREA–SPECIFIC ATTENUATION FACTOR (CUMULATIVE FLOW–BASED ATTENUATION OCCURING FOR "LEACHATE" BETWEEN SPECIFIED WELL LOCATION AND THE POINT OF EXPOSURE.

0 90 180 360
SCALE IN FEET

ROEDER AVENUE LANDFILL RI/FS PORTB-03809-710			MODEL DERIVED FLOW-BASED GROUNDWATER ATTENUATION FACTORS
DATE: 06/02/01	DRWN: N.S.	FILE: 3809S214	FIGURE 6-9

Table 6-1. Landfill Water Balance

Estimated Recharge Rates for Landfill Groundwater *				
Total Est. Recharge	Precipitation [1]	Overspray from G.P. Lagoon [2]	Subsurface Recharge from Lagoon [2]	Subsurface Recharge from Across Roeder Avenue [3]
PRE-WAREHOUSE SCENARIO				
7,657	4,160	864	2,384	249
100%	54%	11%	31%	3%
DEVELOPMENT BASELINE SCENARIO				
5,492	1,659	186	2,933	714
100%	30%	3%	53%	13%
TOTAL LANDFILL COVER [5]				
3,960	0	0	3,109	851
100%	0	0	79%	21%

Note:

* Recharge units are shown in cubic feet per day.

This table defines the estimated recharge of groundwater within the footprint of the buried refuse. This table does not address recharge of groundwater in non-landfill areas.

1. Precipitation and recharge rates were established using the assumptions in Figure 4-2.
2. Differentiation between lagoon overspray and subsurface groundwater flow from the lagoon area was performed using the groundwater model as described in Section 6.
3. Subsurface recharge from cross-Roeder groundwater flow was estimated using the groundwater model as described in Section 6.
4. Development Baseline scenario includes the G.P. Warehouse and development of adjacent sites as described in Figure 4-2.
5. A total cover scenario was tested using the groundwater model to evaluate the impacts of complete capping of the landfill area on lagoon and Roeder Avenue groundwater recharge rates. An environmental capping alternative was fully evaluated as part of the evaluation of remedial alternatives for the Landfill site (see Section 9).

Table 6-2. Examples of Calculated Area-Specific Attenuation Factors -- Baseline Development Scenario (Year 2035) [1]

Well ID	Coord[3]	Layer 1 Transmissivity	Weight	Layer 1 Concentration	Layer 2 Transmissivity	Weight	Layer 2 Concentration	Layer 3 Transmissivity	Weight	Layer 3 Concentration	Layer 4 Transmissivity	Weight	Layer 4 Concentration	Layer 5 Transmissivity	Weight	Layer 5 Concentration	Model Predicted Well Concentration [1]	Point-of-Exposure Concentration [2]	Discharge Cell [3]	Calculated ASF [1]
Hilton Avenue																				
RMW-10	61,20	13.5	0.0233	3.9	120	0.207	57	120	0.207	80	232.5	0.400	76	94.55	0.163	63	69.1	16.2	59 7	4.3
51 18 deep	51,18										127.5	0.559	91	100.65	0.441	74	83.5	8.3	50 5	10.1
Hilton Avenue / I&J Shoreline																				
MW-4(O)	62, 8	24.5	0.0811	0.1	75	0.248	14	75	0.248	38	127.5	0.422	48				33.2	4.4	62 6	7.5
C-Street Landfill Boundary																				
RMW-11	70,70	18	0.0368	52	153	0.313	89	153	0.313	97	164.5	0.337	66	0	0.000		82.4	4.2	63 97	19.6
57 69 deep	57, 69										115.5	0.534	100	100.7	0.466	100	100.0	7.1	52 97	14.1
C-Street Area																				
MW-4(B)	75,81	21.6	0.0859	0.3	103.5	0.412	17	80.5	0.320	32	45.75	0.182	34	0	0.000		23.5	2.9	71 97	8.1
RMW-12D	75,81	0	0		13.5	0.0422	17	80.5	0.252	32	137.25	0.429	34	88.45	0.277	24	30.0	2.9	71 97	10.3
C-Street / Whatcom Shoreline																				
'W-3(B)	66,94	30.6	0.162	0.1	130.5	0.690	17	28	0.148	41							17.8	4.4	66 97	4.0
RMW-13D	66,94										112.85	0.389	65	176.9	0.611	54	58.3	4.4	66 97	13.2

Notes:

1. The process for calculating Area-Specific Attenuation Factors is described in Section 6.2. Refer to Tables 6-3 and 6-4 for data used to calculate layer transmissivity.
2. Point-of-Exposure concentrations are determined directly from Layer 2 model-predicted concentrations shown in Figure 6-8. Point-of-Exposure cells were selected based on the results of pathline analyses (see Figure 6-6).
3. Model coordinates: The first number shown represents the "cell number" from the model grid. Matching cell numbers run parallel to Roeder Avenue and increase from west to east. The second number shown represents the model grid "row number". Model rows run parallel to Hilton Avenue and increase from north to south.

Table 6-3. Examples of Calculated Transmissivities for Development of Area-Specific Attenuation Factors -- Baseline Development Scenario (Year 2035) [1]

Well	Coord [2]	Model surface elevation	Actual surface Elevation	Screen Portion Layer 1	Cell K value	Transmissivity Layer 1	Screen Portion Layer 2	Cell K value	Transmissivity Layer 2	Screen Portion Layer 3	Cell K value	Transmissivity Layer 3	Screen Portion Layer 4	Cell K value	Transmissivity Layer 4	Screen Portion Layer 5	Cell K value	Transmissivity Layer 5
Hilton Avenue																		
RMW-10	61,20	11.8	11.7	2.7	5	13.5	1.6	75	120	1.6	75	120	3.1	75	232.5	3.1	30.5	94.55
51 18 deep	51,18												1.7	75	127.5	3.3	30.5	100.65
Hilton Avenue / I&J Shoreline																		
MW-4(O)	62,8	9	15.5	4.9	5	24.5	1	75	75	1	75	75	1.7	75	127.5			
C-Street Landfill Boundary																		
RMW-11	70,70	14.3	13.8	2	9	18	3.4	45	153	3.4	45	153	4.7	35	164.5	0	30.5	0
57 69 deep	57,69												3.3	35	115.5	3.3	30.5	100.65
C-Street Area																		
MW-4(B)	75,81	14	13	2.4	9	21.6	2.3	45	103.5	2.3	45	80.5	1.5	35	45.75	0	30.5	0
RMW-12D	75,81	14	13.2	0	9	0	0.3	45	13.5	2.3	45	80.5	4.5	35	137.25	2.9	30.5	88.45
C-Street / Whatcom Nearshore Area																		
MW-3(B)	66,94	14.1	13.1	3.4	9	30.6	2.9	45	130.5	0.8	45	28	0	35	0	0	30.5	0
RMW-13D	66,94	14.1	12.9	0	9	0	0	45	0	0	45	0	3.7	35	112.85	5.8	30.5	176.9

Notes:

1. The process for calculating Area-Specific Attenuation Factors is described in Section 6.2. Refer to Table 6-2 for calculated ASF values and 6-4 for data on model layer thicknesses intersected by each well or test location.
2. Model coordinates: The first number shown represents the "cell number" from the model grid. Matching cell numbers run parallel to Roeder Avenue and increase from west to east. The second number shown represents the model grid "row number". Model rows run parallel to Hilton Avenue and increase from north to south.

Table 6-4. Examples of Calculated Well Screen Intervals for Development of Area-Specific Attenuation Factors -- Development Baseline Scenario (Year 2035) [1]

Well	Coord [2]	Model surface elevation	Actual surface Elevation	Layer 1 Thickness	Warehouse model head value	Bottom Layer 1 Elevation	Layer 2 Thickness	Bottom Layer 2 Elevation	Layer 3 Thickness	Bottom Layer 3 Elevation	Layer 4 Thickness	Bottom Layer 4 Elevation	Layer 5 Thickness	Bottom Layer 5 Elevation	Screen top elevation	Top saturated screen interval	Screen Bottom elevation	Average Saturated Screen elevation	Layer of Avg Screen Elevation	Screen Portion Layer 1	Screen Portion Layer 2	Screen Portion Layer 3	Screen Portion Layer 4	Screen Portion Layer 5
Hilton Avenue																								
RMW-10	61,20	11.8	11.7	6.9	7.6	4.9	1.6	3.3	1.6	1.7	3.1	-1.4	3.1	-4.5	7.7	7.6	-7.3	0.15	4	2.7	1.6	1.6	3.1	3.1
C51 R18	51, 18	14		9.6	7.2	4.4	1.6	2.8	1.6	1.2	3.3	-2.1	3.3	-5.4						2.8	1.6	1.6	3.3	3.3
Hilton Avenue / I&J Shoreline																								
MW-4(O)	62,8	9	15.5	7.8	6.1	1.2	1	0.2	1	-0.8	1.9	-2.7	1.9	-4.6	7.5	6.1	-2.5	1.8	1	4.9	1	1	1.7	0
C-Street Landfill Boundary																								
RMW-11	70,70	14.3	13.8	8	8.3	6.3	3.4	2.9	3.4	-0.5	6.8	-7.3	6.8	-14.1	9.8	8.3	-5.2	1.55	3	2	3.4	3.4	4.7	0
C57 R69	57,69	13.8		17.8	8.1	-4.0	1.7	-5.7	1.7	-7.4	3.3	-10.7	3.3	-14.0						12.1	1.7	1.7	3.3	3.3
C-Street Area																								
MW-4(B)	75,81	14	13	8.8	7.6	5.2	2.3	2.9	2.3	0.6	4.5	-3.9	4.5	-8.4	9.1	7.6	-0.9	3.35	2	2.4	2.3	2.3	1.5	0
RMW-12D	75,81	14	13.2	8.8	7.6	5.2	2.3	2.9	2.3	0.6	4.5	-3.9	4.5	-8.4	3.2	3.2	-6.8	-1.8	4	0	0.3	2.3	4.5	2.9
C-Street / Whatcom Nearshore Area																								
MW-3(B)	66,94	14.1	13.1	11.3	6.2	2.8	2.9	-0.1	2.9	-3	5.8	-8.8	5.8	-14.6	9.1	6.2	-0.9	2.65	2	3.4	2.9	0.8	0	0
RMW-13D	66,94	14.1	12.9	11.3	6.2	2.8	2.9	-0.1	2.9	-3	5.8	-8.8	5.8	-14.6	-5.1	-5.1	-15.1	-10.1	5	0	0	0	3.7	5.8

Notes:

1. The process for calculating Area-Specific Attenuation Factors is described in Section 6.2. Refer to Table 6-2 for calculated ASF values and 6-3 for transmissivity calculations for each model layer.
2. Model coordinates: The first number shown represents the "cell number" from the model grid. Matching cell numbers run parallel to Roeder Avenue and increase from west to east. The second number shown represents the model grid "row number". Model rows run parallel to Hilton Avenue and increase from north to south.

Table 6-5. Evaluation of Worst-Case Attenuated Discharge -- Development Baseline Scenario (Year 2035)

Groundwater Parameter	ARAR Value	Exceedance Ratios for Landfill Groundwater (See Table 4-8)		Estimated Exceedance Ratios for Attenuated Discharge (see notes 1 & 2)							
				Foot of Hilton		Hilton Avenue Gap [3]		Other Hilton Avenue [3]		C-Street Landfill Boundary	
				Gross AF: 3.6 X		Gross AF: 6 X		Gross AF: 10 X		Gross AF: 13 X	
		(Ar. Mean)	(95% UCL)	(Ar. Mean)	(95% UCL)	(Ar. Mean)	(95% UCL)	(Ar. Mean)	(95% UCL)	(Ar. Mean)	(95% UCL)
Contaminants Above ARARs											
1,4-Dichlorobenzene (ug/L)	4.86	1.09	1.63	0.31	0.46	0.18	0.27	0.11	0.16	0.08	0.13
Arsenic	0.005	1.1	1.8	0.30	0.51	0.18	0.30	0.11	0.18	0.08	0.14
Diesel Range Hydrocarbons	0.5	2.17	3.20	0.61	0.89	0.36	0.53	0.22	0.32	0.17	0.25
Lead	0.0081	1.8	3.5	0.50	0.97	0.30	0.58	0.18	0.35	0.14	0.27
Mercury	0.00005	1.21	1.40	0.34	0.39	0.20	0.23	0.12	0.14	0.09	0.11
Pentachlorophenol (ug/L)	4.91	10.7	25.1	3.01	7.03	1.79	4.18	1.07	2.51	0.83	1.93
Weak Acid Dissoc. Cyanide	0.0028	1.7	3.1	0.49	0.86	0.29	0.51	0.17	0.31	0.13	0.24
Zinc	0.081	1.00	1.68	0.28	0.47	0.17	0.28	0.10	0.17	0.08	0.13
Contaminants Below ARARs											
Bis(2-Ethylhexyl)phthalate (ug/L)	3.56	0.43	0.65	0.12	0.18	0.071	0.11	0.04	0.07	0.03	0.05
Bis(2-Ethylhexyl)phthalate (ug/L)	0.7 [4]	2.17	3.33	0.61	0.93	0.36	0.56	0.22	0.33	0.17	0.26
Copper	0.0031	0.85	1.46	0.24	0.41	0.14	0.24	0.08	0.15	0.07	0.11
Nickel	0.0082	0.87	1.31	0.24	0.37	0.14	0.22	0.09	0.13	0.07	0.10
Leachate Indicators											
Total Chromium	162	0.010	0.018	0.0028	0.0049	0.0017	0.0029	0.0010	0.0018	0.00077	0.00135
Total Organic Carbon	—	na	na	na	na	na	na	na	na	na	na

Note:

Values with exceedance ratios greater than 1.0 have been underlined.

1 Estimated exceedance ratios for each discharge location were determined using gross attenuation factors calculated from Figure 6-9.

2 Only flow-based attenuation is included in the attenuation factors. Biological and geochemical processes which may further reduce contaminant transport have not been included.

3 Hilton Avenue exceedance ratios are calculated separately for the bulkhead gap area and for the area outside of the bulkhead gap.

4 Results of sediment source control evaluations suggest that the surface water cleanup level for bis(2-ethylhexyl)pthalate may need to be reduced by a factor of 5X (from 3.56 to 0.7 ug/L) to be protective of marine sediment concentrations. Statistical calculations are shown both for the surface water ARAR (MTCA Method B surface water cleanup level) and for the lower sediment source-control value.

7 Contaminant Fate & Transport

This section summarizes the results of contaminant measurements and fate & transport analyses for the Roeder Avenue Landfill. In conjunction with the groundwater flow modeling performed as described in Section 6, the fate & transport work provides the information necessary to assess the compliance of landfill groundwater concentrations with the requirements of MTCA and other applicable regulations.

7.1 Objectives of Fate & Transport Analysis

The findings of the groundwater flow and solute transport modeling analyses described in Section 6 indicate that exceedances of surface water criteria at the point of exposure are not anticipated for most Landfill contaminants, provided that the natural attenuation of Landfill groundwater is not short-circuited. As shown in Table 6-5, the flow-based attenuation factors provide sufficient reduction in contaminant concentrations to ensure compliance with surface water cleanup levels.

But for three of the Landfill contaminants, attenuation by geochemical and biological factors are signifiant to the outcome of fate and transport modeling:

- **Pentachlorophenol:** For pentachlorphenol, flow-based attenuation may not be adequate to prevent exceedances of surface water criteria along the I&J Waterway shoreline. But this compound has been shown to be biodegradable under anaerobic conditions similar to those occurring in the Landfill.Monitoring data from the RI/FS indicate that such degradation is occurring and should be incorporated into the fate and transport assumptions for this compound.

- **Chromium:** The data from the remedial investigation has shown that the elevated levels of chromium present in the Landfill are present as the less toxic trivalent chromium. The groundwater levels of this contaminant are are well below applicable surface water standards, even if Landfill groundwater was discharged to the Bay without prior attenuation. However, there are circumstances under which this trivalent chromium could be converted to the more toxic hexavalent form. If such conversion were to occur, the point-of-exposure concentrations predicted the groundwater flow model would not be protective.

- **Bis(2-ethylhexyl)phthalate:** The compound bis(2-ethylhexyl)phthalate strongly adsorbs to organic carbon. This tends to reduce its mobility in groundwater.However, this same tendency also poses a risk of sediment contamination. It is appropriate to modify surface water standards applicable to the point-of-exposure in order to prevent accumulation of phthalate compounds in sediments.

The work described in this section clarifies the biological and geochemical factors that affect each of the above-listed compounds. Implications for the evaluation of remedial alternatives are then presented.

7.2 Overview of Potential Geochemical Influences

Table 7-1 provides an overview of the the geochemical factors that can influence the mobility of each of the Landfill Contaminants of Concern. These factors fall into three major groups: 1) soil/water partitioning, 2) precipitation, complexing and redox reactions, and 3) contaminant biodegradation.

Contaminant Soil/Water Partitioning

As groundwater contaminants move through aquifer solids, they partition between the solid and aqueous phases. Some compounds partition more strongly to soils than others. Partitioning coefficients are measures of this tendency.

Table 7-2 summarizes partioning coefficients reported in EPA and Ecology publications for various Landfill contaminants. For inorganic compounds, the range in partitioning coefficients is extremely high, indicating that geochemical factors have a larger effect on contaminant mobility than simple partitioning. However, for organic compounds, the partitioning to organic carbon in the soil matrix is the strongest predictor of contaminant mobility. As the organic carbon content of the soil increases, the mobility of organic compounds decreases.

In the Landfill area, the total organic carbon (TOC) content of soils and sediments varies. The TOC content of Whatcom Waterway sediments has been measured and shown to average 3.2 percent. The TOC content of Landfill refuse is expected to be higher (10 to 30 percent), whereas the TOC content of fill unit and sand unit soils is expected to be lower (0.1 to 1 percent). Table 7-2 shows the effect of TOC content on soil/water partitioning coefficients for various compounds.

The soil/water partitioning behavior of pentachlorophenol is influenced significantly by groundwater alkalinity as well as the TOC content of the aquifer solids. This compound is less mobile in acidic groundwater like that occuring in the Landfill area. The effect of pH variations on pentachlorphenol partitioning are shown in Table 7-2.

Precipitation and Redox Reactions

For inorganic compounds, mobility is most strongly influenced by geochemical interactions. Typical influences for each of the contaminants of concern are listed in Table 7-1.

Precipitation reactions can cause soluble metal ions to drop out of solution. The precipitated metals are then relatively immobile. Iron oxides for example tend to cause other heavy metal ions to precipitate out of solution. Reduced sulfide compounds can also cause precipitation of heavy metal ions.

Chemical reactions known as oxidation/reduction reactions (redox reactions) can be significant factors in the mobility of some metals. For example, the hexavalent form of chromium typically has a much higher solubility and lower soil/water partitioning coefficient than the trivalent form (see Table 7-2). Hexavalent chromium persists only under strongly aerobic or oxidizing conditions. In the presence of reduced iron, hydrogen sulfide or dissolved organic carbon, hexavalent chromium is typically converted to the less mobile trivalent form. Once converted to its trivalent form, chromium is stable and has a solubility typically two to three orders of magnitude lower than that of the hexavalent form. Chromium will tend to remain in the trivalent state unless it comes into contact with strong oxiizing agents such as hydrogen peroxide or ozone.

Contaminant Biodegradation

Of the contaminants of concern identified during the RI/FS, four are organic compounds with known biodegradation potentials. In conducting the flow and fate & transport modeling described in Section 6, contaminant biodegradation was assumed NOT to occur. However, available literature demonstrates that biodegradation does occur and can be a significant factor controlling contaminant migration.

Biodegradation processes for pentachlorphenol have been defined for both aerobic and anaerobic conditions. ThermoRetec has conducted numerous lab-scale and full-scale bioremediation projects for pentachlorophenol. Recent studies of anaerobic biodegradation rates have documented continuous biological dechlorination and destruction of pentachlorophenol (Water Environment Research Foundation, 1998). In those studies, anaerobic biodegradation rates for acclimated systems were shown to be extremely short, with half-lives of less than 2 days. Similar results were observed for the anaerobic biodegradation of chlorobenzenes including 1,4-dichlorobenzene. The reducing conditions and high organic loadings in the Landfill would favor this type of biodegradation.

7.3 Transport Evaluation for Pentachlorophenol

In Section 6 the groundwater flow and solute transport modeling was conducted using a hypothetical, high-mobility contaminant. This was performed to develop conservative flow-based attenuation factors. If compound-specific assumptions relevant to pentachlorphenol are incorporated, the predictions regarding its transport change dramatically. The two effects relevant to pentachlorphenol transport are soil/water partitioning and biodegradation.

In the groundwater flow modeling performed in Section 6, the hypothetical solute simulated was given a retardation factor of 11 (see Section 6 discussion). As described in Section 6, the retardation factor of 11 is consistent with a soil/water partitioning coefficient of 1.6, a soil organic carbon content of 0.5 percent and absolutely no biodegradation. Based on that conservatively low retardation factor, the travel time calculated between well location RGP-3 and the nearest point-of-exposure cell was 2400 days. Under these assumptions, long-term steady-state point-of-exposure concentrations for pentachlorophenol would be expected to exceed surface water standard in the point-of-exposure by factors of 1.1X to 3X (see Table

6-5) along Hilton Avenue, but would be below applicable cleanup levels in areas along C-street.

Consistent with EPA (1996) and Ecology (2001) published values, the actual soil/water partitioning coefficient applicable to pentachlorophenol in pH 6.0 groundwater and in the presence of aquifer solids with a 0.5% total organic carbon content would be nearly five times higher (see Table 7-2). This would result in groundwater travel times five times greater. If the assumption of TOC content was increased from 0.5% to 10% to simulate the high-TOC matrix present in much of the Landfill refuse, the partitioning coefficient and the corresponding travel times would increase another 20-fold. These two changes would result in travel times for pentachlorophenol increasing 100-fold.

The final correction to pentachlorophenol transport calculations would be the incorporation of natural biodegradation into the fate and transport assumptions. In performing this step, a degradation rate constant would be applied and the affects on contaminant transport calculated. Given the long travel times for pentachlorophenol, even a very low biodegradation rate would result in dramatic reductions in contaminant transport potential. Literature-reported half-lives for pentachlorophenol in high organic carbon anaerobic systems are as low as 1/2-day (Water Environment Research Foundation, 1998). Even the use of a conservatively low half life 50 to 100 times slower than this reported value would result in immobilization of PCP within the Landfill footprint, and would prevent any exceedances of PCP cleanup levels at the point-of-exposure. Copies of contaminant fate and transport runs performed with the transport model Solute (version 3.0) are included as part of Appendix D. Those runs demonstrated that long-term immobilization of the PCP within a 200-foot transport distance would occur a half-life of 40 days. Flow-based dilution/attenuation and site heterogeneity would further reduce the transport potential of this contaminant.

As described in Section 4.2, pentachlorophenol was only detected in a single well location within the Landfill. Even in that well, the detections were sporadic. Pentachlorophenol was never detected in the other Landfill wells or in any of the wells outside the Landfill footprint. The absence of PCP detections in the other areas are reasonable given the dramatic effects of soil/water partitioning and anaerobic biodegradation on the mobility of this compound. Natural attenuation processes confine elevated PCP concentrations to the Landfill, supplementing the attenuation that occurs via groundwater flow and mixing.

7.4 Chromium Speciation Issues

For the inorganic Contaminants of Concern present in the Landfill, potential geochemical influences would generally tend to decrease the mobility and decrease the potential point-of-exposure concentrations of these compounds. Given that the projected point-of-exposure concentrations for these compounds are below applicable criteria in a worst-case attenuated discharge analysis (Table 6-5), further evaluation was not performed for these compounds. For chromium, however, there is one consideration that has been incorporated into the evaluation of remedial action objectives and remedial alternatives for the site.

Analytical testing performed during the RI/FS confirmed that the chromium at the Landfill was present in the trivalent form. For chromium, the most stringent surface water cleanup level applicable trivalent form is 162 mg/L. This cleanup level is more than 10 times higher than the highest chromium concentration ever measured in the Landfill groundwater. Provided that chromium is not converted to the more toxic hexavalent form, there is no potential risk of the Landfill causing cleanup level exceedances at the point-of-exposure.

The issue of potential concern for chromium is that under certain conditions it is possible for trivalent chromium to be converted to the more toxic hexavalent form. Such conversion would not occur naturally, but could be triggered by chemical oxidizing agents used in certain in situ groundwater treatment systems. Specifically, hydrogen peroxide, potassium permanganate and ozone are all capable of causing trivalent chromium to oxidize to hexavalent chromium. Milder oxidizing conditions like those naturally present in aerobic groundwater or those potentially caused by air injection systems would not result in this transformation.

In the event that the Landfill-associated chromium at the point-of-exposure was present in the hexavalent form, cleanup levels could be exceeded by factors of up to 9X under a worst-case attenuated discharge analysis. Ensuring that such conversion does not occur can be and has been incorporated into the remedial action objectives and remedial alternatives evaluated for the site.

7.5 Sediment Source Control Analysis

As part of the evaluation of cleanup levels for the Landfill site, the potential cross-media impacts of groundwater on sediments was evaluated. The outcome of this analysis was generally to verify that the surface water cleanup levels determined using MTCA surface water cleanup levels and ARARs were protective of sediment concentrations. Only in the case of bis(2-ethylhexyl)phthalate is a more stringent cleanup level potentially appropriate.

The output from groundwater flow modeling provides the basis for evaluating potential sediment source control requirements. Specifically, the groundwater model defines the flux of groundwater from the model area into marine sediment areas (i.e., the point-of-exposure cells of the flow model) for all areas around the site. This flux varies from location to location due to geologic and hydrogeologic factors.

The first step in sediment source control analysis was to define for each shoreline area the cell or cells with the highest flux of groundwater into the point-of-exposure. The calculated flux for these worst-case cells was then used for the sediment source control analysis. Table 7-3 summarizes these values.

The second step in the evaluation was to assess the properties of the marine sediments present in the point-of-exposure areas. The required data include the TOC content of the sediments, the net sediment deposition rate and the depth of the sediment bioactive zone. All three sets of data are available from the Whatcom Waterway RI/FS (Hart Crowser, 1997 and Anchor Environmental 2000). From those documents, the average TOC content of shallow sediments in the Whatcom and I&J Waterway areas was 3.2 percent, the net sediment deposition rate was measured at 1.6 centimeters per year, and the thickness of the sediment bioactive zone was determined to be 12 centimeters.

Using the groundwater flux calculations and the empirical data available from the Whatcom Waterway study, worst-case sediment source control calculations were conducted. For inorganic compounds this analysis was performed by first assuming that constituents were present in point-of-exposure groundwater at the surface water cleanup levels specified in Table 4-6. Second, the flux of groundwater containing these constituents was assumed to occur at the rates shown in Table 7-3. Third, 100% of the inorganic constituents present in the groundwater were assumed to precipitate and to accumulate within the bioactive zone sediments. This assumption is extremely conservative, but was used in the source control screening step to assess whether further evaluation was required. Finally, the potential accumulation of inorganic constituents in the sediments was estimated based on the net deposition rate, and assuming that no resuspension and dispersion of these sediments occurs. This assumption is also extremely conservative, as resuspension and dispersion were both reported to be significant as described in the Whatcom Waterway RI/FS. Using these conservative assumptions, the worst-case potential sediment concentrations were calculated for each of the Landfill-associated heavy metals.

Table 7-4 summarizes the results of the source control calculations for Landfill-associated metals. In all cases, the worst-case sediment concentrations were well below applicable sediment criteria, even for the areas with the highest groundwater discharge rates (i.e., Hilton Avenue bulkhead gap). These results confirm that the surface water cleanup levels in Table 4-6 will be protective of marine sediment quality if applied to the Landfill site.

For organic Landfill-associated compounds, source control calculations were performed based on known soil/water partitioning characteristics of each compound. Using the partitioning coefficients from Table 7-2, the potential worst-case sediment concentrations were calculated. These are shown in Table 7-5.

For pentachlorophenol and 1,4-dichlorobenzene, the estimated worst-case sediment concentrations were calculated to be well below sediment cleanup levels. This confirms that the surface water criteria for these compounds would be protective of sediment quality.

For the copound bis(2-ethylhexyl)phthalate, the high partitioning coefficient for this compound results in a different conclusion. If the compound bis(2-ethylhexyl)phthalate were present in the point-of-exposure area groundwater at the Method B surface water cleanup level, sorption to sediments could potentially result in exceedances of the Sediment Cleanup Screening Levels. In order to ensure that sediment levels were not exceeded, a five-fold reduction in point-of-exposure groundwater concentrations would be required. Based on this consideration, the surface water cleanup level in Table 4-6 has been modified downward five-fold for use in the RI/FS. This modification applies only to the point-of-exposure where impacts to sediment could result.

The implications of the change in bis(2-ethylhexyl)phthalate cleanup levels are limited. As developed in Section 6, the worst-case Landfill-associated concentrations of this compound in the point-of-exposure sediments would be compliant with the adjusted cleanup level for all site areas (see Table 6-5). Second, the strong tendence of this compound to adsorb to aquifer solids and organic carbon further reduces its mobility. This provides an additional degree of protection against sediment recontamination.

7.6 Conclusions of Contaminant Transport Analysis

Based on the contaminant-specific fate and transport properties summarized this section, there are three signficant conclusions that are incorporated into decision-making for the RI/FS.

- **Decreased Pentachlorophenol Mobility:** For the compound pentachlorophenol, the groundwater flow modeling results suggested that worst-case discharges from the Landfill could potentially result in exceedances of surface water cleanup levels at the point-of-exposure. However, when these calculations are adjusted to take into account contaminant-specific partitioning characteristics and and biodegradation potential, the point-of-exposure concentrations are not expected to exceed applicable cleanup levels. Results from empirical groundwater testing have not shown any detections of pentachlorphenol outside of the Landfill, confirming the limited potential for migration of this compound under actual site conditions. The incorporation of these fate and transport properties into the decision-making process for the RI/FS is recommended.

- **Precautions Regarding Chromium Speciation:** For chromium, the existing groundwater concentrations within the Landfill are well below applicable surface water cleanup standards. This conclusion could be changed if the chromium were converted to the more toxic hexavalent species. That conversion could occur if chromium-impacted groundwater were subjected to in situ treatment with chemical oxidation systems. As part of the site remedial action objectives, measures should be taken to ensure that site conditions are controlled to prevent production of hexavalent chromium at concentrations that would cause exceedances of applicable cleanup levels at the point-of-exposure.

- **Adjustments to Bis(2-ethylhexyl)phthalate Cleanup Levels:** For all but one of the Landfill contaminants of concern, compliance with the surface water cleanup levels developed in Table 4-6 would prevent any potential exceedances of sediment cleanup levels. However, for bis(2-ethylhexyl)phthalate, a five-fold reduction in the groundwater cleanup levels at the point-of-exposure may be warranted to prevent potential water quality impacts. Based on these evaluations, conducted using conservative assumptions, the more stringent sediment source control value has been adopted for use in the RI/FS.

[Ta]ble 7-1. Overview of Geochemical Factors Affecting Contaminant Mobility

[C]ontaminant Type	Geochemical Factors Promoting Increased Mobility	Geochemical Factors Factors that reduce mobility
Heavy Metals		
Arsenic	Acidic pH Moderately reducing conditions (reduction to As-III) Methylation	Precipitation by iron oxides Precipitation by sulfide Oxidation to arsenate (less mobile) Formation of carbonates with iron or calcium
Copper	Acidic pH Moderately reducing conditions Formation of mobile sulfide complexes Some formation of complexes with organic acids	Precipitation by or sorption on iron oxides Reduced solubility at elevated pH
Lead	Acidic pH Increased mobility in oxidizing conditions (typically countered by complexing) Formation of complexes with dissolved organic carbon	Precipitation by iron oxides Precipitation by sulfide Precipitation with calcium hydroxide (at pH >10)
Mercury	Acidic pH Moderately reducing conditions Potential methylation under strongly reducing conditions	Precipitation by iron oxides Precipitation by sulfide
Nickel	Acidic pH Moderately reducing conditions Formation of complexes with dissolved organic carbon	Precipitation by iron oxides Some precipitation by sulfide Precipitation with calcium hydroxide (at pH >10)
Zinc	Acidic pH Moderately reducing conditions Formation of complexes with dissolved organic carbon	Precipitation by iron oxides Precipitation by sulfide
Trivalent Chromium	Formation of transient complexes with organic acids Chemical oxidation (conversion to Cr-VI) Oxidation by manganese (conversion to Cr-VI)	Precipitation by iron oxides Precipitation by sulfide Reducing conditions.
Hexavalent Chromium	Maintenance of oxidizing conditions	Reduction to Cr-III by ferrous iron Precipitation of Cr-III on iron oxides Precipitation with sulfide Reduction by dissolved organic carbon
Inorganic Contaminants		
WAD Cyanide	Metal complexes have a high solubility / mobility	Alkaline conditions Precipitation by iron oxide Destruction by chemical oxidation
Organic Contaminants		
Diesel Hydrocarbons	Sorption is TOC dependent	Oxygenated conditions promote biodegradation Sorption/retardation is greatest in high TOC soils
Pentachlorophenol	Increasing solubility at alkaline pH Sorption is also TOC dependent	Aerobic biodegradation Anaerobic biodegradation Sorption by high TOC soils Increasing sorption at acidic pH
Bis(2-ethylhexyl)phthalate	Sorption is TOC dependent	Sorption/retardation is highest in high TOC soils Aerobic biodegradation
1,4-Dichlorobenzene	Sorption is TOC dependent	Sorption/retardation is highest in high TOC soils Anaerobic biodegradation Some aerobic biodegradation

Table 7-2. Partitioning Coefficients for Landfill Contaminants of Concern

Contaminant of Concern	Reported Soil/Water Partitioning Coefficient Values (L/kg): EPA Guidance Low	EPA Guidance High	EPA Guidance Median	Ecology 2000[2] Table 747-3	Reported Organic Carbon Partitioning Coefficient Values (L/kg): EPA Koc Values [1] Low	EPA Koc Values [1] Geo Mean	EPA Koc Values [1] High	Ecology 2000 Tables 747-1 & 747-4
Heavy Metals								
Arsenic	0.005	20,412	**225**	**29**	na	na	na	na
Copper	25	4,318	**476**	**22**	na	na	na	na
Lead	14	67,856	**5,310**	**10,000**	na	na	na	na
Mercury	0.22	10,527	**4,500**	**52**	na	na	na	na
Nickel	3	7,250	**445**	**65**	na	na	na	na
Zinc	2.7	28,000	**2,020**	**62**	na	na	na	na
Trivalent Chromium	25	24217	**5,977**	**1,000**	na	na	na	na
Hexavalent Chromium	0.2	1729	**26.9**	**19**	na	na	na	na

Organic Compounds	Kd values at varying Koc Values: Low TOC Soil [4] (0.5% TOC)	Kd values at varying Koc Values: Waterway Sediments [5] (3.2% TOC)	EPA Koc Values [1] Low	EPA Koc Values [1] Geo Mean	EPA Koc Values [1] High	Ecology 2000 Tables 747-1 & 747-4
Diesel (Fraction Dependent)						
Aliphatics (C12-C16)	**25,050**	**160,320**	na	na	na	5,010,000
Aromatics (C12-C16)	**25**	**160**	na	na	na	5,010
PCP (pH-Dependent)						
pH 6.0	**7.8**	**49.9**	na	1,560	na	1,560
pH 6.8	**3.0**	**18.9**	na	592	na	592
pH 8.0	**2.6**	**16.7**	na	410	na	410
Bis(2-ethylhexyl)phthalate [3]	556	3,556	87,420	111,123	141,254	111123
1,4-Dichlorobenzene	3.1	19.7	273	616	1375	616

Notes:

During solute transport modeling, a retardation factor of 11 was used, simulating a Kd value of approximately 1.6 L/kg. This is conservative relative to anticipated Kd values of each of the contaminants of concern.

1. Koc values obtained from EPA Soil Screening Guidance: Technical Background Document (EPA 540/R95/128, May 1996).
2. Proposed Amendments to the Model Toxics Control Act (Ecology Publication Number 00-09-056, August 2000)
3. The EPA document lists only two Koc values for BEP. Values as much as 5 times lower were available from other references (e.g., Fetter, 1988; p. 403-405.)
4. Default TOC content used in RBCA site analysis and Fate 5 transport modeling. Actual values may be higher.
5. A mean TOC content of 3.2% was measured in shallow sediments during the Whatcom Waterway RI/FS.

na: Not applicable.

Table 7-3. Groundwater Flux Calculations for Use in Sediment Source Control Evaluation

	Number of Cells from Model Grid	Total Area (sq. ft.)	Model-Predicted Discharge Rates (cft/day)	(L/day)	Normalized Discharge (L/day/sq. ft.)	Discharge in 7.5 Years (L/sq. ft.)	Est. Sed. Accumulation in 7.5 Years (cm)	GW/Sediment Discharge Ratio (L/kg dry sed.)
Pre-Warehouse Discharge Scenario								
I&J Bulkhead Gap	1	400	246	6,967	17.42	47,678	12.0	8,227
I&J Waterway	13	5200	987	27,952	5.38	14,715	12.0	2,539
Foot of Hilton	8	3200	165	4,673	1.46	3,997	12.0	690
Whatcom Waterway	11	4400	591	16,737	3.80	10,413	12.0	1,797
Development Baseline Discharge Scenario								
I&J Bulkhead Gap	1	400	193	5,466	13.66	37,406	12.0	6,454
I&J Waterway	13	5200	770	21,806	4.19	11,480	12.0	1,981
Foot of Hilton	8	3200	133	3,767	1.18	3,222	12.0	556
Whatcom Waterway	11	4400	481	13,622	3.10	8,475	12.0	1,462

Notes:

Based on the Whatcom Waterway RI/FS data, the net sedimentation rate for the Inner Bay is 1.6 cm/year and the biologically active zone was estimated to be 12 cm in depth. Based on these measurements, the biologically active zone is replaced by new sediments once every 7.5 years.

Average sediment wet densities were assumed to be 1.3 g/cm3 based on data presented in the Whatcom Waterway RI/FS.

Dry sediment densities were calculated using an assumed solids content of 40%, with an estimated density of 14.7 kg dry sed/cft.

Average sediment TOC content was assumed to be 3.2% TOC based on data presented in the Whatcom Waterway RI/FS.

Conversion Factor: wet sediment density to dry sediment density

1.3 g wet sed	0.4 g dry sed	1 kg dry sed	28317 cm3 sed
1 cm3 sed	1 g wet sed	1000 g dry sed	1 cft sed

Table 7-4. Preliminary Sediment Source-Control Calculations for Landfill-Associated Metals

Landfill COC	Surface Water Criteria or ARAR (mg/L)	Worst-Case Sediment Concentrations Estimated Using Area-Specific Groundwater to Sediment Discharge Ratios from Table 7-3 (mg/kg dry weight)				SMS Sediment Cleanup Screening Levels (mg/kg)
		Hilton Bulkhead Gap 6454 L/kg[1]	Other Hilton Areas 556 L/kg[1]	Foot of Hilton 1981 L/kg[1]	C-Street Areas 1797 L/kg[1]	
Arsenic	0.005	32	3	10	9	93
Copper	0.0031	20	2	6	6	390
Lead	0.0081	52	5	16	15	530
Mercury	0.00005	0.32	0.03	0.10	0.09	0.59
Nickel	0.0082	53	5	16	15	nv
Zinc	0.081	523	45	160	146	960

Notes:

Refer to Table 4-6 for the derivation of applicable surface water cleanup levels and ARARs.

1. Ratios of groundwater/sediment discharge are provided in Table 7-3. Values are expressed as liters of groundwater discharging through each kg of dry sediment. Net sedimentation rates and sediment densities are as reported in the Whatcom Waterway RI/FS.

Table 7-5. Preliminary Sediment Source-Control Calculations for Organic Compounds

Landfill COC	Surface Water Criteria or ARAR (mg/L)	SMS Cleanup Screening Levels		Reported Partitioning Values (Koc) [1]	Estimated Worst-Case Sediment Concentrations	
		mg/kg dry wt.	ppm TOC		(ppm TOC) [3]	mg/kg dry wt.
PCP	0.00491	0.69	nv	410 [2]	2.01	**0.064**
Bis(2-ethylhexyl)phthalate	0.00356	nv	78	111,123	**396**	12.7
1,4-Dichlorobenzene	0.00486	nv	9	616	**3.0**	0.1

Notes:

nv: No value.

See Table 4-6 for the derivation of applicable surface water criteria.

1. The sources for the Koc values used here are listed in Table 7-2.
2. Koc value for PCP is dependent on groundwater pH. A Point-of-Exposure pH of 8.0 was conservatively assumed.
3. Conversions between dry weight and ppm TOC were based on an assumed sediment organic carbon content of 3.2%.

8 Remedial Action Objectives, ARARs and Available Cleanup Technologies

Based on the information developed during the remedial investigation, this section defines remedial action objectives and cleanup levels applicable to the Landfill. Permitting requirements and ARARs potentially applicable to a cleanup action at the site are discussed. Then remedial technologies are screened for effectiveness. Technologies that are potentially effective and implementable are then assembled into remedial alternatives for evaluation in Section 9.

8.1 Remedial Action Objectives

Table 8-1 summarizes the remedial action objectives required to ensure compliance of the Roeder Avenue Landfill with the cleanup requirements of MTCA and other applicable regulations. These objectives are based on the findings of the remedial investigation as described in the preceding sections.

- Direct contact with Landfill refuse is currently prevented by existing cover soils and site development features. Actions are required to ensure that such direct contact is prevented during long-term site care.

- Landfill gas (principally methane) is known to be generated within the Landfill, and has been detected at elevated levels in monitoring wells up to 200 feet from the Landfill boundary. Actions are required to ensure that methane accumulation in buildings or other enclosed spaces does not occur.

- Potable use of groundwater within the Central Waterfront area is currently prohibited by existing state water supply regulations. This precludes human health exposure to impacted groundwater. Additional actions may be warranted to ensure communication of groundwater use restrictions to area property owners or tenants.

- Chromium is a contaminant of concern within the Landfill area. Site geochemical conditions have caused the chromium to be present in the trivalent form. Certain actions such as aggressive chemical oxidation of groundwater could cause the chromium to be converted to the more toxic hexavalent form. Controls are required to ensure that such conversion does not occur in areas of the site where it could adversely effect water quality within the point-of-exposure.

- The results of the remedial investigation have demonstrated that the natural discharge of groundwater at the point of exposure (benthic zone along shoreline of Bellingham Bay) is compliant with state, federal and other applicable criteria necessary to protect human health and the environment. However, direct discharge of Landfill area groundwater to surface waters in a manner which short-circuits natural attenuation process would not be compliant with these criteria. Actions are required to prevent such direct discharge of Landfill area groundwater.

- The results of the remedial investigaiton indicate that the Landfill does not pose a risk of sediment recontamination in Bellingham Bay provided that Landfill refuse exposure and direct discharge of Landfill area groundwater are prevented. Assuming that these other action objectives are completed, no additional measures are required to prevent sediment contamination.

8.2 Site Cleanup Levels

Groundwater Cleanup Levels

Groundwater cleanup levels applicable to the site have been extensively discussed in preceding sections of this report. Table 8-2 reiterates the criteria that were evaluated to ensure that final groundwater cleanup levels are compliant with MTCA requirements and ARARs, and to ensure that groundwater conditions are protective of other media such as surface water and sediments.

Table 4-6 lists the numeric groundwater criteria that are applicable to the point of exposure. The point of exposure is identified as the groundwater discharging into the sediment bioactive zone along the shoreline of Bellingham Bay. These numeric criteria were developed based on the following considerations:

- **Surface water criteria:** For most Landfill COCs the criteria applicable to the point-of-exposure represent federal or state water quality criteria, or MTCA Method B cleanup levels for surface waters. These contaminants include 1,4-dichlorobenzene, pentachlorophenol, weak-acid dissociable cyanide, copper, lead, nickel and zinc.

- **Natural background:** In the case of arsenic and mercury, it is necessary to adjust the point-of-exposure criteria to account for natural background concentrations. Each compound is naturally present in seawater. Arsenic is also naturally occuring in Washington state groundwater. Consistent with MTCA regulations, the cleanup levels for these compounds are based on background considerations.

- **Sediment source control:** In most cases, compliance with surface water criteria ensures protection of sediment quality. The compound bis(2-ethylhexyl)phthalate strongly sorbs to organic carbon and has relatively low sediment cleanup levels. As a result, the final numeric criterion for bis(2-ethylhexyl)phthalate in the point-of-exposure has been adjusted downward by a factor of 5X to ensure protection of sediment quality (see Section 7).

- **Aquatic toxicity data:** As described in Section 2.4, a cleanup screening level of 0.5 mg/L was adopted for use during the RI/FS. This cleanup level is based on recent toxicological data reported in the scientific literature for petroleum mixtures. A higher cleanup level for petroleum is likely appropriate, but would be subject to additional verification testing. The site-specific screening level of 0.5 mg/L will be used unless additional testing is performed to support the use of a higher cleanup level for the point-of-exposure. The screening level is consistent with the MTCA Method A groundwater cleanup level (based on aesthetic standards), and ensures that aesthetic characteristics of surface waters are not adversely impacted.

Because the groundwater cleanup levels are derived directly from the most stringent water quality criteria, compliance with these criteria at the point-of-exposure ensures protection of ecological receptors. Additional ecological risk evaluations are not required.

In most cases, the cleanup levels derived for the protection of surface water (see Table 4-6) are similar to, or are actually more stringent than the potable use criteria. Potable uses are currently prohibited in the Landfill area by state water supply regulations. Excepting potable uses (which are prohibited) site groundwater quality as defined during the RI/FS does not pose a health and safety risk to utility workers or to other personnel who could potentially come into contact with groundwater at the site.

Groundwater modeling and contaminant fate and transport evaluations conducted in Sections 6 and 7 of this report provide the empirical information necessary to develop a compliance monitoring framework for the site. Specifically, those portions of the Landfill area that would be most likely to impact water quality in the point-of-exposure have been identified. For each of the remedial alternatives presented in Section 9, optimum compliance monitoring locations are presented for groundwater to ensure that water quality remains protective of human health and the environment.

Cleanup Levels for Other Media

Cleanup levels for sediments are based on existing Sediment Management Standards cleanup screening levels. As described above, the groundwater cleanup levels applicable to the site have been defined at levels that will prevent potential impacts to sediments.

The Landfill was not found to contain elevated levels of volatile organic compounds. The only air exposure risk associated with the site from landfill gas. Landfill gas is produced by the natural decomposition of organic matter within the refuse. The constituent of greatest concern in landfill gas is methane due to its combustibility at high concentrations. Landfill gas also contains the inert constituents carbon monoxide and carbon dioxide, which can displace oxygen in underground enclosed spaces, and low levels of hydrogen sulfide which is regulated under state and federal safety standards. State and federal safety requirements specifiy minimum levels of oxygen in air and set limits on acceptable exposures for hydrogen sulfide. Methane is not toxic and does not have state or federal exposure limits, but is regulated indirectly through control of oxygen levels and combustibility. The point at which a mixture of methane and oxygen is combustible is defined as the lower explosive limit (LEL). Revised MTCA regulations set the maximum cleanup levels for hazardous substances in air at 10 percent of the Lower Explosive Limit.

For soils, prevention of direct contact with landfill refuse is required to ensure compliance with MTCA soil cleanup levels. Prevention of direct contact with landfill refuse, in conjunction with compliance with groundwater cleanup levels, also protects against adverse effects to ecological receptors.

Groundwater Points of Compliance

The point of compliance is the specific location or locations at which measurements are performed to demonstrate compliance of a cleanup action with the established site cleanup levels.

Regulatory Requirements

The default groundwater point of compliance under MTCA is within groundwater throughout the contaminated site. For cleanup actions that involve residual hazardous substances, a conditional point of compliance may be established. Specific considerations listed under MTCA regulations include the following:

- **Proximity to Source:** Conditional points of compliance shall be as close as practicable to the source of hazardous substances, not to exceed the property boundary (WAC 173-340-720(6)(c).

- **Surface Water as Alternative Point of Compliance:** MTCA allows points of compliance to be established within the surface water, (WAC 173-340-720(6)(d)). However, as noted in the responses to comments on the First Progress Memorandum, a point of compliance located within the surface water is not requested as part of the RI/FS.

- **Impacts of MTCA Amendments:** Proposed amendments to the MTCA regulations include an allowance to points of compliance to be located past the property boundaries for sites that are near, but not abutting surface waters (proposed citation WAC 173-340-720(9)(d)(ii)). These amendments are effective as of August 15, 2001.

Based on current MTCA regulations as recently amended, the points of compliance applicable to the Roeder Avenue Landfill may be located anywhere between the Landfill refuse and the shoreline, but there is a regulatory preference for areas that are within the Landfill properties and that are near the Landfill refuse (the source). Likely locations for the compliance monitoring well network have been incorporated into each of the cleanup alternatives evaluated in this RI/FS (see Figures 9-1 through 9-5).

Final locations will be established as part of a Compliance Monitoring Plan (WAC 173-340-410) to be prepared in conjunction with the Cleanup Action Plan. That plan will also specifiy the attenuation factors applicable to each location can be defined using the results of the remedial investigation. Cleanup levels applicable to each compliance well will consist of the surface water cleanup level corrected by the appropriate area-specific attenuation factor. Figure 6-9 shows how these attenuation factors vary across the project area.

8.3 Regulatory Requirements and ARARs

Table 8-3 and 8-4 document regulatory requirements and ARARs that may be applicable to site remediation. In selecting a final cleanup remedy for the Landfill site, potential cleanup technologies and alternatives must be evaluated against MTCA remedy selection requirements and must comply other ARARs. These requirements are summarized briefly below.

MTCA Remedy Selection Requirements

MTCA remedy selection criteria are defined in WAC 173-340-360. MTCA requirements for cleanup remedies include the following:

- Protection of human health and the environment;
- Compliance with cleanup levels at the points of compliance;
- Compliance with applicable state, local and federal laws;
- Provisions for compliance monitoring;
- Use of permanent solutions to the maximum extent practicable;
- Provision of a reasonable restoration time frame; and,
- Consideration of public concerns raised during public comment.

MTCA regulations include a strong preference for the use of "permanent solutions", and include a preference hierarchy that is to be used during evaluation of alternatives and remedy cost-effectiveness. That hierarchy establishes as highest preference those technologies using reuse or recycling, destruction, detoxification, and/or separation or volume reduction.

The regulations acknowledge that the sole use of permanent solutions may not be practicable for all sites and indicate how and when lower-preference alternatives may be selected. As described in WAC 173-340-360(5)(d-e), lower- preference alternatives are appropriate where the incremental costs of using the higher-preference alternatives are substantial and disproportionate to the degree of risk reduction achieved using the higher-preference alternative. Using these criteria, other types of technologies may be selected including, in descending order of MTCA preference: immobilization, disposal in an engineered facility, isolation or containment, and institutional controls and monitoring. In selecting from among these types of alternatives, MTCA requires evaluation of the following factors:

- Overall protectiveness of human health and the environment, including the degree to which overall risks are reduced, the time required to reduce the risk at the facility and attain cleanup standards, on-site and off-site risks resulting from implementing the alternative, the degree the cleanup action may perform to a higher level than specific standards in MTCA, and improvement of overall environmental quality.

- Long-term effectiveness including the degree of certainty that the alternative will be successful, long-term reliability, magnitude of residual risk, and effectiveness of controls required to manage treatment residues or remaining wastes.

- Short-term effectiveness and protection of human health and the environment during implementation of the cleanup action.

- Reduction in the toxicity, mobility and volume of hazardous substances.

- Implementability, including integration with facility characteristics and other current or potential remedial actions.

- Cost-effectiveness, as measured by the degree of permanence and the level of risk reduction achieved in relation to the overall remedy cost.

- The degree to which community concerns are addressed.

The MTCA threshold and remedy selection criteria listed above are used in Section 9 as part of the evaluation of remedial alternatives.

Treatment and Disposal Requirements

Table 8-3 summarizes regulatory requirements potentially applicable to cleanup actions requiring the generation and treatment or disposal of contaminated media.

Construction activities that require off-site disposal of contaminated soils or debris are subject to state and federal waste disposal regulations. Federal RCRA regulations and Washington State Dangerous Waste regulations require special provisions for management of certain materials. Disposal of solid wastes is regulated under WAC 173-304, the Minimal Functional Standards.

For alternatives involving refuse/contaminated soil treatment or upland handling, air emissions control regulations may apply. These requirements result in limitations on materials accepted by fixed treatment facilities. These regulations impose requirements such as dust and odor control on upland material handling or treatment activities.

For remediation alternatives involving water generation, the discharge of generated waters may be regulated under state and federal regulations. Discharges from upland areas to surface waters require permits under the National Pollutant Discharge Elimination System program. Discharges to the sanitary sewer are subject to local discharge standards and permitting.

Project Permits and ARARs

Table 8-4 summarizes regulatory requirements that may impact project permitting and implementation. For actions conducted under a MTCA Order or a Consent Decree, the project would be exempt from state and local permits and procedural requirements. However, MTCA requires compliance with the substantive provisions of these regulatory programs, and certain long-term actions may be best administered as part of a local building permit process. MTCA does not contain a procedural exemption from federal permitting.

Construction projects are subject to environmental impact review under SEPA and/or NEPA regulations. For most projects, this review consists of a SEPA checklist. In some cases, an environmental impact statement can be required.

Shoreline Master Plan requirements impact projects occurring within 200 feet of the shoreline. However, shoreline regulations defer to Ecology for site-specific review of cleanup actions conducted under MTCA.

Federal permitting for in-water construction (if required) can be implemented under either a Federal 404 Individual permit or under a Nationwide 38 permit. The federal permitting process includes review of issues relating to wetlands, tribal treaty rights, threatened & endangered species, habitat impacts and other factors.

8.4 Screening of Remedial Technologies

This section briefly describes the remedial technologies that are potentially applicable to a cleanup of the Landfill site. Available technologies are listed in Table 8-5. These technologies were screened for effectiveness and implementability. Technologies that were retained for development of remedial alternatives (Section 9) are underlined in the table. Each technology in Table 8-5 is described briefly below.

Recycling, Destruction/Detoxification & Volume Reduction

Excavation of the landfill refuse was evaluated as a possible approach to site remediation. Such excavation would remove the source of site contamination and could be coupled to various off-site treatment or disposal alternatives. Both wet and dry excavation alternatives were evaluated for implementability. Neither excavation alternative was retained for further evaluation due to the implementability considerations described below.

Because the site has been redeveloped over the past 25 years, a majority of the site is not accessible for excavation. Structures that would require removal prior to site excavation include the Puget Sound Energy electrical substation, the Sanitary Services building, the GP Warehouse building, and the GP Compressor building. These actions would impact local electrical power supplies, and would disrupt or displace important public and private services. While theoretically possible, this degree of displacement is not realistically implementable. In addition, any excavation of the landfill refuse would require a planned sequence for control of surface and groundwater, shoring of slopes to prevent damage to

Roeder Avenue utilities and buildings on adjacent properties, segregation and containment of materials, stockpiling for treatment or other disposition, transportation impacts for shipment of excavated materials and excavation backfilling and regrading. Wet excavation methods are not practicable for the refuse, because wet excavation would result in additional contaminant suspension and further degradation of groundwater quality. Dry excavation is not feasible without very high (over 2,000 gallons per minute for a mass excavation) water generation rates from dewatering systems. Finally, the odors and transportation impacts associated with mass excavation of the landfill refuse would result in excessive disruption to the community.

Were site soils and refuse to be generated through excavation, off-site landfill disposal is the only realistic alternative for management of those materials. Thermal desorption is a proven and rapid means for treating soil contaminated with petroleum hydrocarbons, volatile and semivolatile organics. But that technology cannot destroy or detoxify heavy metals. Further, local fixed treatment facilities cannot accept soils containing excessive wastes or debris. Recycling options (e.g., refuse-derived fuels) are practical for certain waste streams, but cannot be effectively used with mixtures of soil and refuse. Incineration can be used for treatment of soils and waste mixtures, but even incineration does not destory toxic metals or debris. Incineration costs are prohibitive, and the process generates toxic byproducts that offset the environmental benefit associated with the volume reduction and organic contaminant destruction achievable with the technology. If landfill disposal of excavated materials was performed, it would likely occur at an off-site commercial landfill. Such disposal is not implementable due to the inability to excavate the materials as described above.

In situ groundwater treatment can be used to destroy, detoxify or immobilize certain organic and inorganic constituents. Such treatment can be performed using reducing or oxygenating systems. Geochemical conditions within and adjacent to the Landfill are already highly reducing, such that no further benefit would be achieved through enhancement of these existing conditions (e.g., the use of hydrogen release agents for reductive dechlorination).

Oxidation-based in situ groundwater treatment systems include both strongly oxidizing and moderately oxidizing systems. In both cases, the use of oxidizing treatment systems would be limited to non-refuse areas. The introduction of oxygen into refuse areas is not appropriate, because the oxygen can stimulate refuse decomposition, resulting in ground settlement and additional pollutant releases. In the presence of methane, oxygen can also result in refuse fires.

Strongly oxidizing in situ groundwater treatment systems are commercially available using hydrogen peroxide, ozone or potassium permangenate. These systems could be used to destroy or immobilize certain of the Landfill contaminants. However, use of chemical oxidation systems of this type is not appropriate in areas of the site containing elevated chromium in groundwater. These systems can transform the less-toxic trivalent form of chromium into the more toxic and more mobile hexavalent form. Moderately oxidizing systems such as air sparging do not trigger this transformation. Moderately oxidizing systems can be effective at enhancing degradation of organic constituents such as petroleum, and can trigger metals precipitation as discussed in Section 7. Strongly oxidizing in situ groundwater treatment systems are not retained for further evaluation. Moderately oxidizing systems such as groundwater sparging are not retained for site-wide use, but could be implemented in specific areas outside the Landfill footprint to enhance control of particular contaminants.

Natural attenuation can be an effective means for containment and eventual cleanup of contaminated groundwater. Attenuation processes for groundwater include passive flow and mixing of water, geochemical transformations that precipitate, detoxify or destroy pollutants, and biologically-mediated pollutant decomposition processes. All three of these processes are occurring at the Landfill site. The remedial investigation findings provide information regarding measures that can be taken to enhance the attenuation processes (e.g., by lengthening groundwater travel times or reducing the flux of Landfill leachate). Monitoring is required to verify the performance of natural attenuation. The information from the remedial investigation provide a baseline against which long-term monitoring data can be compared. Natural attenuation, including enhancements and monitoring, is retained as a technology for evaluation as part of the RI/FS.

Immobilization Technologies

Contaminant immobilization has been performed at cleanup sites using solidification/stabilization, vitrification and ground freezing technologies. These technologies were evaluated for applicability to the Landfill site, but were determined to be not implementable due to the site-specific conditions.

Stabilization of contaminated soil using additive materials such as cement, fly ash and lime has been demonstrated effective in eliminating mobility and leachability of many contaminants. In most cases, design level laboratory testing is required to determine the optimal mixing ratios of soil and additives. While stabilization can be completed either insitu or ex situ, only in situ methods were evaluated for the Landfill site. Ex situ methods were not evaluated because they require refuse excavation which is not realistically implementable at the site.

In situ solidification/stabilization was initially developed for civil engineering applications to provide additional bearing capacity for soft soils. The appropriate slurry or dry mix is injected directly into the soil under high pressure and mixed in situ with the contaminated soil by a tracked unit which provides rotary mixing. Soil is mixed with a single-blade auger or with a combination of augers ranging from 3 to 12 feet in diameter. Mixing can be accomplished to depths exceeding 100 feet using this method. However, the technology is not implementable at sites with excessive debris. Debris causes interference with the stabilization equipment and must be pre-excavated. At landfill sites where the debris is part of the waste matrix, the technology is reduced to perimeter containment uses (e.g., grout walls and slurry walls) as described below. In addition, the technology cannot be applied beneath pile-supported buildings and could not be applied to previously-developed portions of the site. In situ stabilization is not retained for further evaluation.

In situ vitrification is analogous to in situ stabilization. However, the stabilization of the soil matrix is achieved by melting and resolidification of the soil, rather than through the addition of stabilization agents. Soil melting is achieved using electrodes that are inserted into the soil. The technology is not compatible with high organic matrices, excessive debris or potentially-explosive atmospheres. All three of these conditions exist within the Landfill. Vitrification is not retained for further evaluation.

In situ soil freezing has been used for over a hundred years to accomplish difficult soil stabilization or excavation projects in the mining industry. In the technology a brine solution is chilled and circulated in underground piping systems, resulting in freezing of the ground. Once frozen, the ground can be maintained in a solid form as necessary by continuous brine cooling and circulation. The technology requires significant electrical power inputs, and is temporary in nature. Large-scale applications are impractical because of the power requirements, the logistical requirements associated with system installation and maintenance, as well as other complications unique to the technology (frost heave, underground utility damage, etc.). Stabilization by ground freezing is not retained for further evaluation.

Containment Technologies

Containment technologies are widely applied at landfill sites and can be used to address environmental concerns in soil, groundwater and air. Like natural attenuation, containment technologies require monitoring to ensure long-term effectiveness.

Enhanced development capping represents a hybrid of technologies that have been applied for development of Brownfields and landfill sites in Washington State and elsewhere in the U.S. and Canada. Under this technology, the building, paving and landscape features of site development are controlled to accomplish environmental objectives (e.g., prevention of direct contact, reduction of infiltration). Additional systems (such as methane control systems) are incorporated into the development features to address other concerns. If applied to the Landfill site, enhanced development capping would include measures to prevent refuse exposure, requirements for collection and off-site conveyance of stormwater generated from buildings and other impervious surfaces, gas control systems beneath occupied buildings or other enclosed structures, and provisions allowing for long-term monitoring and the implementation (as necessary) of contingent corrective actions. Enhanced development capping has been applied to Brownfield redevelopment of recreational, residential commercial and industrial areas. Deed restrictions and local building permit approval processes provide the mechanisms for implementing enhanced development capping. Ongoing maintenance and monitoring are required. Enhanced development capping is retained for further consideration.

Low-permeability caps have been widely used at landfill and other contaminated sites with highly-contaminated groundwater. The permeability of the final cap is determined by the percent coverage of the cap, the extent of drainage provided, and the permeability of the capping materials. There are a wide range of effective capping materials including low-permeability asphalt, compacted clay, geomembrane systems and concrete. Low permeability caps over active landfills are typically include gas collection systems. Inclusion of gas collection offsets the tendency for impermeable caps to exacerbate lateral gas migration, and also prevents gas production from damaging the low-permeability cap layers. In developed areas where buildings are to be pile-supported, measures must be taken to ensure that the development actions and capping design are compatible with one another. Otherwise the capping effectiveness can be compromised (e.g., leakage through the cap via penetrations caused by the foundation pilings). Low-permeability capping is retained as a technology for further evaluation.

Groundwater extraction systems can be used to contain areas of contaminated groundwater. These systems are known as hydraulic capture or pump and treat systems. The approach uses extraction wells to pump groundwater from the subsurface where it is treated and/or discharged. Where water production rates are relatively low and where water treatment/disposal options are readily available, hydraulic capture can be a cost-effective and implementable approach to site containment. Pumping wells and associated piping can typically be sited in inconspicuous areas so that they only minimally impact property use. However, for sites with highly productive groundwater aquifers and those near surface water, groundwater extraction rates can be excessive. At the Landfill, water production rates necessary to achieve complete capture of area groundwater were estimated at over 100 gallons per minute. At these rates, water treatment/disposal is costly and problematic. Hydraulic capture is retained as a technology for further evaluation, but only in conjunction with physical containment and capping alternatives that would minimize water production rates (see below).

Physical barrier systems can be used to modify groundwater flow patterns. Technology options include sheet-piling walls, slurry walls, grout curtains and polymer wall designs. The barrier systems can be used to fully or partially encircle a site, or they can be applied in a more selective manner to modify certain elements of groundwater flow patterns. Based on the hydrogeologic conditions present at the Landfill, barrier walls would need to penetrate from the water table down across the sand layer to the top of the clay in order to be effective. Because the depth to the top of the clay unit varies across the site, the penetration depth of installed barrier walls would also vary across the site. The use of a shallower hanging wall would have relatively little effect on groundwater gradients due to the high hydraulic conductivities measured in the sand and refuse units, but hanging walls could be used to influence groundwater mixing patterns. The influence of fully penetrating barrier systems on groundwater flow patterns would depend on the length, placement and permeability of the barrier system, and on any other actions performed in parallel with the barrier system. Diversion barriers are retained for further evaluation, both alone and in conjunction with other remedial technologies.

As noted above, hydraulic capture alone (without physical barrier systems) is not considered implementable at the Landfill. However, a hybrid approach using a largely or fully encircling barrier system in conjunction with hydraulic capture could be used to contain impacted groundwater. Based on the measured groundwater quality measured in the Landfill, direct discharge to the sanitary sewer (publicly-owned treatment works or POTW) is assumed to be feasible without pretreatment. Discharge to surface waters would require a discharge permit and either a dilution zone or groundwater treatment. Discharge to the POTW is assumed as the likely disposal method for groundwater from a hydraulic capture system. Combinations of hydraulic capture and physical barrier systems are retained for further consideration.

Institutional Controls and Monitoring

Under any cleanup approach not involving full refuse removal, long-term site management will require the use of institutional controls and monitoring. Because refuse excavation is not realistically implementable, institutional controls and monitoring will be essential features of the final site cleanup. Such controls and deed restrictions are appropriate both for the Landfill as well as for the properties along Hilton Avenue and along C-street that are located between the Landfill and the shoreline. Potentially applicable monitoring requirements and institutional controls for the Landfill include the following:

- Cap maintenance: For Landfill properties, cap maintenance activities will be required. The extent of these activities will depend on the type of cap and associated requirements of the cleanup remedy. Deed restrictions would be used to ensure continued adherence to cap maintenance requirements.

- Methane Controls and Monitoring: For Landfill properties and adjacent properties, methane monitoring and/or controls may be required for buildings and certain other enclosed structures. Methane monitoring and control requirements would be incorporated into deed restrictions and local building permit processes.

- Groundwater Monitoring: Groundwater compliance monitoring will be required for the site. The scope of the monitoring program will vary somewhat with the cleanup alternative.

- Groundwater Use Restrictions: Consumptive groundwater use within the Central Waterfront area is prohibited under existing state law (WAC 173-160-205). However, additional use restrictions may be required depending on the final cleanup remedy selected. For example, drainage and surface water discharge of groundwater (e.g., during construction dewatering) from the Landfill or adjacent areas is not appropriate. Deed restrictions would be used to clarify this and any other applicable use restrictions not already codified in existing regulations.

Table 8-1. Remedial Action Objectives

Media	Exposure Risk	Remedial Action Objectives
Soils	➢ Exposures to Landfill refuse	➢ Protect human and ecological receptors by preventing direct contact with Landfill refuse
Air Exposures	➢ Methane accumulation in enclosed spaces and resultant combustible atmospheres	➢ Use monitoring and engineered systems to ensure that methane accumulation in buildings or other enclosed spaces on or adjacent to the Landfill does not result in combustible atmospheres.
Groundwater	➢ Human exposure by ingestion ➢ Non-attenuated discharge to surface waters ➢ Formation of hexavalent chromium	➢ Ensure that potable groundwater uses are prevented ➢ Ensure that direct discharge of Landfill groundwater does not occur ➢ Limit uses of in situ groundwater oxidation technologies in areas of high chromium
Surface Water	➢ Exposure of benthic organisms to groundwater at concentrations above applicable surface water criteria	➢ Ensure that groundwater discharging to surface water (point-of-exposure) complies with applicable surface water criteria
Sediments	➢ Contaminant deposition in sediments above applicable sediment criteria	➢ Ensure that groundwater discharging to surface water (point-of-exposure) does not result in exceedance of applicable sediment cleanup levels

Table 8-2 Potential ARARs—Cleanup Levels

Medium	Standard/Criterion	Citation	Comments
Sediment	Criteria used to identify sediments that have no adverse effects on biological resources and correspond to no significant health risk to humans.	Sediment Management Standards (WAC 173-204)	Groundwater discharges must not cause sediment quality exceedances in adjacent surface waters. Source control analysis performed for contaminants of concern in Section 7.
Surface Water	Requirements for establishing numeric or risk-based goals and selecting cleanup actions.	Model Toxics Control Act (WAC 173-340, Sections 720 and 730)	MTCA provides numeric and narrative criteria for surface waters. Cleanup levels for groundwater must prevent exceedances of surface water criteria at point of exposure. Method A groundwater cleanup level for TPH adopted as screening level for surface water exposures to address recent eco-toxicity data in literature for petroleum.
	Ambient water quality criteria for the protection of aquatic organisms and human health.	Federal Water Pollution Control Act/ Clean Water Act (CWA) (33 USC 1251–1376; 40 CFR 100–149) 40 CFR 131	Federal standards incorporated as ARAR under MTCA. Groundwater criteria applied to site must prevent exceedance of federal criteria at point of exposure.
	State water quality standards; conventional water quality parameters and toxic criteria.	Washington Water Pollution Control Act - State Water Quality Standards for Surface Water (RCW 90.48) WAC 173-201A-130	Narrative and quantitative limitations for surface water protection.
Soil and Groundwater	State cleanup levels for soils	Model Toxics Control Act (WAC 173-340, Section 740 and 745)	Applicable to upland portions of site.
	State cleanup levels for groundwater	Model Toxics Control Act (WAC 173-340, Section 720)	Groundwater standards are based on potable uses. Not relevant to site. However, MTCA Method A values for TPH adopted as screening level for RI/FS, and Method A value for arsenic adopted as indicator of background for arsenic in groundwater.
	Federal criteria for drinking water	Safe Drinking Water Act (40 CFR 141, 143)	Project must not impact drinking water supplies. Hydrogeologic conditions of site prevent water supply impact.
Air Exposure	MTCA criteria for air exposures	WAC 173-340-750	Air cleanup levels shall not exceed ten percent of the LEL for any hazardous substance or mixture.
	Federal worker exposure regulations	OSHA (29 CFR 1910.1000)	Site conditions must result in exposures of site workers to airborne pollutant levels above permissible exposure limits.

Table 8-3 Potential ARARs—Treatment and Disposal

Activity	Requirement	Citation	Comments
Upland Disposal of Refuse, Contaminated Soils	State criteria for dangerous waste (which are broader than federal hazardous waste criteria)	Washington Dangerous Waste Regulations (WAC 173-303) Designation procedures (Section -070)	State and federal laws prohibit land disposal of certain hazardous or dangerous wastes.
	Requirements for solid waste management.	Solid Waste Disposal Act (42 USC Sec. 325103259, 6901-6991), as administered under 40 CFR 257, 258; WAC 173-304, Minimum Functional Standards for Solid Waste Handling	Applicable to non-hazardous waste generated during remedial activities and disposed of off site unless wastes meet recycling exemptions.
Air Emissions	State implementation of ambient air quality standards. NWAPA or PSCAA ambient and emission standards.	Washington State Clean Air Act (70.94 RCW) General Requirements for Air Pollution Sources (WAC 173-400)	Potentially applicable to alternatives involving waste treatment, or to emissions from air pollution sources constructed as part of site cleanup.
Wastewater	Permitting & treatment requirements for direct discharges into surface water.	National Pollutant Discharge Elimination System (NPDES) (40 CFR 122, 125) State Discharge Permit Program; NPDES Program (WAC 173-216, -220)	Anticipated to be relevant if discharged to surface waters. Discharges must comply with NPDES permitting requirements. Dilution zone or treatment would be required prior to surface discharge of extracted groundwaters.
	Stormwater permitting	National Pollutant Discharge Elimination System (NPDES) (40 CFR 122, 125) State Discharge Permit Program; NPDES Program (WAC 173-216, -220)	Construction projects exceeding threshold requirements require stormwater permits and implementation of best management practices for stormwater pollutant control.
	Permitting & pre-treatment requirements for discharges to a POTW	National Pretreatment Standards (40 CFR 403); City of Bellingham Wastewater treatment requirements	Discharges to POTWs are considered off-site activities; pretreatment and permitting requirements would be applicable.

Table 8-4 Potential ARARs—Project Permitting and Implementation

Location/Activity	Requirement/Prerequisite	Citation	Comments
Evaluation of environmental impacts	Evaluation of project environmental impacts and definition of appropriate measures for impact mitigation	State Environmental Policy Act (SEPA; WAC 197-11), National Environmental Policy Act (42 WSC 4321 et seq.)	SEPA checklist expected to satisfy these requirements.
Construction Activities within 200 Feet of Shoreline	Construction near shorelines of statewide significance, including marine waters and wetlands.	Shoreline Management Act (WAC 173-14), Bellingham Bay Shoreline Master Program Coastal Zone Management Act (16 USC 1451 et seq.)	Shoreline permitting process includes exemptions for remedial activities conducted under MTCA.
Construction in State Waters	Requirements for construction and development projects for the protection of fish and shellfish in state waters.	Construction in State Waters, Hydraulic Code Rules (RCW 75.20; WAC 220-1101), Rivers and Harbors Appropriation Act (33 USC 401, 40 CFR 230, 33 CFR 320, 322, 323, 325)	Applicable to I&J bulkhead gap closure if performed below ordinary high water line. State HPA permit required unless project implemented under MTCA Consent Decree or Order. Applicable to I&J bulkhead gap closure if performed below the mean higher high water line. Army Corps 404 permit or Nationwide permit to be used for project implementation.
Activities within/Adjacent to Wetlands	Actions must be performed so as to minimize the destruction, loss, or degradation of wetlands as defined by Executive Order 11990 Section 7. Requirement for no net loss of remaining wetlands.	Executive Order 11990, Protection of Wetlands (40 CFR 6, Appendix A) EPA Wetland Actions Plan. (January 1989, OWWP)	Project must result in no net loss or degradation of wetlands. Mitigation may be required for changes to shoreline conditions if required to close gap in I&J bulkhead.
Impacts to Tribal Treaty Rights	United States treaties protect certain rights of recognized tribes of native Americans, including property rights, water rights and fish/shellfish gathering rights.	Treaty of Point Elliott (12 Stat. 927) Treaty of Medicine Creek (10 Stat. 1132)	Impacts to treaty rights are typically addressed during project permitting..
Endangered & Threatened Species	Actions must be performed so as to conserve endangered or threatened species, including consultation with the Department of the Interior.	Endangered Species Act of 1973 (16 USC 1531 et seq.) (50 CFR Part 200) (50 CFR Part 402)	Chinook salmon listed as threatened species. Federal agencies must confer with the National Marine Fisheries Services on any action that may impact listed species.

Location/Activity	Requirement/Prerequisite	Citation	Comments
Habitat Impacts and Mitigation	Policies and procedures have been established by state and federal agencies to evaluate and mitigate habitat impacts	Memorandum of Agreement between EPA and U.S. Army Corps of Engineers (Mitigation under CWA Section 404(b)(1), U.S. Fish & Wildlife Mitigation Policy (46 FR 7644), Fish and Wildlife Coordination Act (16 USC 661 et seq.), Washington Department of Fisheries Habitat Management Policy (POL-410), Compensatory Mitigation Policy for Aquatic Resources (Chapters 75.20 and 90.48 RCW)	Mitigation requirements may or may not be triggered and are typically addressed during project permitting.
Health and Safety	Development of a health and safety plan with appropriate controls, worker certifications and monitoring	WISHA (WAC 296-62) OSHA (29 CFR 1910.120)	Relevant requirement for environmental remediation operations.

Table 8-5. Screening of Remedial Technologies

Type of Technology	Description	Technology Retained?	Rationale for Technology Retention or Exclusion
1. Reuse & Recycling			
	Refuse Excavation and Recycling	No	Excavation of refuse not realistically implementable. Excavation would require removal of structures overlying refuse including Warehouse building, PSE substation and Sanitary Services building. Any excavation would trigger heavy traffic, noise and odor impacts to community. Wet excavation would result in contaminant resuspension and degradation of existing groundwater quality. Dry excavation not practicable due to high required rates of dewatering and difficulties of managing generated waters. Materials in waste cannot be cost-effectively separated from landfill cover soils and non-recycleable materials.
2. Destruction/Detoxification			
	Refuse Excavation and Treatment	No	Excavation not realistically implementable as described under number 1 above. Treatment technologies not available for mixed soil and refuse (excepting those that also involve final landfill disposal of treated residuals).
	Groundwater In Situ Treatment by chemical oxidation	No	Groundwater treatment by oxidation technologies suitable for immobilizing and detoxifying certain inorganic and organic constituents. However, highly oxidative treatments such as peroxide or ozone can result in oxidation of trivalent chromium to the more toxic hexavalent form. Application precluded in areas with high total chromium. Application within refuse can also exacerbate settlement due to refuse decomposition or trigger landfill fires due to oxygen evolution.
	Groundwater In Situ Treatment by aeration	No	Groundwater treatment by aquifer sparging is potentially implementable in non-refuse areas for enhancing immobilization of certain contaminants. Sparging would not cause formation of hexavalent chromium. However, application within refuse not retained due to potential exacerbation of settlement due to refuse decomposition and potential of triggering landfill fires. Potential application only as contingent remedy in localized areas.
	Groundwater Natural Attenuation	**Yes**	**Remedial investigation has documented significant attenuation of organic and inorganic contaminants. Use of monitored natural attenuation is suitable under site conditions. Attenuation can be enhanced by coupling with alternative technologies.**
3. Separation & Volume Reduction			
	See above - Refuse Excavation and Recycling	No	Excavation not realistically implementable as described under number 1 above. Recycleable portions of refuse not significant. Cost-effective separation of refuse from landfill cover soils and non-recycleable wastes not available.
4. Immobilization			
	In Situ Stabilization	No	In situ stabilization technologies not suitable for areas containing extensive debris. Portions of refuse located beneath structures/buildings not accessible.
	In Situ Vitrification	No	Suitable for soil matrices. Not suitable for high-organic wastes and debris.
	Ground Freezing	No	Impractical for application to large areas or for long-term uses.
5. Disposal			
	Refuse Excavation and Off-Site Disposal	No	Refuse excavation not realistically implementable (see No. 1 above)
6. Containment Technologies			
	Enhanced Development Capping	**Yes**	**Land use planning for area anticipates further site development. Methane controls can be incorporated into design of buildings and development features to address vapor exposure risks. Infiltration control from structures and paving can be enhanced through appropriate stormwater conveyance off of Landfill. Maintenance of Landfill cover soils can be accomplished through development controls.**
	Low-Permeability Capping	**Yes**	**If greater infiltration control is required, site capping can be enhanced using low-permeability materials or composite caps. Design alternatives include low-permeability asphalt, geomembrane, and clay capping systems. Cap design can be integrated with land-use planning and methane control requirements. Low-permeability cap designs would substantially increase stormwater generation.**
	Hydraulic Capture (Pump & Treat)	No	Hydraulic capture without physical barriers would generate very high groundwater production rates. Hydraulic capture should be applied only after implementation of other measures (I.e., physical barriers) to minimize pumping rates.
	Groundwater Diversion Barriers	**Yes**	**Groundwater diversion barriers can be applied alone or in conjunction with other alternatives. Barrier walls may include sheet piling, slurry wall, grout wall or polymer designs. Barriers can be used to reduce groundwater flow into landfill, enhance natural attenuation of site contaminants, or in conjunction with hydraulic capture. Specific design of barrier walls will vary with alternatives and site location.**
	Barrier Walls with Hydraulic Capture	**Yes**	**In conjunction with hydraulic barriers, groundwater extraction can be performed at reasonable water production rates. POTW disposal suitable following permitting and assuming long-term availability of treatment capacity. Surface water disposal without treatment not feasible without dilution zone; also subject to permitting considerations.**
7. Institutional Controls and Monitoring			
	Institutional Controls and Monitoring	**Yes**	**Appropriate for application to site. Specific requirements vary with alternative.**

9 Evaluation of Remedial Alternatives

Using the technologies retained during the preliminary screening described in Section 8.4 and Table 8-5, ThermoRetec assembled and evaluated five comprehensive remedial alternatives for the Landfill site. Each alternative was developed with engineering assumptions to produce an implementable alternative with an associated cost estimate.

Each of the five cleanup alternatives complies with MTCA threshold requirements for final cleanup actions. Key among these threshold requirements is compliance with cleanup levels. The alternatives differ in the technologies used, the mix of active and passive measures, and other factors. The differences between the alternatives are discussed below along with the factors that support the identification of a preferred alternative (Section 9.6) consistent with MTCA remedy selection requirements.

The detailed cost estimates prepared by ThermoRetec are included as Appendix E. Groundwater flow modeling tests were performed for each alternative. Output from those model runs is provided in Appendix F and is discussed along with each alternative.

9.1 Alternative A: Enhanced Development Capping, Institutional Controls and Monitoring

The first alternative evaluated for the site uses enhanced development capping to minimize rain water infiltration into the Landfill, to address refuse containment and to control Landfill gas. Natural attenuation provides compliance with groundwater cleanup levels. Institutional controls and groundwater monitoring are provided consistent with the Alternative. Figure 9-1 provides a graphical representation of Alternative A.

Description of Alternative A

Land use planning for the area anticipates continued commercial and light industrial uses of the properties in the Central Waterfront area. The largest portion of the Landfill has already been developed during the GP Warehouse project. That project included additional soil capping, provisions for off-site management of stormwater collected from impervious surfaces, and an integral Landfill gas control system beneath the building.

Under Alternative A, development/redevelopment of other site areas would proceed as dictated by economic and land use considerations. Controls would be imposed to ensure remedy protectiveness and to maximize the environmental benefits associated with site development. Specific requirements to be imposed on new development include the following:

- **Methane Control Systems:** Any new construction located on the Landfill would be required to incorporate a methane control system. The type of system would be specific to the building. However, passive venting systems are preferred over active systems because they minimize maintenance needs and thereby improve the certainty of long-term system performance. A typical system will include a vapor barrier, a permeable gas collection layer in the subgrade, perforated pipe laterals, venting risers and an in-building methane detector.

- **Stormwater Collection & Conveyance:** New construction on the Landfill will also be obligated to manage stormwater collected from building roofs, parking areas and other impervious surfaces by collection and off-site conveyance. The use of stormwater ponds or infiltration areas (e.g., biofiltration swales) will be prohibited unless water infiltration into the Landfill refuse is prevented by the use of liners or other engineered measures.

- **Soil Cover Maintenance:** Site development projects will be obligated to maintain a minimum soil cover of at least 1 foot thickness over landfill refuse for "hardscape" areas such as parking lots, buildings or gravel drives and 2 feet thickness over landscape areas. Cover soils are already present, and site development will typically result in placement of additional new materials (e.g., gravel addition as part of asphalt subgrade preparation). Therefore, this requirement is not anticipated to trigger new capital costs for Landfill properties. Rather, the requirement is intended to ensure that the existing soil cover is maintained or upgraded as sites are developed.

For existing construction on the Landfill, the same use restrictions will apply. However, methane controls will be required only after completion of in-building monitoring. For example, the Sanitary Services building and GP Compressor buildings are located on the Landfill, but they were not constructed with methane venting systems. For existing buildings of this type, methane detectors would be installed and monitored. Results from monitoring would then be used to assess whether building retrofits are required. Decisions regarding the need for and design of any retrofits would be performed by a licensed professional engineer. Retrofits could include interior or exterior vapor collection systems, using either active or passive venting designs as appropriate. The GP Warehouse was constructed with an integral methane control system, such that no further actions are required for this building.

New and existing buildings located within 200 feet (see Figure 9-1) of the Landfill refuse will also be subject to methane monitoring and contingent control requirements. New construction in these areas will be required to include a methane control system unless pre-construction monitoring and engineering demonstrate that a system is not required. All certifications and associated engineering will be performed by licensed professional engineers. The City building permit process will be used to mediate the system design and construction process. For existing buildings located within 200 feet of the landfill, in-building monitors will be installed. The results of monitoring will be reviewed by a licensed professional engineer. If necessary, building retrofits will be performed to mitigate elevated Landfill gas concentrations.

Institutional controls and monitoring are an integral part of Alternative A. Groundwater monitoring will include a network of wells located between the Landfill and the shoreline along documented groundwater migration pathways. The groundwater monitoring program will include testing for the Landfill Contaminants of Concern (Table 4-6).

Figure 9-1 shows compliance monitoring locations appropriate to this alternative. A reasonable groundwater monitoring schedule is provided along with the remedy cost estimate in Appendix E.. Cleanup levels applied at each compliance monitoring well will be specific to that location, based on the point-of-exposure cleanup levels (Table 4-6) and a scaling factor representing the attenuation occurring between the well and the downgradient point-of-exposure. Cleanup levels and final well locations will be documented in the site Compliance Monitoring Plan to be prepared in conjunction with the Cleanup Action Plan.

Institutional controls applicable to the site will include deed restrictions on Landfill properties, and on the properties located between the Landfill and the Shoreline as follow:

- **Landfill Properties (Figure 9-1; Zone 1):** Deed restrictions for properties located on the Landfill will ensure that 1) cover soils are maintained over Landfill refuse as necessary to prevent human or ecological exposures, 2) stormwater generated from building roofs, paved parking areas and impervious surfaces will be collected and conveyed off-site rather than being allowed to infiltrate into the ground, 3) future development will include landfill gas controls appropriate to the design of the buildings, 4) extraction of site groundwater for consumptive use will be prohibited, 5) extraction of groundwater for other purposes will be allowed only if provisions are included for monitoring and appropriate treatment/disposal of Landfill contaminants of concern, and 6) the use of oxidative in situ treatment technologies that could cause the formation of hexavalent chromium in site groundwater (e.g., peroxide injection) will be prohibited unless measures are taken to monitor and control hexavalent chromium concentrations.

- **Adjacent Properties (Figure 9-1; Zone-2):** Properties located within 200 feet of the Landfill refuse will be subject to landfill gas control requirements for new and existing buildings and groundwater use restrictions consistent with numbers 4, 5 and 6 above.

- **Shoreline Properties (Figure 9-1; Zone-3):** Properties located in between the Landfill and the shoreline, but not within 200 feet of the Landfill will be subject to groundwater use restrictions consistent with numbers 4, 5 and 6 above.

Compliance with the above-listed requirements will ensure that natural attenuation processes occurring at the site are not "short-circuited". Consistent with the Development Baseline Scenario tested with the flow model (see Section 6), the gross attenuation factors applicable to this alternative range from 3.6X (at the foot of Hilton Avenue) to over 20X (see Figure 6-9). Coupled with continued attenuation of pentachlorophenol and bis(2-ethylhexyl)phthalate through biological and sorptive processes, no additional actions will be required to comply with site cleanup levels. The Cleanup Action Plan and Compliance Monitoring Plan for the site will define contingent evaluations or other actions to be initiated if groundwater monitoring detects exceedances of site cleanup levels at the compliance monitoring wells.

Regulatory process costs associated with Alternative A include completion of a Cleanup Action Plan, Compliance Monitoring Plan and a Consent Decree for the site. In addition, deed restrictions must be developed and filed for the properties located within the Landfill and between the Landfill and the shoreline. Costs for the development of deed restrictions are included in the costs of this alternative, but no costs are included to cover property owner disputes should those arise.

Estimated Costs

The probable costs of Alternative A are estimated at $1.6 million. Detailed cost assumptions are provided in Appendix E. After applying a contingency factor of +30/-25%, the range of probable costs is from $1.2 to $2.1 million. The principal costs and cost variables for this alternative include the following:

- **Landfill Gas Management -- New Construction:** Management of Landfill gas is included for both Landfill areas and areas located (laterally) within 200 feet of the Landfill refuse. The final costs of gas control will depend on the extent of new construction within the control areas, and the type of controls applied. A total future construction area of 230,000 square feet is assumed for this area based on current land use planning and typical lot densities. However, the actual square footage of building area may be significantly greater or less than the assumed value. The discrepancy between estimated and final area will have a direct impact on gas control system costs. The unit cost of $2.50 per square foot is a reasonable average construction cost for passive venting systems based on recently completed projects in the Puget Sound area. Higher costs may be incurred for small structures, and economies of scale may be achieved for larger structures. In some cases, the building design (e.g., open structures) may allow construction without requiring a venting system. Only incremental costs associated with venting system construction are included in the estimated costs. Other construction requirements (foundations, grading work, building floor slabs, standard vapor barriers, etc.) are excluded from the unit cost calculation.

- **Landfill Gas Management -- Existing Construction:** Currently there are eight enclosed buildings on or adjacent to the Landfill. These include two Port buildings along Hilton Avenue, the Sanitary Services shop/office building, the GP Warehouse building, the GP compressor building and three of the BMI/Colony Wharf buildings. Of these, only the GP Warehouse building includes a methane control system. Costs are included in this alternative for installation of monitoring equipment within the other buildings. Costs included under this Alternative ($250,000) assume that up to three of the buildings will require installation of vapor extraction equipment. If additional buildings require control measures, a higher cost would likely be incurred.

- **Regulatory Process Costs:** Costs are included for completing a MTCA Cleanup Action Plan, Compliance Monitoring Plan and a Consent Decree. The costs assume the use of a collaborative process for development of these documents. Under an adversarial or an enforcement driven approach, process costs would be higher. Concurrence of the area property owners with the required institutional controls is also assumed, given that the controls do not significantly impair property uses. The controls are also compatible with reasonably foreseeable investigation and cleanup actions that could be required at the Colony Wharf, Olivine and Chevron sites. Property owner disputes would tend to result in increased process costs.

- **Groundwater monitoring:** Costs for groundwater monitoring are based on a reasonable, sequenced monitoring program. Alterations to this program would affect (increase or decrease) estimated monitoring costs.

Alternative A Evaluation

Tables 9-1 and 9-6 summarize the compliance of Alternative A with MTCA threshold remedy requirements and remedy selection criteria. The alternative is compliant with MTCA threshold requirements, but the overall ranking of Alternative A (Table 9-6) is moderate as described below.

By preventing direct discharge of impacted groundwater the alternative achieves a substantial reduction in potential point-of-exposure concentrations. Groundwater monitoring data collected during the RI/FS suggest that average or UCL concentrations for attenuated discharges to the point-of-exposure will continue to be below applicable cleanup levels. However, because the level of attenuation occurring between the Landfill and the shoreline is not directly enhanced under this alternative, this alternative provides a lower degree of protection than the other evaluated alternatives. The long-term effectiveness and the reduction in contaminant mobility achieved by Alternative A are considered moderate in comparison to these other alternatives.

This alternative builds upon the benefits of the GP Warehouse project, further enhancing infiltration reductions in the Landfill area. Active measures are also used to manage landfill gas. The mix of passive and active measures under this alternative provides the lowest overall cost. Therefore, the cost-effectiveness of Alternative A is considered high. However additional active measures can be performed to further reduce point of exposure groundwater concentrations without resulting in incremental costs that are substantial and disproportionate to the level of risk reduction achieved. For this reason, Alternative A receives a moderate raking for the use of "permanent solutions to the maximum extent practicable."

Alternative A maintains existing and forseeable land use flexibility within the Central Waterfront area, and has minimal impact to adjacent properties. Community disruption and construction hazards will be minimal under this alternative, resulting in a high degree of short-term effectiveness.

9.2 Alternative B: Enhanced Development Capping, Groundwater Diversion Barriers, Institutional Controls and Monitoring

The second alternative evaluated for the site is similar to Alternative A, but with an increased use of active measures to control groundwater contaminant migration. The enhanced development capping, institutional controls and monitoring elements of Alternative A are maintained under this alternative. Figure 9-2 provides a graphical representation of Alternative B.

Description of Alternative B

Under Alternative B, all of the cleanup elements described in Section 9.1 for Alternative A will be maintained. The additional actions taken under this alternative will improve the attenuation of groundwater contaminants and reduce the ultimate concentrations of these contaminants at the point-of-exposure. This additional attenuation is achieved through the use of two physical groundwater barriers at the locations shown in Figure 9-2.

Under Alternative A, the two areas of the site with the lowest gross attenuation factors are located at the foot of Hilton Avenue and upgradient of the gap in the I&J Waterway bulkhead (see Figure 6-9). Placement of physical diversion barriers in these locations results in a substantial improvement in overall site attenuation factors with a moderate capital investment.

The attenuation factors at the foot of Hilton are low because of the short pathlines and travel time between the Landfill refuse and the point of exposure in this area. Groundwater discharges are also influenced in this area by the Lagoon effect and the proximity of the sheetpile bulkhead in the northwest corner of the site. Extension of the existing sheet-pile bulkhead across this area to the edge of the lagoon results in a substantial lengthening of the groundwater pathlines and travel times. This scenario was directly simulated using the groundwater flow model (see modeling output in Appendix F). The modeled groundwater barrier substantially reduces the discharge of Landfill-area groundwater at the foot of Hilton Avenue, with diversion of that flow toward the I&J Waterway. This produces an effective drop in point-of-exposure leachate concentrations from a high of 27.3 percent (at the foot of Hilton Avenue) to 6 percent (along the I&J Waterway), resulting in the beneficial increase in the gross attenuation factor from 3.66X to 16.7X.

The gross attenuation factor for the I&J Waterway bulkhead gap (Figure 9-2) is low due to the geometry of the gap. The gap results in discharge of groundwater from three sides, with an effective funneling of groundwater toward the point-of-exposure cells in this area. Under the Baseline Development Scenario, the effective leachate concentration in the bulkhead gap is estimated at 16.3 percent, for a gross attenuation factor of 6.1X. Partial closing of the bulkhead gap produces a slight decrease in point of exposure concentrations (Appendix F) to 14 percent. Refinements to the gap closure produce an even lower effective concentration, to as low as 10 percent. Gap closure can be performed physically by extending the bulkheads across the gap, or hydrologically by installing groundwater barriers across the upland side of the gap. Final design for gap closure would be based on detailed design and permitting considerations.

Under this alternative, additional long-term maintenance would be required for the physical barrier systems. The use of cathodic protection is assumed for the sheet-piling across the foot of Hilton Avenue. Permitting would be limited to Ecology mediation of the Consent Decree process and completion of a SEPA Checklist. The same construction could be used across the I&J bulkhead gap if the barrier is placed upland of the shoreline. Alternatively, the bulkhead gap could be closed by reconnection of the two existing bulkheads at the Olivine site and at the Bornstein Seafoods lease area. In-water construction required for bulkhead closure would trigger federal permitting requirements. Federal permitting is not exempted by the MTCA Consent Decree process. The need for mitigation actions as part of the project would be dependent on the outcome of the permitting process and the determinations made by the permitting agencies.

The regulatory process requirements for this alternative would be similar to Alternative A. The same MTCA documents would be required, including a Cleanup Action Plan, Groundwater Monitoring Plan and Consent Decree. Appropriate groundwater monitoring locations and compliance levels would change slightly under this alternative as shown in Figure 9-2. Other elements of this alternative (deed restrictions, institutional controls) would remain unchanged from Alternative A, except for the additional maintenance requirements associated with the groundwater physical barrier systems.

Estimated Costs

The probable costs of Alternative B are estimated to be $2.1 million. Detailed cost assumptions are provided in Appendix E. After applying a contingency factor of +30/-25%, the range of probable costs is from $1.6 to $2.7 million. The principal costs and cost variables for this alternative are the same as those in Alternative A.

The alternative selected for closure of the I&J Waterway bulkhead gap will influence the construction and permitting cost for this item. The upland wall placement results in a lower permitting and capital cost, but with a reduction in available land area. O&M costs are estimated assuming that cathodic protection is required for the groundwater barrier at the foot of Hilton Avenue.

Alternative B Evaluation

Tables 9-2 and 9-6 summarize the compliance of Alternative B with MTCA threshold remedy requirements and remedy selection criteria. The alternative receives the highest overall ranking of the evaluated Alternatives. The high ranking is based on the best overall balance between remedy protectiveness and cost-effectiveness.

Relative to Alternative A, the lowest predicted gross attenuation factor for the project area is increased from 3.66X to between 7X and 10X (depending on final design of I&J bulkhead gap closure). This improves the permanence and the long-term effectiveness of the remedy, and results in additional reductions in contaminant mobility. This change substantially reduces the likelihood that groundwater cleanup levels at the site are exceeded during long-term operation and monitoring. This three-fold increase in remedy protectiveness is achieved with only a 28 percent increase in total remedy cost. This relationship between incremental costs and increased risk reduction is more proportionate than those achieved by additional actions (Alternatives C through E).

Additional construction activities will be required to install the barrier systems. However, the installation areas are isolated from public right-of-ways and heavy traffic areas. The overall impact of this additional construction is insignificant, and the short-term effectiveness of the alternative remains high.

Other aspects of the alternative remain consistent with Alternative A. Like the preceding alternative, this alternative retains maximum land use flexibility within the Central Waterfront area and has minimal impact to adjacent properties.

9.3 Alternative C: Low-Permeability Capping, Groundwater Diversion Barriers, Institutional Controls and Monitoring

The third alternative evaluated for the Landfill builds on Alternative B, with an increased use of active measures to control groundwater contaminant migration. Under Alternative C, a low permeability cap is applied to the entire Landfill area. This substantially increases capital and operating costs of the alternative, providing only a marginal reduction in point-of-exposure contaminant concentrations over Alternative B. Other aspects of the alternative are the same as those in Alternative B. Figure 9-3 provides a graphical representation of Alternative C.

Description of Alternative C

Under Alternative C, the main cleanup elements described in Section 9.2 for Alternative B will be retained. The principal additional action taken under this alternative is the application of a low-permeability cap over the entire Landfill area. The goal of the cap is to further reduce infiltration of rainwater into the Landfill refuse.

Under this alternative, the target infiltration control percentage for the Landfill area is 95%. The cost, design flexibility and maintenance requirements for low-permeability caps increase disproportionately as the infiltration control target is increased from 95% to 98% and above. Because infiltration is not the only source of recharge to the Landfill, setting an extremely high target for infiltration reduction is inappropriate.

Alternative cap designs considered for application to the Landfill include composite clay and geomembrane systems and asphalt. The former design is best suited for large areas where long-term land use is controlled, and perforation of the cap is not required. Perforations of the composite caps must be prevented, because they interfere with the drainage patterns and cap integrity. In areas where property ownership and development phasing is staggered, this type of capping approach is not practical.

Asphalt caps can provide infiltration control in excess of 95 percent, depending on the asphalt permeability, the grade of the final surface, and the type and extent of drainage provided. Asphalt caps are typically cheaper to install than clay/geomembrane systems, but they require more ongoing maintenance. Maintenance includes crack sealing and pothole repair, as well as periodic replacement of heavy use sections. The higher maintenance costs of asphalt caps offset the savings in installation cost, resulting in similar overall costs compared to geomembrane and clay cap systems. The main advantage with asphalt caps is that they can be more easily integrated with site development activities, and do not require control of area-wide grading or drainage patterns. Perforations of asphalt caps (e.g., foundation work for placement or expansion of a building) can be more readily repaired without triggering substantial additional actions.

Under Alternative C, the Landfill area (excluding areas already covered by paving and existing buildings) will be covered with a low-permeability asphalt cap. The work can be phased with site development or can be performed in a single project. Each capping area will be regraded to enhance drainage patterns. Storm drains and catch basins will be installed to manage stormwater generated form the cap surface. Passive venting lines will also be installed to mitigate lateral gas migration that could otherwise be triggered by the capping work. Finally, two asphalt lifts will be applied for a final thickness of 4 inches.

Long-term maintenance assumptions for the cap include annual inspections, resealing and repairs of potholes or cracks. Depending on the type and intensity of use, portions of the cap may require replacement on a frequency of 5 to greater than 15 years. Maintenance cost assumptions are conservatively based on replacement of the cap surface every 10 years.

Where portions of the Landfill are covered by buildings as part of future site development, the building will provide the equivalent of a low-permeability cap. Total capping costs for the Landfill surface would therefore be minimized by future development activities. However, this savings is partially offset by the costs of providing methane control systems for buildings to be constructed on the Landfill in these locations.

As under Alternative B, methane controls would be applied to buildings within 200 feet of the Landfill refuse, as well as to buildings located on the Landfill. The groundwater diversion barriers, institutional controls, deed restrictions and monitoring included in that Alternative would also be maintained.

The incremental benefits of the environmental cap were quantified using the groundwater flow model. Appendix F includes the modeling output. The peak point-of-exposure leachate concentrations predicted under Alternative C range between 7 and 10 percent. This is only slightly lower than under alternative B (10 to 14 percent). The achieved reductions are minimal due to the residual flux of groundwater from across Roeder and from the GP Lagoon. As infiltration into the Landfill is reduced by the capping activities, the change in groundwater gradients results in a corresponding increase in groundwater recharge from these other sources (see water balance, Table 6-1).

The regulatory process requirements for this alternative would be similar to Alternative B. The same MTCA documents would be required, including a Cleanup Action Plan, Groundwater Monitoring Plan and Consent Decree.

Estimated Costs

The probable costs of Alternative C are estimated to be $4.4 million. Detailed cost assumptions are shown in Appendix E. After applying a contingency factor of +30/-25%, the range of probable costs are from $3.3 to $5.7 million. The principal costs and cost variables for this alternative are similar to those in Alternative B. The extent of Landfill cap is determined by the refuse boundary. However, the distribution of buildings and paving and potentially the phasing of the work will be dependant on site development activity.

As with Alternative B, the methods selected for closure of the I&J Bulkhead gap will influence the construction and permitting cost for Alternative C. Upland wall placement results in a lower permitting and capital cost, but with a reduction in available land area.

Alternative C Evaluation

Tables 9-3 and 9-6 summarize the compliance of Alternative C with MTCA threshold remedy requirements and remedy selection criteria. The alternative is compliant with MTCA threshold requirements. The overall ranking of Alternative C is moderate, because the incremental costs associated with Landfill capping are substantial and disproportionate relative to the additional degree of risk reduction achieved. The alternative also requires extensive construction activity, resulting in additional community impacts during remedy implementation.

The main impact of capping will be to permit a slight reduction in point of exposure contaminant concentrations. Under alternative B, these concentrations would already be well below the surface water cleanup levels. The incremental costs of capping would result in a reduction in these concentrations from between 10 and 14 percent of leachate, to a new range of between 7 and 10 percent. This small incremental reduction is dependent on a substantial increase in long-term maintenance activity and results in a doubling of the overall project cost compared to Alternative B (see Figure 9-7). Due to the additional construction activities, community impacts during construction would be higher under Alternative C.

9.4 Alternative D: Low-Permeability Capping, Additional Groundwater Diversion Barriers, Institutional Controls and Monitoring

The fourth alternative evaluated for the Landfill builds on Alternative C, with an increased use of active measures to control groundwater contaminant migration. Under Alternative D, two additional groundwater diversion barriers are installed. These barriers provide additional reductions to Landfill recharge. Other aspects of the alternative are the same as those in Alternative C. Figure 9-4 provides a graphical representation of Alternative D.

Description of Alternative D

Under Alternative D, the main cleanup elements described in Section 9.3 for Alternative C will be retained. These include the low-permeability Landfill cap, installation of groundwater diversion barriers at the foot of Hilton Avenue and across the gap in the I&J Waterway bulkheads, methane controls, institutional controls and monitoring. The new elements of this alternative include two additional groundwater diversion barriers.

The first of the groundwater barriers to be installed will run along Roeder Avenue (Figure 9-4). The purpose of this barrier is to reduce or eliminate the flow of groundwater into the Landfill from across Roeder Avenue (see water balance, Table 6-1). This area includes a number of public and private utilities, and is adjacent to the main transportation corridor of Roeder Avenue. Preliminary evaluations suggest that installation of a sheet-piling wall is impractical in this area, and that use of a grout-injection wall would be preferable. A grout wall design located as shown in Figure 9-4 was used as the basis for cost estimation. Appendix E includes the detailed cost estimate for this alternative.

The second groundwater barrier to be installed under this alternative is a cutoff wall along the GP Lagoon. This wall would extend from Hilton Avenue across the Lagoon face to the southern corner of the Landfill. Preliminary engineering evaluations suggest that a slurry wall design may be most cost-effective for this location. The costs of slurry wall installation will depend on the measures required for spoils disposal, the mix design, the extent of utility conflicts (assumed to be minimal in this location) and the geotechnical requirements associated with construction activity in the vicinity of the GP Lagoon. This Alternative assumes that the section of wall at the foot of Hilton Avenue (Alternatives B and C) is replaced by the northern end of the new wall.

Maintenance requirements associated with grout and slurry walls are minimal. The main requirements associated with these wall designs are the reductions in buildable land area. Construction of new utilities or foundation pilings within the immediate vicinity of the walls would generally be prohibited by deed restrictions. In some cases it may be possible to install new utilities through the grout/slurry walls, but this would require review on a case-by-case basis. The restrictions on land use would negatively impact the properties on which the walls were located.

Other maintenance requirements associated with this alternative are the same as under Alternative C. These include maintenance of the low-permeability cap, maintenance of methane control systems and completion of periodic groundwater monitoring.

The regulatory process requirements for this alternative would be similar to Alternative C. The same MTCA documents would be required, including a Cleanup Action Plan, Groundwater Monitoring Plan and Consent Decree.

Estimated Costs

The probable costs of Alternative D are estimated to be $5.6 million. Detailed cost assumptions are shown in Appendix E. After applying a contingency factor of +30/-25%, the range of probable costs is from $4.2 to $7.3 million. The principal costs and cost variables for this alternative are the same as those in Alternative C.

Detailed design activities would need to review diversion barrier construction alternatives. Final selection will not have a large impact on overall project cost, but is critical to minimizing conflicts with site development potential, public utilities and other important considerations. Long-term use of the GP Lagoon may also affect the level of benefits provided by this alternative over Alternative D. If Lagoon use is not anticipated in the distant future, then the benefits associated with the barrier wall along the Lagoon (Figure 9-4) would be minimized or negated.

As with Alternatives B and C, the option selected for closure of the I&J Bulkhead gap will influence the construction and permitting cost for Alternative D. The upland wall placement results in a lower permitting and capital cost, but with a reduction in available land area.

Alternative D Evaluation

Tables 9-4 and 9-6 summarize the compliance of Alternative D with MTCA threshold requirements and remedy selection criteria. The alternative is compliant with MTCA threshold requirements. However, the overall ranking of Alternative D is low, because the incremental costs associated with this Alternative are substantial and disproportionate relative to the additional degree of risk reduction achieved over Alternative B. The alternative also requires extensive construction activity both on the Landfill and along public right-of-ways, resulting in additional community impacts and short-term risks during remedy implementation.

The main benefit of Alternative D will be to achieve a slight reduction in point of exposure contaminant concentrations. Under alternative B, these concentrations would already be well below applicable surface water cleanup levels. The incremental costs of capping would result in a reduction in these concentrations from between 10 and 14 percent of leachate, to a new maximum of 5 percent. This is small incremental reduction in point-of-exposure concentrations is offset by a near tripling of cleanup costs over Alternative B (see Figure 9-7). Community impacts associated with this alternative would be even greater than that under Alternative C due to the additional construction activities, especially those along the Roeder Avenue right-of-way.

9.5 Alternative E: Encircling Barrier Wall, Low-Permeability Cap, Hydraulic Capture with POTW Discharge, Institutional Controls and Monitoring

The final alternative evaluated for the Landfill includes the greatest use of active measures to control groundwater migration. Under this alternative the Landfill refuse would be encircled by a complete barrier wall system and would be covered by a low-permeability cap. Pumping wells would be installed within the Landfill area to maintain hydraulic control over the Landfill area. Extracted groundwater would be discharged to the City of Bellingham POTW system. Figure 9-5 provides a graphical representation of Alternative E. The relationship between alternative costs and environmental benefits is shown in Figure 9-7.

Description of Alternative E

Under Alternative E, groundwater barrier walls would be placed around the entire Landfill perimeter. Placement of the walls would be adjusted to minimize land use conflicts with utility corridors and neighboring properties. A preliminary wall alignment is shown in Figure 9-5. The final alignment may be different from that shown.

Three of the four wall lengths (excluding the wall along Roeder Avenue) are anticipated to use a slurry wall design. The Roeder Avenue wall may require use of grout injection methods due to space constraints and utility conflicts. These assumptions have been incorporated into the cost estimates attached in Appendix E. Under alternative E, closure of the gap in the I&J Waterway bulkhead would not be performed.

The low-permeability cap required under Alternatives C and D would be completed, and may require expansion. The cap would need to cover all areas inside the groundwater barrier wall in order to minimize groundwater infiltration and groundwater pumping rates. Adjustments to the wall alignment will therefore impact the total capping area.

Groundwater extraction wells will be required inside the barrier wall to maintain hydraulic control. Use of a barrier wall without pumping system is not recommended, because residual infiltration within the barrier wall could result in excessive groundwater accumulations. Pumping wells would be sited as necessary to maintain groundwater heads slightly below those outside the wall. A conceptual pumping well distribution is shown in Figure 9-5.

Based on existing groundwater quality data, discharge of the extracted groundwater to the POTW is assumed without pre-treatment. Surface water discharge may be feasible, but only after completion of necessary permitting. Treatment and/or a dilution zone would be required for surface water discharge of extracted groundwater.

Average pumping rates for groundwater are estimated to be at or below 15 gallons per minute. Actual rates would vary seasonally and would be dependant on the performance of the groundwater barrier walls and cap. Final remedy design would include revised estimates of groundwater pumping rates and specific control requirements for wall installation.

Maintenance requirements associated with this alternative will include 1) maintenance and monitoring of the pumping wells, 2) permit-required analytical sampling for the POTW discharge, 3) additional groundwater monitoring as required under MTCA, 4) cap maintenance, and 5) maintenance of methane controls.

Under this alternative, extensive coordination would be required prior to construction. The barrier walls, the low-permeability cap and the pumping systems are all inter-dependant. Construction of all systems would need to be coordinated, and phasing of the cleanup action would not be practicable. Additionally, the pumping systems, barrier walls and POTW discharge lines would all adversely impact land usability within the project area. To maintain the development potential of the area, utility, transportation and construction impacts would need to be anticipated and incorporated into the design of the cleanup action.

Construction activities under this alternative would be extensive and would include all areas of the Landfill, as well as work on adjacent properties and in surrounding right-of-ways. Land use impacts associated with permanent remedy installations and with construction activities may precipitate a need for a full Environmental Impact Statement (EIS). The cost estimates in Appendix E assume that environmental impacts associated with this Alternative can be mitigated without requiring an EIS document.

Estimated Costs

The probable costs of Alternative E are estimated to be $7.9 million. Detailed cost assumptions are shown in Appendix E. After applying a contingency factor of +30/-25%, the range of probable costs is from $5.9 to $10.3 million. The principal costs and cost variables for this alternative include 1) wall type and alignment, 2) capping design and extent, 3) costs associated with mitigation of land use impacts, 4) groundwater pumping rates and disposal fees, and 5) the extent of methane controls required for buildings on or adjacent to the Landfill.

As described above, extensive coordination would be required during detailed remedy design to successfully implement Alternative E. It is assumed that Alternative E could be implemented within 3 years, but this will be dependent on project coordination efforts.

Alternative E Evaluation

Tables 9-5 and 9-6 summarize the compliance of Alternative E with MTCA threshold requirements and remedy selection criteria. The alternative is compliant with MTCA threshold requirements. However, the overall ranking of Alternative E is low, because the incremental costs associated with this alternative are substantial and disproportionate relative to the additional degree of risk reduction achieved over Alternative B. The alternative also has the highest degree of land use impacts during construction, and the greatest limitations on future land use within the project area.

A properly designed and implemented version of this Alternative would provide complete capture of groundwater from within the Landfill. This water would be translocated to the POTW system, with treatment and disposal of associated contaminants occurring as part of the sewage treatment process. However, improper remedy maintenance could trigger a release of extracted groundwater to off-site soils or surface water. Because this remedy is reliant on off-site treatment performed by others, and because pumping system upsets or spills may compromise the effectiveness of the remedy, the long-term effectiveness of this Alternative is considered moderate.

The point-of-exposure concentrations of Landfill constituents can be maintained well below applicable criteria under less-expensive alternatives. The incremental risk reduction achieved by complete hydraulic control of the Landfill area is negligible. In contrast, the costs of this alternative are nearly four times higher than Alternative B. As a result this alternative receives a low ranking for practicability and cost-effectiveness.

While Alternative E is implementable, the extensive construction work and project coordination required under this Alternative increase the potential for safety hazards or other construction problems. Land use conflicts are likely due to the space requirements associated with the alternative. Short-term effectiveness and consideration of community concerns for this alternative are given low rankings.

9.6 Selection & Evaluation of the Preferred Alternative

Table 9-6 provides a comparison among each of the five remedial alternatives considered for application to the Landfill site. The alternatives are evaluated against the MTCA threshold requirements and remedy selection criteria. The following paragraphs discuss the rationale for selection of Alternative B, based on the MTCA remedy selection criteria.

Each of the five remedial alternatives evaluated in this RI/FS comply with the minimum requirements for final remedies under MTCA. All of them are anticipated to comply with cleanup levels at the point-of-exposure, and all of them ensure protection of human health and the environment.

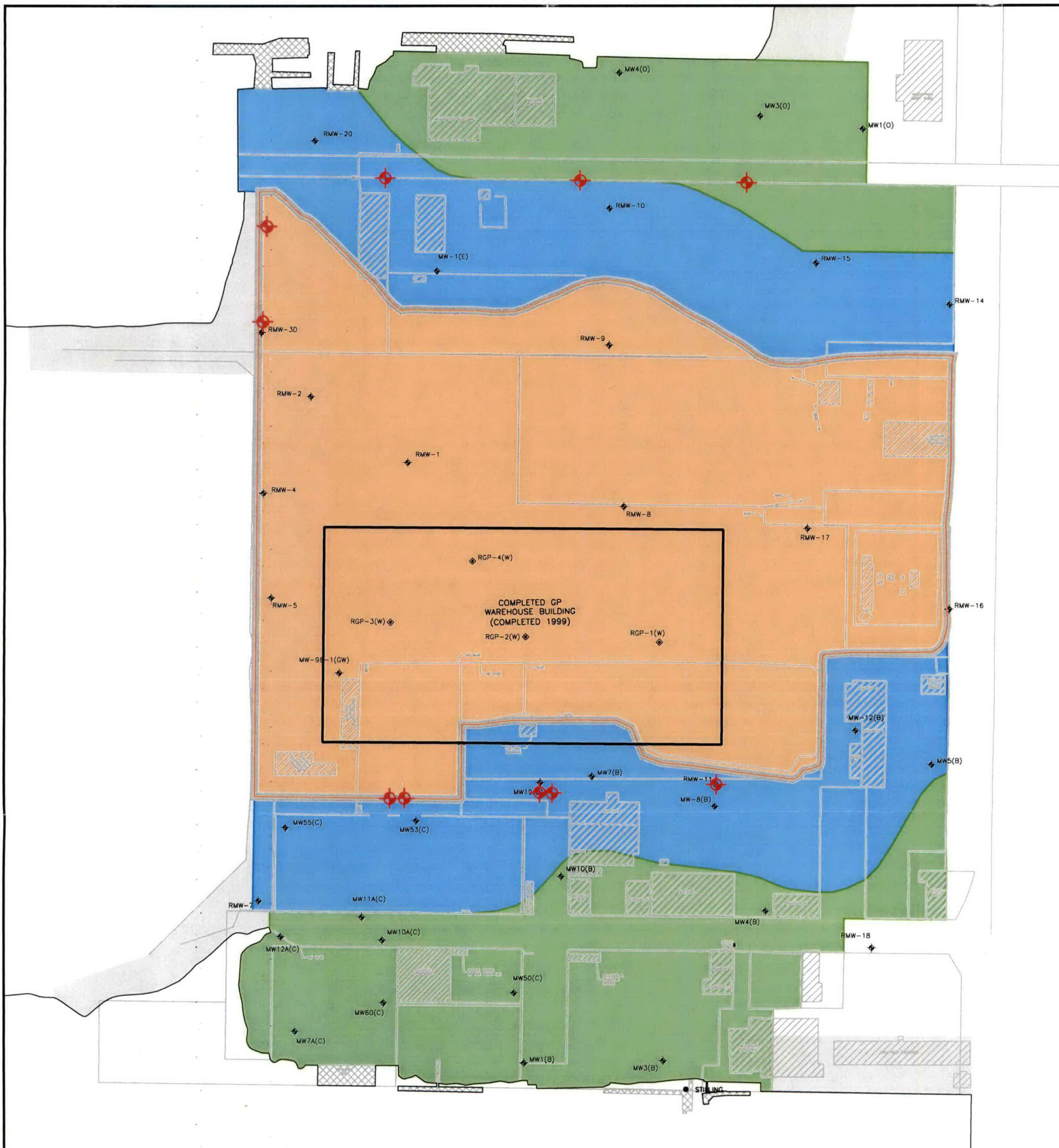
Figure 9-7 summarizes the anticipated worst-case concentrations of Landfill constituents at the point-of-exposure. The concentrations are normalized to applicable cleanup levels. Exceedance of a value of 1.0 represents an exceedance of one or more contaminant cleanup levels. A value of less than 1.0 means that predicted concentrations are below the applicable cleanup levels. Alternative A provides estimated contaminant concentrations well below applicable cleanup levels. Subsequent alternatives result in further reductions of concentrations at the point-of-exposure. Because the concentrations move closer and closer to zero with each Alternative, the incremental reduction in concentration becomes smaller and smaller.

Alternative B provides expected contaminant concentrations well below the applicable cleanup levels, and does so with the best mix of active and passive measures, and with the greatest ratio of benefits to costs. Alternative B is the most cost-effective of the evaluated alternatives.

Protection of human health and the environment is achieved with each of the five alternatives. The main community impacts associated with the cleanup action will be 1) disruptions during construction, and 2) impacts to long-term land use within the project area. Alternatives A and B have relatively low levels of construction and land use impacts. These remedies receive high rankings for addressing community concerns, being implementable and for short-term effectiveness. As additional actions are required under Alternatives C, D and E, the level of community impact and land use limitation increases. As a result, Alternatives C, D and E receive decreasing rankings for these parameters.

Long-term effectiveness of the alternatives varies with both the aggressiveness of the initial action, as well as the success of long-term maintenance and monitoring activities. The dependance on long-term care is most clearly demonstrated with Alternative E. That alternative is the most aggressive cleanup approach, but pumping well or discharge line upsets could cause contaminant releases to off-site soils or surface waters, exacerbating environmental conditions rather than mitigating them. The blended approach of active and passive measures in Alternative B provides the best overall environmental protectiveness.

Alternative B is recommended for use during the final cleanup of the Roeder Avenue Landfill, and is identified as the preferred remedial alternative.



DESCRIPTION

ZONE 1 CONTROLS: MAINTENANCE OF LANDFILL COVER SOILS, STORMWATER COLLECTION FROM IMPERVIOUS SURFACES, METHANE CONTROLS AND RESTRICTIONS ON GROUNDWATER USES

ZONE 2 CONTROLS: METHANE CONTROLS AND RESTRICTIONS ON GROUNDWATER USES

ZONE 3 CONTROLS: RESTRICTIONS ON GROUNDWATER USES

PROPOSED GROUNDWATER COMPLIANCE MONITORING LOCATION

LEGEND

DOCKS OR PIERS

EXISTING BUILDINGS

EXISTING SHORELINE

PROPERTY BOUNDARIES

LANDFILL REFUSE BOUNDARY (MTCA SITE BOUNDARY NOT DETERMINED)

N

0 90 180 360

SCALE IN FEET

ThermoRetec

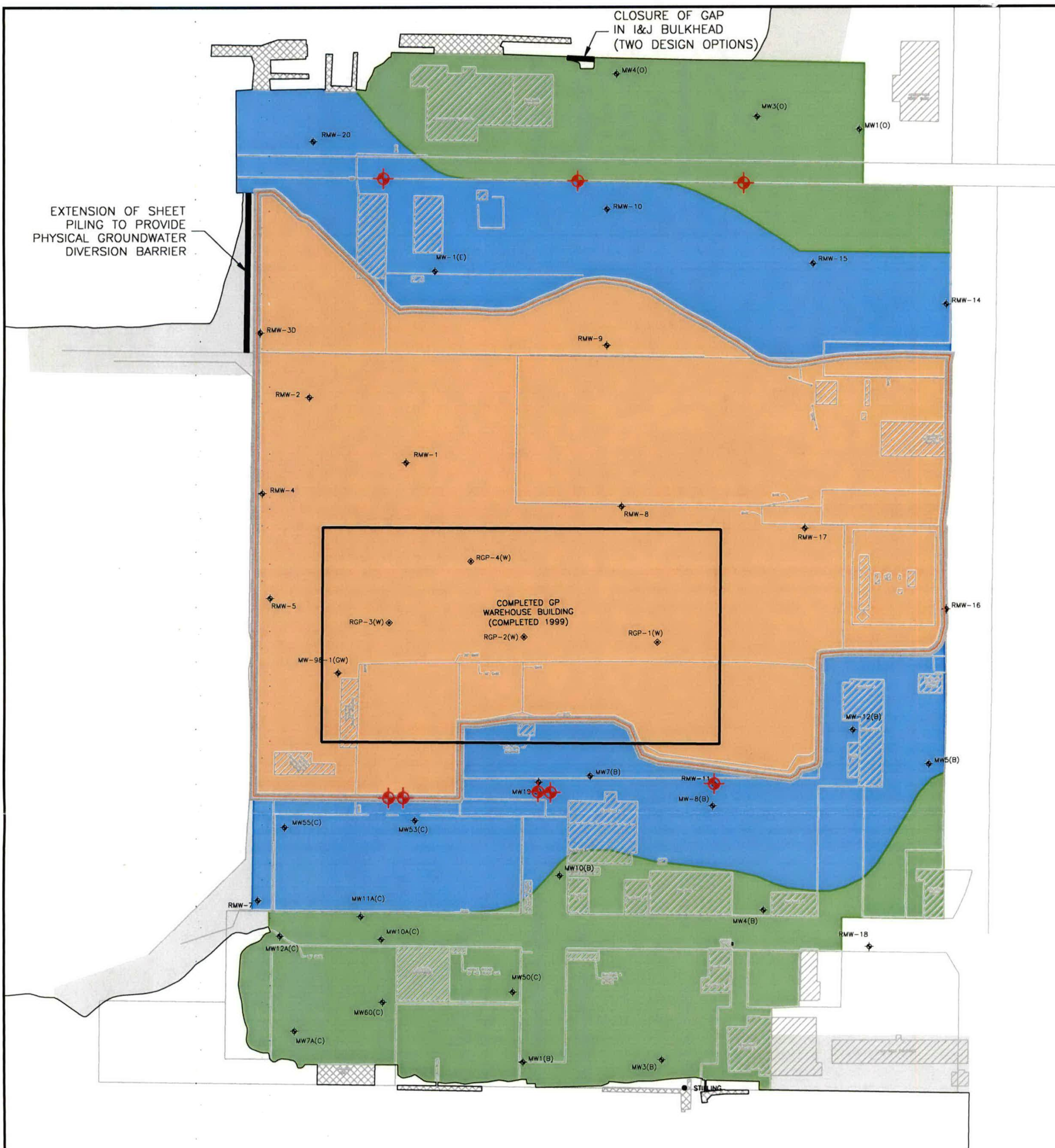
ROEDER AVENUE LANDFILL RI/FS

PORTB-03809-710

DATE: 06/02/01 | DRWN: N.S. | FILE: 3809S220

ENGINEERING CONCEPT FOR ALTERNATIVE A

FIGURE 9-1



DESCRIPTION

- (orange) ZONE 1 CONTROLS: MAINTENANCE OF LANDFILL COVER SOILS, STORMWATER COLLECTION FROM IMPERVIOUS SURFACES, METHANE CONTROLS AND RESTRICTIONS ON GROUNDWATER USES
- (blue) ZONE 2 CONTROLS: METHANE CONTROLS AND RESTRICTIONS ON GROUNDWATER USES
- (green) ZONE 3 CONTROLS: RESTRICTIONS ON GROUNDWATER USES
- PHYSICAL GROUNDWATER DIVERSION STRUCTURES
- PROPOSED GROUNDWATER COMPLIANCE MONITORING LOCATION

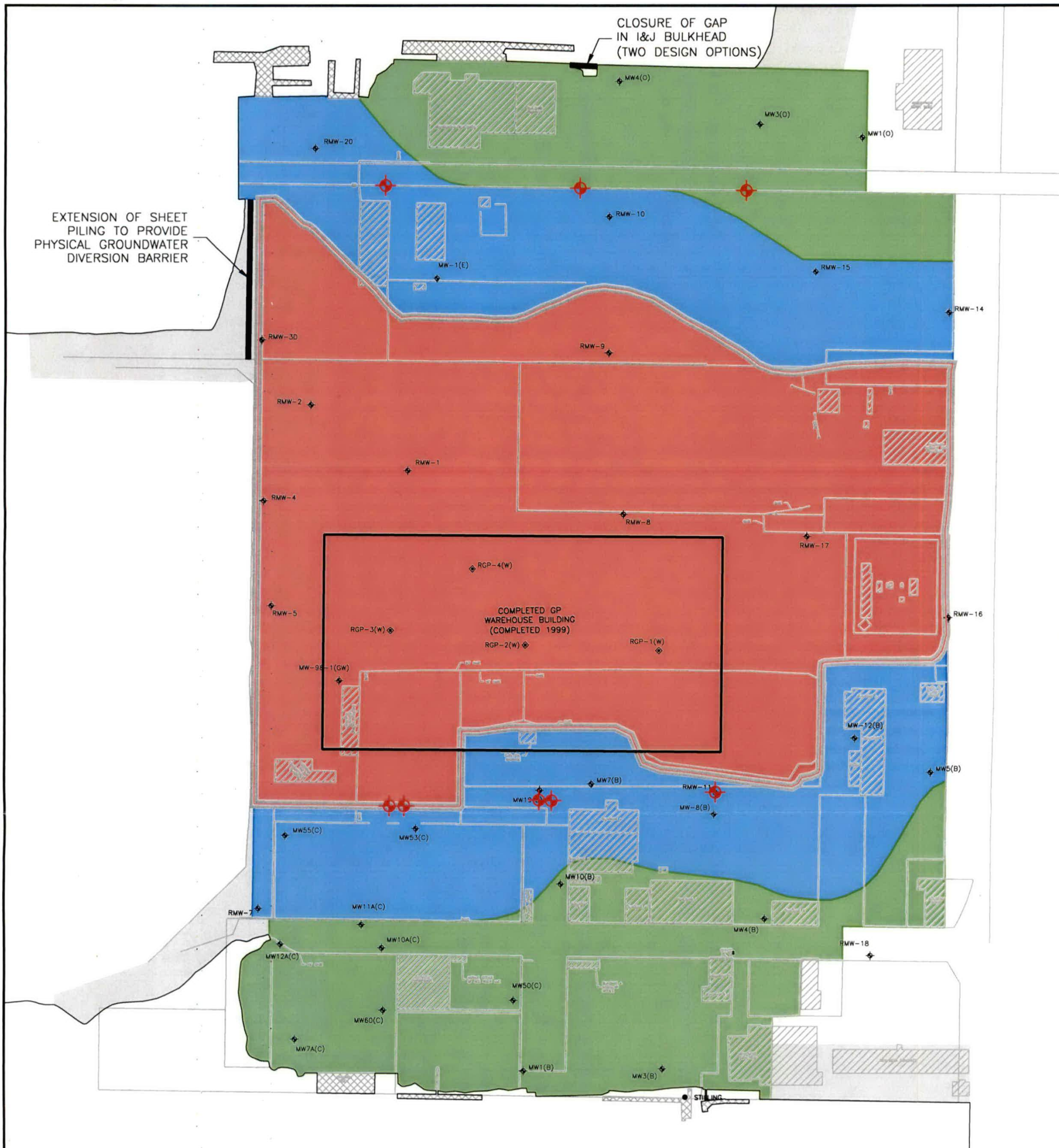
LEGEND

- DOCKS OR PIERS
- EXISTING BUILDINGS
- EXISTING SHORELINE
- PROPERTY BOUNDARIES
- LANDFILL REFUSE BOUNDARY (MTCA SITE BOUNDARY NOT DETERMINED)

0 90 180 360
SCALE IN FEET

ThermoRetec

ROEDER AVENUE LANDFILL RI/FS PORTB-03809-710			ENGINEERING CONCEPT FOR ALTERNATIVE B
DATE: 06/02/01	DRWN: N.S.	FILE: 3809S216	FIGURE 9-2



DESCRIPTION

- ZONE 1 CONTROLS: COMPLETE LANDFILL CAP WITH GAS COLLECTION AND STORMWATER DIVERSION AND COLLECTION
- ZONE 2 CONTROLS: METHANE CONTROLS AND RESTRICTIONS ON GROUNDWATER USES
- ZONE 3 CONTROLS: RESTRICTIONS ON GROUNDWATER USES
- PHYSICAL GROUNDWATER DIVERSION STRUCTURES
- PROPOSED GROUNDWATER COMPLIANCE MONITORING LOCATION

LEGEND

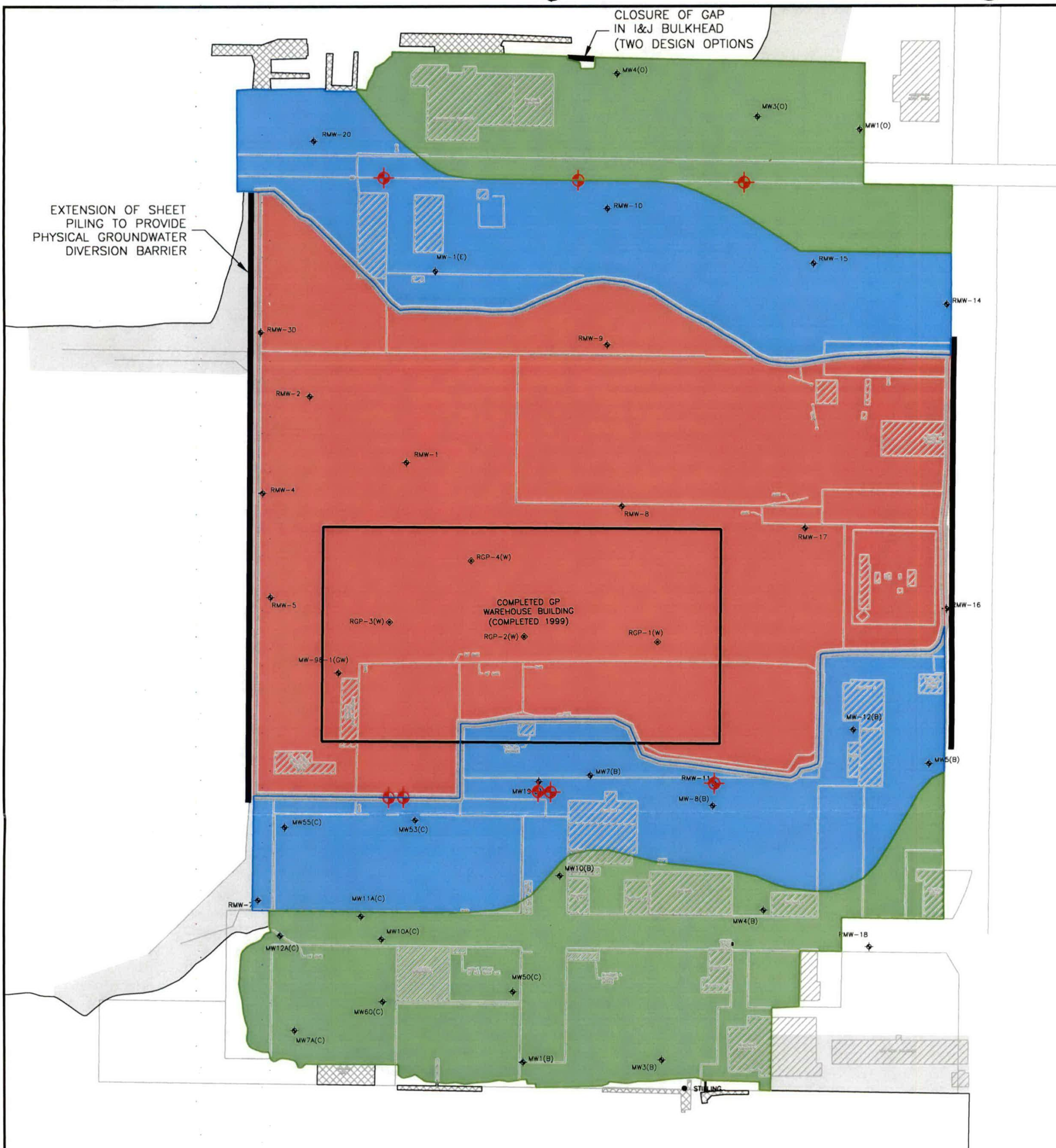
- DOCKS OR PIERS
- EXISTING BUILDINGS
- EXISTING SHORELINE
- PROPERTY BOUNDARIES
- LANDFILL REFUSE BOUNDARY (MTCA SITE BOUNDARY NOT DETERMINED)

0 90 180 360

SCALE IN FEET

ThermoRetec

ROEDER AVENUE LANDFILL RI/FS PORTB-03809-710			ENGINEERING CONCEPT FOR ALTERNATIVE C
DATE: 06/02/01	DRWN: N.S.	FILE: 3809S217	FIGURE 9-3



DESCRIPTION	
(red)	ZONE 1 CONTROLS: COMPLETE LANDFILL CAP WITH GAS COLLECTION AND STORMWATER DIVERSION COLLECTION
(blue)	ZONE 2 CONTROLS: METHANE CONTROLS AND RESTRICTIONS ON GROUNDWATER USES
(green)	ZONE 3 CONTROLS: RESTRICTIONS ON GROUNDWATER USES
(black line)	PHYSICAL GROUNDWATER DIVERSION STRUCTURES
(red symbol)	PROPOSED GROUNDWATER COMPLIANCE MONITORING LOCATION

LEGEND	
(cross-hatch)	DOCKS OR PIERS
(hatch)	EXISTING BUILDINGS
(line)	EXISTING SHORELINE
(box)	PROPERTY BOUNDARIES
(grey band)	LANDFILL REFUSE BOUNDARY (MTCA SITE BOUNDARY NOT DETERMINED)

0 90 180 360
SCALE IN FEET

ThermoRetec

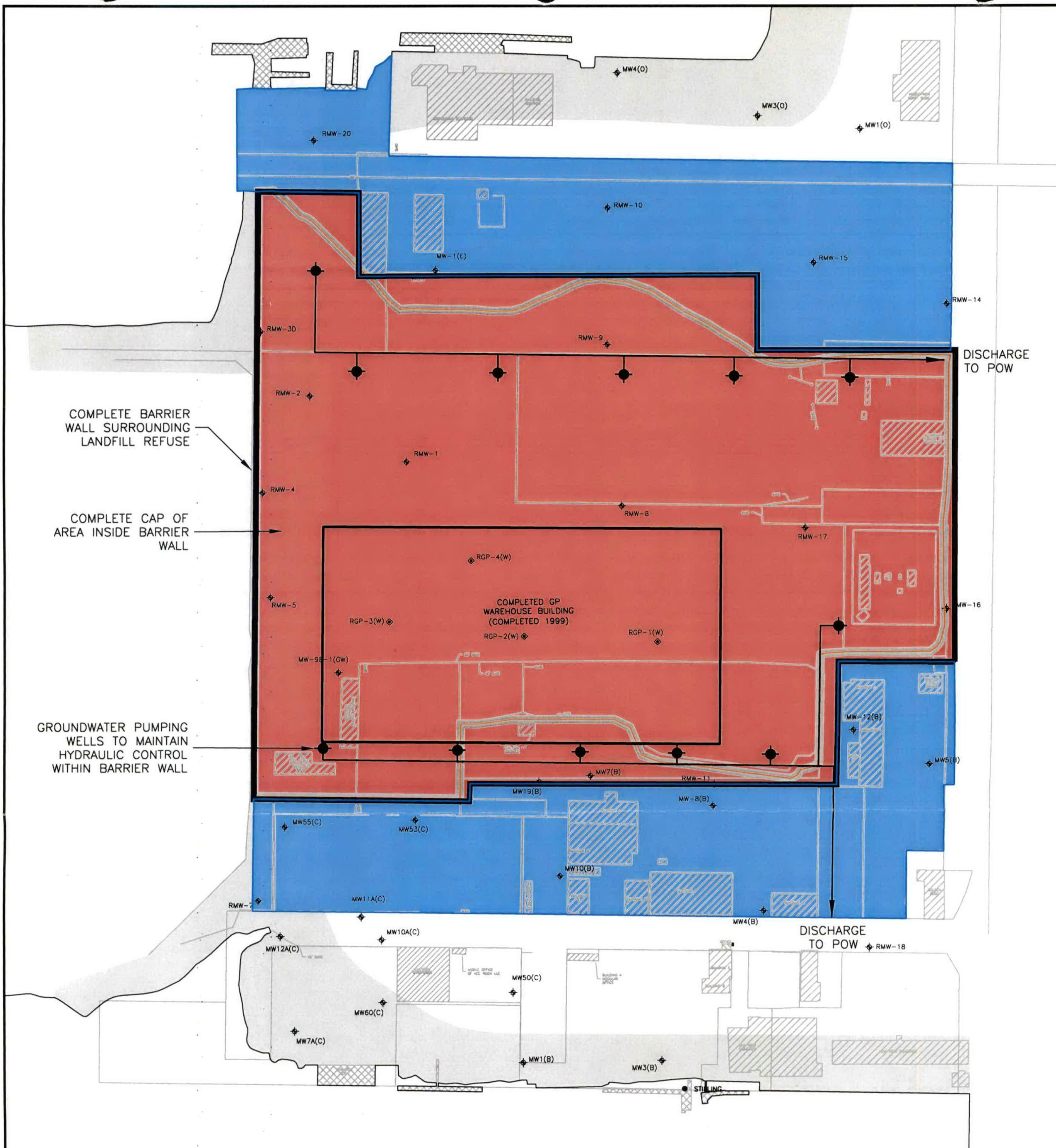
ROEDER AVENUE LANDFILL RI/FS

PORTB-03809-710

DATE: 06/02/01 DRWN: N.S. FILE: 3809S218

ENGINEERING CONCEPT FOR ALTERNATIVE D

FIGURE 9-4



DESCRIPTION

- ZONE 1 CONTROLS: COMPLETE LANDFILL CAP WITH GAS COLLECTION AND STORMWATER DIVERSION COLLECTION
- ZONE 2 CONTROLS: METHANE CONTROLS AND RESTRICTIONS ON GROUNDWATER USES
- ZONE 3 CONTROLS: RESTRICTIONS ON GROUNDWATER USES
- PHYSICAL GROUNDWATER DIVERSION STRUCTURES
- GROUNDWATER EXTRACTION WELL

LEGEND

- DOCKS OR PIERS
- EXISTING BUILDINGS
- EXISTING SHORELINE
- PROPERTY BOUNDARIES
- LANDFILL REFUSE BOUNDARY (MTCA SITE BOUNDARY NOT DETERMINED)

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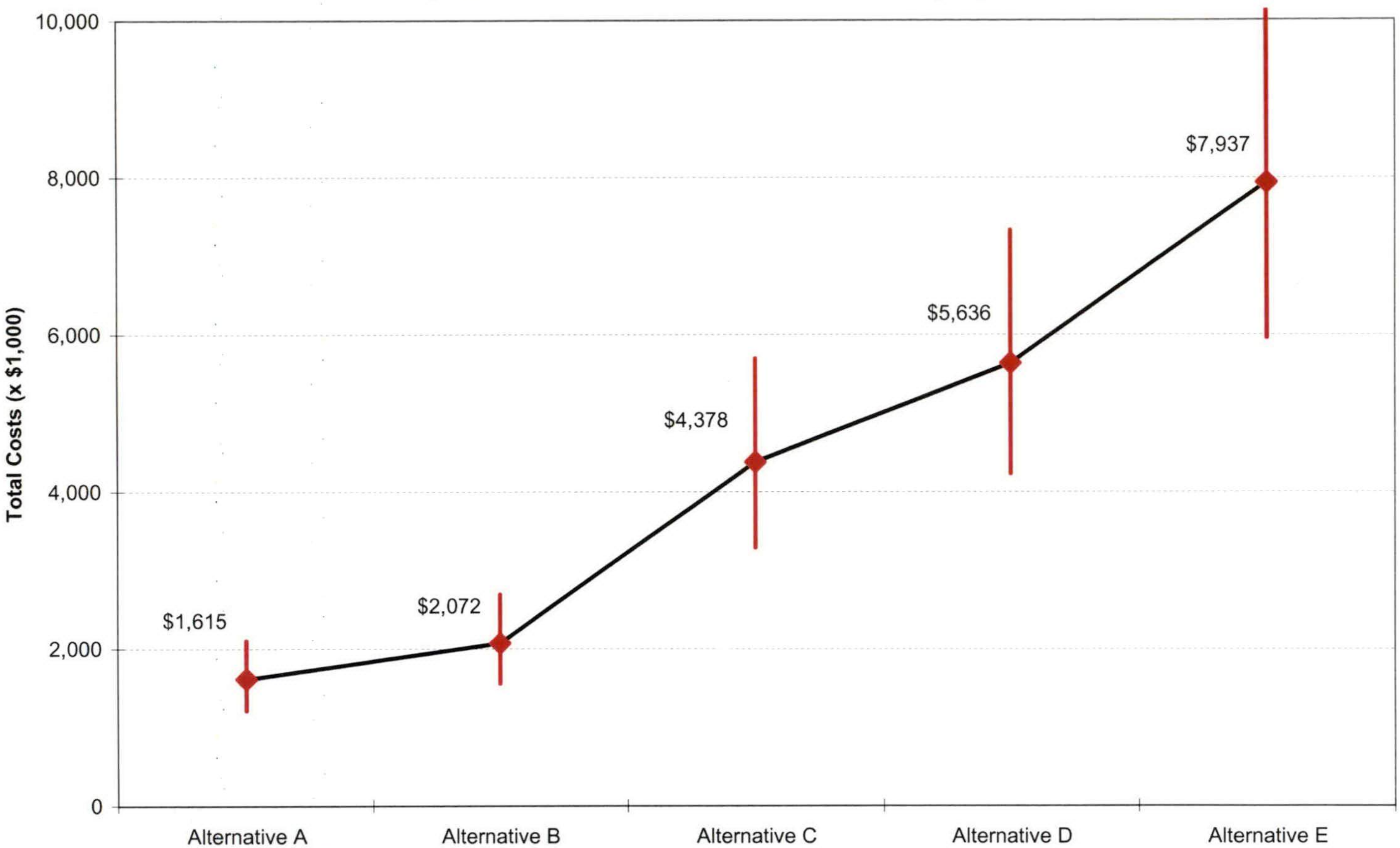
ENGINEERING CONCEPT FOR ALTERNATIVE E

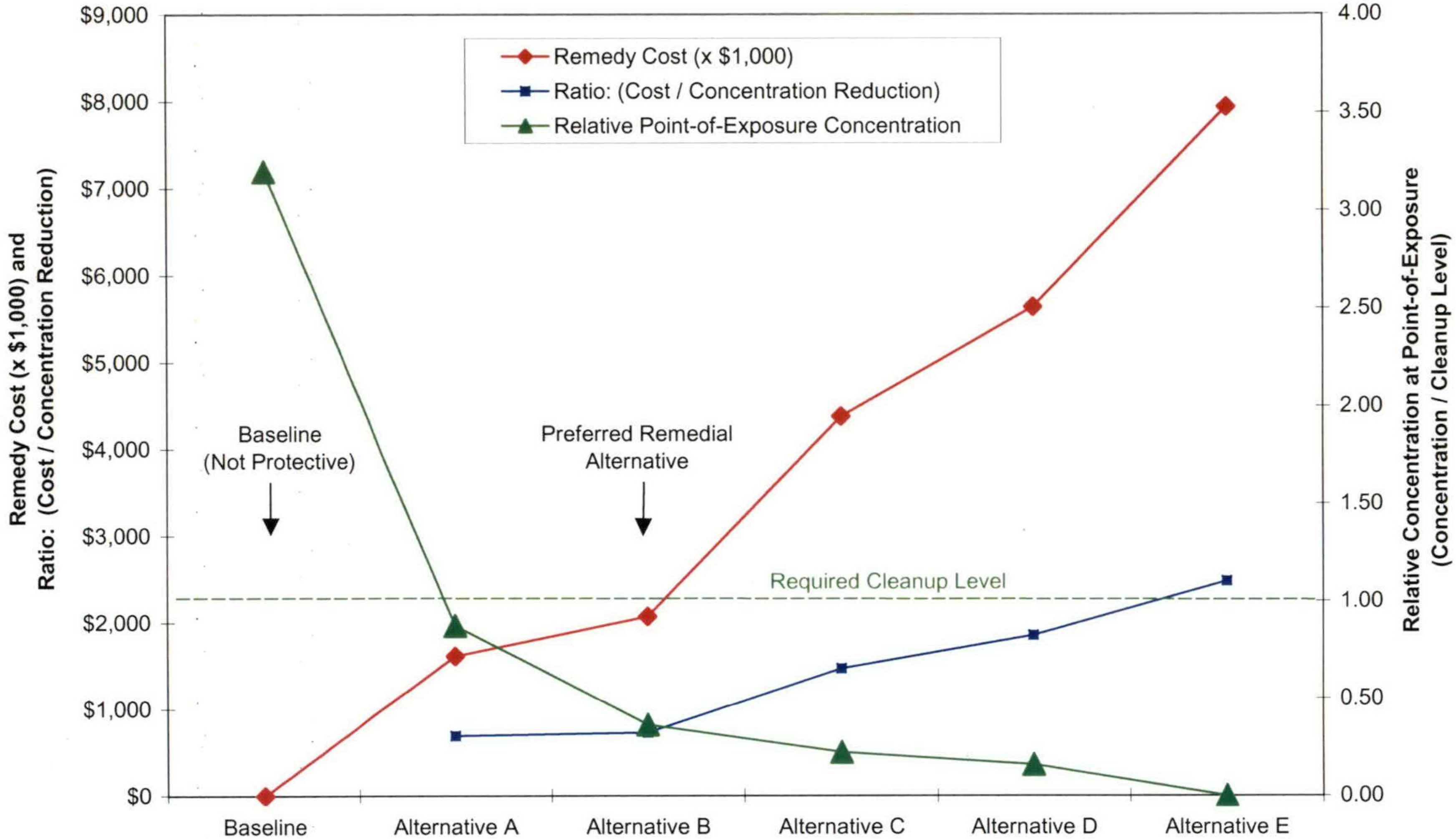
FIGURE 9-5

Figure 9-6. Estimated Costs for Evaluated Alternatives (Excludes Costs of RI/FS & Warehouse Project)



Note: Only future costs associated with the RI/FS alternatives are shown. The costs of the RI/FS and those of the Warehouse project are excluded from the totals. These previous costs are estimated to be approximately $1.5 million.

Figure 9-7. Practicability Analysis of Evaluated Remedial Alternatives



Note: All evaluated alternatives comply with MTCA cleanup levels and ARARs. Costs of incremental risk-reduction beyond alternative B become substantial & disproportionate relative to the degree of risk reduction achieved.

Table 9-1 Alternative A: Enhanced Development Capping, Institutional Controls and Monitoring

Category of Control/Action	Features of this Alternative
Elements of the Remedial Action	• Enhanced development capping for infiltration control on Landfill • Methane controls applied to buildings on/adjacent to Landfill • Maintenance of soil cover over refuse • Long-term monitoring & institutional controls
Long-Term Care Requirements	• Maintenance of cap and methane controls • Long-term groundwater monitoring
Estimated Remedy Cost	Probable cost is $1.6 million (Cost range $1.2 to $2.1 million)

Criteria	Comments	Rating
Threshold Requirements for Cleanup Remedies		
Overall Protection of Human Health and the Environment	Provides for complete protection of human health and the environment.	Moderate
Compliance with Cleanup Standards	Complies with applicable cleanup levels, but greater risk of exceedances than subsequent alternatives. Protectiveness to be verified with long-term monitoring.	Moderate
Compliance with State and Federal Laws	Permitting limited to City of Bellingham requirements for methane controls installation.	High
Provides for Compliance Monitoring	Compliance monitoring incorporated into remedy.	High
Use of Permanent Solutions to the Maximum Extent Practicable	Utilizes mix of destruction/detoxification (natural attenuation) and containment (enhanced development capping, methane controls, cap maintenance). Utilizes both active and passive measures.	Moderate
Provision of a Reasonable Restoration Time Frame	Site restoration achieved in first year of implementation. Capping and associated methane controls phased with site development.	High
Consideration of community concerns	Permits full range of uses of site. Compatible with land use planning. Required institutional controls will not impair use of Landfill site or adjacent properties.	High
Remedy Selection Criteria		
Implementability	Remedy uses proven technologies that have been implemented at other sites. Experienced contractors and appropriate equipment are locally available. Remedy is consistent with facility characteristics.	High
Long-term Effectiveness	Long-term effectiveness dependant on institutional controls and groundwater monitoring. Higher risk of cleanup level exceedance than other alternatives.	Moderate
Short-term Effectiveness	Cleanup action does not require invasive construction work that would trigger short-term effectiveness concerns.	High
Reduction in toxicity, mobility or volume of hazardous substances	Active measures (enhanced development capping) reduce contaminant mobility.	Moderate
Cost-Effectiveness	Remedy has lowest overall cost. Provides greatest cost-effectiveness.	High

Table 9-2 Alternative B: Enhanced Development Capping, Groundwater Diversion Barriers, Institutional Controls and Monitoring

Category of Control/Action	Features of this Alternative
Elements of the Remedial Action	• Enhanced development capping for infiltration control on Landfill • Methane controls applied to buildings on/adjacent to Landfill • Maintenance of soil cover over refuse • Enhanced groundwater attenuation with diversion barriers at foot of Hilton, closure of I&J bulkhead gap • Long-term monitoring & institutional controls
Long-Term Care Requirements	• Maintenance of cap, diversion barriers and methane controls • Long-term groundwater monitoring
Estimated Remedy Cost	Probable cost is $2.1 million (Cost range $1.6 to $2.7 million)

Criteria	Comments	Rating
Threshold Requirements for Cleanup Remedies		
Overall Protection of Human Health and the Environment	Provides for complete protection of human health and the environment.	High
Compliance with Cleanup Standards	Complies with applicable cleanup levels. Improved compliance assurance over Alternative A. Protectiveness to be verified with long-term monitoring.	High
Compliance with State and Federal Laws	Assuming Consent Decree process for remedy implementation, permitting limited to possible Army Corps of Engineers and associated permits for closure of I&J Bulkhead gap. Long-term permitting limited to City of Bellingham mediated permits for development capping & methane controls installation.	High
Provides for Compliance Monitoring	Compliance monitoring incorporated into remedy.	High
Use of Permanent Solutions to the Maximum Extent Practicable	Utilizes mix of destruction/detoxification (natural attenuation) and containment (enhanced development capping, methane controls, groundwater diversion barriers, cap maintenance). Employs greater use of active measures over Alternative A. Incremental costs not disproportionate to reduction in point-of-exposure concentration.	High
Provision of a Reasonable Restoration Time Frame	Site restoration achieved in first year of implementation. Barrier walls and bulkheads completed by Year 3. Capping and associated methane controls phased with site development.	High
Consideration of community concerns	Permits full range of site uses. Compatible with land use planning. Required institutional controls will not impair use of Landfill site or adjacent properties.	High
Remedy Selection Criteria		
Implementability	Remedy uses proven technologies that have been implemented at other sites. Experienced contractors and appropriate equipment are locally available. Remedy is consistent with facility characteristics.	High
Long-term Effectiveness	Long-term effectiveness dependant on institutional controls and groundwater monitoring. Substantial increase in long-term effectiveness over Alternative A.	High
Short-term Effectiveness	Cleanup action does requires invasive construction work for barrier wall installation. Appropriate planning and oversight required to address construction hazards.	High
Reduction in toxicity, mobility or volume of hazardous substances	Active measures (enhanced development capping, barrier wall installation) reduce contaminant mobility.	High
Cost-Effectiveness	Remedy has second lowest overall cost. Provides significant incremental reduction in point-of-exposure contaminant concentrations at reasonable incremental cost.	High

Table 9-3 Alternative C: Complete Landfill Capping, Groundwater Diversion Barriers, Institutional Controls and Monitoring

Category of Control/Action	Features of this Alternative
Elements of the Remedial Action	• Low-permeability capping over all refuse areas • Methane controls applied to buildings on/adjacent to Landfill • Enhanced groundwater attenuation with diversion barriers at foot of Hilton, closure of I&J bulkhead gap • Long-term monitoring & institutional controls
Long-Term Care Requirements	• Maintenance of cap, diversion barriers and methane controls • Long-term groundwater monitoring
Estimated Remedy Cost	Probable cost is $4.4 million (Cost range $3.3 to $5.7 million)

Criteria	Comments	Rating
Threshold Requirements for Cleanup Remedies		
Overall Protection of Human Health and the Environment	Provides for complete protection of human health and the environment.	High
Compliance with Cleanup Standards	Complies with applicable cleanup levels including ARARs. Protectiveness to be verified with long-term monitoring.	High
Compliance with State and Federal Laws	Assuming Consent Decree process for remedy implementation, permitting limited to stormwater permit for capping, and Army Corps of Engineers permits for closure of I&J Bulkhead gap. Long-term permitting limited to City-mediated permits for methane controls installation.	High
Provides for Compliance Monitoring	Compliance monitoring incorporated into remedy.	High
Use of Permanent Solutions to the Maximum Extent Practicable	Utilizes mix of destruction/detoxification (natural attenuation) and containment (site capping, methane controls, groundwater diversion, cap maintenance). Increased use of active measures over Alternative B, but incremental costs substantial and disproportionate to reductions achieved in point-of-exposure concentrations.	Moderate
Provision of a Reasonable Restoration Time Frame	Site restoration achieved in first year of implementation. Barrier walls and bulkhead gap repair completed by Year 3. Capping and associated methane controls phased with development.	High
Consideration of community concerns	Permits full range of uses of site, providing that capping is coordinated with development planning. Compatible with land use planning. Required institutional controls will not impair use of Landfill site or adjacent properties. Increased community impacts caused by increase in invasive activities.	Moderate
Remedy Selection Criteria		
Implementability	Remedy uses proven technologies that have been implemented at other sites. Experienced contractors and appropriate equipment are locally available. Capping must anticipate development to be consistent with facility characteristics.	Moderate
Long-term Effectiveness	Long-term effectiveness dependant on institutional controls maintenance. Increased maintenance obligations over Alternative B.	Moderate
Short-term Effectiveness	Cleanup action involves significant construction activities (capping, barrier wall installation). Project coordination and health and safety controls required to mitigate short-term hazards.	Moderate
Reduction in toxicity, mobility or volume of hazardous substances	Active measures (site capping, groundwater diversion) reduce contaminant mobility.	High
Cost-Effectiveness	Remedy substantially higher cost than Alternative B while using same preference alternatives. Incremental cost substantial and disproportionate relative to achieved reduction in point-of-exposure concentrations.	Moderate

Table 9-4 Alternative D: Low-Permeability Landfill Capping, Additional Groundwater Diversion Barriers, Institutional Controls and Monitoring

Category of Control/Action	Features of this Alternative
Elements of the Remedial Action	• Low-permeability capping over all refuse areas • Methane controls applied to buildings on/adjacent to Landfill • Enhanced groundwater attenuation with diversion barriers along BP lagoon, at foot of Hilton, & closure of I&J bulkhead gap • Long-term monitoring & institutional controls
Long-Term Care Requirements	• Maintenance of cap, diversion barriers and methane controls • Long-term groundwater monitoring
Estimated Remedy Cost	Probable cost is $5.6 million (Cost range $4.2 to $7.3 million)

Criteria	Comments	Rating
Threshold Requirements for Cleanup Remedies		
Overall Protection of Human Health and the Environment	Provides for complete protection of human health and the environment.	High
Compliance with Cleanup Standards	Complies with applicable cleanup levels including ARARs. Protectiveness to be verified with long-term monitoring.	High
Compliance with State and Federal Laws	Assuming Consent Decree process for remedy implementation, permitting limited to stormwater permit for capping, and possible Army Corps of Engineers permits for closure of I&J Bulkhead gap. Long-term permitting limited to City-mediated permits for methane controls installation.	High
Provides for Compliance Monitoring	Compliance monitoring incorporated into remedy.	High
Use of Permanent Solutions to the Maximum Extent Practicable	Utilizes mix of destruction/detoxification (natural attenuation) and containment (site capping, methane controls, groundwater diversion, cap maintenance). Increased use in active measures over Alternatives B and C, but at substantial & disproportionate incremental costs.	Low
Provision of a Reasonable Restoration Time Frame	Site restoration achieved in first year. Groundwater barriers and bulkhead gap closure completed by Year 3. Capping and methane controls phased with site development.	High
Consideration of community concerns	Additional land requirements over previous alternatives. Extensive planning and coordination required to integrate remedy with site development.	Moderate
Remedy Selection Criteria		
Implementability	Remedy uses proven technologies that have been implemented at other sites. Experienced contractors and appropriate equipment are locally available. Remedy requires more extensive planning & coordination with site development.	Moderate
Long-term Effectiveness	Long-term effectiveness dependant on institutional controls maintenance. Additional maintenance obligations.	Moderate
Short-term Effectiveness	Cleanup action involves significant construction activities (capping, barrier wall installation) including work along major public right-of-ways. Project coordination and health and safety controls required to mitigate short-term hazards.	Low
Reduction in toxicity, mobility or volume of hazardous substances	Active measures (site capping, groundwater diversion) reduce contaminant mobility.	High
Cost-Effectiveness	Remedy substantially higher cost than Alternatives B & C while using same preference alternatives. Incremental cost substantial and disproportionate relative to achieved reduction in point-of-exposure concentrations.	Low

Table 9-5 Alternative E: Low-Permeability Landfill Capping, Encircling Groundwater Barriers, Groundwater Extraction & POTW Discharge, Institutional Controls and Monitoring

Category of Control/Action	Features of this Alternative
Elements of the Remedial Action	• Low-permeability capping over all refuse areas • Methane controls applied to buildings on/adjacent to Landfill • Encirclement of Landfill with Barrier Walls • Groundwater extraction and POTW discharge for hydraulic control • Long-term monitoring & institutional controls
Long-Term Care Requirements	• Maintenance of cap, barrier walls and methane controls • Maintenance & monitoring of groundwater extraction, POTW discharge • Long-term groundwater monitoring
Estimated Remedy Cost	Probable cost is $7.9 million (Cost range $5.9 to $10.3 million)

Criteria	Comments	Rating
Threshold Requirements for Cleanup Remedies		
Overall Protection of Human Health and the Environment	Provides for complete protection of human health and the environment.	High
Compliance with Cleanup Standards	Complies with applicable cleanup levels including ARARs. Protectiveness to be verified with long-term monitoring.	High
Compliance with State and Federal Laws	Assuming Consent Decree process for remedy implementation, permitting limited to stormwater permit for capping. POTW permit required for on-going discharge. City-mediated permits for methane controls.	High
Provides for Compliance Monitoring	Compliance monitoring incorporated into remedy. Requires effluent monitoring and compliance with POTW requirements.	High
Use of Permanent Solutions to the Maximum Extent Practicable	Utilizes mix of destruction/detoxification (natural attenuation) and containment (site capping, methane controls, groundwater extraction, cap maintenance). Highest use of active measures, but at substantial & disproportionate cost.	Low
Provision of a Reasonable Restoration Time Frame	Site restoration achieved in first year of implementation. Capping, barrier walls and pumping systems installed by Year 3. Methane controls phased with area development. Phasing of capping not practicable.	Moderate
Consideration of community concerns	Requires additional land area for barrier walls and pumping systems, resulting in decreased use of Landfill and adjacent properties. Invasive actions increase concerns regarding noise, odors and other community impacts.	Low
Remedy Selection Criteria		
Implementability	Requires extensive planning and coordination. Construction activities will be disruptive to community. Remedy uses proven technologies that have been implemented at other sites. Experienced contractors and appropriate equipment are locally available.	Moderate
Long-term Effectiveness	Long-term effectiveness requires maintenance of both institutional controls and active groundwater pumping system. Disruption in POTW discharge could compromise alternative.	Moderate
Short-term Effectiveness	Cleanup action involves significant construction activities. Extensive project coordination and health and safety controls required to mitigate short-term hazards.	Low
Reduction in toxicity, mobility or volume of hazardous substances	Active measures (site capping) reduce contaminant mobility. Groundwater extraction results in contaminant translocation from site to POTW system.	Moderate
Cost-Effectiveness	Highest cost alternative while providing no improvement in remedy permanence. Incremental cost substantial and disproportionate relative to achieved reduction in point-of-exposure concentrations.	Low

Table 9-6 Comparative Analysis of Evaluated Remedial Alternatives

Alternative	A	B	C	D	E
Probable Cost ($Million)	$1.6	$2.1	$4.4	$5.6	$7.9
Remedy Elements	Enhanced Development Cap, Institutional Controls, Monitoring	Enhanced Development Cap, Groundwater Diversion Barriers, Institutional Controls, Monitoring	Low-Permeability Cap, Groundwater Diversion Barriers, Institutional Controls, Monitoring	Low-Permeability Cap, Additional Groundwater Diversion Barriers, Institutional Controls, Monitoring	Low-Permeability Cap, Encircling Groundwater Barriers, Groundwater Pumping & POTW Discharge, Institutional Controls & Monitoring
Evaluation – MTCA Threshold Requirements					
Protects Human Health and the Environment	Moderate	High	High	High	High
Complies with Cleanup Standards	Moderate	High	High	High	High
Complies with State/Federal Laws	High	High	High	High	High
Provides for Compliance Monitoring	High	High	High	High	High
Use of Permanent Remedies to the Maximum Extent Practicable	Moderate	High	Moderate	Low	Low
Reasonable Restoration Time Frame	High	High	High	High	Moderate
Addresses Community Concerns	High	High	Moderate	Moderate	Low
Evaluation – MTCA Remedy Selection Criteria					
Implementability	High	High	Moderate	Moderate	Moderate
Long-Term Effectiveness	Moderate	High	Moderate	Moderate	Moderate
Short-Term Effectiveness	High	High	Moderate	Low	Low
Reduction in Toxicity, Mobility or Volume of Hazardous Substances	Moderate	High	High	High	Moderate
Cost-Effectiveness	High	High	Moderate	Low	Low
Overall Rating	**Moderate**	**High**	**Moderate**	**Low**	**Low**

10 Conclusions

The objectives of the Landfill RI/FS were successfully completed. This document summarizes the findings of the remedial investigation, defines five site cleanup alternatives, and selects a preferred remedial alternative consistent with MTCA remedy selection requirements.

10.1 Remedial Investigation Findings

The findings of the remedial investigation are summarized in Sections 4, 6 and 7 of this report. The results of Land Use Planning conducted in parallel with the RI/FS are summarized in Section 5. Key findings from the remedial investigation include the following:

- The size and characteristics of the Landfill, including the vertical and lateral distribution of Landfill refuse, was consistent with earlier findings presented in the Pre-Design Testing Report for the Roeder Avenue Warehouse Project (RETEC, 1997).

- The rate and patterns of groundwater movement in the project area were defined. A 3-dimensional groundwater flow model was constructed using MODFLOW and SEAWAT model codes. The model was successfully calibrated to site conditions, including simulation of tidally-influenced mixing in shoreline areas.

- Extensive groundwater contaminant data were collected for the Landfill and for areas between the Landfill and the shoreline. These data were used to define contaminant distribution, differentiate Landfill and non-Landfill contaminants, and to evaluate the potential migration of contaminants toward the shoreline point-of-exposure.

- Groundwater contaminant concentrations within the Landfill were relatively low. No volatile organic compounds were present above surface water standards. Average concentrations of seven contaminants of concern (1,4-dichlorobenzene, arsenic, diesel range hydrocarbons, lead, mercury, cyanide and zinc) were between one and four times the surface water standards applicable to the point-of-exposure. Pentachlorophenol was detected at elevated levels, but only in one isolated location. Total chromium concentrations were elevated, but the chrome was present in the less-toxic trivalent from due to the reducing geochemical conditions within the Landfill. Three Landfill contaminants (copper, nickel and bis(2-ethylhexylphthalate) were present at average concentrations below surface water cleanup levels applicable to the point-of-exposure.

- Groundwater modeling and empirical testing data from the RI/FS were used to assess the extent of natural attenuation processes occurring between the Landfill and the shoreline point-of-exposure. These processes were directly quantified for each portion of the site.

- A sediment source control evaluation was performed for the Landfill. The evaluation concluded that existing attenuation process are adequate to prevent exceedances of sediment cleanup levels in nearshore marine sediments.

- Landfill gas testing performed during the RI/FS confirmed previous findings. Elevated methane levels were present in monitoring wells located on or near the Landfill. Wells located 200 feet or more away from the Landfill did not contain elevated methane concentrations.

10.2 Preferred Remedial Alternative

Based on the findings of the remedial investigation, remedial action objectives were established. The objectives are defined in Section 8 of this report and define the actions necessary to protect human health and the environment. Technologies capable of meeting those objectives were identified through a screening process, and then assembled into remedial alternatives for detailed evaluation.

Five remedial alternatives were evaluated for the Landfill site. Each of the evaluated Alternatives is implementable and is capable of meeting applicable cleanup levels. Of the five evaluated alternatives, Alternative B was selected as the preferred remedial alternative. Key elements of Alternative B include the following:

- **Enhanced Development Capping with Landfill Gas and Stormwater controls:** Landfill gas controls will be applied to new construction to be located on or within 200 of the Landfill. Existing buildings within this same area will be monitored and methane control retrofits will be installed as required. Development in the Landfill areas will also be required to maintain soil cover over Landfill refuse, and to collect and convey off-site the runoff generated from building roofs, paved parking areas and other impermeable surfaces. Such controls will be phased with site development.

- **Groundwater diversion barriers:** Two barriers will be installed within the project area, one at the foot of Hilton Avenue and one across the gap in the I&J Waterway bulkheads. These barriers will increase the travel times and the extent of natural attenuation occurring for groundwater contaminants between the Landfill and the point of exposure.

- **Groundwater Monitoring:** A long-term groundwater monitoring program will be implemented to verify the performance of the cleanup action.

- **Landfill Property Institutional Controls:** Use restrictions will be imposed on properties located on the Landfill. These restrictions are compatible with anticipated future uses of these properties. The use restrictions will ensure that 1) cover soils are maintained over Landfill refuse as necessary to prevent human or ecological exposures, 2) stormwater generated from building roofs, paved parking areas and impervious surfaces will be collected and conveyed off-site rather than being allowed to infiltrate into the ground, 3) future development will include landfill gas controls appropriate to the design of the buildings, 4) extraction of site groundwater for consumptive use will be prohibited, 5) extraction of groundwater for other purposes will be allowed only if provisions are included for monitoring and appropriate treatment/disposal of Landfill contaminants of concern, and 6) the use of oxidative in situ treatment technologies that could cause the formation of hexavalent chromium in site groundwater (e.g., peroxide injection) will be prohibited unless measures are taken to monitor and control hexavalent chromium concentrations.

- **Adjacent Property Institutional Controls:** Central Waterfront area properties located within 200 feet of the Landfill refuse (Figure 9-2) will be subject to the same landfill gas control requirements and groundwater use restrictions as the properties located on the Landfill. Properties located between the Landfill and the shoreline but more than 200 feet from the Landfill will be subject to only the groundwater use restrictions.

The estimated cost to implement Alternative B is $2.1 million. This cost is based on the assumptions described in Section 9 and itemized in Appendix E.

The project is to be implemented under a MTCA Consent Decree. Long-term actions required under the alternative will be mediated through the City of Bellingham building permit process and ensured using property deed restrictions. Assuming that the groundwater diversion barriers along the I&J Waterway are installed upland of the mean higher high water line, project implementation will not require federal permits.

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A Well Installation

Twenty-two monitoring wells were installed during October and November in accordance with the Work Plan (RETEC, 1998). The newly installed monitoring wells were installed to provide data on geochemical parameters, groundwater flow patterns, the influence of tidal fluctuations on groundwater elevations and chemistry, and concentrations of contaminants of concern at the site. These data are used to further characterize the site and to provide input data for groundwater flow and contaminant transport modeling described in the Work Plan.

The newly installed monitor wells are located generally along four transects described in the Work Plan. The transects and monitoring well locations are shown on Figure 2-1 of the Progress Memo. These transects are located in areas of the shortest distance between the refuse layer and Bellingham Bay (Transects A and B), or in areas where elevated concentrations of chromium and other landfill contaminants have been noted in groundwater at adjacent sites (Transects C and D).

Monitor wells were installed to two discrete depth intervals classified as "shallow" and "deep" for the purpose of discussion. The depth intervals are screened to characterize hydraulic and groundwater chemistry variations with depth. Shallow wells are screened across the water table and the well screen is located in the refuse layer or soil fill depending on well location. Shallow well screens extend a few feet into the underlaying sand layer at some monitoring well locations. Deep wells screen a sand bed located across the entire site. Most deep well screen intervals extend 10 feet upward from the bottom of the sand bed. The 10-foot screen length is a variable percentage of the sand bed thickness depending on the thickness of the sand bed at a given deep monitoring well location. Well construction details are provided in Table A-1.

The classification of shallow and deep monitoring wells applies to monitoring wells completed along transects A, B, and D. The classification is more difficult to apply to monitoring wells completed along transect C, because both the soil fill and sand bed units are thinner northwest of the landfill along transect C (less than 10 feet thick) than along any of the other three transects. Monitoring wells completed along transect C screen both the sand bed and the overlying fill or refuse material and are not classified as shallow or deep.

Table A-1 Well Construction Details

Well	Installation Date	Total Depth (feet below ground surface)	Screen Interval (feet below ground surface)		Measuring Point Elevation (feet above MLLW)	Coordinates	
			Top of Screen	Bottom of screen		Northing	Easting
Transect A							
RMW-1	10/26/98	24	9	19	26.41	643763.9	1600287.1
RMW-2	10/27/98	22	7	22	22.39	643725.1	1600084.3
RMW-2D	10/27/98	39	29	39	22.39	643727.0	1600095.8
RMW-3D	10/29/98	35	25	35	15.61	643744.0	1599942.9
Transect B							
RMW-6D	11/2/98	39	29	39	13.91	643166.0	1600583.3
RMW-7	10/30/98	19	4	19	14.67	643037.9	1600647.3
RMW-7D	10/30/98	40	30	40	14.5	643035.1	1600644.7
Transect C							
RMW-8	10/26/98	23	8	23	25.27	643978.5	1600610.6
RMW-9	10/28/98	19	4	19	15.76	644160.5	1600391.9
RMW-10	10/29/98	19	4	19	11.74	644331.8	1600221.5
Transect D							
RMW-11	11/3/98	19	4	19	13.82	643749.1	1601070.4
RMW-11D	11/3/98	29	19	29	13.44	643752.3	1601075.3
RMW-12D	11/2/98	20	10	20	13.19	643659.5	1601284.7
RMW-13D	11/2/98	29	18	28	12.93	643344.7	1601342.5
Other Wells							
Olivine area							
RMW-14	10/27/98	19	4	19	17.94	644633.0	1600763.8
RMW-15	10/28/98	19	4	19	17.25	644520.3	1600547.3
F-Street Alignment Wells							
RMW-16	10/29/98	20	5	20	17.51	644254.7	1601141.8
RMW-17	10/26/98	19	4	19	21.14	644180.0	1600866.4
Chestnut Street Colony Wharf Wells							
RMW-18	10/30/98	19	4	19	14.88	643739.0	1601465.6
G.P. Landfill Area							
RMW-4	10/26/98	22	7	22	22.27	643546.8	1600145.1
RMW-5	10/27/98	19	4	19	21.67	643426.3	1600284.7
Hilton Ave. Bulkhead Well							
RMW-20	10/28/98	19	4	19	14.62	644048.8	1599770.6

Note:
D: Denotes wells that are designated as deep
Surface completion on all newly installed wells is flush mount.

A.1 Utility Locates

Underground utilities were located prior to installing wells. Utility locates were performed by APS Locating, Inc., (Bellingham, Washington) and by local utility companies. Utility companies identified their utilities in areas where off-site utilities enter or pass near the site; APS located utilities on site.

A.2 Drilling and Well Installation

Cascade Drilling installed 22 monitoring wells using a hollow-stem auger rig equipped with 10-inch outer diameter and 6-inch inner diameter continuous flight hollow-stem augers. Well completion was performed in accordance with Ecology requirements for resource protection wells (WAC 173-160-500 through 173-160-540). Soil samples for geologic logging purposes were collected at varying intervals depending on the judgement of the site geologist, but usually on 5-foot intervals when not drilling in refuse. Soil samples were collected using a 1.5-foot long spilt-spoon sampler driven by a 140-pound hammer falling 30 inches.

All newly installed wells are completed with 2-inch schedule 40 PVC with 0.010-inch slotted PVC screens. Screen lengths are 10 or 15 feet depending on subsurface stratigraphy encountered at a given boring location. A minimum separation of 2 feet was maintained between the top of the well screen and the bottom of the refuse at wells screened in the sand bed beneath the refuse. This was done to prevent the direct entry of refuse unit groundwater into monitor wells screened below the landfill. The bottom of each screen is fitted with a flush-threaded bottom cap. Blank 2-inch schedule 40 PVC extends from the top of the screen to ground surface.

A sand pack consisting of #2-12 sand extends from total depth to 1 to 2 feet above each well screen. A bentonite seal consisting of bentonite chips extends from the top of the sand pack to 2 feet below ground. The bentonite chips were hydrated with potable water after placement in the monitoring well annulus. A cement surface seal extends from the top of each bentonite seal to ground surface. Surface completion for all newly-installed wells are flush-mount with traffic-rated covers and a concrete pad.

All newly installed monitoring wells were developed using a surge block and manually operated positive displacement pump. Refer to Table A-2 for a list of developed wells and the volume of water removed from each well. A minimum of 10 casing volumes were removed before a well was considered developed. Previously installed wells located along the transects were redeveloped by removing at least 10 casing volumes using a manually operated positive displacement pump. Certain previously installed monitoring wells on the

Table A-2 Well Development Data

WELL	Volume Purged (gallons)	Comments
MW-1(B)	15	Diesel or sulfide odor, sheen, slow recharge
MW-3(B)	15	Gold-brown tint, clear
MW-4(B)	20	Brown/green tint, clear
MW-5(B)	20	Brown to tan tint: clear
MW-7(B)	17	Green, clear
MW-8(B)	35	olive green, slight sheen, clear
MW-10(B)	12	Light green, slight sheen, clear
MW-12(B)	40	Tan-gray, mostly clear, sewer odor
MW-98-1	10	Yellow-green, clear, no sediments, sulfide odor
RGP-1(W)	17	Very strong sulfide odor
RGP-2(W)	Not recorded	Not recorded
RGP-3(W)	25	Black-gray with particulates, sulfide odor
RGP-4(W)	20	Black tint, clear, sulfide odor
RMW-3D	55	Tan, clear
RMW-6D	55	Brown tint, clear, sulfide odor, slight sheen
RMW-7	25	Light brown to brown, clear
RMW-7D	65	clear
RMW-9	25	Light green tint, clear
RMW-10	40	Light brown, clear
RMW-11	45	Green to brownish, clear
RMW-11D	30	Slow recharge
RMW-12D	60	Brown tint, clear, moderate odor
RMW-13D	55	Green/brown, clear
RMW-16	20	Green-gray
RMW-18	55	Light brown to brown, clear

Chevron property were installed by Chevron about 2 to 3 weeks (early October) before the newly installed wells described in this memorandum. The Chevron wells were developed by Chevron's consultant, Gettler-Ryan, shortly after installation; therefore, redevelopment by ThermoRetec personnel was not performed. Development water was contained in drums and stored at the landfill. Disposal of development water was performed using an appropriate disposal facility.

Soil samples collected for geologic logging were described using standard geological terminology which includes USCS classification, color, grain size, and odors. Soil sample descriptions are provided on well logs at the end of this appendix.

A.3 Decontamination and Waste Disposal

Equipment was decontaminated between boreholes to prevent cross contamination. Sampling equipment was decontaminated between samples by washing with an Alconox solution and rinsing with deionized water. Augers and heavy drilling equipment were decontaminated by steam cleaning.

Disposal of soil cuttings, purge water, and decontamination water drums was performed using an appropriate disposal facility. disposal was coordinated by TPS Technologies.

A.4 Well Survey

The 22 monitoring wells installed during this investigation and the 24 wells from previous investigations that were selected for the tidal study were surveyed to establish vertical and horizontal locations. All wells were surveyed for horizontal location in the North American Datum of 1927 (NAD 27) and for vertical elevation as mean-lower-low-water (MLLW) in the U.S. Coastal & Geodetic Survey datum (USC&GS). This survey was preformed by Larry Steele and Associates (Bellingham, Washington). Survey coordinates are provided at the end of this appendix.

Well Logs of Newly Installed Monitoring Wells

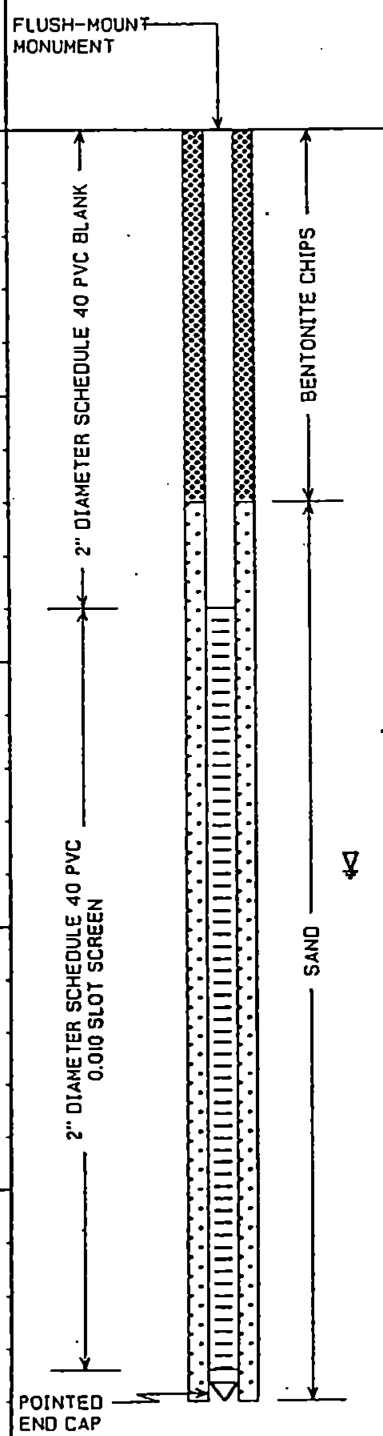
RETEC

WELL INSTALLATION LOG
Monitoring Well RMW-1

1011 S.W. Klickitat Way
Suite #207
Seattle, Washington 98134
(206) 624-9349

PROJECT NO: *3-3809-210 Roeder Avenue Landfill RI/FS*		CLIENT: *Port of Bellingham*
LOCATION: *Bellingham, Washington; Landfill, off in weeds*		DRILLING CO.: *Cascade Drilling*
START DATE: *10/26/98* TIME: *13:15*	BORING ID: *10 inches*	DRILLER: *Brian*
COMPLETION DATE: *10/26/98* TIME: *14:30*	TOTAL DEPTH: *24.0 feet bgs*	RIG TYPE: *CME-75*
WATER LEVEL DURING DRILLING: *14.0' bgs*	TOP OF CASING: *Flush-mount*	METHOD: *Hollow-stem Auger*
SURFACE ELEV.:	MP ELEV.:	LOGGED BY: *C. Alferness*

WELL CONSTRUCTION



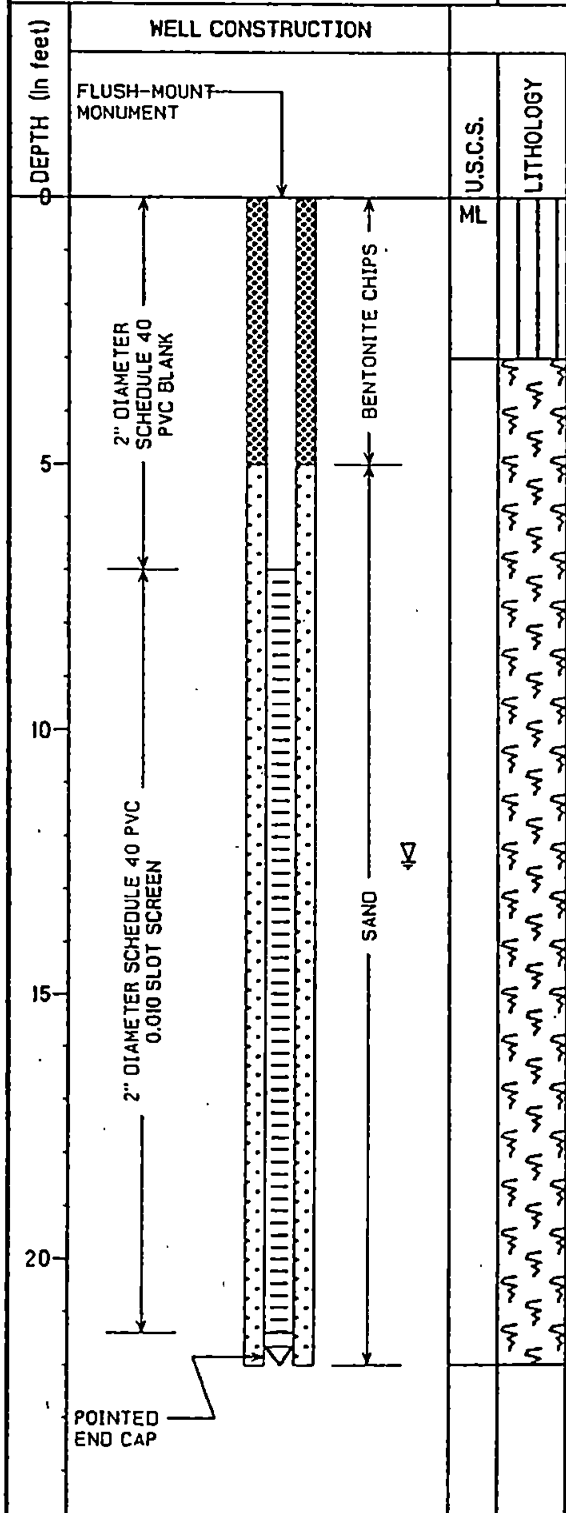
DEPTH (in feet)	U.S.C.S.	SOIL DESCRIPTION	TYPE	DEPTH	BLOWS/6"	% RECOVERY	PID (ppm)
0	ML	<u>SILT</u>; Brown; 20% concrete debris and wood pieces; trace bricks. *0.25'-5.0'* – 20% sand; 15% gravel; trace concrete, wood and bricks; moist; no odor.					
5		<u>WOOD DEBRIS</u>; Black; moist; loose; petroleum-like odor. Difficult drilling past 5.0 feet bgs.					
10		*13.0'* – 35% garbage; 20% silt; moist; stiff; manure-like odor. *14.0'* – Saturated.	SS	⊠	38 38	75	0
15							
20							
25		Total depth = 24.0 feet bgs.					

REMARKS: SS – Split Spoon
⊠ – Sample Interval

WELL INSTALLATION LOG
Monitoring Well RMW-2

RETEC
1011 S.W. Klickitat Way
Suite #207
Seattle, Washington 98134
(206) 624-9349

PROJECT NO: *3-3809-210 Roeder Avenue Landfill RI/FS*		CLIENT: *Port of Bellingham*
LOCATION: *Bellingham, Washington; Landfill by 20*		DRILLING CO.: *Cascade Drilling*
START DATE: *10/27/98* TIME: *12:15*	BORING ID: *10 inches*	DRILLER: *Brian*
COMPLETION DATE: *10/27/98* TIME: *13:15*	TOTAL DEPTH: *22.0 feet bgs*	RIG TYPE: *CME-75*
WATER LEVEL DURING DRILLING: *12.5' bgs*	TOP OF CASING: *Flush-mount*	METHOD: *Hollow-stem Auger*
SURFACE ELEV.:	MP ELEV.:	LOGGED BY: *C. Alferness*



SOIL DESCRIPTION	TYPE	DEPTH	BLOWS/6"	% RECOVERY	PID (ppm)
SANDY SILT; Brown; trace gravel; moist.					
GARBAGE;					
8.0' – Difficult drilling.					
12.5' – Saturation.					
Total depth = 22.0 feet bgs.					

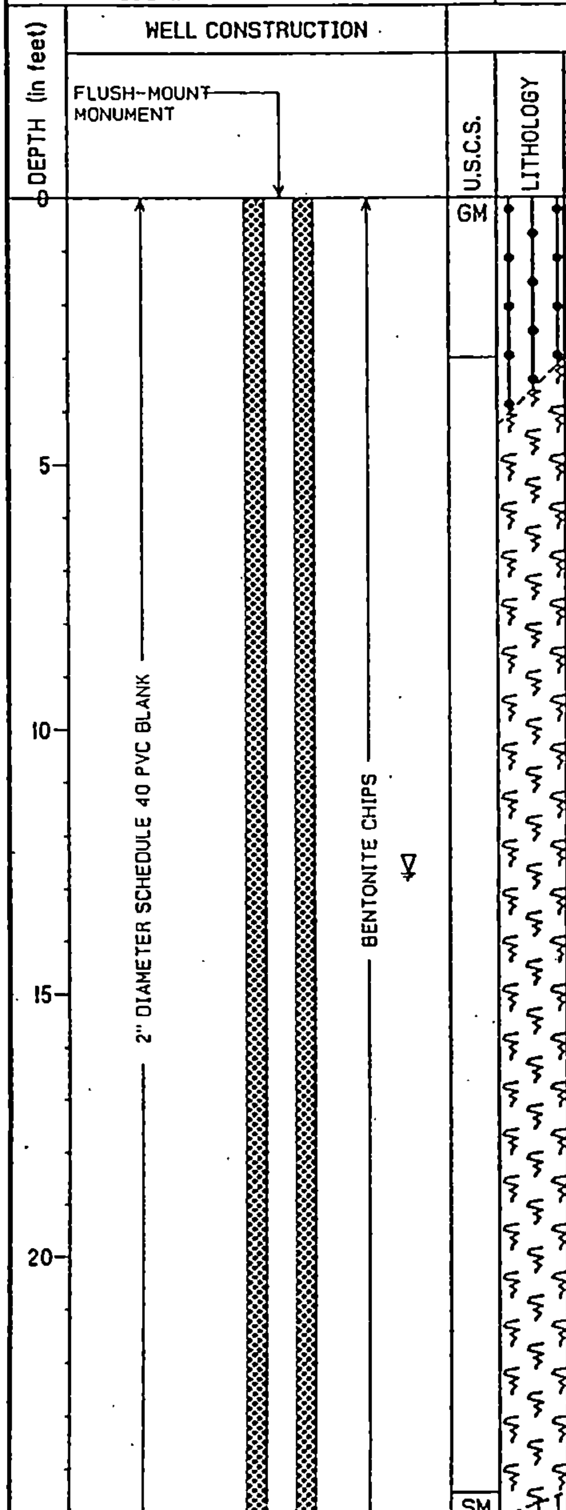
REMARKS: SS – Split Spoon
Ø – Sample Interval

RETEC

WELL INSTALLATION LOG
Monitoring Well RMW-2D

1011 S.W. Klickitat Way
Suite #207
Seattle, Washington 98134
(206) 624-9349

PROJECT NO: *3-3809-210 Roeder Avenue Landfill RI/FS*		CLIENT: *Port of Bellingham*
LOCATION: *Bellingham, Washington; Landfill*		DRILLING CO.: *Cascade Drilling*
START DATE: *10/27/98* TIME: *09:30*	BORING ID: *10 inches*	DRILLER: *Brian*
COMPLETION DATE: *10/27/98* TIME:	TOTAL DEPTH: *39.0 feet bgs*	RIG TYPE: *CME-75*
WATER LEVEL DURING DRILLING: *12.75' bgs*	TOP OF CASING: *Flush-mount*	METHOD: *Hollow-stem Auger*
SURFACE ELEV.:	MP ELEV.:	LOGGED BY: *C. Alferness*



SOIL DESCRIPTION

<u>SANDY GRAVEL WITH SILT</u>; Gray; moist; no odor.

<u>GARBAGE</u>; Moist; odor.

7.0' – Difficult drilling.

SAMPLE DATA

TYPE	DEPTH	BLOWS/6"	% RECOVERY	PID (ppm)
SS	⊠	45	90	

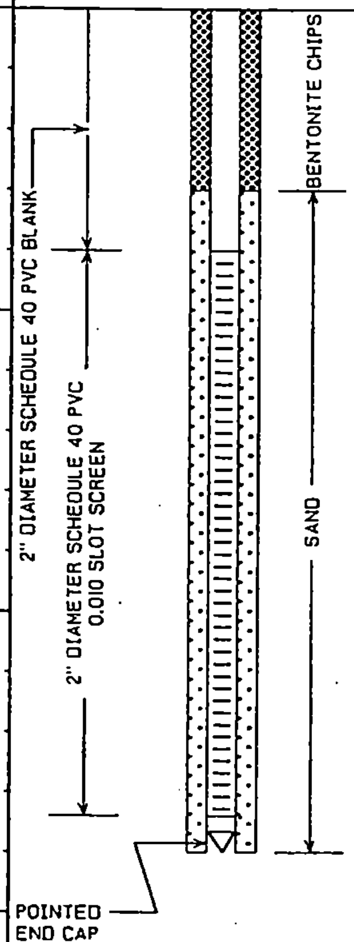
REMARKS: NR – Not Recorded
SS – Split Spoon
⊠ – Sample Interval

RETEC

WELL INSTALLATION LOG
Monitoring Well RMW–2D

1011 S.W. Klickitat Way
Suite #207
Seattle, Washington 98134
(206) 624-9349

WELL CONSTRUCTION



DEPTH (in feet)	U.S.C.S.	SOIL DESCRIPTION	TYPE	BLOWS/6"	% RECOVERY	PID (ppm)
25	SM	SILTY SAND: Fine- to medium-grained; 5% to 10% silt; trace shells, bricks and wood debris; wood debris at top of sample only; saturated; no odor.		27 12		
30	SP	SAND: Gray to dark gray; trace shells; trace silt; trace wood; saturated; no odor.	SS	20 30 50/5"	100	
		32.5'–34.0' – Trace wood at bottom of sampler.	SS	4 7 15	50	
35		*35.0'–35.5'* – Moderately packed.	SS	70	100	
		37.5'–38.0' – Gray; medium- to coarse-grained; trace shells; trace silt; saturated. *38.0'–38.5'* – Coarse-grained; 20% gravel.	SS	45 50	100	
40	CL	CLAY: Gray; moist; plastic.	SS	17 37 40	NR	
		Total depth = 39.0 feet bgs.				
45						
50						

REMARKS: NR – Not Recorded
SS – Split Spoon
☒ – Sample Interval

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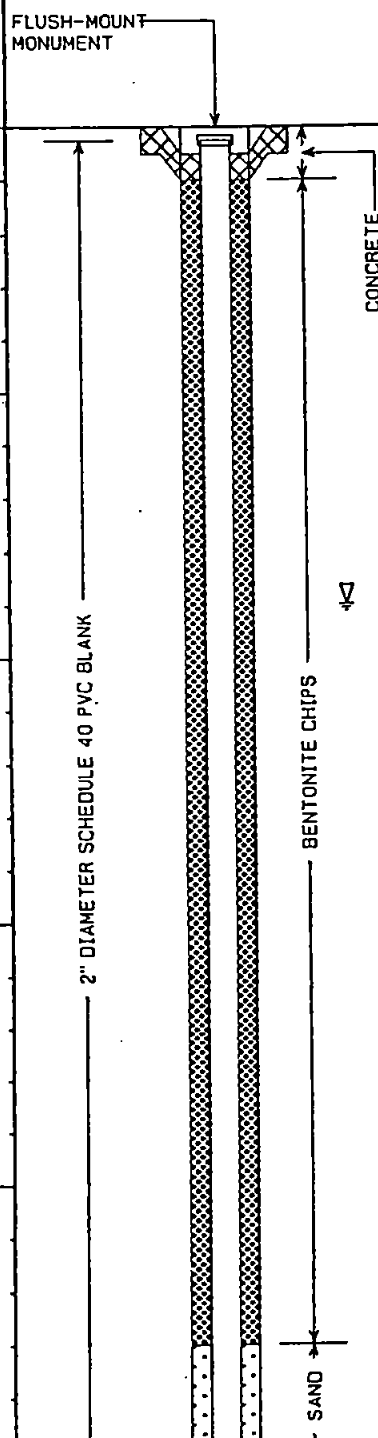
RETEC

WELL INSTALLATION LOG
Monitoring Well RMW-3D

1011 S.W. Klickitat Way
Suite #207
Seattle, Washington 98134
(206) 624-9349

PROJECT NO: *3-3809-210 Roeder Avenue Landfill RI/FS*	CLIENT: *Port of Bellingham*
LOCATION: *Bellingham, Washington; Southeast Corner of Boat Yard*	DRILLING CO.: *Cascade Drilling*
START DATE: *10/29/98* TIME: *10:50* / BORING ID: *10 inches*	DRILLER: *Brian*
COMPLETION DATE: *10/29/98* TIME: *13:15* / TOTAL DEPTH: *35.0 feet bgs*	RIG TYPE: *CME-75*
WATER LEVEL DURING DRILLING: *9.0' bgs* / TOP OF CASING: *0.25 foot bgs*	METHOD: *Hollow-stem Auger*
SURFACE ELEV.: / MP ELEV.:	LOGGED BY: *C. Alferness*

WELL CONSTRUCTION



DEPTH (in feet)	U.S.C.S.	SOIL DESCRIPTION	TYPE	BLOWS/6"	% RECOVERY	PID (ppm)
0	SW	SAND WITH GRAVEL; Brown; 30% gravel; dry; loose; no odor.				
		GARBAGE; Black; wood waste.				
5	CL	SANDY CLAY; Gray; with 5% gravel; trace glass; moist; no odor.	SS	21 10 14	75	
	GP-GC	GRAVEL; Gray; with 10% sand; 10% clay; moist; no odor.				
10	GC	CLAYEY GRAVEL; Gray; 15% sand; saturated.	SS	5 8 5	100	
		WOOD MULCH; Brown; saturated; no odor.				
15	SP	SAND; Gray; fine-grained; trace silt; saturated; no odor.	SS	15 25 20	100	
20	SM	SILTY SAND; Fine-grained; 20% silt; 5% shells; saturated; no odor.	SS	12 20 20	100	
25	SP					

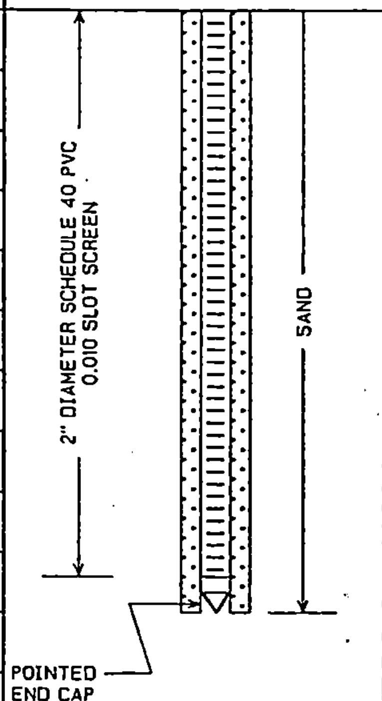
REMARKS: NR - Not Recorded
SS - Split Spoon
⊠ - Sample Interval

RETEC

WELL INSTALLATION LOG
Monitoring Well RMW-3D

1011 S.W. Klickitat Way
Suite #207
Seattle, Washington 98134
(206) 624-9349

WELL CONSTRUCTION



SOIL DESCRIPTION / SAMPLE DATA

DEPTH (in feet)	U.S.C.S.	SOIL DESCRIPTION	TYPE	BLOWS/6"	% RECOVERY	PID (ppm)
25	SP	<u>SAND</u>; Gray; fine-grained; trace shells. *25.5'-26.0'* - Medium-grained.	SS	20 50	NR	
		<u>WOOD DEBRIS</u>				
30	SP	<u>SAND</u>; Gray; fine- to medium-grained; trace shells; trace gravel; trace silt; no odor.	SS	50	100	
35	CL	<u>CLAY</u>; Gray; trace gravel and shells; plastic.	SS	NR	100	
		Total depth = 35.0 feet bgs.				
40						
45						
50						

REMARKS:
NR - Not Recorded
SS - Split Spoon
☒ - Sample Interval

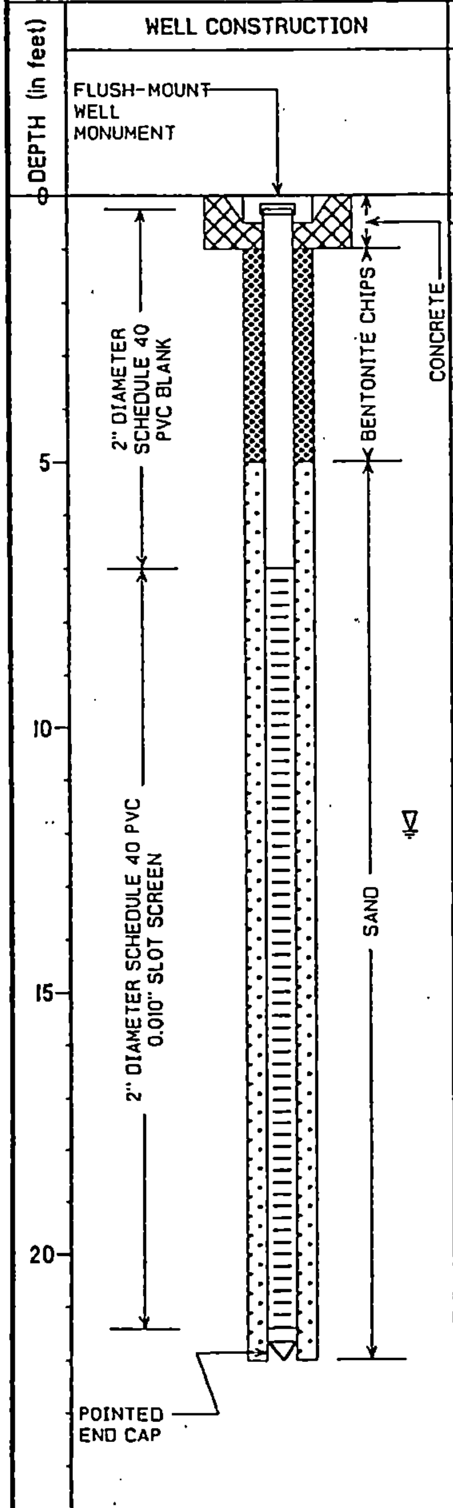
WELL INSTALLATION LOG

Monitoring Well RMW-4

RETEC

1011 S.W. Klickitat Way
Suite #207
Seattle, Washington 98134
(206) 624-9349

PROJECT NO: 3-3809-210 Roeder Avenue Landfill RI/FS		CLIENT: Port of Bellingham
LOCATION: Bellingham, Washington; Along Water Treatment Pond		DRILLING CO.: Cascade Drilling
START DATE: 10/26/98 TIME: 14:50	BORING ID: 10 inches	DRILLER: Brian
COMPLETION DATE: 10/26/98 TIME:	TOTAL DEPTH: 22.0 feet bgs	RIG TYPE: CME-75
WATER LEVEL DURING DRILLING: 12.0' bgs	TOP OF CASING: 0.25 foot bgs	METHOD: Hollow-stem Auger
SURFACE ELEV.:	MP ELEV.:	LOGGED BY: C. Alferness



U.S.C.S.	LITHOLOGY	SOIL DESCRIPTION	TYPE	DEPTH	BLOWS/6"	% RECOVERY	PID (ppm)
GP		GRAVEL: Rock and riprap.					
SM		SAND: With 15% silt; and 15% gravel; moist; loose; no odor.					
		WOOD MULCH: Dark brown; saturated; no odor.					
ML		SILT: Gray; saturated; medium stiff; no odor.					
		Total depth = 22.0 feet bgs.					

REMARKS: All lithologic descriptions are taken from cuttings.

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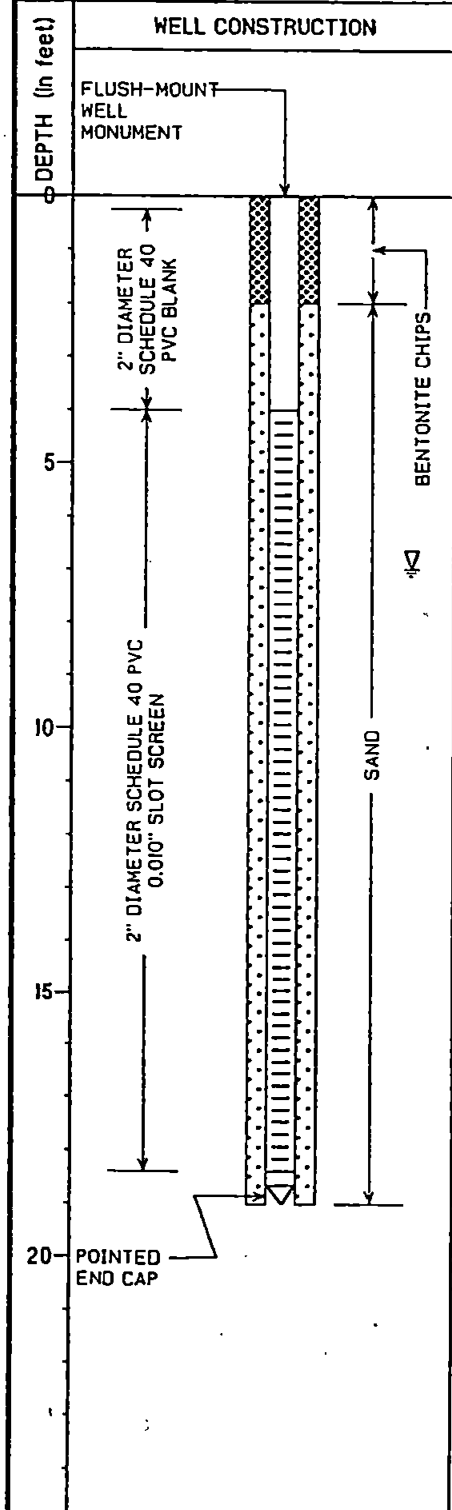
WELL INSTALLATION LOG
Monitoring Well RMW-5

RETEC
1011 S.W. Klickitat Way
Suite #207
Seattle, Washington 98134
(206) 624-9349

PROJECT NO: *3-3809-210 Roeder Avenue Landfill RI/FS*		CLIENT: *Port of Bellingham*
LOCATION: *Bellingham, Washington; Along Road by Water Treatment Pond*		DRILLING CO.: *Cascade Drilling*
START DATE: *10/27/98* TIME: *07:50*	BORING ID: *10 inches*	DRILLER: *Brian*
COMPLETION DATE: *10/27/98* TIME:	TOTAL DEPTH: *19.0 feet bgs*	RIG TYPE: *CME-75*
WATER LEVEL DURING DRILLING: *7.0' bgs*	TOP OF CASING: *Flush-mount*	METHOD: *Hollow-stem Auger*
SURFACE ELEV.:	MP ELEV.:	LOGGED BY: *C. Alferness*



U.S.C.S.	LITHOLOGY	SOIL DESCRIPTION	TYPE	DEPTH	BLOWS/6"	% RECOVERY	PID (ppm)
SP		SAND: Gray; 35% gravel; 10% silt; moist; no odor.					
		WOOD DEBRIS: Moist. *7.0'* – Saturated.					
		GARBAGE: Saturated; hydrogen sulfide odor.					
		Total depth = 19.0 feet bgs.					

REMARKS: All lithologic descriptions are taken from cuttings.

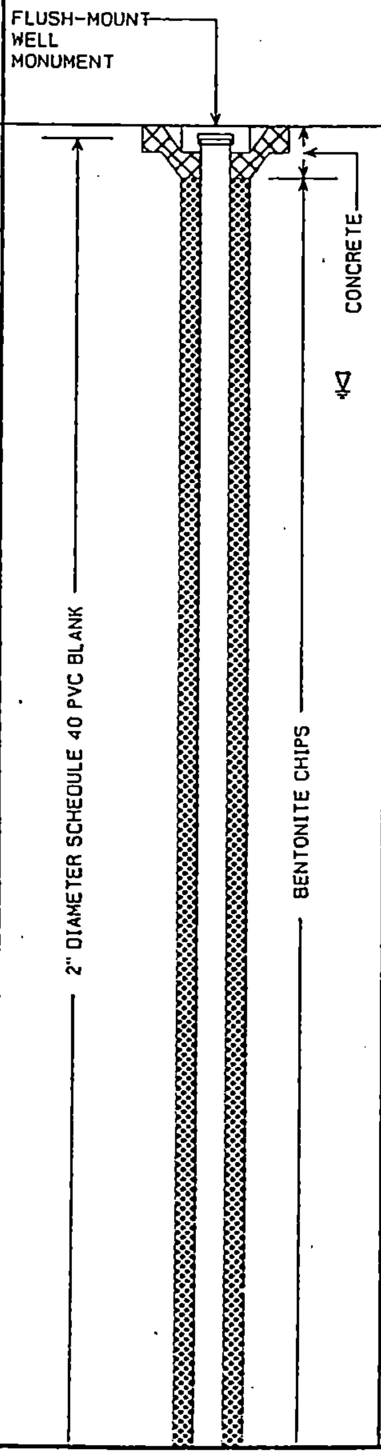
RETEC

1011 S.W. Klickitat Way
Suite #207
Seattle, Washington 98134
(206) 624-9349

WELL INSTALLATION LOG
Monitoring Well RMW-6D

PROJECT NO: 3-3809-210 Roeder Avenue Landfill RI/FS		CLIENT: Port of Bellingham
LOCATION: Bellingham, Washington; Chevron		DRILLING CO.: Cascade Drilling
START DATE: 11/02/98 TIME: 08:10	BORING ID: 10 inches	DRILLER: Brian
COMPLETION DATE: 11/02/98 TIME: 09:30	TOTAL DEPTH: 39.0 feet bgs	RIG TYPE: CME-75
WATER LEVEL DURING DRILLING: 5.0' bgs	TOP OF CASING: 0.25 foot bgs	METHOD: Hollow-stem Auger
SURFACE ELEV.:	MP ELEV.:	LOGGED BY: C. Alferness

WELL CONSTRUCTION



DEPTH (in feet)	U.S.C.S.	LITHOLOGY	SOIL DESCRIPTION	TYPE	DEPTH	BLOWS/6"	% RECOVERY	PID (ppm)
0	SP		SAND; Brown; 20% gravel; 15% silt; moist; no odor.					
5	GP		GRAVEL; Brown; 20% sand.					
10			5.0'–15.0' – Water table.					
15	SP		SAND; Gray; with silt; saturated; no odor.					
20			Sands with silts interbedded.					
25								

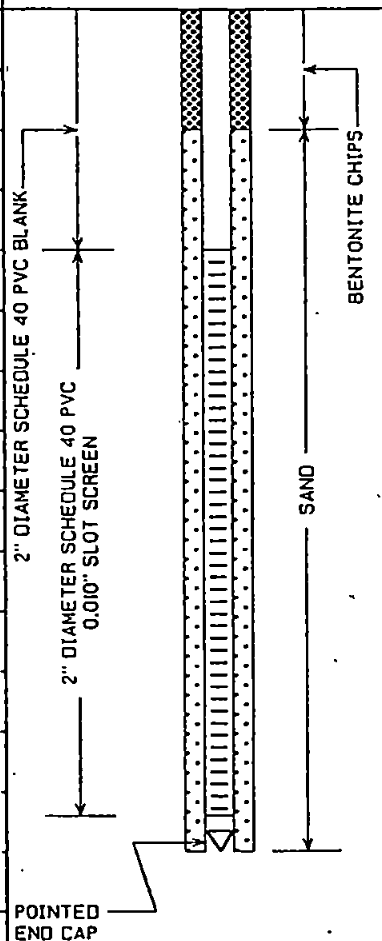
REMARKS: SS - Split Spoon
⊠ - Sample Interval

RETEC

WELL INSTALLATION LOG
Monitoring Well RMW-6D

1011 S.W. Klickitat Way
Suite #207
Seattle, Washington 98134
(206) 624-9349

WELL CONSTRUCTION



DEPTH (in feet)	U.S.C.S.	SOIL DESCRIPTION	TYPE	BLOWS/6"	% RECOVERY	PID (ppm)
25	SP					
30		*30.0'-31.5'* – Medium-grained; with trace silt; 5% shell fragments; trace wood; saturated; no odor.	SS	2 2 10	50	0
35			SS	8 3 15	75	0
	CL	CLAY: Gray; plastic; no odor.	SS	15 20 25	100	0
40		Total depth = 39.0 feet bgs.				
45						
50						

REMARKS: SS – Split Spoon
⊠ – Sample Interval

WELL INSTALLATION LOG

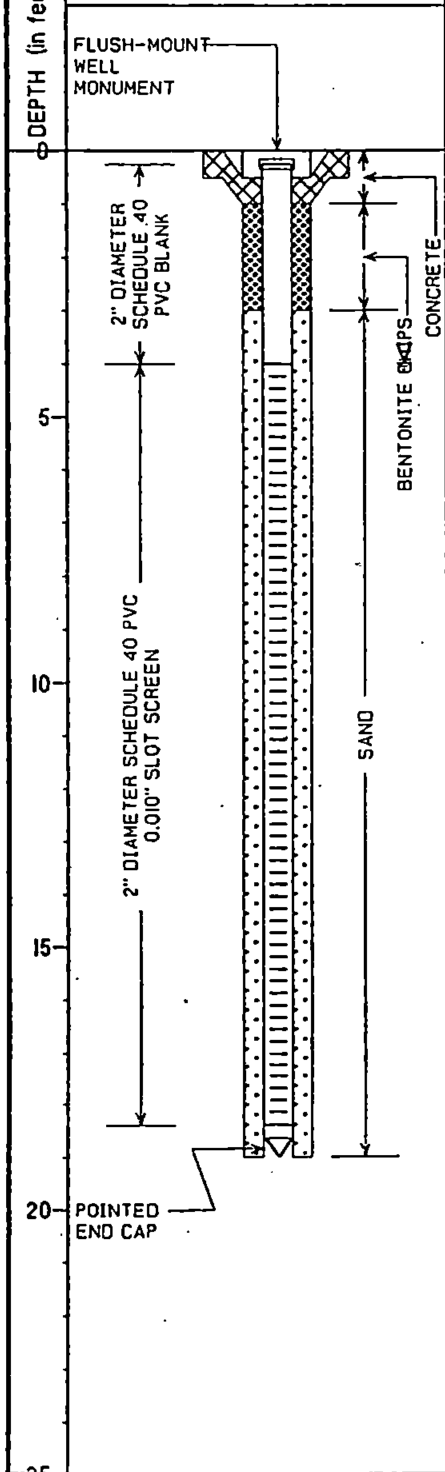
Monitoring Well RMW-7

RETEC

1011 S.W. Klickitat Way
Suite #207
Seattle, Washington 98134
(206) 624-9349

PROJECT NO: *3-3809-210 Roeder Avenue Landfill RI/FS*		CLIENT: *Port of Bellingham*
LOCATION: *Bellingham, Washington; End of "C" Street behind fence*		DRILLING CO.: *Cascade Drilling*
START DATE: *10/30/98* TIME: *14:30*	BORING ID: *10 inches*	DRILLER: *Brian*
COMPLETION DATE: *10/30/98* TIME:	TOTAL DEPTH: *19.0 feet bgs*	RIG TYPE: *CME-75*
WATER LEVEL DURING DRILLING: *4.0' bgs*	TOP OF CASING: *0.25 foot bgs*	METHOD: *Hollow-stem Auger*
SURFACE ELEV.:	MP ELEV.:	LOGGED BY: *C. Alferness*

WELL CONSTRUCTION



SOIL DESCRIPTION

U.S.C.S.	SOIL DESCRIPTION
	ROCK: Crushed.
GP	GRAVEL: Brown; 30% sand; loose; no odor.
	5.0'-6.5' – Grades with 20% sand; trace silt; saturated.
ML	SILT: Gray; 20% sand; 15% gravel; trace glass; trace wood; saturated; organic odor.
	15.0'-15.25' – Very little hydrogen sulfide odor.
SP	SAND: Gray-black; medium-grained; trace shells; very little hydrogen sulfide odor.
ML	SILT: Gray; trace shells; very little hydrogen sulfide odor.
	Total depth = 19.0 feet bgs.

SAMPLE DATA				
TYPE	DEPTH	BLOWS/6"	% RECOVERY	PID (ppm)

REMARKS: Lithologic descriptions are taken from Well Installation Log for RMW-7D.

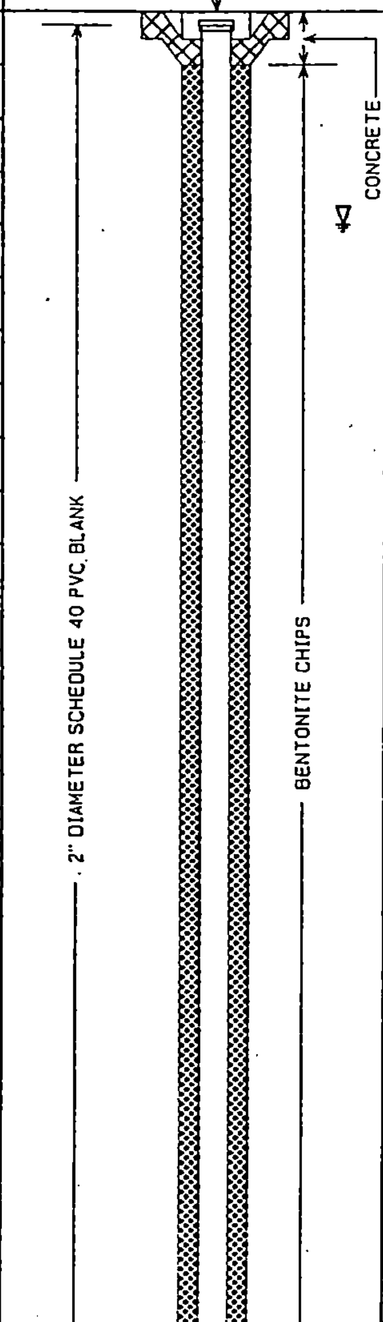
RETEC

WELL INSTALLATION LOG
Monitoring Well RMW-7D

1011 S.W. Klickitat Way
Suite #207
Seattle, Washington 98134
(206) 624-9349

PROJECT NO: 3-3809-210 Roeder Avenue Landfill RI/FS		CLIENT: Port of Bellingham
LOCATION: Bellingham, Washington; End of "C" Street behind fence, 5 feet W of RMW-7		DRILLING CO.: Cascade Drilling
START DATE: 10/30/98 TIME: 12:00	BORING ID: 10 inches	DRILLER: Brian
COMPLETION DATE: 10/30/98 TIME: 13:40	TOTAL DEPTH: 40.0 feet bgs	RIG TYPE: CME-75
WATER LEVEL DURING DRILLING: 4.0' bgs	TOP OF CASING: 0.25 foot bgs	METHOD: Hollow-stem Auger
SURFACE ELEV.:	MP ELEV.:	LOGGED BY: C. Alferness

WELL CONSTRUCTION



DEPTH (in feet)	U.S.C.S.	SOIL DESCRIPTION	TYPE	BLOWS/6"	% RECOVERY	PID (ppm)
0		ROCK: Crushed.				
	GP	GRAVEL: Brown; 30% sand; loose; no odor.				
5		5.0'–6.5' – Grades with 20% sand; trace silt; saturated.	SS	12 10 8	100	0
10			SS	60	60	0
	ML	SILT: Gray; 20% sand; 15% gravel; trace glass; trace wood; saturated; organic odor.				
15		15.0'–15.25' – Very little hydrogen sulfide odor.	SS	31 50	100	0
	SP	SAND: Gray-black; medium-grained; trace shells; very little hydrogen sulfide odor.				
	ML	SILT: Gray; trace shells; very little hydrogen sulfide odor.				
20	SP	SAND: Gray; medium-grained; 5% shells; strong hydrogen sulfide odor.	SS	14 50	100	0
	ML	SILT: Gray; trace sand; strong hydrogen sulfide odor.				
25	SP					

REMARKS: SS – Split Spoon
Ø – Sample Interval

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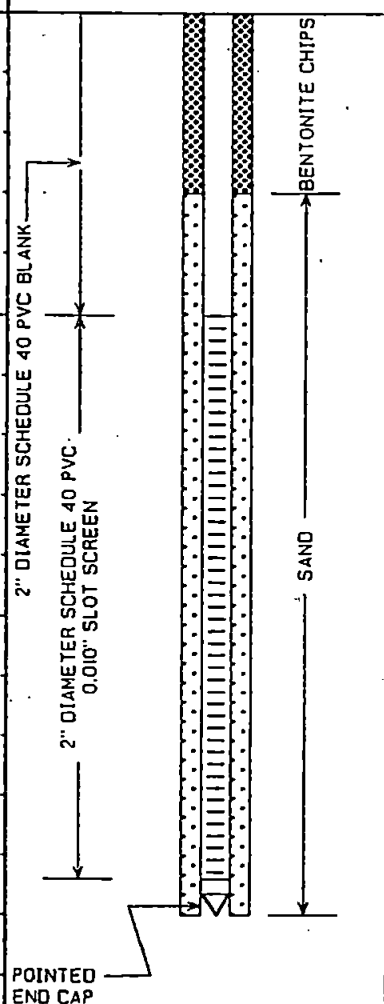
1011 S.W. Klickitat Way
Suite #207
Seattle, Washington 98134
(206) 624-9349

WELL INSTALLATION LOG
Monitoring Well RMW-7D

DEPTH (in feet) | **WELL CONSTRUCTION** | **SOIL DESCRIPTION** | **SAMPLE DATA**



Depth (ft)	U.S.C.S.	Soil Description	Type	Blows/6"	% Recovery	PID (ppm)
25	SP	SAND; Black; medium-grained; 10% silt; hydrogen sulfide odor.	SS	12, 15, 20	100	0
	ML	SILT; Gray-brown; trace wood; hydrogen sulfide odor.				
	SP	SAND; Gray; fine-grained; 10% silt; hydrogen sulfide odor.				
		28.0'-29.5' – Grades to fine- to medium-grained; 15% to 20% silt; 5% shells; strong hydrogen sulfide odor.	SS	11, 14, 19	100	0
30						
35		*35.0'-36.5'* – Grades with 10% silt; 10% gravel; trace shells; no odor.	SS	35, 50	100	0
40	CL	CLAY; Gray; trace shells; no odor.	SS	15, 25, 40	100	0
		Total depth = 40.0 feet bgs.				
45						
50						

REMARKS: SS – Split Spoon
⊠ – Sample Interval

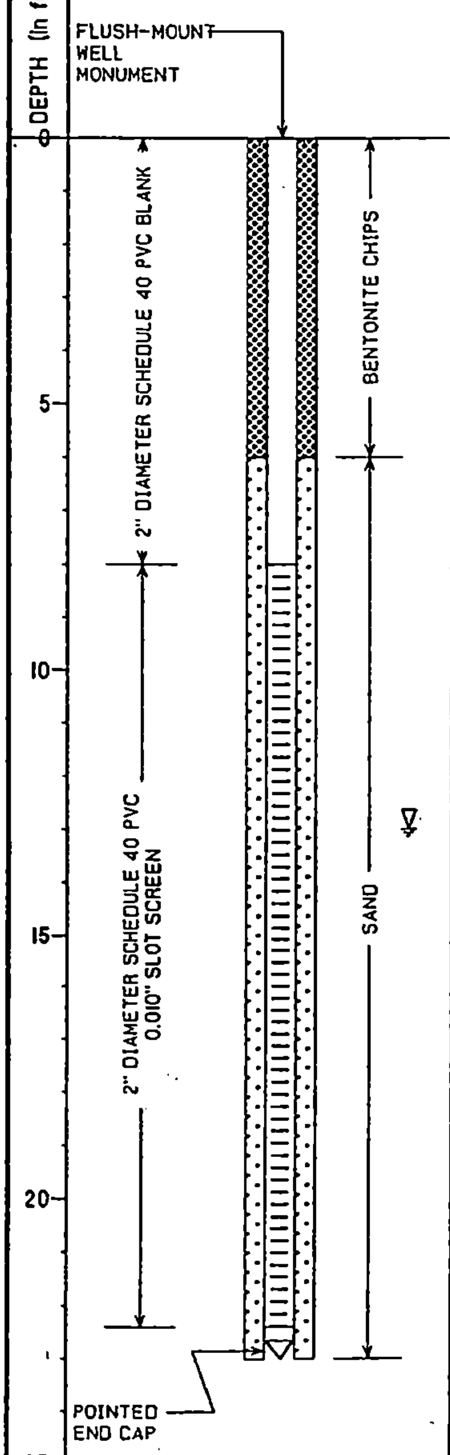
RETEC

WELL INSTALLATION LOG
Monitoring Well RMW-8

1011 S.W. Klickitat Way
Suite #207
Seattle, Washington 98134
(206) 624-9349

PROJECT NO: *3-3809-210 Roeder Avenue Landfill RI/FS*	CLIENT: *Port of Bellingham*
LOCATION: *Bellingham, Washington; Landfill, off fence West of "F" Street end*	DRILLING CO.: *Cascade Drilling*
START DATE: *10/28/98* TIME: *11:40* / BORING ID: *10 inches*	DRILLER: *Brian*
COMPLETION DATE: *10/28/98* TIME: *13:00* / TOTAL DEPTH: *23.0 feet bgs*	RIG TYPE: *CME-75*
WATER LEVEL DURING DRILLING: *13.0' bgs* / TOP OF CASING: *Flush-mount*	METHOD: *Hollow-stem Auger*
SURFACE ELEV.: / MP ELEV.:	LOGGED BY: *C. Alferness*

WELL CONSTRUCTION



Depth (feet)	U.S.C.S.	SOIL DESCRIPTION	TYPE	DEPTH	BLOWS/6"	% RECOVERY	PID (ppm)
0	ML	SILT: Black; 20% sand; 20% gravel; dry to moist; organic odor.					
10		WOOD MULCH: Black; moist; loose.					
11	SP	GRAVELLY SILTY SAND: Black; with garbage and wood; moist; medium stiff; organic odor. *13.0'* – Saturated.	SS		20 24 28	100	0
23		Total depth = 23.0 feet bgs.					

REMARKS:

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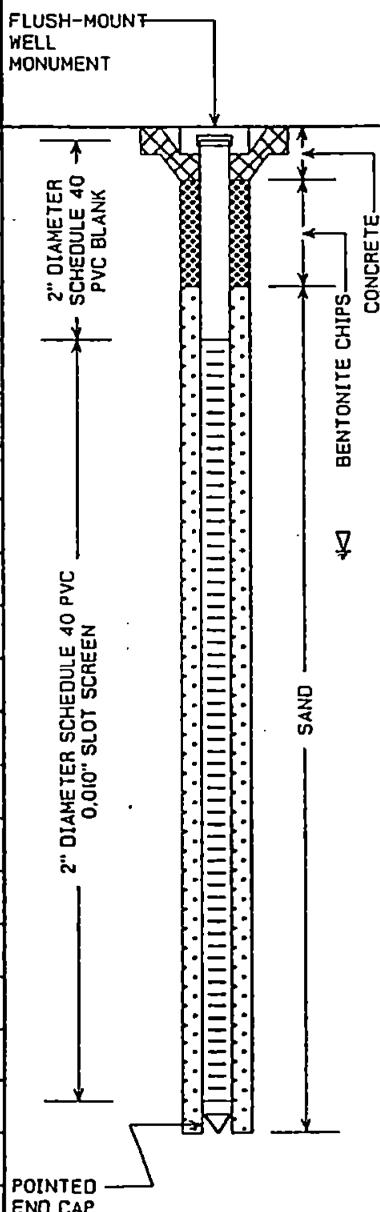
WELL INSTALLATION LOG
Monitoring Well RMW-9

1011 S.W. Klickitat Way
Suite #207
Seattle, Washington 98134
(206) 624-9349

PROJECT NO: 3-3809-210 Roeder Avenue Landfill RI/FS		CLIENT: Port of Bellingham
LOCATION: Bellingham, Washington;		DRILLING CO.: Cascade Drilling
START DATE: 10/28/98 TIME: 08:15	BORING ID: 10 inches	DRILLER: Brian
COMPLETION DATE: 10/28/98 TIME:	TOTAL DEPTH: 19.0 feet bgs	RIG TYPE: CME-75
WATER LEVEL DURING DRILLING: 8.0' bgs	TOP OF CASING: 0.25 foot bgs	METHOD: Hollow-stem Auger
SURFACE ELEV.:	MP ELEV.:	LOGGED BY: J. Henley

WELL CONSTRUCTION



DEPTH (in feet)	U.S.C.S.	LITHOLOGY	SOIL DESCRIPTION	TYPE	DEPTH	BLOWS/6"	% RECOVERY	PID (ppm)
0	SP		SAND 1.0' – Plastic trash.					
5	SM		GRAVELLY SILTY SAND WITH GARBAGE; Dark brown; 5% to 10% trash; bricks; safety pin; wood debris; slightly moist; no odor.	SS	⊠	48 28 34	50	0
			GARBAGE AND SAND; Glass debris; metal debris/sheet metal; no sheen.					
15	SP		SAND; Dary gray; fine- to coarse-grained; trace to 5% silt; trace shells; saturated; no sheen; no odor.	SS	⊠	22 17 18	NR	NR
20			Total depth = 19.0 feet bgs.					

REMARKS: NR – Not Recorded
SS – Split Spoon
⊠ – Sample Interval

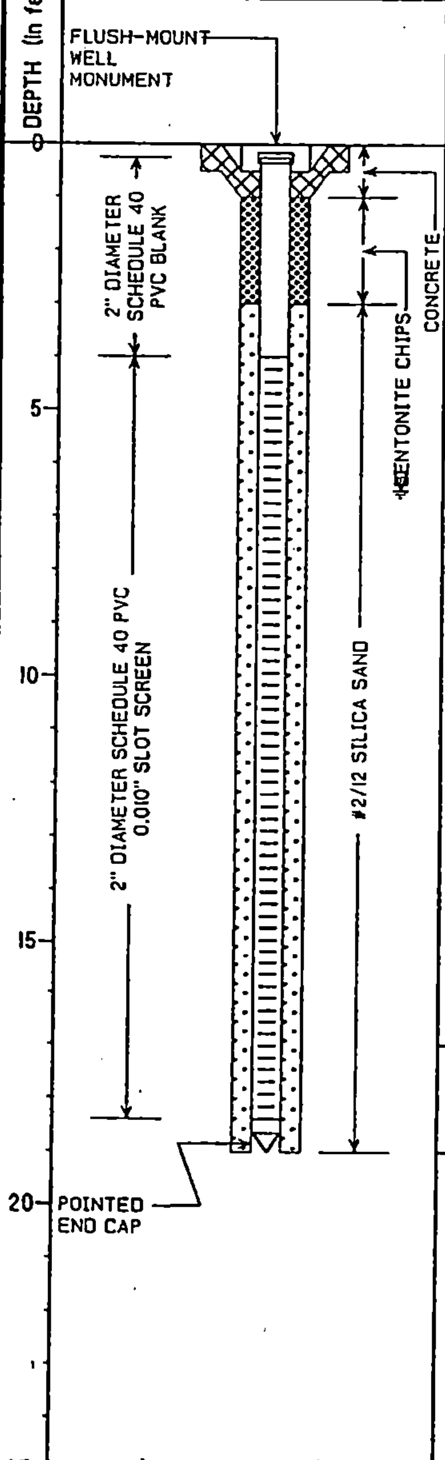
RETEC

WELL INSTALLATION LOG
Monitoring Well RMW-10

1011 S.W. Klickitat Way
Suite #207
Seattle, Washington 98134
(206) 624-9349

PROJECT NO: *3-3809-210 Roeder Avenue Landfill RI/FS*	CLIENT: *Port of Bellingham*
LOCATION: *Bellingham, Washington; South of Hilton*	DRILLING CO.: *Cascade Drilling*
START DATE: *10/29/98* TIME: *15:00* / BORING ID: *10 inches*	DRILLER: *Brian*
COMPLETION DATE: *10/29/98* TIME: *16:03* / TOTAL DEPTH: *19.0 feet bgs*	RIG TYPE: *CME-75*
WATER LEVEL DURING DRILLING: *6.5' bgs* / TOP OF CASING: *0.25 foot bgs*	METHOD: *Hollow-stem Auger*
SURFACE ELEV.: / MP ELEV.:	LOGGED BY: *J. Henley*

WELL CONSTRUCTION



SOIL DESCRIPTION

Depth (in feet)	U.S.C.S.	Soil Description
0	SP	GRAVELLY SAND; Damp; no odor. *5.0'* – Grades to sand; gray; fine- to medium-grained; trace to 5% medium to coarse gravel; trace silt; trace shell fragments; trace wood debris; 2-inch diameter piece of coal; very moist; no sheen; no odor. *7.5'–9.0'* – Grades to medium- to coarse-grained; 5% shell fragments; trace to 5% silt; trace fine to medium gravel; trace wood debris; saturated; no sheen; no odor. *8.5'* – 1-inch thick silty clay lense. *10.0'–11.5'* – As at 7.5 to 9.0 feet bgs; no clay lense.
~17	CL	SANDY SILTY CLAY; Gray; very saturated; plastic; no sheen; no odor.
19.0		Total depth = 19.0 feet bgs.

SAMPLE DATA

TYPE	DEPTH	BLOWS/6"	% RECOVERY	PID (ppm)
SS	☒ (5.0–6.5)	10 14 20	75	0
SS	☒ (7.5–9.0)	12 12 15	90	0
SS	☒ (10.0–11.5)	15 15 10	90	0
SS	☒ (15.0–16.5)	6 10 12	90	0

REMARKS: SS – Split Spoon
☒ – Sample Interval

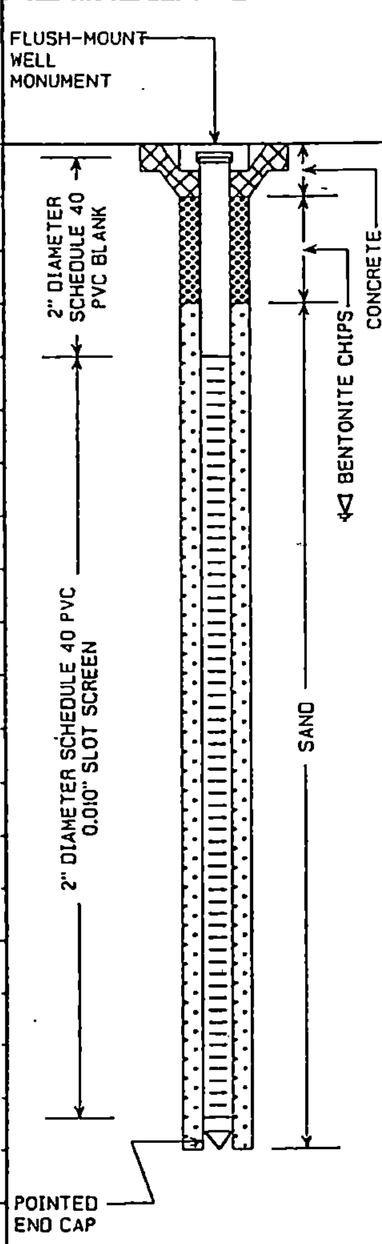
RETEC

WELL INSTALLATION LOG
Monitoring Well RMW-11

1011 S.W. Klickitat Way
Suite #207
Seattle, Washington 98134
(206) 624-9349

PROJECT NO: 3-3809-210 Roeder Avenue Landfill RI/FS		CLIENT: Port of Bellingham
LOCATION: Bellingham, Washington; BMI Property		DRILLING CO.: Cascade Drilling
START DATE: 11/03/98 TIME:	BORING ID: 10 inches	DRILLER: Brian
COMPLETION DATE: 11/03/98 TIME:	TOTAL DEPTH: 19.0 feet bgs	RIG TYPE: CME-75
WATER LEVEL DURING DRILLING: 7.0' bgs	TOP OF CASING: 0.25 foot bgs	METHOD: Hollow-stem Auger
SURFACE ELEV.:	MP ELEV.:	LOGGED BY: C. Alferness

WELL CONSTRUCTION



DEPTH (in feet)	U.S.C.S.	LITHOLOGY	SOIL DESCRIPTION	TYPE	DEPTH	BLOWS/6"	% RECOVERY	PID (ppm)
0			CONCRETE					
	SM		SILTY SAND; 30% gravel (large cobbles to pea sized); 15% silt; moist; no odor.					
			CONCRETE					
	SM		SILTY SAND; As at 0.75 feet bgs.					
5	ML		SILT; Black; 20% wood debris; hydrogen sulfide odor.					
			9.0'-19.0' – 20% sand; 10% gravel; 5% shells; trace silt; no odor.					
10								
15								
			Total depth = 19.0 feet bgs.					
20								
25								

REMARKS: ·Hand auger to a depth of 2.5 feet bgs.

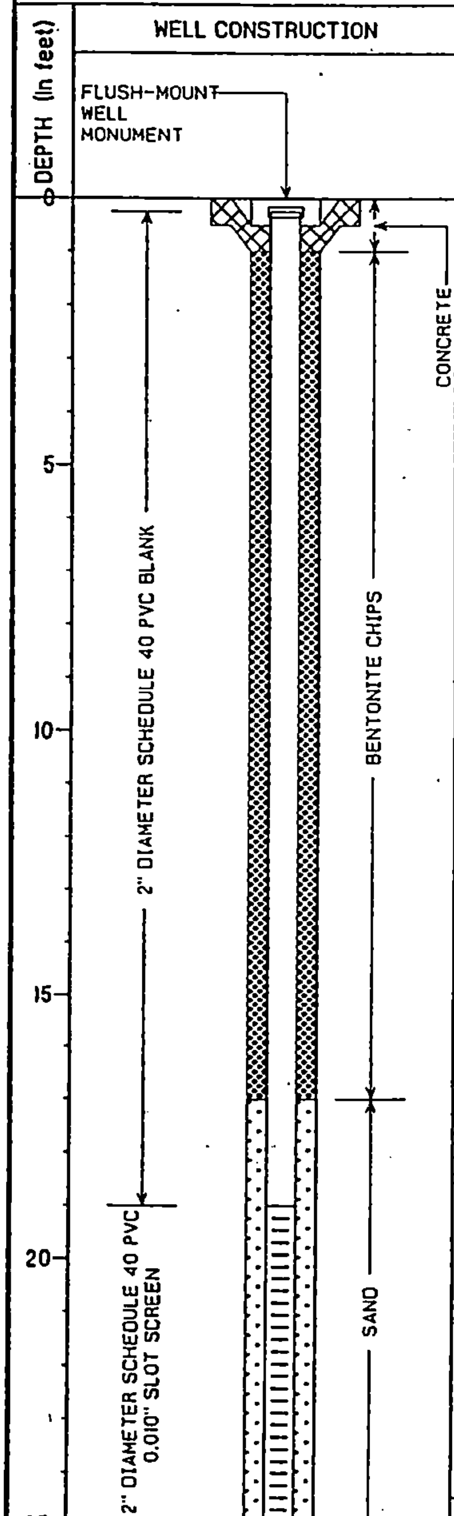
RETEC

WELL INSTALLATION LOG
Monitoring Well RMW-11D

1011 S.W. Klickitat Way
Suite #207
Seattle, Washington 98134
(206) 624-9349

PROJECT NO: 3-3809-210 Roeder Avenue Landfill RI/FS		CLIENT: Port of Bellingham
LOCATION: Bellingham, Washington; BMI Property, East of RMW-11		DRILLING CO.: Cascade Drilling
START DATE: 11/03/98 TIME: 08:30	BORING ID: 10 inches	DRILLER: Brian
COMPLETION DATE: 11/03/98 TIME:	TOTAL DEPTH: 29.0 feet bgs	RIG TYPE: CME-75
WATER LEVEL DURING DRILLING: ' bgs	TOP OF CASING: 0.25 foot bgs	METHOD: Hollow-stem Auger
SURFACE ELEV.:	MP ELEV.:	LOGGED BY: C. Alferness

WELL CONSTRUCTION



SOIL DESCRIPTION

U.S.C.S.	DESCRIPTION	TYPE	DEPTH	BLOWS/6"	% RECOVERY	PID (ppm)
	CONCRETE					
SM	SILTY SAND; 30% gravel (large cobbles to pea sized); 15% silt; moist; no odor.					
	CONCRETE					
SM	SILTY SAND; As at 0.75 feet bgs.					
ML	SILT; Black; 20% wood debris; trace gravel; garbage-like layer; hydrogen sulfide odor.					
	10.0' - Gray.					
	23.0'-24.0' - 20% gravel; 10% sand; 5% shell fragments; no odor.	SS	⊠	20 35 50	100	0
CL		SS	⊠	NR	100	

REMARKS: NR - Not Recorded
SS - Split Spoon
⊠ - Sample Interval

REMEDIATION TECHNOLOGIES, INC.
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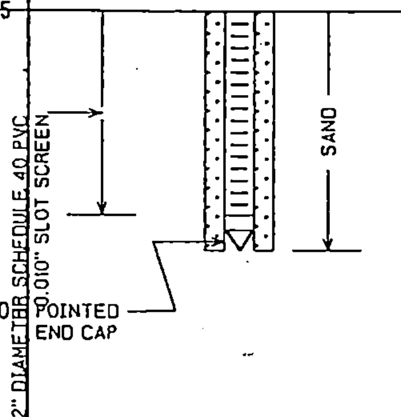
WELL INSTALLATION LOG
Monitoring Well RMW-11D

1011 S.W. Klickitat Way
Suite #207
Seattle, Washington 98134
(206) 624-9349

WELL CONSTRUCTION



DEPTH (in feet)	U.S.C.S.	LITHOLOGY	SOIL DESCRIPTION	TYPE	DEPTH	BLOWS/6"	% RECOVERY	PID (ppm)
25	CL		CLAY: Gray; plastic.					
	SP		SAND: Medium-grained; trace gravel. *26.5'-28.0'* - Fine- to medium-grained; trace silt; no odor.	SS		NR	100	0
	CL		CLAY: Gray; plastic; no odor.	SS		10 14 18	100	0
30			Total depth = 29.0 feet bgs.					
35								
40								
45								
50								

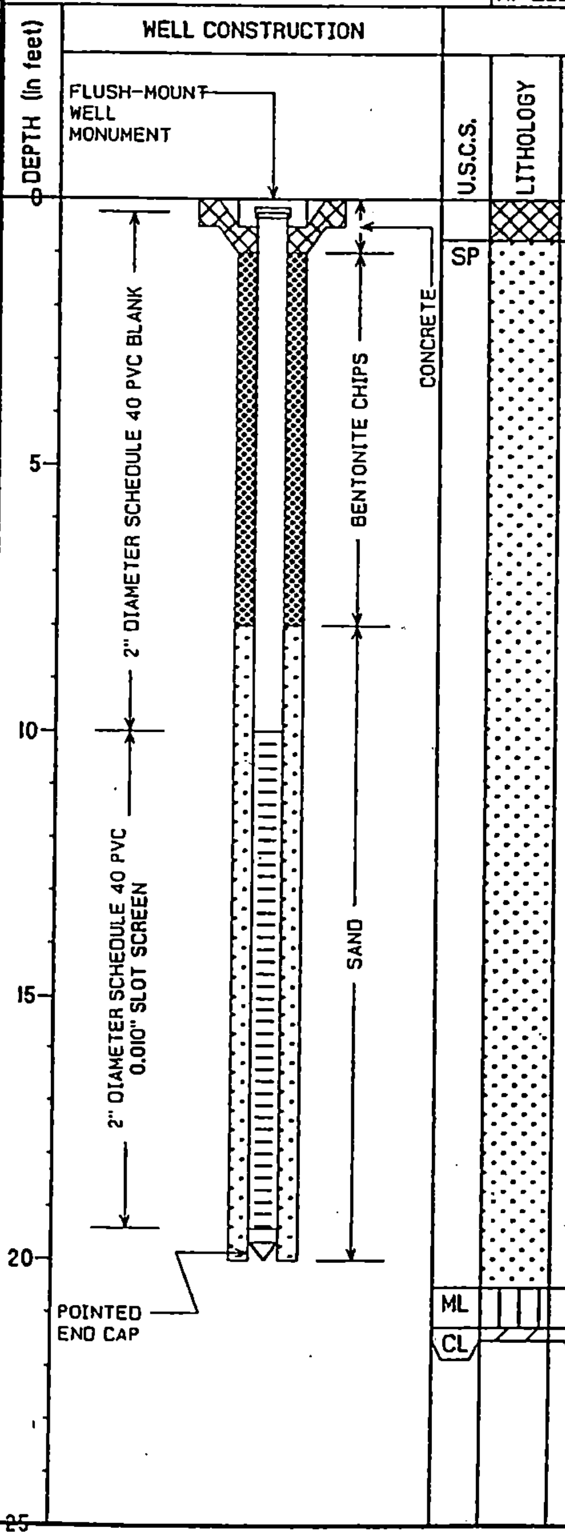
REMARKS: NR - Not Recorded
SS - Split Spoon
⊠ - Sample Interval

RETEC

WELL INSTALLATION LOG
Monitoring Well RMW-12D

1011 S.W. Klickitat Way
Suite #207
Seattle, Washington 98134
(206) 624-9349

PROJECT NO: *3-3809-210 Roeder Avenue Landfill RI/FS*		CLIENT: *Port of Bellingham*
LOCATION: *Bellingham, Washington; Off "C" Street*		DRILLING CO.: *Cascade Drilling*
START DATE: *11/02/98* TIME: *12:20*	BORING ID: *10 inches*	DRILLER: *Brian*
COMPLETION DATE: *11/02/98* TIME:	TOTAL DEPTH: *20.0 feet bgs*	RIG TYPE: *CME-75*
WATER LEVEL DURING DRILLING: *' bgs*	TOP OF CASING: *0.25 foot bgs*	METHOD: *Hollow-stem Auger*
SURFACE ELEV.:	MP ELEV.:	LOGGED BY: *C. Alferness*



U.S.C.S.	SOIL DESCRIPTION
	CONCRETE
SP	SAND; Brown; 10% gravel; no odor.
	5.0'-6.5' - Grades with trace shells; dry to moist; no odor.
	10.0'-11.0' - Gray; medium-grained; hydrogen sulfide odor.
	11.0'-11.5' - Grades to fine-grained; trace gravel; hydrogen sulfide odor.
	15.0'-16.5' - Grades to coarse-grained; 10% gravel; trace fines; no odor.
ML	SILT; Trace shells.
CL	CLAY; Gray; stiff.
	Total depth = 20.0 feet bgs.

SAMPLE DATA

TYPE	DEPTH	BLOWS/6"	% RECOVERY	PID (ppm)
SS	5.0'-6.5'	22, 28, 28	100	NR
SS	10.0'-11.5'	9, 10, 14	100	NR
SS	15.0'-16.5'	5, 9, 14	100	NR
SS		12, 20, 25	100	NR

REMARKS: Clay found at 21.25 feet bgs may be a lens.
NR - Not Recorded
SS - Split Spoon
⊠ - Sample Interval

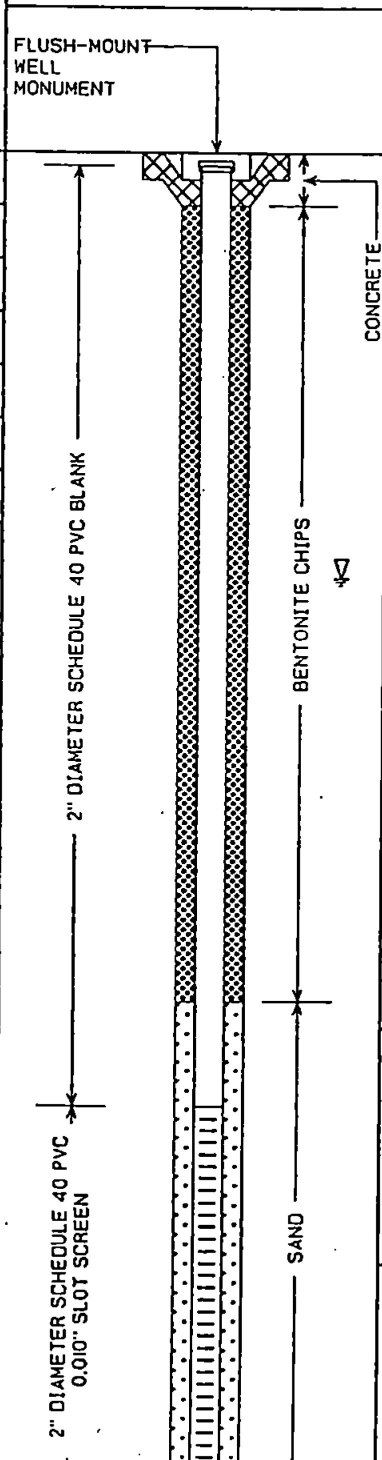
RETEC

WELL INSTALLATION LOG
Monitoring Well RMW-13D

1011 S.W. Klickitat Way
Suite #207
Seattle, Washington 98134
(206) 624-9349

PROJECT NO: *3-3809-210 Roeder Avenue Landfill RI/FS*		CLIENT: *Port of Bellingham*
LOCATION: *Bellingham, Washington; BMI Dock Area/Colony Wharf*		DRILLING CO.: *Cascade Drilling*
START DATE: *11/02/98* TIME: *10:20*	BORING ID: *10 inches*	DRILLER: *Brian*
COMPLETION DATE: *11/02/98* TIME:	TOTAL DEPTH: *29.0 feet bgs*	RIG TYPE: *CME-75*
WATER LEVEL DURING DRILLING: *8.0' bgs*	TOP OF CASING: *0.25 foot bgs*	METHOD: *Hollow-stem Auger*
SURFACE ELEV.:	MP ELEV.:	LOGGED BY: *C. Alferness*

WELL CONSTRUCTION



SOIL DESCRIPTION / SAMPLE DATA

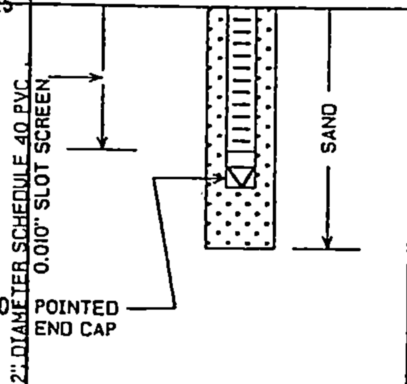
DEPTH (in feet)	U.S.C.S.	SOIL DESCRIPTION	TYPE	BLOWS/6"	% RECOVERY	PID (ppm)
0	SP	GRAVELLY SAND (FILL); Dark brown; trace silt; moist; no sheen; no odor.				
5			SS	20 18 12	75	0
	SP	SAND; Red; coarse-grained; trace silt and gravel; dry to moist; highly oxidized; no sheen; no odor.				
10		*10.0'-11.5'* - Gray; grades to very coarse-grained; with trace gravel; trace silt; saturated; no sheen; no odor.	SS	15 18 20	100	11
15			SS	5 12 25	100	13
	GP	GRAVEL; With 30% sand; trace silt; sautrated; no sheen; no odor.				
20		*20.0'-21.0'* - Grades with 10% silt.	SS	20 50	75	11
	SP	SAND; Gray; fine-grained; 5% silt; 5% shells; saturated; no sheen; no odor.				
25						

REMARKS: SS - Split Spoon
⊠ - Sample Interval

WELL INSTALLATION LOG
Monitoring Well RMW-13D

RETEC
1011 S.W. Klickitat Way
Suite #207
Seattle, Washington 98134
(206) 624-9349

WELL CONSTRUCTION



DEPTH (in feet)	U.S.C.S.	SOIL DESCRIPTION	TYPE	BLOWS/6"	% RECOVERY	PID (ppm)
25	SP					
	CL	CLAY: Gray; plastic; no sheen; no odor.	SS	14 40 22	100	14.5
	SP	SAND: Coarse-grained; 15% gravel; trace silt; no sheen; no odor.				
	CL	CLAY: Gray; plastic; no sheen; no odor.	SS	8 14 18	100	10.3
30		Total depth = 29.0 feet bgs.				
35						
40						
45						
50						

REMARKS: SS – Split Spoon
⊠ – Sample Interval

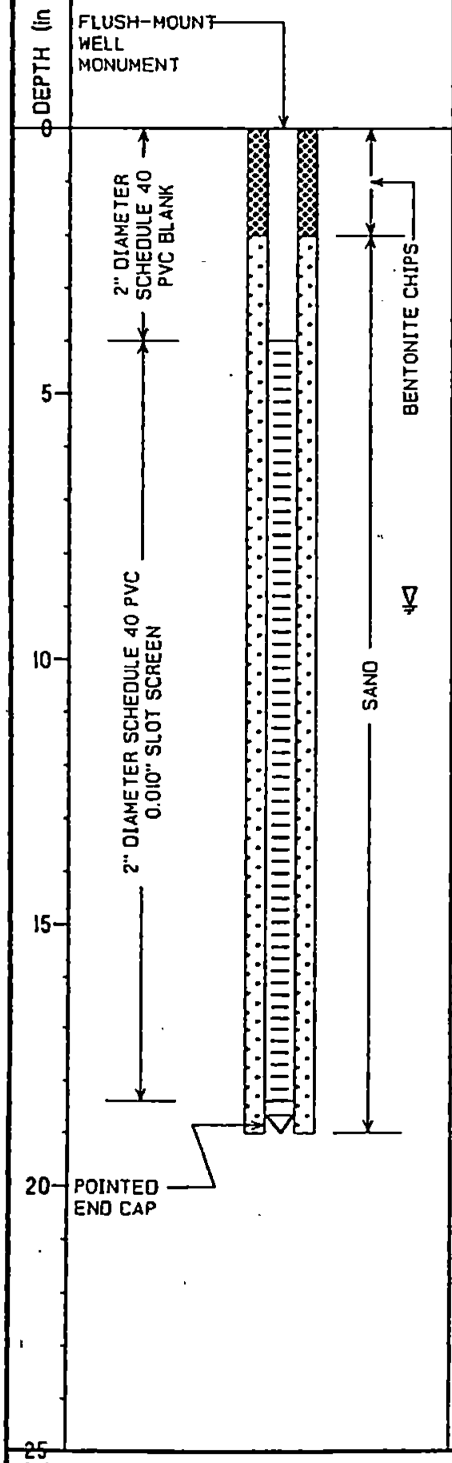
RETEC

WELL INSTALLATION LOG
Monitoring Well RMW-14

1011 S.W. Klickitat Way
Suite #207
Seattle, Washington 98134
(206) 624-9349

PROJECT NO: 3-3809-210 Roeder Avenue Landfill RI/FS		CLIENT: Port of Bellingham
LOCATION: Bellingham, Washington; Parking Lot next to San. Serv.		DRILLING CO.: Cascade Drilling
START DATE: 10/27/98 TIME: 15:00	BORING ID: 10 inches	DRILLER: Brian
COMPLETION DATE: 10/27/98 TIME:	TOTAL DEPTH: 19.0 feet bgs	RIG TYPE: CME-75
WATER LEVEL DURING DRILLING: 9.0' bgs	TOP OF CASING: Flush-mount	METHOD: Hollow-stem Auger
SURFACE ELEV.:	MP ELEV.:	LOGGED BY: C. Alferness

DEPTH (in feet) | WELL CONSTRUCTION



SOIL DESCRIPTION

Depth (ft)	U.S.C.S.	Soil Description
0		ASPHALT
	SP	SAND; Brown; with 10% gravel; dry to moist; no odor.
		9.0' – Saturation.
		10.0'–11.0' – Gray; grades to medium- to coarse-grained gravelly sand; saturated; loose.
		11.0'–11.5' – Grades to medium- to fine-grained.
		15.0'–16.0' – Grades with trace shells.
	CL	SILTY CLAY; Gray; plastic.
19.0		Total depth = 19.0 feet bgs.

SAMPLE DATA

Depth (ft)	TYPE	BLOWS/6"	% RECOVERY	PID (ppm)
5	SS	12 / 10 / 17	75	0
10	SS	30 / 20 / 20	100	0
15	SS	8 / 10 / 12	100	0

REMARKS: SS – Split Spoon
⊠ – Sample Interval

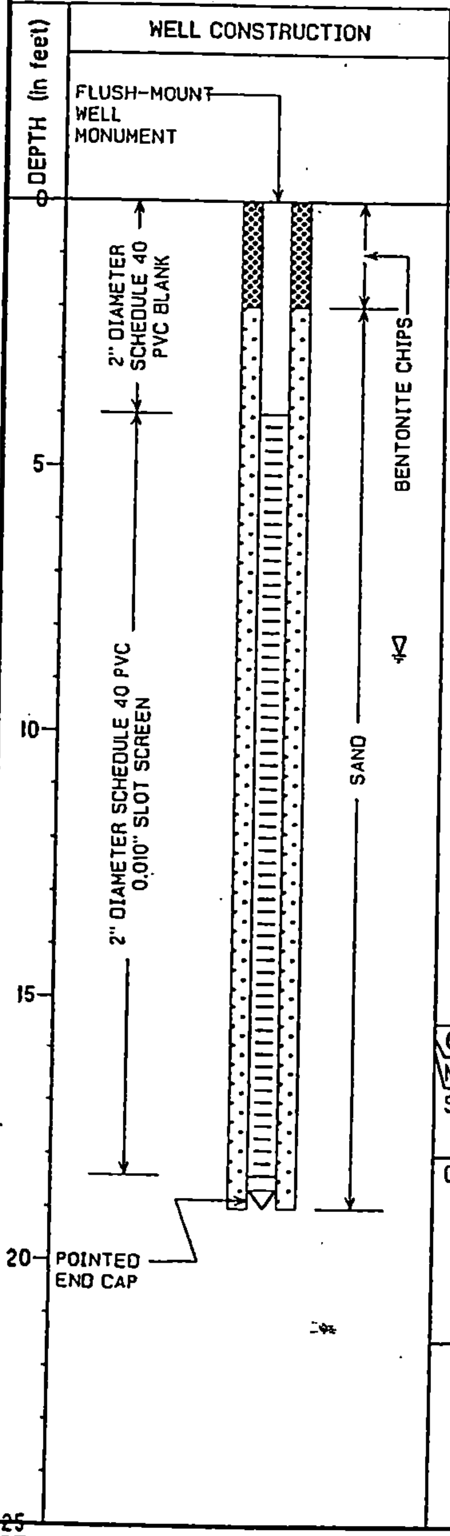
RETEC

WELL INSTALLATION LOG
Monitoring Well RMW-15

1011 S.W. Klickitat Way
Suite #207
Seattle, Washington 98134
(206) 624-9349

PROJECT NO: 3-3809-210 Roeder Avenue Landfill RI/FS		CLIENT: Port of Bellingham
LOCATION: Bellingham, Washington; Off Hilton Avenue		DRILLING CO.: Cascade Drilling
START DATE: 10/28/98 TIME: 09:50	BORING ID: 10 inches	DRILLER: Brian
COMPLETION DATE: 10/28/98 TIME:	TOTAL DEPTH: 19.0 feet bgs	RIG TYPE: CME-75
WATER LEVEL DURING DRILLING: 8.5' bgs	TOP OF CASING: Flush-mount	METHOD: Hollow-stem Auger
SURFACE ELEV.:	MP ELEV.:	LOGGED BY: C. Alferness

WELL CONSTRUCTION



SOIL DESCRIPTION / SAMPLE DATA

U.S.C.S.	Soil Description	Type	Blows/6"	% Recovery	PID (ppm)
SP	SAND; Brown; with 20% gravel; dry to moist; no odor.				
	5.0'–5.5' – Yellow-brown; medium-grained; 5% gravel; dry to moist; no odor. 5.5'–6.5' – Gray; fine-grained; trace silt; dry to moist; no odor.	SS	30 35 35	100	0
	7.5'–8.5' – Trace wood debris. 8.5'–9.0' – Gray to dark gray; medium-grained; 15% gravel; trace wood; saturated; organic odor.	SS	10 18 19	100	20
	10.0'–11.0' – Grades with trace shells; trace wood debris. 11.0'–11.5' – Gray; grades to fine-grained; trace shells; saturated; no odor.	SS	48 50	100	80
	12.5'–14.0' – Grades with trace silt.	SS	15 25 20	100	620
CL	CLAY; Gray; plastic.	SS	20 50	NR	NR
ML	SILT; Gray; with 20% sand; trace wood; saturated.				
SP	SAND; Gray; medium-grained; trace shells; no odor.				
CL	CLAY; Gray; trace shells; saturated; plastic.	SS	10 15 25	NR	NR

Total depth = 19.0 feet bgs.

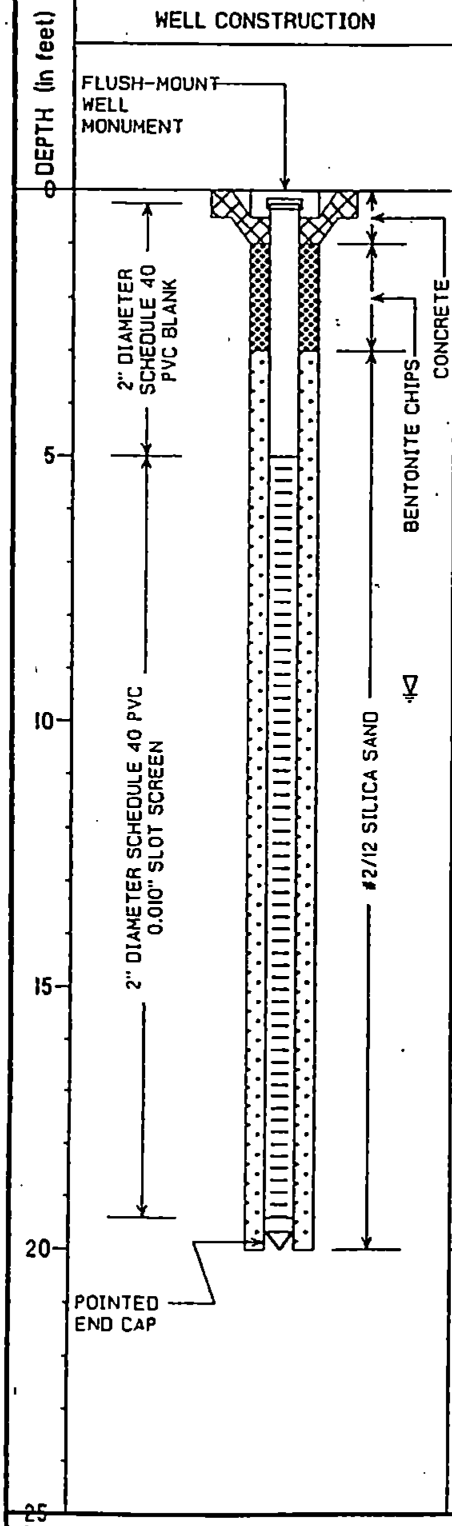
REMARKS: NR – Not Recorded
SS – Split Spoon
⊠ – Sample Interval

REMEDIATION TECHNOLOGIES, INC.
A Thermo Electron Company

WELL INSTALLATION LOG
Monitoring Well RMW-16

RETEC
1011 S.W. Klickitat Way
Suite #207
Seattle, Washington 98134
(206) 624-9349

PROJECT NO: 3-3809-210 Roeder Avenue Landfill RI/FS		CLIENT: Port of Bellingham
LOCATION: Bellingham, Washington;		DRILLING CO.: Cascade Drilling
START DATE: 10/29/98 TIME: 08:30	BORING ID: 10 inches	DRILLER: Brian
COMPLETION DATE: 10/29/98 TIME:	TOTAL DEPTH: 20.0 feet bgs	RIG TYPE: CME-75
WATER LEVEL DURING DRILLING: 9.5' bgs	TOP OF CASING: 0.25 foot bgs	METHOD: Hollow-stem Auger
SURFACE ELEV.:	MP ELEV.:	LOGGED BY: J. Henley



U.S.C.S.	LITHOLOGY	SOIL DESCRIPTION	TYPE	DEPTH	BLOWS/6"	% RECOVERY	PID (ppm)
		TOPSOIL; With gravel.					
		GARBAGE; With sand and silt.					
ML		SANDY SILT; Gray; very saturated; pudding-like cuttings.					
		Total depth = 20.0 feet bgs.					

REMARKS:

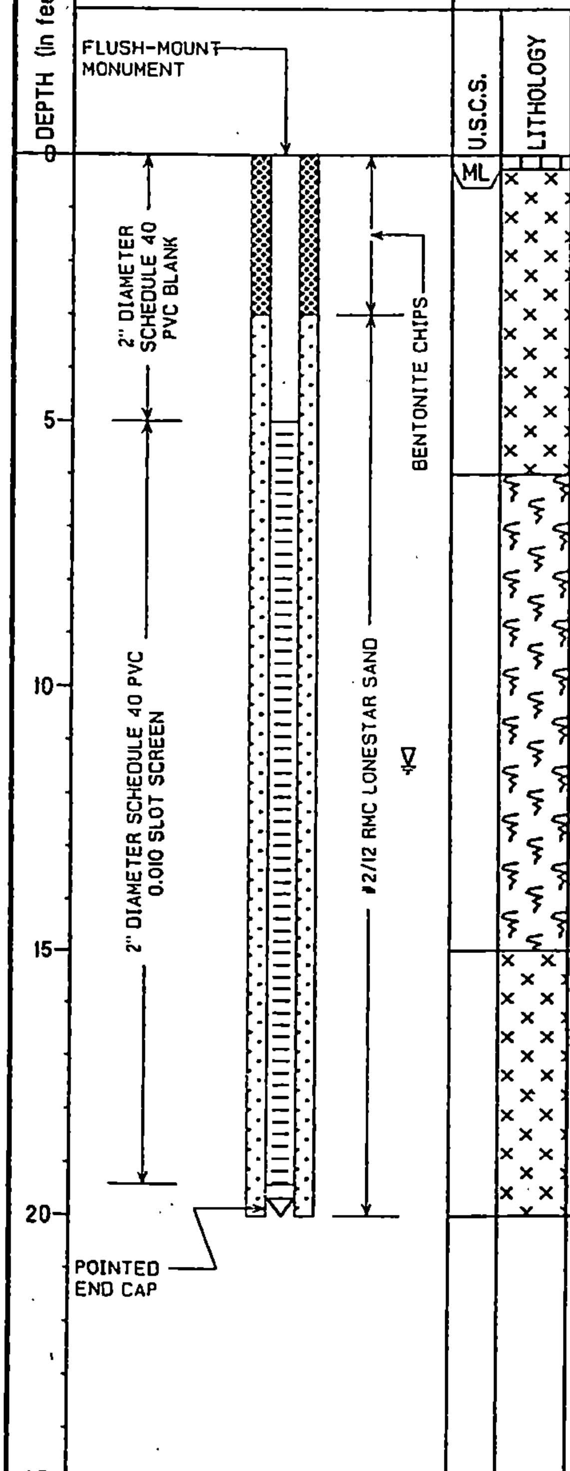
RETEC

WELL INSTALLATION LOG
Monitoring Well RMW-17

1011 S.W. Klickitat Way
Suite #207
Seattle, Washington 98134
(206) 624-9349

PROJECT NO: *3-3809-210 Roeder Avenue Landfill RI/FS*		CLIENT: *Port of Bellingham*
LOCATION: *Bellingham, Washington; Roeder Avenue and "F" Street*		DRILLING CO.: *Cascade Drilling*
START DATE: *10/26/98* TIME: *09:30*	BORING ID: *10 inches*	DRILLER: *Brian*
COMPLETION DATE: *10/26/98* TIME: *10:22*	TOTAL DEPTH: *20.0 feet bgs*	RIG TYPE: *CME-75*
WATER LEVEL DURING DRILLING: *11.5' bgs*	TOP OF CASING: *Flush-mount*	METHOD: *Hollow-stem Auger*
SURFACE ELEV.:	MP ELEV.:	LOGGED BY: *C. Alferness*

WELL CONSTRUCTION



SOIL DESCRIPTION

U.S.C.S.	Soil Description
ML	SILT; 20% gravel; moist; loose; sewer-like odor, but not hydrogen sulfide.
	WOOD MULCH; Red; some plastic bags; moist; loose; slight petroleum, slight hydrogen sulfide odor.
	GARBAGE; Black; plastic bags; moist; loose; slight petroleum-like, slight hydrogen sulfide odor. *8.0'-9.0'* – Rag in split spoon. *11.5'* – Saturated.
	WOOD DEBRIS; Black; saturated. *18.0'* – Difficult drilling.
	Total depth = 20.0 feet bgs.

SAMPLE DATA

TYPE	DEPTH	BLOWS/6"	% RECOVERY	PID (ppm)
SS	8.0–9.0	30 50/4"	20	
SS	10.0–11.0	100/2"	0	0

REMARKS: SS – Split Spoon
⊠ – Sample Interval

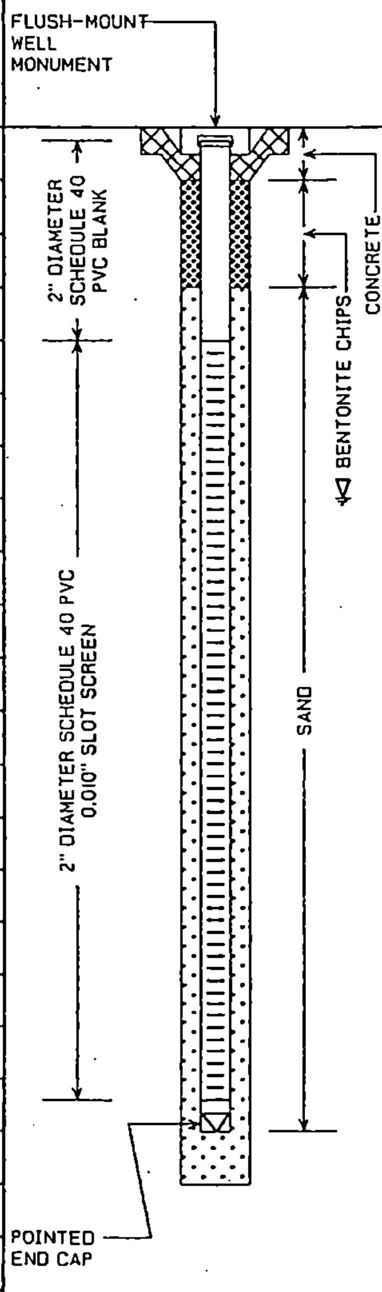
RETEC

WELL INSTALLATION LOG
Monitoring Well RMW-18

1011 S.W. Klickitat Way
Suite #207
Seattle, Washington 98134
(206) 624-9349

PROJECT NO: 3-3809-210 Roeder Avenue Landfill RI/FS		CLIENT: Port of Bellingham
LOCATION: Bellingham, Washington; Off "C" Street by Sump Station		DRILLING CO.: Cascade Drilling
START DATE: 10/30/98 TIME: 08:30	BORING ID: 10 inches	DRILLER: Brian
COMPLETION DATE: 10/30/98 TIME:	TOTAL DEPTH: 19.0 feet bgs	RIG TYPE: CME-75
WATER LEVEL DURING DRILLING: 7.0' bgs	TOP OF CASING: 0.25 foot bgs	METHOD: Hollow-stem Auger
SURFACE ELEV.:	MP ELEV.:	LOGGED BY: C. Alferness

WELL CONSTRUCTION



DEPTH (in feet)	U.S.C.S.	SOIL DESCRIPTION	TYPE	DEPTH	BLOWS/6"	% RECOVERY	PID (ppm)
0		ASPHALT					
	SP	SAND; Brown; 25% cobble-sized gravel; 10% silt; dry; loose; no odor.					
	ML	CLAYEY SANDY SILT; Dark gray; trace shells (dredge fill); dry; loose; no odor.					
5	ML	SILT; Brown; moist; no odor. 7.0' – Saturation.					
	SP	SAND WITH SILT AND GRAVEL; Medium-grained; with 2- to 3-inch lenses of clayey silt; 5% shell fragments; fine to coarse gravel; saturated; no sheen; no odor.	SS	⊠	5 8 14	100	NR
10							
15							
		Total depth = 19.0 feet bgs.					
20							
25							

REMARKS:
NR – Not Recorded
SS – Split Spoon
⊠ – Sample Interval

REMEDIATION TECHNOLOGIES, INC.
A Thermo Electron Company

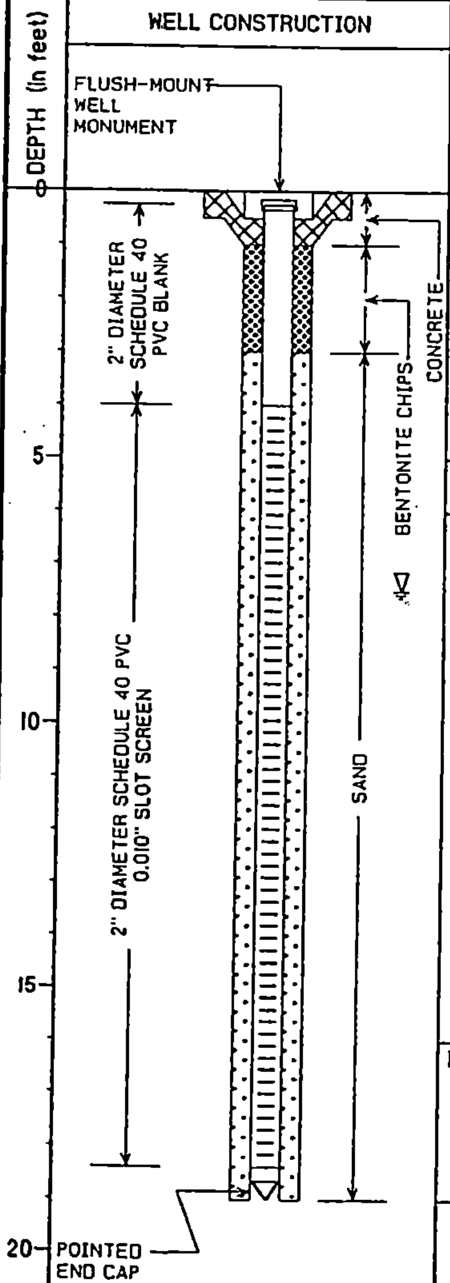
WELL INSTALLATION LOG
Monitoring Well RMW-20

RETEC

1011 S.W. Klickitat Way
Suite #207
Seattle, Washington 98134
(206) 624-9349

PROJECT NO: 3-3809-210 Roeder Avenue Landfill RI/FS	CLIENT: Port of Bellingham
LOCATION: Bellingham, Washington; Boat Yard	DRILLING CO.: Cascade Drilling
START DATE: 10/28/98 TIME: 12:45 — BORING ID: 10 inches	DRILLER: Brian
COMPLETION DATE: 10/28/98 TIME: 13:50 — TOTAL DEPTH: 19.0 feet bgs	RIG TYPE: CME-75
WATER LEVEL DURING DRILLING: 7.5' bgs — TOP OF CASING: 0.25 foot bgs	METHOD: Hollow-stem Auger
SURFACE ELEV.: — MP ELEV.:	LOGGED BY: J. Henley

WELL CONSTRUCTION



SOIL DESCRIPTION / SAMPLE DATA

Depth (ft)	U.S.C.S.	Soil Description	Type	Depth	Blows/6"	% Recovery	PID (ppm)
0		ASPHALT					
0–5	SP	SAND: Gray; 20% gravel; trace shells; moist.					
5–6	ML	SILT: 20% sand; 15% gravel; 5% shells; dry; no odor.	SS	☒	14 30 50/5"	100	0
6–16	SP	SAND: Medium-grained; trace silt and shells; dry; no odor. 15.0'–15.5' – Saturated; no odor. 15.5'–16.0' – Fine-grained; trace silt; saturated; no odor.	SS	☒	5 17 50/5"	100	0
16–19	ML	SILT: 20% wood fragments; saturated; hydrogen sulfide odor.					
19		Total depth = 19.0 feet bgs.					

REMARKS: Drilled at "abnormal" high tide.
SS – Split Spoon
☒ – Sample Interval

REMEDIATION TECHNOLOGIES, INC.
A Thermo Electron Company

Survey Coordinates

Survey Data

Point	Northing	Easting	Elevation	Description
2713	643722.8	1600490.3	28.69	RGP-4(W) GROUND=26.3
2737	643544.4	1600463.9	25.44	RGP-3(W) GROUND=23.3
2738	643694.9	1600650.7	27.9	RGP-2(W) GROUND=25.8
2739	643854.3	1600823.7	29.08	RGP-1(W) GROUND=26.5
5027	643872.7	1600961.5	31.9	C\L MW 98-3(GW) GROUND=27.6
5047	643417.8	1600462.6	24.3	C\L MW 98-1(GW) GROUND=21.7
6004	644633	1600763.8	17.94	C\L RMW-14
6005	644520.3	1600547.3	17.25	C\L RMW-15
6008	644048.8	1599770.6	14.62	C\L RMW-20
6009	644039.1	1600084.7	16.72	C\L MW-1(E) GROUND=14.5
6010	644510.7	1600066.8	18.14	C\L MW 4(O) GROUND=15.5
6011	644633	1600295.2	18.7	C\L MW 3(O) GROUND=15.8
6012	644744.3	1600438.5	18.35	C\L MW 1(O) GROUND=15.7
6013	644160.5	1600391.9	15.76	C\L RMW-9
6014	644331.8	1600221.5	11.74	C\L RMW-10
6017	643744	1599942.9	15.61	C\L RMW-3D
6018	643725.1	1600084.3	22.39	C\L RMW-2
6019	643727	1600095.8	22.39	C\L RMW-2D
6020	643763.9	1600287.1	26.41	C\L RMW-1
6022	643546.8	1600145.1	22.27	C\L RMW-4
6023	643426.3	1600284.7	21.67	C\L RMW-5
6025	644254.7	1601141.8	17.51	C\L RMW-16
6026	644180	1600866.4	21.14	C\L RMW-17
6027	643978.5	1600610.6	25.27	C\L RMW-8
6030	644040.5	1601312.3	13.02	C\L MW 5(B)
6033	643653.4	1601289	13.07	C\L MW 4(B)
6034	643659.5	1601284.7	13.19	C\L RMW-12D
6035	643739	1601465.6	14.88	C\L RMW-18
6038	643720.1	1601095.9	13.92	C\L MW 8(B)
6039	643749.1	1601070.4	13.82	C\L RMW-11
6040	643752.3	1601075.3	13.44	C\L RMW-11D
6041	643988.8	1601176.3	12.16	C\L MW 12(B)
6044	642919	1600851.9	12.97	C\L MW 7A(C)
6045	643442.3	1600991.8	13.15	C\L MW 10(B)
6046	643166	1600583.3	13.91	C\L RMW-6D
6047	643159.1	1600587.5	14.01	C\L MW 55(C)
6048	643037.9	1600647.3	14.67	C\L RMW-7
6049	643035.1	1600644.7	14.5	C\L RMW-7D
6053	643344.7	1601342.5	12.93	C\L RMW-13D
6054	643340.7	1601347.5	13.06	C\L MW 3(B)
6055	643334.1	1601411.2	13.09	STILLING GAUGE
6059	643330.4	1600742.3	14.29	C\L MW 53(C)
6060	643533	1600849.2	14.13	C\L MW 19(B)
6061	643604.9	1600905.4	13.62	C\L MW 7(B)
6062	643165.2	1601177.2	12.15	C\L MW 1(B)
6063	643239.8	1601077.3	14.71	C\L MW 50(C)
6064	643143.6	1600793.3	13.95	C\L MW 11A(C)

6066	643064.7	1600926.6	13.43	C\L MW 60(C)
6067	643136.4	1600844.9	14.06	C\L MW 10A(C)
6068	643012.8	1600728	14.2	C\L MW 12A(C)

Table B-1: Groundwater Analytical Data Collected During the RI/FS

Parameter	Controlling ARAR	MW-3(B)				MW-4(0)				MW-4(B)				MW-55(C)			
		2/10/99	4/14/99	8/11/99	11/4/99	2/10/99	4/13/99	8/10/99	11/4/99	2/9/99	4/13/99	8/11/99	11/3/99	2/10/99	4/14/99	8/10/99	8/10/99 Duplicate
Conventionals - Geochemical Parameters (mg/L)																	
Total Dissolved Solids	—	12,000	2,000	1,800	15,000	1,800	1,600	1,300	1,300	1,000	770	830	1,100	620	630	550	530
Total Suspended Solids	—	3.5	< 1	1.2	7.1	24	17	16	5.5	25	18	37	42	78	34	46	44
Total Organic Carbon	—	3.7	17	16	7.2	28	26	24	24	7.5	11	16	20	18	16	16	17
N-Ammonia (mg-N/L)	—	0.81	17	16	23	12	12	12	11	2.8	2.7	2.6	3.2	1.9	2	2.3	2.2
Nitrate + Nitrite (mg-N/L)	—	0.6	0.2	3.6	3.2	0.027	< 0.01	0.044	< 0.01	0.21	0.011	0.014	0.19	0.014	< 0.05	0.017	0.018
Calcium	—	138	84.4	69.8	310	192	208	162	160	232	220	224	255	155	166	158	154
Chloride	—	7,400	700	610	9,000	280	320	400	170	17	16	43	100	14	16	14	14
Iron	—	0.04	3.49	0.25	0.03	5.29	6.17	5.45	5.21	22.1	23.6	24.3	27.6	24.7	27	23.1	22.7
Ferrous Iron	—	< 0.04	4.4	0.31	0.17	3.8	6.7	6.2	5.7	23	24	26	29	12	27	24	24
Magnesium	—	390	91.7	76.8	550	75.6	77.2	57.4	56.4	19	17.9	18.6	23.7	19.2	18.9	15.4	15.5
Manganese	—	0.002	0.239	0.108	0.49	1.37	1.46	1.07	1.09	0.853	0.803	0.771	0.881	3.54	3.66	3.02	2.8
Sodium	—	NA	NA	519	4,000	NA	NA	242	197	NA	NA	55.5	80.7	NA	NA	32.5	33.3
Sulfate	—	NA	NA	NA	1,200	NA	NA	NA	16	NA	NA	NA	47	NA	NA	NA	NA
Sulfide	—	< 0.1	< 0.05	< 0.05	< 0.05	< 0.1	< 0.05	< 0.05	< 0.05	< 0.09	0.39	< 0.05	< 0.05	< 0.1	< 0.05	< 0.05	< 0.05
Alkalinity	—	110	830	650	220	1,300	1,200	950	960	240	510	700	720	510	480	480	490
Metals (mg/L)																	
Arsenic	0.005	< 0.005	0.001	0.002	< 0.005	< 0.001	< 0.001	< 0.001	< 0.001	0.016	0.02	0.021	0.021	0.019	0.021	0.046	0.046
Barium	500	0.024	0.006	0.006	0.043	0.038	0.039	0.029	0.025	0.026	0.025	0.029	0.04	0.034	0.037	0.047	0.045
Chromium	162	< 0.005	0.028	0.026	< 0.005	0.034	0.028	0.039	0.045	0.007	0.006	0.016	0.03	0.042	0.048	0.057	0.052
Hexavalent Chrome	0.05	< 0.01	< 0.01	< 0.01	< 0.01	< 0.1	< 0.11	< 0.01	< 0.01	< 0.06	< 0.06	< 0.01	0.02	< 0.1	0.02	< 0.01	< 0.01
Copper	0.0031	0.01	0.03	0.026	0.018	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002
Lead	0.0081	< 0.001	< 0.001	< 0.001	< 0.005	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Mercury	0.00005	< 0.0001	< 0.0002	0.0001	< 0.0001	< 0.0001	< 0.0002	< 0.0001	< 0.0001	< 0.0001	< 0.0002	< 0.0001	< 0.0001	< 0.0001	< 0.0002	< 0.0001	< 0.0001
Nickel	0.0082	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Zinc	0.081	0.028 B	0.015 B	0.012	0.047	0.008 B	0.531	< 0.004	< 0.006	0.044 B	0.011 B	0.005	0.008	0.019 B	0.008 B	0.008	0.007
Other Contaminants (mg/L)																	
Weak Acid Dissoc. Cyanide	0.0028	< 0.005	< 0.005	< 0.005	0.006	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	0.008	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005
Diesel Range Hydrocarbons	0.5	< 0.25	< 0.25	< 0.25	< 0.25	< 0.25	< 0.25	< 0.25	< 0.25	< 0.25	< 0.25	< 0.25	< 0.25	0.26	0.3	0.26	0.26
Semivolatile Organics (EPA Method 8270) (µg/L)																	
1,2,4-Trichlorobenzene	227	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
1,2-Dichlorobenzene	4,200	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
1,3-Dichlorobenzene	2,600	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
1,4-Dichlorobenzene	4.86	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
2,2'-Oxybis(1-Chloropropane)	—	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
2,4,5-Trichlorophenol	—	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5
2,4,6-Trichlorophenol	3.93	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5
2,4-Dichlorophenol	191	< 3	< 3	< 3	< 3	< 3	< 3	< 3	< 3	< 3	< 3	< 3	< 3	< 3	< 3	< 3	< 3
2,4-Dimethylphenol	553	< 3	< 3	< 3	< 3	< 3	< 3	< 3	< 3	< 3	< 3	< 3	< 3	< 3	< 3	< 3	< 3
2,4-Dinitrophenol	3,460	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10
2,4-Dinitrotoluene	9.1	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5
2,6-Dinitrotoluene	—	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5
2-Chloronaphthalene	—	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
2-Chlorophenol	97	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
2-Methylnaphthalene	—	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
2-Methylphenol	—	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2
2-Nitroaniline	—	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5
2-Nitrophenol	—	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5
3,3'-Dichlorobenzidine	0.0462	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5
3-Nitroaniline	—	< 6	< 6	< 6	< 6	< 6	< 6	< 6	< 6	< 6	< 6	< 6	< 6	< 6	< 6	< 6	< 6
4,6-Dinitro-2-Methylphenol	765	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10
4-Bromophenyl-phenylether	—	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
4-Chloro-3-methylphenol	—	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2
4-Chloroaniline	—	< 3	< 3	< 3	< 3	< 3	< 3	< 3	< 3	< 3	< 3	< 3	< 3	< 3	< 3	< 3	< 3
4-Chlorophenyl-phenylether	—	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
4-Methylphenol	—	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	2.9	< 1	< 1	< 1	< 1	< 1	< 1
4-Nitroaniline	—	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5
4-Nitrophenol	—	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5

Table B-1: Groundwater Analytical Data Collected During the RI/FS

Parameter	Controlling ARAR	MW-3(B)				MW-4(0)				MW-4(B)				MW-55(C)			
		2/10/99	4/14/99	8/11/99	11/4/99	2/10/99	4/13/99	8/10/99	11/4/99	2/9/99	4/13/99	8/11/99	11/3/99	2/10/99	4/14/99	8/10/99	8/10/99 Duplicate
Semivolatile Organics (EPA Method 8270) (µg/L)																	
Acenaphthene	643	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
Acenaphthylene	—	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
Anthracene	25,900	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
Benzo(a)anthracene	0.0296	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
Benzo(a)pyrene	0.0296	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
Benzo(b)fluoranthene	0.0296	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
Benzo(g,h,i)perylene	—	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
Benzo(k)fluoranthene	0.0296	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
Benzoic Acid	—	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10
Benzyl Alcohol	—	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5
bis(2-Chloroethoxy) Methane	—	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
Bis-(2-Chloroethyl) Ether	0.854	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2
bis(2-Ethylhexyl)phthalate	3.56	**9**	< 1	< 1	< 1	2	**5.5**	< 1	< 1	1.4	**6**	< 1	< 1	< 1	< 1	< 1	< 1
Butylbenzylphthalate	1,250	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
Carbazole	—	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
Chrysene	0.0296	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
Dibenz(a,h)anthracene	0.0296	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
Dibenzofuran	—	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
Diethylphthalate	28,400	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
Dimethylphthalate	72,000	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
Di-n-Butylphthalate	2,910	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
Di-n-Octyl phthalate	—	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
Fluoranthene	90.2	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
Fluorene	3,460	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
Hexachlorobenzene	0.000466	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
Hexachlorobutadiene	29.9	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2
Hexachlorocyclopentadiene	4,180	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5
Hexachloroethane	5.33	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2
Indeno(1,2,3-cd)pyrene	0.0296	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
Isophorone	600	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
Naphthalene	9,880	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
Nitrobenzene	449	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
N-Nitroso-di-n-propylamine	0.819	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2
N-Nitrosodiphenylamine	9.73	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
Pentachlorophenol	4.91	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5
Phenanthrene	—	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
Phenol	1,110,000	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2
Pyrene	2,590	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
Volatile Organics (EPA Method 8260) (µg/L)																	
1,1,1,2-Tetrachloroethane	—	< 1	NA	NA	NA	< 1	NA	NA	NA	< 1	NA	NA	NA	< 1	NA	NA	NA
1,1,1-Trichloroethane	417,000	< 1	NA	NA	NA	< 1	NA	NA	NA	< 1	NA	NA	NA	< 1	NA	NA	NA
1,1,2,2-Tetrachloroethane	6.48	< 1	NA	NA	NA	< 1	NA	NA	NA	< 1	NA	NA	NA	< 1	NA	NA	NA
1,1,2-Trichloroethane	25.3	< 1	NA	NA	NA	< 1	NA	NA	NA	< 1	NA	NA	NA	< 1	NA	NA	NA
1,1,2-Trichlorotrifluoroethane	—	< 2	NA	NA	NA	< 2	NA	NA	NA	< 2	NA	NA	NA	< 2	NA	NA	NA
1,1-Dichloroethane	—	< 1	NA	NA	NA	< 1	NA	NA	NA	< 1	NA	NA	NA	< 1	NA	NA	NA
1,1-Dichloroethene	1.93	< 1	NA	NA	NA	< 1	NA	NA	NA	< 1	NA	NA	NA	< 1	NA	NA	NA
1,1-Dichloropropene	—	< 1	NA	NA	NA	< 1	NA	NA	NA	< 1	NA	NA	NA	< 1	NA	NA	NA
1,2,3-Trichlorobenzene	—	< 5	NA	NA	NA	< 5	NA	NA	NA	< 5	NA	NA	NA	< 5	NA	NA	NA
1,2,3-Trichloropropane	—	< 1	NA	NA	NA	< 1	NA	NA	NA	< 1	NA	NA	NA	< 1	NA	NA	NA
1,2,4-Trichlorobenzene	227	< 5	NA	NA	NA	< 5	NA	NA	NA	< 5	NA	NA	NA	< 5	NA	NA	NA
1,2,4-Trimethylbenzene	—	< 1	NA	NA	NA	< 1	NA	NA	NA	< 1	NA	NA	NA	< 1	NA	NA	NA
1,2-Dibromo-3-chloropropane	—	< 5	NA	NA	NA	< 5	NA	NA	NA	< 5	NA	NA	NA	< 5	NA	NA	NA
1,2-Dichlorobenzene	4,200	< 1	NA	NA	NA	< 1	NA	NA	NA	< 1	NA	NA	NA	< 1	NA	NA	NA
1,2-Dichloroethane	59.4	< 1	NA	NA	NA	< 1	NA	NA	NA	< 1	NA	NA	NA	< 1	NA	NA	NA
1,2-Dichloropropane	23.2	< 1	NA	NA	NA	< 1	NA	NA	NA	< 1	NA	NA	NA	< 1	NA	NA	NA
1,3,5-Trimethylbenzene	—	< 1	NA	NA	NA	< 1	NA	NA	NA	< 1	NA	NA	NA	< 1	NA	NA	NA
1,3-Dichlorobenzene	2,600	< 1	NA	NA	NA	< 1	NA	NA	NA	< 1	NA	NA	NA	< 1	NA	NA	NA
1,3-Dichloropropane	—	< 1	NA	NA	NA	< 1	NA	NA	NA	< 1	NA	NA	NA	< 1	NA	NA	NA
1,4-Dichlorobenzene	4.86	< 1	NA	NA	NA	< 1	NA	NA	NA	< 1	NA	NA	NA	< 1	NA	NA	NA

Table B-1: Groundwater Analytical Data Collected During the RI/FS

Parameter	Controlling ARAR	MW-3(B)				MW-4(0)				MW-4(B)				MW-55(C)			
		2/10/99	4/14/99	8/11/99	11/4/99	2/10/99	4/13/99	8/10/99	11/4/99	2/9/99	4/13/99	8/11/99	11/3/99	2/10/99	4/14/99	8/10/99	8/10/99 Duplicate
Volatile Organics (EPA Method 8260) (µg/L)																	
2,2-Dichloropropane	—	< 1	NA	NA	NA	< 1	NA	NA	NA	< 1	NA	NA	NA	< 1	NA	NA	NA
2-Butanone	—	< 5	NA	NA	NA	< 5	NA	NA	NA	< 5	NA	NA	NA	< 5	NA	NA	NA
2-Chloroethylvinylether	—	< 5	NA	NA	NA	< 5	NA	NA	NA	< 5	NA	NA	NA	< 5	NA	NA	NA
2-Chlorotoluene	—	< 1	NA	NA	NA	< 1	NA	NA	NA	< 1	NA	NA	NA	< 1	NA	NA	NA
2-Hexanone	—	< 5	NA	NA	NA	< 5	NA	NA	NA	< 5	NA	NA	NA	< 5	NA	NA	NA
4-Chlorotoluene	—	< 1	NA	NA	NA	< 1	NA	NA	NA	< 1	NA	NA	NA	< 1	NA	NA	NA
4-Isopropyltoluene	—	< 1	NA	NA	NA	< 1	NA	NA	NA	< 1	NA	NA	NA	< 1	NA	NA	NA
4-Methyl-2-Pentanone (MIBK)	—	< 5	NA	NA	NA	< 5	NA	NA	NA	< 5	NA	NA	NA	< 5	NA	NA	NA
Acetone	—	< 5	NA	NA	NA	< 5	NA	NA	NA	< 5	NA	NA	NA	< 5	NA	NA	NA
Acrolein	780	< 50	NA	NA	NA	< 50	NA	NA	NA	< 50	NA	NA	NA	< 50	NA	NA	NA
Acrylonitrile	0.4	< 5	NA	NA	NA	< 5	NA	NA	NA	< 5	NA	NA	NA	< 5	NA	NA	NA
Benzene	43	< 1	NA	NA	NA	< 1	NA	NA	NA	< 1	NA	NA	NA	< 1	NA	NA	NA
Bromobenzene	—	< 1	NA	NA	NA	< 1	NA	NA	NA	< 1	NA	NA	NA	< 1	NA	NA	NA
Bromochloromethane	—	< 1	NA	NA	NA	< 1	NA	NA	NA	< 1	NA	NA	NA	< 1	NA	NA	NA
Bromodichloromethane	22	< 1	NA	NA	NA	< 1	NA	NA	NA	< 1	NA	NA	NA	< 1	NA	NA	NA
Bromoethane	—	< 2	NA	NA	NA	< 2	NA	NA	NA	< 2	NA	NA	NA	< 2	NA	NA	NA
Bromoform	219	< 1	NA	NA	NA	< 1	NA	NA	NA	< 1	NA	NA	NA	< 1	NA	NA	NA
Bromomethane	968	< 2	NA	NA	NA	< 2	NA	NA	NA	< 2	NA	NA	NA	< 2	NA	NA	NA
Carbon Disulfide	—	< 1	NA	NA	NA	< 1	NA	NA	NA	< 1	NA	NA	NA	< 1	NA	NA	NA
Carbon Tetrachloride	2.66	< 1	NA	NA	NA	< 1	NA	NA	NA	< 1	NA	NA	NA	< 1	NA	NA	NA
Chlorobenzene	5,030	< 1	NA	NA	NA	< 1	NA	NA	NA	< 1	NA	NA	NA	< 1	NA	NA	NA
Chloroethane	—	< 2	NA	NA	NA	< 2	NA	NA	NA	< 2	NA	NA	NA	< 2	NA	NA	NA
Chloroform	283	< 1	NA	NA	NA	< 1	NA	NA	NA	< 1	NA	NA	NA	< 1	NA	NA	NA
Chloromethane	133	< 2	NA	NA	NA	< 2	NA	NA	NA	< 2	NA	NA	NA	< 2	NA	NA	NA
cis-1,2-Dichloroethene	—	< 1	NA	NA	NA	< 1	NA	NA	NA	< 1	NA	NA	NA	< 1	NA	NA	NA
cis-1,3-Dichloropropene	—	< 1	NA	NA	NA	< 1	NA	NA	NA	< 1	NA	NA	NA	< 1	NA	NA	NA
Dibromochloromethane	20.6	< 1	NA	NA	NA	< 1	NA	NA	NA	< 1	NA	NA	NA	< 1	NA	NA	NA
Dibromomethane	—	< 1	NA	NA	NA	< 1	NA	NA	NA	< 1	NA	NA	NA	< 1	NA	NA	NA
Ethylbenzene	6,910	< 1	NA	NA	NA	< 1	NA	NA	NA	< 1	NA	NA	NA	< 1	NA	NA	NA
Ethylene Dibromide	—	< 1	NA	NA	NA	< 1	NA	NA	NA	< 1	NA	NA	NA	< 1	NA	NA	NA
Hexachlorobutadiene	29.9	< 5	NA	NA	NA	< 5	NA	NA	NA	< 5	NA	NA	NA	< 5	NA	NA	NA
Isopropylbenzene	—	< 1	NA	NA	NA	< 1	NA	NA	NA	< 1	NA	NA	NA	< 1	NA	NA	NA
m,p-Xylene	—	< 1	NA	NA	NA	< 1	NA	NA	NA	< 1	NA	NA	NA	< 1	NA	NA	NA
Methyl Iodide	—	< 1	NA	NA	NA	< 1	NA	NA	NA	< 1	NA	NA	NA	< 1	NA	NA	NA
Methylene Chloride	1,600	< 2	NA	NA	NA	< 2	NA	NA	NA	< 2	NA	NA	NA	< 2	NA	NA	NA
Naphthalene	9,880	< 5	NA	NA	NA	< 5	NA	NA	NA	< 5	NA	NA	NA	< 5	NA	NA	NA
n-Butylbenzene	—	< 1	NA	NA	NA	< 1	NA	NA	NA	< 1	NA	NA	NA	< 1	NA	NA	NA
n-Propylbenzene	—	< 1	NA	NA	NA	< 1	NA	NA	NA	< 1	NA	NA	NA	< 1	NA	NA	NA
o-Xylene	—	< 1	NA	NA	NA	< 1	NA	NA	NA	< 1	NA	NA	NA	< 1	NA	NA	NA
sec-Butylbenzene	—	< 1	NA	NA	NA	< 1	NA	NA	NA	< 1	NA	NA	NA	< 1	NA	NA	NA
Styrene	—	< 1	NA	NA	NA	< 1	NA	NA	NA	< 1	NA	NA	NA	< 1	NA	NA	NA
tert-Butylbenzene	—	< 1	NA	NA	NA	< 1	NA	NA	NA	< 1	NA	NA	NA	< 1	NA	NA	NA
Tetrachloroethene	4.15	< 1	NA	NA	NA	< 1	NA	NA	NA	< 1	NA	NA	NA	< 1	NA	NA	NA
Toluene	48,500	< 1	NA	NA	NA	< 1	NA	NA	NA	< 1	NA	NA	NA	< 1	NA	NA	NA
trans-1,2-Dichloroethene	32,800	< 1	NA	NA	NA	< 1	NA	NA	NA	< 1	NA	NA	NA	< 1	NA	NA	NA
trans-1,3-Dichloropropene	—	< 1	NA	NA	NA	< 1	NA	NA	NA	< 1	NA	NA	NA	< 1	NA	NA	NA
trans-1,4-Dichloro-2-butene	—	< 5	NA	NA	NA	< 5	NA	NA	NA	< 5	NA	NA	NA	< 5	NA	NA	NA
Trichloroethene	55.6	< 1	NA	NA	NA	< 1	NA	NA	NA	< 1	NA	NA	NA	< 1	NA	NA	NA
Trichlorofluoromethane	—	< 2	NA	NA	NA	< 2	NA	NA	NA	< 2	NA	NA	NA	< 2	NA	NA	NA
Vinyl Acetate	—	< 5	NA	NA	NA	< 5	NA	NA	NA	< 5	NA	NA	NA	< 5	NA	NA	NA
Vinyl Chloride	2.92	< 2	NA	NA	NA	< 2	NA	NA	NA	< 2	NA	NA	NA	< 2	NA	NA	NA

NOTES:

Detected values are highlighted in bold.

Bold and boxed = detected compound above controlling ARAR..

NA - Indicates compound not analyzed for.

B - Contamination in assoc. method blank.

J - Indicates estimated value.

R - Rejected data.

Table B-1: Groundwater Analytical Data Collected During the RI/FS

Parameter	Controlling ARAR	RGP-1(W) 7/1/98	RGP-1(W) 7/1/98 Diss	RGP-1(W) 2/9/99	RGP-1(W) 2/9/99 Duplicate	RGP-1(W) 4/12/99	RGP-2(W) 7/1/98	RGP-2(W) 7/1/98 Duplicate	RGP-2(W) 7/1/98 Diss.	RGP-2(W) 7/1/98 Diss. Duplicate	RGP-3(W) 7/1/98	RGP-3(W) 7/1/98 Diss	RGP-3(W) 2/9/99	RGP-3(W) 3/9/99	RGP-3(W) 4/12/99	RGP-4(W) 7/1/98	RGP-4(W) 7/1/98 Diss
Conventionals - Geochemical Parameters (mg/L)																	
Total Dissolved Solids	—	NA	NA	960	940	940	NA	NA	NA	NA	NA	NA	5,200	NA	4,900	NA	NA
Total Suspended Solids	—	NA	NA	2.3	1.6	< 1	NA	NA	NA	NA	NA	NA	8.1	NA	3.9	NA	NA
Total Organic Carbon	—	NA	NA	17	16	21	NA	NA	NA	NA	NA	NA	170	NA	380	NA	NA
N-Ammonia (mg-N/L)	—	NA	NA	0.8	0.77	4.7	NA	NA	NA	NA	NA	NA	28	NA	69	NA	NA
Nitrate + Nitrite (mg-N/L)	—	NA	NA	< 0.01	< 0.01	< 0.01	NA	NA	NA	NA	NA	NA	0.025	NA	0.05	NA	NA
Calcium	—	255	256	219	210	227	203	202	210	203	144	152	148	NA	137	596	599
Chloride	—	NA	NA	16	16	26	NA	NA	NA	NA	NA	NA	260	NA	460	NA	NA
Iron	—	10.8	11.7	7.05	6.77	8.34	2.1	2.15	2.16	2.1	8.35	8.91	8.98	NA	6	0.19	0.07
Ferrous Iron	—	1.4	NA	7.9	7.7	9.8	1.2	0.39	NA	NA	1.2	NA	6.9	NA	7.4	1.2	NA
Magnesium	—	135	133	23.6	22.8	27.2	36.3	37.1	37.6	37.6	141	140	244	NA	161	103	100
Manganese	—	2.46	2.43	2.66	2.56	2.38	0.45	0.466	0.475	0.497	2.31	2.36	1.26	NA	0.811	1.47	1.47
Sodium	—	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Sulfate	—	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Sulfide	—	< 0.05	NA	< 0.1	< 0.09	< 0.05	< 0.05	4.1	NA	NA	0.05	NA	0.15	NA	0.18	< 0.05	NA
Alkalinity	—	NA	NA	500	500	530	NA	NA	NA	NA	NA	NA	2,200	NA	2,400	NA	NA
Metals (mg/L)																	
Arsenic	0.005	0.014	0.014	0.003	0.003	0.003	0.002	0.002	0.002	0.002	0.016	0.013	< 0.005	NA	0.008	< 0.001	0.001
Barium	500	NA	NA	0.103	0.098	0.122	NA	NA	NA	NA	NA	NA	0.239	NA	0.272	NA	NA
Chromium	162	5.09	5.13	< 0.005	< 0.005	0.093	0.019	0.015	0.017	0.016	9.78	10.1	1.76	NA	5.12	0.072	0.073
Hexavalent Chrome	0.05	< 0.1 R	< 0.1 R	< 0.06	< 0.06	< 0.11	< 0.1 R	< 0.1 R	< 0.1 R	< 0.1 R	< 0.1 R	< 0.1 R	< 0.06	NA	< 0.11	< 0.1 R	< 0.1 R
Copper	0.0031	0.005	< 0.004	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	0.005	< 0.004	< 0.002	NA	0.003	< 0.002	< 0.002
Lead	0.0081	0.015	0.004	< 0.001	< 0.001	< 0.001	0.005	< 0.001	< 0.001	< 0.001	0.046	0.022	0.009	NA	0.014	0.001	< 0.001
Mercury	0.00005	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	NA	< 0.0001	< 0.0001	< 0.0001
Nickel	0.0082	< 0.01	< 0.02	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	0.01	< 0.02	< 0.01	NA	< 0.01	< 0.01	< 0.01
Zinc	0.081	0.057	0.022	0.01 B	0.007 B	0.168	0.04	< 0.004	< 0.004	< 0.004	0.064	0.027	0.04 B	NA	0.044	0.008	< 0.004
Other Contaminants (mg/L)																	
Weak Acid Dissoc. Cyanide	0.0028	< 0.004	NA	< 0.005	< 0.005	< 0.005	0.007	0.006	NA	NA	0.007	NA	< 0.005	NA	< 0.005	0.007	NA
Diesel Range Hydrocarbons	0.5	NA	NA	< 0.25	< 0.25	< 0.25	NA	NA	NA	NA	NA	NA	2.7	NA	2.8	NA	NA
Semivolatile Organics (EPA Method 8270) (µg/L)																	
1,2,4-Trichlorobenzene	227	< 1	< 1	< 1	< 1	< 1	< 1	NA	< 1	NA	< 1	< 1	< 1	< 1	< 1	< 1	< 1 J
1,2-Dichlorobenzene	4,200	< 1	< 1	< 1	< 1	< 1	< 1	NA	< 1	NA	< 1	< 1	1.2	1.2	< 1	< 1	< 1 J
1,3-Dichlorobenzene	2,600	< 1	< 1	< 1	< 1	< 1	< 1	NA	< 1	NA	< 1	< 1	< 1	< 1	< 1	< 1	< 1 J
1,4-Dichlorobenzene	4.86	1.1	< 1	< 1	< 1	< 1	1 J	NA	< 1	NA	3.4	2.2	8.7	9.1	8.2	< 1	< 1 J
2,2'-Oxybis(1-Chloropropane)	—	< 1	< 1	< 1	< 1	< 1	< 1	NA	< 1	NA	< 1	< 1	< 1	< 1	< 1	< 1	< 1 J
2,4,5-Trichlorophenol	—	< 5	< 5	< 5	< 5	< 5	< 5	NA	< 5	NA	< 5	< 5	34	35	< 5	< 5	< 5 J
2,4,6-Trichlorophenol	3.93	< 5	< 5	< 5	< 5	< 5	< 5	NA	< 5	NA	< 5	< 5	5.2	3.6 J	< 5	< 5	< 5 J
2,4-Dichlorophenol	191	< 3	< 3	< 3	< 3	< 3	< 3	NA	< 3	NA	< 3	< 3	19	21	< 3	< 3	< 3 J
2,4-Dimethylphenol	553	< 3	< 3	< 3	< 3	< 3	< 3	NA	< 3	NA	< 3	< 3	< 3	< 2	4	< 3	< 3 J
2,4-Dinitrophenol	3,460	< 10	< 10	< 10	< 10	< 10	< 10	NA	< 10	NA	< 10	< 10	< 10	< 10	< 10	< 10	< 10 J
2,4-Dinitrotoluene	9.1	< 5	< 5	< 5	< 5	< 5	< 5	NA	< 5	NA	< 5	< 5	< 5	< 5	< 5	< 5	< 5 J
2,6-Dinitrotoluene	—	< 5	< 5	< 5	< 5	< 5	< 5	NA	< 5	NA	< 5	< 5	< 5	< 5	< 5	< 5	< 5 J
2-Chloronaphthalene	—	< 1	< 1	< 1	< 1	< 1	< 1	NA	< 1	NA	< 1	< 1	< 1	< 1	< 1	< 1	< 1 J
2-Chlorophenol	97	< 1	< 1	< 1	< 1	< 1	< 1	NA	< 1	NA	< 1	< 1	< 1	< 1	< 1	< 1	< 1 J
2-Methylnaphthalene	—	1.4	< 1	< 1	< 1	< 1	< 1	NA	< 1	NA	36	17	66	74	77	< 1	< 1 J
2-Methylphenol	—	< 2	< 2	< 2	< 2	< 2	< 2	NA	< 2	NA	< 2	< 2	< 2	1.1 J	< 2	< 2	< 2 J
2-Nitroaniline	—	< 5	< 5	< 5	< 5	< 5	< 5	NA	< 5	NA	< 5	< 5	< 5	< 5	< 5	< 5	< 5 J
2-Nitrophenol	—	< 5	< 5	< 5	< 5	< 5	< 5	NA	< 5	NA	< 5	< 5	< 5	< 5	< 5	< 5	< 5 J
3,3'-Dichlorobenzidine	0.0462	< 5	< 5	< 5	< 5	< 5	< 5	NA	< 5	NA	< 5	< 5	< 5	< 5	< 5	< 5	< 5 J
3-Nitroaniline	—	< 6	< 6	< 6	< 6	< 6	< 6	NA	< 6	NA	< 6	< 6	< 6	< 6	< 6	< 6	< 6 J
4,6-Dinitro-2-Methylphenol	765	< 10	< 10	< 10	< 10	< 10	< 10	NA	< 10	NA	< 10	< 10	< 10	< 10	< 10	< 10	< 10 J
4-Bromophenyl-phenylether	—	< 1	< 1	< 1	< 1	< 1	< 1	NA	< 1	NA	< 1	< 1	< 1	< 1	< 1	< 1	< 1 J
4-Chloro-3-methylphenol	—	< 2	< 2	< 2	< 2	< 2	< 2	NA	< 2	NA	< 2	< 2	< 2	10	< 2	< 2	< 2 J
4-Chloroaniline	—	< 3	< 3	< 3	< 3	< 3	< 3	NA	< 3	NA	< 3	< 3	< 3	< 3	< 3	< 3	< 3 J
4-Chlorophenyl-phenylether	—	< 1	< 1	< 1	< 1	< 1	< 1	NA	< 1	NA	< 1	< 1	< 1	< 1	< 1	< 1	< 1 J
4-Methylphenol	—	< 1	< 1	< 1	< 1	< 1	< 1	NA	< 1	NA	< 1	< 1	84 E	54	5.7	< 1	< 1 J
4-Nitroaniline	—	< 5	< 5	< 5	< 5	< 5	< 5	NA	< 5	NA	< 5	< 5	< 5	< 5	< 5	< 5	< 5 J
4-Nitrophenol	—	< 5	< 5	< 5	< 5	< 5	< 5	NA	< 5	NA	< 5	< 5	< 5	< 5	< 5	< 5	< 5 J

Table B-1: Groundwater Analytical Data Collected During the RI/FS

Parameter	Controlling ARAR	RGP-1(W) 7/1/98	RGP-1(W) 7/1/98 Diss	RGP-1(W) 2/9/99	RGP-1(W) 2/9/99 Duplicate	RGP-1(W) 4/12/99	RGP-2(W) 7/1/98	RGP-2(W) 7/1/98 Duplicate	RGP-2(W) 7/1/98 Diss.	RGP-2(W) 7/1/98 Diss. Duplicate	RGP-3(W) 7/1/98	RGP-3(W) 7/1/98 Diss	RGP-3(W) 2/9/99	RGP-3(W) 3/9/99	RGP-3(W) 4/12/99	RGP-4(W) 7/1/98	RGP-4(W) 7/1/98 Diss
Semivolatile Organics (EPA Method 8270) (µg/L)																	
Acenaphthene	643	2.4	1.2	< 1	< 1	< 1	2.4	NA	1.7	NA	< 1	< 1	2.2	3.1	3.3	2	1.1 J
Acenaphthylene	—	< 1	< 1	< 1	< 1	< 1	< 1	NA	< 1	NA	< 1	< 1	1.1	< 1	< 1	< 1	< 1 J
Anthracene	25,900	< 1	< 1	< 1	< 1	< 1	< 1	NA	< 1	NA	< 1	< 1	< 1	< 1	< 1	< 1	< 1 J
Benzo(a)anthracene	0.0296	< 1	< 1	< 1	< 1	< 1	< 1	NA	< 1	NA	< 1	< 1	< 1	< 1	< 1	< 1	< 1 J
Benzo(a)pyrene	0.0296	< 1	< 1	< 1	< 1	< 1	< 1	NA	< 1	NA	< 1	< 1	< 1	< 1	< 1	< 1	< 1 J
Benzo(b)fluoranthene	0.0296	< 1	< 1	< 1	< 1	< 1	< 1	NA	< 1	NA	< 1	< 1	< 1	< 1	< 1	< 1	< 1 J
Benzo(g,h,i)perylene	—	< 1	< 1	< 1	< 1	< 1	< 1	NA	< 1	NA	< 1	< 1	< 1	< 1	< 1	< 1	< 1 J
Benzo(k)fluoranthene	0.0296	< 1	< 1	< 1	< 1	< 1	< 1	NA	< 1	NA	< 1	< 1	< 1	< 1	< 1	< 1	< 1 J
Benzoic Acid	—	< 10	< 10	< 10	< 10	< 10	< 10	NA	< 10	NA	< 10	< 10	58	39	< 10	< 10	< 10 J
Benzyl Alcohol	—	< 5	< 5	< 5	< 5	< 5	< 5	NA	< 5	NA	< 5	< 5	< 5	< 5	2.6 J	< 5	< 5 J
bis(2-Chloroethoxy) Methane	—	< 1	< 1	< 1	< 1	< 1	< 1	NA	< 1	NA	< 1	< 1	< 1	< 1	< 1	< 1	< 1 J
Bis-(2-Chloroethyl) Ether	0.854	< 2	< 2	< 2	< 2	< 2	< 2	NA	< 2	NA	< 2	< 2	< 2	< 2	< 2	< 2	< 2 J
bis(2-Ethylhexyl)phthalate	3.56	7.8 B	1.4 B	1.3	< 1	< 1	1.8 B	NA	< 1	NA	2.8 B	1.8 B	< 1	< 1	< 1	1.4 B	< 1 J
Butylbenzylphthalate	1,250	< 1	< 1	< 1	< 1	< 1	< 1	NA	< 1	NA	< 1	< 1	< 1	< 1	< 1	< 1	< 1 J
Carbazole	—	2	1.3	< 1	< 1	< 1	< 1	NA	< 1	NA	< 1	< 1	1.4	1.9	1.5	< 1	< 1 J
Chrysene	0.0296	< 1	< 1	< 1	< 1	< 1	< 1	NA	< 1	NA	< 1	< 1	< 1	< 1	< 1	< 1	< 1 J
Dibenz(a,h)anthracene	0.0296	< 1	< 1	< 1	< 1	< 1	< 1	NA	< 1	NA	< 1	< 1	< 1	< 1	< 1	< 1	< 1 J
Dibenzofuran	—	< 1	< 1	< 1	< 1	< 1	< 1	NA	< 1	NA	< 1	< 1	< 1	1.3	1.5	< 1	< 1 J
Diethylphthalate	28,400	< 1	< 1	< 1	< 1	< 1	< 1	NA	< 1	NA	< 1	< 1	7.7	7.9	3.7	< 1	< 1 J
Dimethylphthalate	72,000	< 1	< 1	< 1	< 1	< 1	< 1	NA	< 1	NA	< 1	< 1	< 1	< 1	< 1	< 1	< 1 J
Di-n-Butylphthalate	2,910	< 1	< 1	< 1	< 1	< 1	< 1	NA	< 1	NA	< 1	< 1	< 1	< 1	< 1	< 1	< 1 J
Di-n-Octyl phthalate	—	< 1	< 1	< 1	< 1	< 1	< 1	NA	< 1	NA	< 1	< 1	< 1	< 1	< 1	< 1	< 1 J
Fluoranthene	90.2	< 1	< 1	< 1	< 1	< 1	< 1	NA	< 1	NA	< 1	< 1	< 1	< 1	< 1	< 1	< 1 J
Fluorene	3,460	1.1	< 1	< 1	< 1	< 1	1.4	NA	< 1	NA	< 1	< 1	2.0	3.3	3.5	< 1	< 1 J
Hexachlorobenzene	0.000466	< 1	< 1	< 1	< 1	< 1	< 1	NA	< 1	NA	< 1	< 1	< 1	< 1	< 1	< 1	< 1 J
Hexachlorobutadiene	29.9	< 2	< 2	< 2	< 2	< 2	< 2	NA	< 2	NA	< 2	< 2	< 2	< 2	< 2	< 2	< 2 J
Hexachlorocyclopentadiene	4,180	< 5	< 5	< 5	< 5	< 5	< 5	NA	< 5	NA	< 5	< 5	< 5	< 5	< 5	< 5	< 5 J
Hexachloroethane	5.33	< 2	< 2	< 2	< 2	< 2	< 2	NA	< 2	NA	< 2	< 2	< 2	< 2	< 2	< 2	< 2 J
Indeno(1,2,3-cd)pyrene	0.0296	< 1	< 1	< 1	< 1	< 1	< 1	NA	< 1	NA	< 1	< 1	< 1	< 1	< 1	< 1	< 1 J
Isophorone	600	< 1	< 1	< 1	< 1	< 1	< 1	NA	< 1	NA	< 1	< 1	< 1	< 1	< 1	< 1	< 1 J
Naphthalene	9,880	27	15	5	4.7	10	< 1	NA	< 1	NA	12	8	120 E	22	27	< 1	< 1 J
Nitrobenzene	449	< 1	< 1	< 1	< 1	< 1	< 1	NA	< 1	NA	< 1	< 1	< 1	< 1	< 1	< 1	< 1 J
N-Nitroso-di-n-propylamine	0.819	< 2	< 2	< 2	< 2	< 2	< 2	NA	< 2	NA	< 2	< 2	< 2	< 2	< 2	< 2	< 2 J
N-Nitrosodiphenylamine	9.73	< 1	< 1	< 1	< 1	< 1	< 1	NA	< 1	NA	< 1	< 1	< 1	< 1	< 1	< 1	< 1 J
Pentachlorophenol	4.91	< 5	< 5	< 5	< 5	< 5	< 5	NA	< 5	NA	< 5	< 5	640 E	370 E	< 5	< 5	< 5 J
Phenanthrene	—	2	1.3	< 1	< 1	< 1	< 1	NA	< 1	NA	1.6	1	2.6	4.9	5.3	< 1	< 1 J
Phenol	1,110,000	< 2	< 2	< 2	< 2	< 2	< 2	NA	< 2	NA	< 2	< 2	17	11	< 2	< 2	< 2 J
Pyrene	2,590	1.3	< 1	< 1	< 1	< 1	< 1	NA	< 1	NA	< 1	< 1	< 1	< 1	< 1	< 1	< 1 J
Volatile Organics (EPA Method 8260) (µg/L)																	
1,1,1,2-Tetrachloroethane	—	< 1	NA	< 1	< 1	NA	< 1	< 1	NA	NA	< 1	NA	< 2	< 5	NA	< 1	NA
1,1,1-Trichloroethane	417,000	< 1	NA	< 1	< 1	NA	< 1	< 1	NA	NA	< 1	NA	< 2	< 5	NA	< 1	NA
1,1,2,2-Tetrachloroethane	6.48	< 1	NA	< 1	< 1	NA	< 1	< 1	NA	NA	< 1	NA	< 2	< 5	NA	< 1	NA
1,1,2-Trichloroethane	25.3	< 1	NA	< 1	< 1	NA	< 1	< 1	NA	NA	< 1	NA	< 2	< 5	NA	< 1	NA
1,1,2-Trichlorotrifluoroethane	—	< 2	NA	< 2	< 2	NA	< 2	< 2	NA	NA	< 2	NA	< 4	< 10	NA	< 2	NA
1,1-Dichloroethane	—	< 1	NA	< 1	< 1	NA	< 1	< 1	NA	NA	< 1	NA	< 2	< 5	NA	< 1	NA
1,1-Dichloroethene	1.93	< 1	NA	< 1	< 1	NA	< 1	< 1	NA	NA	< 1	NA	< 2	< 5	NA	< 1	NA
1,1-Dichloropropene	—	< 1	NA	< 1	< 1	NA	< 1	< 1	NA	NA	< 1	NA	< 2	< 5	NA	< 1	NA
1,2,3-Trichlorobenzene	—	< 5	NA	< 5	< 5	NA	< 5	< 5	NA	NA	< 5	NA	< 10	< 25	NA	< 5	NA
1,2,3-Trichloropropane	—	< 1	NA	< 1	< 1	NA	< 1	< 1	NA	NA	< 1	NA	< 2	< 15	NA	< 1	NA
1,2,4-Trichlorobenzene	227	< 5	NA	< 5	< 5	NA	< 5	< 5	NA	NA	< 5	NA	< 10	< 25	NA	< 5	NA
1,2,4-Trimethylbenzene	—	7.3	NA	3	2.9	NA	3.4	4.7	NA	NA	30	NA	26	33	NA	1.6	NA
1,2-Dibromo-3-chloropropane	—	< 5	NA	< 5	< 5	NA	< 5	< 5	NA	NA	< 5	NA	< 10	< 25	NA	< 5	NA
1,2-Dichlorobenzene	4,200	NA	NA	< 1	< 1	NA	NA	NA	NA	NA	NA	NA	< 2	< 5	NA	NA	NA
1,2-Dichloroethane	59.4	< 1	NA	< 1	< 1	NA	< 1	< 1	NA	NA	< 1	NA	< 2	< 5	NA	< 1	NA
1,2-Dichloropropane	23.2	< 1	NA	< 1	< 1	NA	< 1	< 1	NA	NA	< 1	NA	< 2	< 5	NA	< 1	NA
1,3,5-Trimethylbenzene	—	< 1	NA	< 1	< 1	NA	< 1	< 1	NA	NA	1.3	NA	3.3	< 5	NA	< 1	NA
1,3-Dichlorobenzene	2,600	NA	NA	< 1	< 1	NA	NA	NA	NA	NA	NA	NA	< 2	< 5	NA	NA	NA
1,3-Dichloropropane	—	< 1	NA	< 1	< 1	NA	< 1	< 1	NA	NA	< 1	NA	< 2	< 5	NA	< 1	NA
1,4-Dichlorobenzene	4.86	NA	NA	< 1	< 1	NA	NA	NA	NA	NA	NA	NA	11	16	NA	NA	NA

Table B-1: Groundwater Analytical Data Collected During the RI/FS

Parameter	Controlling ARAR	RGP-1(W)					RGP-2(W)				RGP-3(W)					RGP-4(W)	
		7/1/98	7/1/98 Diss	2/9/99	2/9/99 Duplicate	4/12/99	7/1/98	7/1/98 Duplicate	7/1/98 Diss.	7/1/98 Diss. Duplicate	7/1/98	7/1/98 Diss	2/9/99	3/9/99	4/12/99	7/1/98	7/1/98 Diss
Volatile Organics (EPA Method 8260) (µg/L)																	
2,2-Dichloropropane	—	< 1	NA	< 1	< 1	NA	< 1	< 1	NA	NA	< 1	NA	< 2	< 5	NA	< 1	NA
2-Butanone	—	< 5	NA	< 5	< 5	NA	< 5	< 5	NA	NA	< 5	NA	< 10	< 25	NA	< 5	NA
2-Chloroethylvinylether	—	< 5	NA	< 5	< 5	NA	< 5	< 5	NA	NA	< 5	NA	< 10	< 25	NA	< 5	NA
2-Chlorotoluene	—	< 1	NA	< 1	< 1	NA	< 1	< 1	NA	NA	< 1	NA	< 2	< 5	NA	< 1	NA
2-Hexanone	—	< 5	NA	< 5	< 5	NA	< 5	< 5	NA	NA	< 5	NA	< 10	< 25	NA	< 5	NA
4-Chlorotoluene	—	< 1	NA	< 1	< 1	NA	< 1	< 1	NA	NA	< 1	NA	< 2	< 5	NA	< 1	NA
4-Isopropyltoluene	—	**1.4**	NA	< 1	< 1	NA	< 1	< 1	NA	NA	**2.9**	NA	**2.4**	< 5	NA	< 1	NA
4-Methyl-2-Pentanone (MIBK)	—	< 5	NA	< 5	< 5	NA	< 5	< 5	NA	NA	< 5	NA	< 10	< 25	NA	< 5	NA
Acetone	—	**5.5**	NA	< 5	< 5	NA	< 5	< 5	NA	NA	< 5	NA	< 10	< 25	NA	< 5	NA
Acrolein	780	< 50	NA	< 50	< 50	NA	< 50	< 50	NA	NA	< 50	NA	< 100	< 250	NA	< 50	NA
Acrylonitrile	0.4	< 5	NA	< 5	< 5	NA	< 5	< 5	NA	NA	< 5	NA	< 10	< 25	NA	< 5	NA
Benzene	43	**4.1**	NA	**1.2**	**1.1**	NA	**1.9**	**2.1**	NA	NA	**8.1**	NA	**6.5**	**8.9**	NA	**2.3**	NA
Bromobenzene	—	< 1	NA	< 1	< 1	NA	< 1	< 1	NA	NA	< 1	NA	< 2	< 5	NA	< 1	NA
Bromochloromethane	—	< 1	NA	< 1	< 1	NA	< 1	< 1	NA	NA	< 1	NA	< 2	< 5	NA	< 1	NA
Bromodichloromethane	22	< 1	NA	< 1	< 1	NA	< 1	< 1	NA	NA	< 1	NA	< 2	< 5	NA	< 1	NA
Bromoethane	—	< 2	NA	< 2	< 2	NA	< 2	< 2	NA	NA	< 2	NA	< 4	< 10	NA	< 2	NA
Bromoform	219	< 1	NA	< 1	< 1	NA	< 1	< 1	NA	NA	< 1	NA	< 2	< 5	NA	< 1	NA
Bromomethane	968	< 2	NA	< 2	< 2	NA	< 2	< 2	NA	NA	< 2	NA	< 4	< 5	NA	< 2	NA
Carbon Disulfide	—	< 1	NA	< 1	< 1	NA	< 1	< 1	NA	NA	< 1	NA	< 2	< 5	NA	< 1	NA
Carbon Tetrachloride	2.66	< 1	NA	< 1	< 1	NA	< 1	< 1	NA	NA	< 1	NA	< 2	< 5	NA	< 1	NA
Chlorobenzene	5,030	**3.8**	NA	**3.5**	**3.5**	NA	**2.6**	**3**	NA	NA	**1.9**	NA	**4.2**	**6.1**	NA	**2.3**	NA
Chloroethane	—	< 2	NA	< 2	< 2	NA	< 2	< 2	NA	NA	< 2	NA	< 4	< 5	NA	< 2	NA
Chloroform	283	< 1	NA	< 1	< 1	NA	< 1	< 1	NA	NA	< 1	NA	< 2	< 5	NA	< 1	NA
Chloromethane	133	< 2	NA	< 2	< 2	NA	< 2	< 2	NA	NA	< 2	NA	< 4	< 5	NA	< 2	NA
cis-1,2-Dichloroethene	—	< 1	NA	< 1	< 1	NA	< 1	< 1	NA	NA	< 1	NA	< 2	< 5	NA	< 1	NA
cis-1,3-Dichloropropene	—	< 1	NA	< 1	< 1	NA	< 1	< 1	NA	NA	< 1	NA	< 2	< 5	NA	< 1	NA
Dibromochloromethane	20.6	< 1	NA	< 1	< 1	NA	< 1	< 1	NA	NA	< 1	NA	< 2	< 5	NA	< 1	NA
Dibromomethane	—	< 1	NA	< 1	< 1	NA	< 1	< 1	NA	NA	< 1	NA	< 2	< 5	NA	< 1	NA
Ethylbenzene	6,910	**1.4**	NA	< 1	< 1	NA	< 1	< 1	NA	NA	**66**	NA	**340**	**590**	NA	**1.4**	NA
Ethylene Dibromide	—	< 1	NA	< 1	< 1	NA	< 1	< 1	NA	NA	< 1	NA	< 2	< 5	NA	< 1	NA
Hexachlorobutadiene	29.9	< 5	NA	< 5	< 5	NA	< 5	< 5	NA	NA	< 5	NA	< 10	< 25	NA	< 5	NA
Isopropylbenzene	—	**2**	NA	< 1	< 1	NA	**2.1**	**2.4**	NA	NA	**3.6**	NA	**3.3**	< 5	NA	**1.7**	NA
m,p-Xylene	—	< 1	NA	< 1	< 1	NA	< 1	< 1	NA	NA	**5.2**	NA	**34**	**39**	NA	**1.1**	NA
Methyl Iodide	—	< 1	NA	< 1	< 1	NA	< 1	< 1	NA	NA	< 1	NA	< 2	< 5	NA	< 1	NA
Methylene Chloride	1,600	< 2	NA	< 2	< 2	NA	< 2	< 2	NA	NA	< 2	NA	< 4	< 10	NA	< 2	NA
Naphthalene	9,880	NA	NA	**17**	**17**	NA	NA	NA	NA	NA	NA	NA	**26**	**39**	NA	NA	NA
n-Butylbenzene	—	< 1	NA	< 1	< 1	NA	< 1	< 1	NA	NA	< 1	NA	< 2	< 5	NA	< 1	NA
n-Propylbenzene	—	**1.9**	NA	< 1	< 1	NA	**1.9**	**2.3**	NA	NA	**3.6**	NA	**4.6**	**5.9**	NA	**1.4**	NA
o-Xylene	—	**1**	NA	< 1	< 1	NA	< 1	< 1	NA	NA	< 1	NA	**7**	**7.7**	NA	< 1	NA
sec-Butylbenzene	—	< 1	NA	< 1	< 1	NA	< 1	< 1	NA	NA	< 1	NA	< 2	< 5	NA	< 1	NA
Styrene	—	< 1	NA	< 1	< 1	NA	< 1	< 1	NA	NA	< 1	NA	< 2	< 5	NA	< 1	NA
tert-Butylbenzene	—	< 1	NA	< 1	< 1	NA	< 1	< 1	NA	NA	< 1	NA	< 2	< 5	NA	< 1	NA
Tetrachloroethene	4.15	< 1	NA	< 1	< 1	NA	< 1	< 1	NA	NA	< 1	NA	< 2	< 5	NA	< 1	NA
Toluene	48,500	< 1	NA	< 1	< 1	NA	< 1	< 1	NA	NA	< 1	NA	< 2	< 5	NA	< 1	NA
trans-1,2-Dichloroethene	32,800	< 1	NA	< 1	< 1	NA	< 1	< 1	NA	NA	< 1	NA	< 2	< 5	NA	< 1	NA
trans-1,3-Dichloropropene	—	< 1	NA	< 1	< 1	NA	< 1	< 1	NA	NA	< 1	NA	< 2	< 5	NA	< 1	NA
trans-1,4-Dichloro-2-butene	—	< 5	NA	< 5	< 5	NA	< 5	< 5	NA	NA	< 5	NA	< 10	< 25	NA	< 5	NA
Trichloroethene	55.6	< 1	NA	< 1	< 1	NA	< 1	< 1	NA	NA	< 1	NA	< 2	< 5	NA	< 1	NA
Trichlorofluoromethane	—	< 2	NA	< 2	< 2	NA	< 2	< 2	NA	NA	< 2	NA	< 4	< 5	NA	< 2	NA
Vinyl Acetate	—	< 5	NA	< 5	< 5	NA	< 5	< 5	NA	NA	< 5	NA	< 10	< 25	NA	< 5	NA
Vinyl Chloride	2.92	< 2	NA	< 2	< 2	NA	< 2	< 2	NA	NA	< 2	NA	< 4	< 5	NA	< 2	NA

NOTES:

Detected values are highlighted in **bold**.
Bold and boxed = detected compound above controlling ARAR..
NA - Indicates compound not analyzed for.
B - Contamination in assoc. method blank.
J - Indicates estimated value.
R - Rejected data.

Table B-1: Groundwater Analytical Data Collected During the RI/FS

Parameter	Controlling ARAR	RMW-10				RMW-11							RMW-11D				
		2/9/99	4/14/99	8/10/99	11/3/99	3/9/99	4/14/99	8/11/99	10/12/99	10/19/99	11/4/99	11/4/99 Duplicate	3/9/99	4/13/99	8/11/99	10/19/99	11/4/99
Conventionals - Geochemical Parameters (mg/L)																	
Total Dissolved Solids	—	890	890	1,100	1,000	4,800	1,200	5,200	NA	NA	1,500	1,400	7,100	7,000	6,800	NA	6,200
Total Suspended Solids	—	30	47	74	24	14	52	320	NA	NA	100	120	4.9	4.4	8	NA	2.3
Total Organic Carbon	—	23	29	27	29	180	25	300	NA	NA	51	53	260	260	270	NA	220
N-Ammonia (mg-N/L)	—	8.7	14	15	8.8	130	31	170	NA	NA	45	44	120	270	150	NA	120
Nitrate + Nitrite (mg-N/L)	—	< 0.01	< 0.05	0.017	< 0.01	0.023	< 0.05	0.016	NA	NA	0.015	< 0.01	0.024	0.02	0.014	NA	0.018
Calcium	—	137	145	155	150	158	247	97.3	NA	NA	232	232	114	118	102	NA	104
Chloride	—	70	82	200	130	1,700	150	1,800	NA	NA	260	260	2,600	2,900	2,800	NA	1,400
Iron	—	24	28.1	29	27.6	13.4	43.3	8.53	NA	NA	38.2	37.7	0.93	0.98	0.92	NA	0.81
Ferrous Iron	—	52	29	30	29	12	44	3.4	NA	NA	38	39	0.9	2.1	2.1	NA	1.6
Magnesium	—	42.3	44.6	50.9	47.4	198	46.4	177	NA	NA	48.8	49.2	283	285	239	NA	229
Manganese	—	0.97	1.03	1.22	1.04	0.464	1.22	0.174	NA	NA	0.975	0.978	0.167	0.168	0.149	NA	0.124
Sodium	—	NA	NA	193	164	NA	NA	1,350	NA	NA	202	204	NA	NA	1,830	NA	1,710
Sulfate	—	NA	NA	NA	14	NA	NA	NA	NA	NA	18	14	NA	NA	NA	NA	77
Sulfide	—	< 0.09	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	NA	NA	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	NA	< 0.05
Alkalinity	—	740	740	810	780	2,200	1,100	2,400	NA	NA	1,100	1,000	2,800	2,700	2,600	NA	2,300
Metals (mg/L)																	
Arsenic	0.005	< 0.001	0.001	0.001	< 0.001	0.002	0.003	0.004	0.004	NA	0.004	0.004	0.002	0.003	0.003	NA	0.003
Barium	500	0.033	0.037	0.049	0.047	0.422	0.362	0.365	NA	NA	0.338	0.339	0.462	0.461	0.363	NA	0.373
Chromium	162	0.075	0.16	0.088	0.096	0.596	0.12	1.56	NA	NA	0.319	0.317	0.868	0.931	0.945	NA	1.05
Hexavalent Chrome	0.05	< 0.06	< 0.01	< 0.01	< 0.06	< 0.11	< 0.01	< 0.01	NA	NA	< 0.06	< 0.06	< 0.11	< 0.06	< 0.01	NA	< 0.06
Copper	0.0031	< 0.002	< 0.002	< 0.002	< 0.002	0.004	< 0.002	0.021	0.003	NA	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	NA	< 0.002
Lead	0.0081	< 0.001	< 0.001	< 0.001	< 0.001	0.008	< 0.001	0.056	0.006	NA	0.002	0.003	< 0.001	< 0.001	0.005	NA	0.004
Mercury	0.00005	< 0.0001	< 0.0002	< 0.0001	< 0.0001	< 0.0001	< 0.0002	0.0001	NA	NA	< 0.0001	< 0.0001	< 0.0001	< 0.0002	< 0.0001	NA	< 0.0001
Nickel	0.0082	< 0.01	0.01	< 0.01	< 0.01	< 0.01	< 0.01	0.02	< 0.01	NA	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	NA	< 0.01
Zinc	0.081	0.008 B	0.006 B	0.006	0.007	0.012	0.019 B	0.115	0.018	NA	< 0.006	< 0.006	0.005	0.013 B	0.013	NA	0.007
Other Contaminants (mg/L)																	
Weak Acid Dissoc. Cyanide	0.0028	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	0.005	NA	< 0.004	< 0.005	< 0.005	< 0.005	< 0.005	0.006	0.005	0.005
Diesel Range Hydrocarbons	0.5	< 0.25	< 0.25	< 0.25	0.25	0.36	0.4	1.3	NA	NA	0.41	0.44	0.61	0.72	0.82	NA	0.86
Semivolatile Organics (EPA Method 8270) (µg/L)																	
1,2,4-Trichlorobenzene	227	< 1	< 1	< 1	< 1	NA	< 1	< 1	NA	NA	< 1	< 1	NA	< 1	< 1	NA	< 1
1,2-Dichlorobenzene	4,200	< 1	< 1	< 1	< 1	NA	< 1	< 1	NA	NA	< 1	< 1	NA	< 1	< 1	NA	< 1
1,3-Dichlorobenzene	2,600	< 1	< 1	< 1	< 1	NA	< 1	< 1	NA	NA	< 1	< 1	NA	< 1	< 1	NA	< 1
1,4-Dichlorobenzene	4.86	< 1	< 1	< 1	< 1	NA	< 1	< 1	NA	NA	< 1	< 1	NA	< 1	< 1	NA	< 1
2,2'-Oxybis(1-Chloropropane)	—	< 1	< 1	< 1	< 1	NA	< 1	< 1	NA	NA	< 1	< 1	NA	< 1	< 1	NA	< 1
2,4,5-Trichlorophenol	—	< 5	< 5	< 5	< 5	NA	< 5	< 5	NA	NA	< 5	< 5	NA	< 5	< 5	NA	< 5
2,4,6-Trichlorophenol	3.93	< 5	< 5	< 5	< 5	NA	< 5	< 5	NA	NA	< 5	< 5	NA	< 5	< 5	NA	< 5
2,4-Dichlorophenol	191	< 3	< 3	< 3	< 3	NA	< 3	< 3	NA	NA	< 3	< 3	NA	< 3	< 3	NA	< 3
2,4-Dimethylphenol	553	< 3	< 3	< 3	< 3	NA	< 3	< 3	NA	NA	< 3	< 3	NA	< 3	< 3	NA	< 3
2,4-Dinitrophenol	3,460	< 10	< 10	< 10	< 10	NA	< 10	< 10	NA	NA	< 10	< 10	NA	< 10	< 10	NA	< 10
2,4-Dinitrotoluene	9.1	< 5	< 5	< 5	< 5	NA	< 5	< 5	NA	NA	< 5	< 5	NA	< 5	< 5	NA	< 5
2,6-Dinitrotoluene	—	< 5	< 5	< 5	< 5	NA	< 5	< 5	NA	NA	< 5	< 5	NA	< 5	< 5	NA	< 5
2-Chloronaphthalene	—	< 1	< 1	< 1	< 1	NA	< 1	< 1	NA	NA	< 1	< 1	NA	< 1	< 1	NA	< 1
2-Chlorophenol	97	< 1	< 1	< 1	< 1	NA	< 1	< 1	NA	NA	< 1	< 1	NA	< 1	< 1	NA	< 1
2-Methylnaphthalene	—	< 1	< 1	< 1	< 1	NA	< 1	< 1	NA	NA	< 1	< 1	NA	< 1	< 1	NA	< 1
2-Methylphenol	—	< 2	< 2	< 2	< 2	NA	< 2	< 2	NA	NA	< 2	< 2	NA	< 2	< 2	NA	< 2
2-Nitroaniline	—	< 5	< 5	< 5	< 5	NA	< 5	< 5	NA	NA	< 5	< 5	NA	< 5	< 5	NA	< 5
2-Nitrophenol	—	< 5	< 5	< 5	< 5	NA	< 5	< 5	NA	NA	< 5	< 5	NA	< 5	< 5	NA	< 5
3,3'-Dichlorobenzidine	0.0462	< 5	< 5	< 5	< 5	NA	< 5	< 5	NA	NA	< 5	< 5	NA	< 5	< 5	NA	< 5
3-Nitroaniline	—	< 6	< 6	< 6	< 6	NA	< 6	< 6	NA	NA	< 6	< 6	NA	< 6	< 6	NA	< 6
4,6-Dinitro-2-Methylphenol	765	< 10	< 10	< 10	< 10	NA	< 10	< 10	NA	NA	< 10	< 10	NA	< 10	< 10	NA	< 10
4-Bromophenyl-phenylether	—	< 1	< 1	< 1	< 1	NA	< 1	< 1	NA	NA	< 1	< 1	NA	< 1	< 1	NA	< 1
4-Chloro-3-methylphenol	—	< 2	< 2	< 2	< 2	NA	< 2	< 2	NA	NA	< 2	< 2	NA	< 2	< 2	NA	< 2
4-Chloroaniline	—	< 3	< 3	< 3	< 3	NA	< 3	< 3	NA	NA	< 3	< 3	NA	< 3	< 3	NA	< 3
4-Chlorophenyl-phenylether	—	< 1	< 1	< 1	< 1	NA	< 1	< 1	NA	NA	< 1	< 1	NA	< 1	< 1	NA	< 1
4-Methylphenol	—	< 1	< 1	< 1	< 1	NA	< 1	< 1	NA	NA	< 1	< 1	NA	< 1	< 1	NA	< 1
4-Nitroaniline	—	< 5	< 5	< 5	< 5	NA	< 5	< 5	NA	NA	< 5	< 5	NA	< 5	< 5	NA	< 5
4-Nitrophenol	—	< 5	< 5	< 5	< 5	NA	< 5	< 5	NA	NA	< 5	< 5	NA	< 5	< 5	NA	< 5

Table B-1: Groundwater Analytical Data Collected During the RI/FS

Parameter	Controlling ARAR	RMW-10				RMW-11							RMW-11D				
		2/9/99	4/14/99	8/10/99	11/3/99	3/9/99	4/14/99	8/11/99	10/12/99	10/19/99	11/4/99	11/4/99 Duplicate	3/9/99	4/13/99	8/11/99	10/19/99	11/4/99
Semivolatile Organics (EPA Method 8270) (µg/L)																	
Acenaphthene	643	< 1	< 1	< 1	< 1	NA	< 1	< 1	NA	NA	< 1	< 1	NA	< 1	< 1	NA	< 1
Acenaphthylene	—	< 1	< 1	< 1	< 1	NA	< 1	< 1	NA	NA	< 1	< 1	NA	< 1	< 1	NA	< 1
Anthracene	25,900	< 1	< 1	< 1	< 1	NA	< 1	< 1	NA	NA	< 1	< 1	NA	< 1	< 1	NA	< 1
Benzo(a)anthracene	0.0296	< 1	< 1	< 1	< 1	NA	< 1	< 1	NA	NA	< 1	< 1	NA	< 1	< 1	NA	< 1
Benzo(a)pyrene	0.0296	< 1	< 1	< 1	< 1	NA	< 1	< 1	NA	NA	< 1	< 1	NA	< 1	< 1	NA	< 1
Benzo(b)fluoranthene	0.0296	< 1	< 1	< 1	< 1	NA	< 1	< 1	NA	NA	< 1	< 1	NA	< 1	< 1	NA	< 1
Benzo(g,h,i)perylene	—	< 1	< 1	< 1	< 1	NA	< 1	< 1	NA	NA	< 1	< 1	NA	< 1	< 1	NA	< 1
Benzo(k)fluoranthene	0.0296	< 1	< 1	< 1	< 1	NA	< 1	< 1	NA	NA	< 1	< 1	NA	< 1	< 1	NA	< 1
Benzoic Acid	—	< 10	< 10	< 10	< 10	NA	< 10	< 10	NA	NA	< 10	< 10	NA	< 10	< 10	NA	< 10
Benzyl Alcohol	—	< 5	< 5	< 5	< 5	NA	< 5	< 5	NA	NA	< 5	< 5	NA	< 5	< 5	NA	< 5
bis(2-Chloroethoxy) Methane	—	< 1	< 1	< 1	< 1	NA	< 1	< 1	NA	NA	< 1	< 1	NA	< 1	< 1	NA	< 1
Bis-(2-Chloroethyl) Ether	0.854	< 2	< 2	< 2	< 2	NA	< 2	< 2	NA	NA	< 2	< 2	NA	< 2	< 2	NA	< 2
bis(2-Ethylhexyl)phthalate	3.56	5.8	< 1	< 1	< 1	NA	< 1	< 1	NA	NA	< 1	< 1	NA	< 1	< 1	NA	< 1
Butylbenzylphthalate	1,250	< 1	< 1	< 1	< 1	NA	< 1	< 1	NA	NA	< 1	< 1	NA	< 1	< 1	NA	< 1
Carbazole	—	< 1	< 1	< 1	< 1	NA	< 1	< 1	NA	NA	< 1	< 1	NA	< 1	< 1	NA	< 1
Chrysene	0.0296	< 1	< 1	< 1	< 1	NA	< 1	< 1	NA	NA	< 1	< 1	NA	< 1	< 1	NA	< 1
Dibenz(a,h)anthracene	0.0296	< 1	< 1	< 1	< 1	NA	< 1	< 1	NA	NA	< 1	< 1	NA	< 1	< 1	NA	< 1
Dibenzofuran	—	< 1	< 1	< 1	< 1	NA	< 1	< 1	NA	NA	< 1	< 1	NA	< 1	< 1	NA	< 1
Diethylphthalate	28,400	< 1	< 1	< 1	< 1	NA	< 1	< 1	NA	NA	< 1	< 1	NA	< 1	< 1	NA	< 1
Dimethylphthalate	72,000	< 1	< 1	< 1	< 1	NA	< 1	< 1	NA	NA	< 1	< 1	NA	< 1	< 1	NA	< 1
Di-n-Butylphthalate	2,910	< 1	< 1	< 1	< 1	NA	< 1	< 1	NA	NA	< 1	< 1	NA	< 1	< 1	NA	< 1
Di-n-Octyl phthalate	—	< 1	< 1	< 1	< 1	NA	< 1	< 1	NA	NA	< 1	< 1	NA	< 1	< 1	NA	< 1
Fluoranthene	90.2	< 1	< 1	< 1	< 1	NA	< 1	< 1	NA	NA	< 1	< 1	NA	< 1	< 1	NA	< 1
Fluorene	3,460	< 1	< 1	< 1	< 1	NA	< 1	< 1	NA	NA	< 1	< 1	NA	< 1	< 1	NA	< 1
Hexachlorobenzene	0.000466	< 1	< 1	< 1	< 1	NA	< 1	< 1	NA	NA	< 1	< 1	NA	< 1	< 1	NA	< 1
Hexachlorobutadiene	29.9	< 2	< 2	< 2	< 2	NA	< 2	< 2	NA	NA	< 2	< 2	NA	< 2	< 2	NA	< 2
Hexachlorocyclopentadiene	4,180	< 5	< 5	< 5	< 5	NA	< 5	< 5	NA	NA	< 5	< 5	NA	< 5	< 5	NA	< 5
Hexachloroethane	5.33	< 2	< 2	< 2	< 2	NA	< 2	< 2	NA	NA	< 2	< 2	NA	< 2	< 2	NA	< 2
Indeno(1,2,3-cd)pyrene	0.0296	< 1	< 1	< 1	< 1	NA	< 1	< 1	NA	NA	< 1	< 1	NA	< 1	< 1	NA	< 1
Isophorone	600	< 1	< 1	< 1	< 1	NA	< 1	< 1	NA	NA	< 1	< 1	NA	< 1	< 1	NA	< 1
Naphthalene	9,880	< 1	< 1	< 1	< 1	NA	< 1	3.6	NA	NA	< 1	< 1	NA	< 1	< 1	NA	1
Nitrobenzene	449	< 1	< 1	< 1	< 1	NA	< 1	< 1	NA	NA	< 1	< 1	NA	< 1	< 1	NA	< 1
N-Nitroso-di-n-propylamine	0.819	< 2	< 2	< 2	< 2	NA	< 2	< 2	NA	NA	< 2	< 2	NA	< 2	< 2	NA	< 2
N-Nitrosodiphenylamine	9.73	< 1	< 1	< 1	< 1	NA	< 1	< 1	NA	NA	< 1	< 1	NA	< 1	< 1	NA	< 1
Pentachlorophenol	4.91	< 5	< 5	< 5	< 5	NA	< 5	< 5	NA	NA	< 5	< 5	NA	< 5	< 5	NA	< 5
Phenanthrene	—	< 1	< 1	< 1	< 1	NA	< 1	< 1	NA	NA	< 1	< 1	NA	< 1	< 1	NA	< 1
Phenol	1,110,000	< 2	< 2	< 2	< 2	NA	< 2	< 2	NA	NA	< 2	< 2	NA	< 2	< 2	NA	< 2
Pyrene	2,590	< 1	< 1	< 1	< 1	NA	< 1	< 1	NA	NA	< 1	< 1	NA	< 1	< 1	NA	< 1
Volatile Organics (EPA Method 8260) (µg/L)																	
1,1,1,2-Tetrachloroethane	—	< 1	NA	NA	NA	< 1	NA	NA	NA	NA	NA	NA	< 1	NA	NA	NA	NA
1,1,1-Trichloroethane	417,000	< 1	NA	NA	NA	< 1	NA	NA	NA	NA	NA	NA	< 1	NA	NA	NA	NA
1,1,2,2-Tetrachloroethane	6.48	< 1	NA	NA	NA	< 1	NA	NA	NA	NA	NA	NA	< 1	NA	NA	NA	NA
1,1,2-Trichloroethane	25.3	< 1	NA	NA	NA	< 1	NA	NA	NA	NA	NA	NA	< 1	NA	NA	NA	NA
1,1,2-Trichlorotrifluoroethane	—	< 2	NA	NA	NA	< 5	NA	NA	NA	NA	NA	NA	< 5	NA	NA	NA	NA
1,1-Dichloroethane	—	< 1	NA	NA	NA	< 1	NA	NA	NA	NA	NA	NA	< 1	NA	NA	NA	NA
1,1-Dichloroethene	1.93	< 1	NA	NA	NA	< 1	NA	NA	NA	NA	NA	NA	< 1	NA	NA	NA	NA
1,1-Dichloropropene	—	< 1	NA	NA	NA	< 1	NA	NA	NA	NA	NA	NA	< 1	NA	NA	NA	NA
1,2,3-Trichlorobenzene	—	< 5	NA	NA	NA	< 5	NA	NA	NA	NA	NA	NA	< 5	NA	NA	NA	NA
1,2,3-Trichloropropane	—	< 1	NA	NA	NA	< 3	NA	NA	NA	NA	NA	NA	< 3	NA	NA	NA	NA
1,2,4-Trichlorobenzene	227	< 5	NA	NA	NA	< 5	NA	NA	NA	NA	NA	NA	< 5	NA	NA	NA	NA
1,2,4-Trimethylbenzene	—	< 1	NA	NA	NA	< 1	NA	NA	NA	NA	NA	NA	< 1	NA	NA	NA	NA
1,2-Dibromo-3-chloropropane	—	< 5	NA	NA	NA	< 5	NA	NA	NA	NA	NA	NA	< 5	NA	NA	NA	NA
1,2-Dichlorobenzene	4,200	< 1	NA	NA	NA	< 1	NA	NA	NA	NA	NA	NA	< 1	NA	NA	NA	NA
1,2-Dichloroethane	59.4	< 1	NA	NA	NA	< 1	NA	NA	NA	NA	NA	NA	< 1	NA	NA	NA	NA
1,2-Dichloropropane	23.2	< 1	NA	NA	NA	< 1	NA	NA	NA	NA	NA	NA	< 1	NA	NA	NA	NA
1,3,5-Trimethylbenzene	—	< 1	NA	NA	NA	< 1	NA	NA	NA	NA	NA	NA	< 1	NA	NA	NA	NA
1,3-Dichlorobenzene	2,600	< 1	NA	NA	NA	< 1	NA	NA	NA	NA	NA	NA	< 1	NA	NA	NA	NA
1,3-Dichloropropane	—	< 1	NA	NA	NA	< 1	NA	NA	NA	NA	NA	NA	< 1	NA	NA	NA	NA
1,4-Dichlorobenzene	4.86	< 1	NA	NA	NA	< 1	NA	NA	NA	NA	NA	NA	< 1	NA	NA	NA	NA

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		2/9/99	4/14/99	8/10/99	11/3/99	3/9/99	4/14/99	8/11/99	10/12/99	10/19/99	11/4/99	11/4/99 Duplicate	3/9/99	4/13/99	8/11/99	10/19/99	11/4/99
Volatile Organics (EPA Method 8260) (µg/L)																	
2,2-Dichloropropane	—	< 1	NA	NA	NA	< 1	NA	NA	NA	NA	NA	NA	< 1	NA	NA	NA	NA
2-Butanone	—	< 5	NA	NA	NA	< 5	NA	NA	NA	NA	NA	NA	< 5	NA	NA	NA	NA
2-Chloroethylvinylether	—	< 5	NA	NA	NA	< 5	NA	NA	NA	NA	NA	NA	< 5	NA	NA	NA	NA
2-Chlorotoluene	—	< 1	NA	NA	NA	< 1	NA	NA	NA	NA	NA	NA	< 1	NA	NA	NA	NA
2-Hexanone	—	< 5	NA	NA	NA	< 5	NA	NA	NA	NA	NA	NA	< 5	NA	NA	NA	NA
4-Chlorotoluene	—	< 1	NA	NA	NA	< 1	NA	NA	NA	NA	NA	NA	< 1	NA	NA	NA	NA
4-Isopropyltoluene	—	< 1	NA	NA	NA	< 1	NA	NA	NA	NA	NA	NA	< 1	NA	NA	NA	NA
4-Methyl-2-Pentanone (MIBK)	—	< 5	NA	NA	NA	< 5	NA	NA	NA	NA	NA	NA	< 5	NA	NA	NA	NA
Acetone	—	< 5	NA	NA	NA	< 10	NA	NA	NA	NA	NA	NA	< 10	NA	NA	NA	NA
Acrolein	780	< 50	NA	NA	NA	< 50	NA	NA	NA	NA	NA	NA	< 50	NA	NA	NA	NA
Acrylonitrile	0.4	< 5	NA	NA	NA	< 10	NA	NA	NA	NA	NA	NA	< 10	NA	NA	NA	NA
Benzene	43	< 1	NA	NA	NA	< 1	NA	NA	NA	NA	NA	NA	< 1	NA	NA	NA	NA
Bromobenzene	—	< 1	NA	NA	NA	< 1	NA	NA	NA	NA	NA	NA	< 1	NA	NA	NA	NA
Bromochloromethane	—	< 1	NA	NA	NA	< 1	NA	NA	NA	NA	NA	NA	< 1	NA	NA	NA	NA
Bromodichloromethane	22	< 1	NA	NA	NA	< 1	NA	NA	NA	NA	NA	NA	< 1	NA	NA	NA	NA
Bromoethane	—	< 2	NA	NA	NA	< 2	NA	NA	NA	NA	NA	NA	< 2	NA	NA	NA	NA
Bromoform	219	< 1	NA	NA	NA	< 1	NA	NA	NA	NA	NA	NA	< 1	NA	NA	NA	NA
Bromomethane	968	< 2	NA	NA	NA	< 2	NA	NA	NA	NA	NA	NA	< 2	NA	NA	NA	NA
Carbon Disulfide	—	< 1	NA	NA	NA	< 1	NA	NA	NA	NA	NA	NA	< 1	NA	NA	NA	NA
Carbon Tetrachloride	2.66	< 1	NA	NA	NA	< 1	NA	NA	NA	NA	NA	NA	< 1	NA	NA	NA	NA
Chlorobenzene	5,030	< 1	NA	NA	NA	< 1	NA	NA	NA	NA	NA	NA	< 1	NA	NA	NA	NA
Chloroethane	—	< 2	NA	NA	NA	< 2	NA	NA	NA	NA	NA	NA	< 2	NA	NA	NA	NA
Chloroform	283	< 1	NA	NA	NA	< 1	NA	NA	NA	NA	NA	NA	< 1	NA	NA	NA	NA
Chloromethane	133	< 2	NA	NA	NA	< 2	NA	NA	NA	NA	NA	NA	< 2	NA	NA	NA	NA
cis-1,2-Dichloroethene	—	< 1	NA	NA	NA	< 1	NA	NA	NA	NA	NA	NA	< 1	NA	NA	NA	NA
cis-1,3-Dichloropropene	—	< 1	NA	NA	NA	< 1	NA	NA	NA	NA	NA	NA	< 1	NA	NA	NA	NA
Dibromochloromethane	20.6	< 1	NA	NA	NA	< 1	NA	NA	NA	NA	NA	NA	< 1	NA	NA	NA	NA
Dibromomethane	—	< 1	NA	NA	NA	< 1	NA	NA	NA	NA	NA	NA	< 1	NA	NA	NA	NA
Ethylbenzene	6,910	< 1	NA	NA	NA	< 1	NA	NA	NA	NA	NA	NA	< 1	NA	NA	NA	NA
Ethylene Dibromide	—	< 1	NA	NA	NA	< 1	NA	NA	NA	NA	NA	NA	< 1	NA	NA	NA	NA
Hexachlorobutadiene	29.9	< 5	NA	NA	NA	< 5	NA	NA	NA	NA	NA	NA	< 5	NA	NA	NA	NA
Isopropylbenzene	—	< 1	NA	NA	NA	< 1	NA	NA	NA	NA	NA	NA	< 1	NA	NA	NA	NA
m,p-Xylene	—	< 1	NA	NA	NA	< 1	NA	NA	NA	NA	NA	NA	< 1	NA	NA	NA	NA
Methyl Iodide	—	< 1	NA	NA	NA	< 1	NA	NA	NA	NA	NA	NA	< 1	NA	NA	NA	NA
Methylene Chloride	1,600	< 2	NA	NA	NA	< 2	NA	NA	NA	NA	NA	NA	< 2	NA	NA	NA	NA
Naphthalene	9,880	< 5	NA	NA	NA	< 5	NA	NA	NA	NA	NA	NA	< 5	NA	NA	NA	NA
n-Butylbenzene	—	< 1	NA	NA	NA	< 1	NA	NA	NA	NA	NA	NA	< 1	NA	NA	NA	NA
n-Propylbenzene	—	< 1	NA	NA	NA	< 1	NA	NA	NA	NA	NA	NA	< 1	NA	NA	NA	NA
o-Xylene	—	< 1	NA	NA	NA	< 1	NA	NA	NA	NA	NA	NA	< 1	NA	NA	NA	NA
sec-Butylbenzene	—	< 1	NA	NA	NA	< 1	NA	NA	NA	NA	NA	NA	< 1	NA	NA	NA	NA
Styrene	—	< 1	NA	NA	NA	< 1	NA	NA	NA	NA	NA	NA	< 1	NA	NA	NA	NA
tert-Butylbenzene	—	< 1	NA	NA	NA	< 1	NA	NA	NA	NA	NA	NA	< 1	NA	NA	NA	NA
Tetrachloroethene	4.15	< 1	NA	NA	NA	< 1	NA	NA	NA	NA	NA	NA	< 1	NA	NA	NA	NA
Toluene	48,500	< 1	NA	NA	NA	< 1	NA	NA	NA	NA	NA	NA	< 1	NA	NA	NA	NA
trans-1,2-Dichloroethene	32,800	< 1	NA	NA	NA	< 1	NA	NA	NA	NA	NA	NA	< 1	NA	NA	NA	NA
trans-1,3-Dichloropropene	—	< 1	NA	NA	NA	< 1	NA	NA	NA	NA	NA	NA	< 1	NA	NA	NA	NA
trans-1,4-Dichloro-2-butene	—	< 5	NA	NA	NA	< 5	NA	NA	NA	NA	NA	NA	< 5	NA	NA	NA	NA
Trichloroethene	55.6	< 1	NA	NA	NA	< 1	NA	NA	NA	NA	NA	NA	< 1	NA	NA	NA	NA
Trichlorofluoromethane	—	< 2	NA	NA	NA	< 2	NA	NA	NA	NA	NA	NA	< 2	NA	NA	NA	NA
Vinyl Acetate	—	< 5	NA	NA	NA	< 5	NA	NA	NA	NA	NA	NA	< 5	NA	NA	NA	NA
Vinyl Chloride	2.92	< 2	NA	NA	NA	< 2	NA	NA	NA	NA	NA	NA	< 2	NA	NA	NA	NA

NOTES:

Detected values are highlighted in bold.
Bold and boxed = detected compound above controlling ARAR..
NA - Indicates compound not analyzed for.
B - Contamination in assoc. method blank.
J - Indicates estimated value.
R - Rejected data.

Table B-1. Summary of Groundwater Analytical Data Collected During the RI/FS

Parameter	Controlling ARAR	RMW-1		RMW-12D					RMW-13D					RMW-2	
		2/10/99	4/12/99	2/9/99	4/13/99	8/11/99	10/19/99	11/3/99	2/10/99	4/14/99	8/11/99	10/19/99	11/4/99	2/9/99	4/12/99
Conventionals - Geochemical Parameters (mg/L)															
Total Dissolved Solids	—	3,200	2,900	1,100	900	3,900	NA	5,900	2,900	2,900	2,600	NA	2,600	1,800	1,700
Total Suspended Solids	—	4.5	3.6	32	42	2.9	NA	2.1	1.9	< 1.1	1.4	NA	< 1.1	3.6	3.9
Total Organic Carbon	—	32	47	8.3	13	57	NA	200	50	54	55	NA	53	120	120
N-Ammonia (mg-N/L)	—	5.4	15	6.7	8.2	30	NA	140	37	37	40	NA	41	20	28
Nitrate + Nitrite (mg-N/L)	—	0.08	0.048	< 0.01	0.24	0.014	NA	< 0.1	0.012	0.082	0.02	NA	< 0.01	0.019	0.073
Calcium	—	526	504	223	223	169	NA	111	207	211	184	NA	175	205	217
Chloride	—	110	190	53	72	1,500	NA	2,300	950	950	790	NA	750	180	180
Iron	—	1.47	1.15	16.4	14.2	8.07	NA	1.12	0.41	0.26	0.32	NA	0.29	13	9.42
Ferrous Iron	—	1.1	1.8	17	15	16	NA	1.7	0.41	0.72	0.58	NA	0.52	13	10
Magnesium	—	110	103	24.3	28.3	149	NA	251	125	129	114	NA	110	45.6	50.9
Manganese	—	4.18	3.34	0.69	0.588	0.333	NA	0.092	0.12	0.122	0.103	NA	0.107	1.82	1.72
Sodium	—	NA	NA	NA	NA	974	NA	1,670	NA	NA	587	NA	574	NA	NA
Sulfate	—	NA	NA	NA	NA	NA	NA	63	NA	NA	NA	NA	28	NA	NA
Sulfide	—	24	14	< 0.09	< 0.05	< 0.05	NA	0.09	< 0.1	< 0.05	< 0.05	NA	0.18	< 0.1	0.2
Alkalinity	—	1,200	1,200	330	660	1,800	NA	2,300	1,400	1,400	1,400	NA	1,300	940	1,100
Metals (mg/L)															
Arsenic	0.005	0.002	0.002	0.007	0.009	0.003	NA	0.001	< 0.002	< 0.001	0.001	NA	< 0.001	0.003	0.002
Barium	500	0.147	0.192	0.029	0.027	0.167	NA	0.273	0.156	0.16	0.136	NA	0.133	0.264	0.268
Chromium	162	0.044	0.28	0.012	0.016	0.352	NA	0.648	0.096	0.11	0.105	NA	0.107	0.884	0.766
Hexavalent Chrome	0.05	< 0.1	< 0.11	< 0.06	< 0.06	< 0.01	NA	< 0.02	< 0.1	< 0.01	< 0.01	NA	< 0.06	< 0.06	< 0.11
Copper	0.0031	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	NA	< 0.002	0.002	0.002	< 0.002	NA	< 0.002	0.004	< 0.002
Lead	0.0081	0.004	< 0.001	< 0.001	< 0.001	< 0.001	NA	< 0.001	< 0.001	< 0.001	< 0.001	NA	< 0.001	0.026	0.008
Mercury	0.00005	< 0.0001	< 0.0001	< 0.0001	< 0.0002	< 0.0001	NA	< 0.0001	< 0.0001	< 0.0002	< 0.0001	NA	< 0.0001	0.0001	< 0.0001
Nickel	0.0082	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	NA	< 0.01	< 0.01	< 0.01	< 0.01	NA	< 0.01	< 0.01	< 0.01
Zinc	0.081	0.025 B	0.008	0.004 B	0.016 B	0.006	NA	< 0.006	0.008 B	< 0.004	0.004	NA	0.009	0.071 B	0.02
Other Contaminants (mg/L)															
Weak Acid Dissoc. Cyanide	0.0028	< 0.005	0.029	< 0.005	< 0.005	0.012	< 0.004	< 0.005	< 0.005	< 0.005	0.008	< 0.004	< 0.005	< 0.005	< 0.005
Diesel Range Hydrocarbons	0.5	0.28	0.35	< 0.25	< 0.25	0.34	NA	0.57	< 0.25	< 0.25	< 0.25	NA	0.26	0.76	0.78
Semivolatile Organics (EPA Method 8270) (µg/L)															
1,2,4-Trichlorobenzene	227	< 1	< 1	< 1	< 1	< 1	NA	< 1	< 1	< 1	< 1	NA	< 1	< 1	< 1
1,2-Dichlorobenzene	4,200	< 1	< 1	< 1	< 1	< 1	NA	< 1	< 1	< 1	< 1	NA	< 1	< 1	< 1
1,3-Dichlorobenzene	2,600	< 1	< 1	< 1	< 1	< 1	NA	< 1	< 1	< 1	< 1	NA	< 1	< 1	< 1
1,4-Dichlorobenzene	4.86	< 1	< 1	< 1	< 1	< 1	NA	< 1	< 1	< 1	< 1	NA	< 1	< 1	< 1
2,2'-Oxybis(1-Chloropropane)	—	< 1	< 1	< 1	< 1	< 1	NA	< 1	< 1	< 1	< 1	NA	< 1	< 1	< 1
2,4,5-Trichlorophenol	—	< 5	< 5	< 5	< 5	< 5	NA	< 5	< 5	< 5	< 5	NA	< 5	< 5	< 5
2,4,6-Trichlorophenol	3.93	< 5	< 5	< 5	< 5	< 5	NA	< 5	< 5	< 5	< 5	NA	< 5	< 5	< 5
2,4-Dichlorophenol	191	< 3	< 3	< 3	< 3	< 3	NA	< 3	< 3	< 3	< 3	NA	< 3	< 3	< 3
2,4-Dimethylphenol	553	< 3	< 3	< 3	< 3	< 3	NA	< 3	< 3	< 3	< 3	NA	< 3	< 3	< 3
2,4-Dinitrophenol	3,460	< 10	< 10	< 10	< 10	< 10	NA	< 10	< 10	< 10	< 10	NA	< 10	< 10	< 10
2,4-Dinitrotoluene	9.1	< 5	< 5	< 5	< 5	< 5	NA	< 5	< 5	< 5	< 5	NA	< 5	< 5	< 5
2,6-Dinitrotoluene	—	< 5	< 5	< 5	< 5	< 5	NA	< 5	< 5	< 5	< 5	NA	< 5	< 5	< 5
2-Chloronaphthalene	—	< 1	< 1	< 1	< 1	< 1	NA	< 1	< 1	< 1	< 1	NA	< 1	< 1	< 1
2-Chlorophenol	97	< 1	< 1	< 1	< 1	< 1	NA	< 1	< 1	< 1	< 1	NA	< 1	< 1	< 1
2-Methylnaphthalene	—	2.9	2.4	< 1	< 1	< 1	NA	< 1	< 1	< 1	< 1	NA	< 1	< 1	< 1
2-Methylphenol	—	< 2	< 2	< 2	< 2	< 2	NA	< 2	< 2	< 2	< 2	NA	< 2	< 2	< 2
2-Nitroaniline	—	< 5	< 5	< 5	< 5	< 5	NA	< 5	< 5	< 5	< 5	NA	< 5	< 5	< 5
2-Nitrophenol	—	< 5	< 5	< 5	< 5	< 5	NA	< 5	< 5	< 5	< 5	NA	< 5	< 5	< 5
3,3'-Dichlorobenzidine	0.0462	< 5	< 5	< 5	< 5	< 5	NA	< 5	< 5	< 5	< 5	NA	< 5	< 5	< 5
3-Nitroaniline	—	< 6	< 6	< 6	< 6	< 6	NA	< 6	< 6	< 6	< 6	NA	< 6	< 6	< 6
4,6-Dinitro-2-Methylphenol	765	< 10	< 10	< 10	< 10	< 10	NA	< 10	< 10	< 10	< 10	NA	< 10	< 10	< 10
4-Bromophenyl-phenylether	—	< 1	< 1	< 1	< 1	< 1	NA	< 1	< 1	< 1	< 1	NA	< 1	< 1	< 1
4-Chloro-3-methylphenol	—	< 2	< 2	< 2	< 2	< 2	NA	< 2	< 2	< 2	< 2	NA	< 2	< 2	< 2
4-Chloroaniline	—	< 3	< 3	< 3	< 3	< 3	NA	< 3	< 3	< 3	< 3	NA	< 3	< 3	< 3
4-Chlorophenyl-phenylether	—	< 1	< 1	< 1	< 1	< 1	NA	< 1	< 1	< 1	< 1	NA	< 1	< 1	< 1
4-Methylphenol	—	< 1	< 1	< 1	< 1	< 1	NA	< 1	< 1	< 1	< 1	NA	< 1	< 1	< 1
4-Nitroaniline	—	< 5	< 5	< 5	< 5	< 5	NA	< 5	< 5	< 5	< 5	NA	< 5	< 5	< 5
4-Nitrophenol	—	< 5	< 5	< 5	< 5	< 5	NA	< 5	< 5	< 5	< 5	NA	< 5	< 5	< 5

Table B-1. Summary of Groundwater Analytical Data Collected During the RI/FS

Parameter	Controlling ARAR	RMW-1		RMW-12D					RMW-13D					RMW-2	
		2/10/99	4/12/99	2/9/99	4/13/99	8/11/99	10/19/99	11/3/99	2/10/99	4/14/99	8/11/99	10/19/99	11/4/99	2/9/99	4/12/99
Semivolatile Organics (EPA Method 8270) (µg/L)															
Acenaphthene	643	3.2	4.3	< 1	< 1	< 1	NA	< 1	< 1	< 1	< 1	NA	< 1	1.2	1.2
Acenaphthylene	—	< 1	< 1	< 1	< 1	< 1	NA	< 1	< 1	< 1	< 1	NA	< 1	< 1	< 1
Anthracene	25,900	< 1	< 1	< 1	< 1	< 1	NA	< 1	< 1	< 1	< 1	NA	< 1	< 1	< 1
Benzo(a)anthracene	0.0296	< 1	< 1	< 1	< 1	< 1	NA	< 1	< 1	< 1	< 1	NA	< 1	< 1	< 1
Benzo(a)pyrene	0.0296	< 1	< 1	< 1	< 1	< 1	NA	< 1	< 1	< 1	< 1	NA	< 1	< 1	< 1
Benzo(b)fluoranthene	0.0296	< 1	< 1	< 1	< 1	< 1	NA	< 1	< 1	< 1	< 1	NA	< 1	< 1	< 1
Benzo(g,h,i)perylene	—	< 1	< 1	< 1	< 1	< 1	NA	< 1	< 1	< 1	< 1	NA	< 1	< 1	< 1
Benzo(k)fluoranthene	0.0296	< 1	< 1	< 1	< 1	< 1	NA	< 1	< 1	< 1	< 1	NA	< 1	< 1	< 1
Benzoic Acid	—	< 10	< 10	< 10	< 10	< 10	NA	< 10	< 10	< 10	< 10	NA	< 10	< 10	< 10
Benzyl Alcohol	—	< 5	< 5	< 5	< 5	< 5	NA	< 5	< 5	< 5	< 5	NA	< 5	< 5	< 5
Bis(2-Chloroethoxy) Methane	—	< 1	< 1	< 1	< 1	< 1	NA	< 1	< 1	< 1	< 1	NA	< 1	< 1	< 1
Bis-(2-Chloroethyl) Ether	0.854	< 2	< 2	< 2	< 2	< 2	NA	< 2	< 2	< 2	< 2	NA	< 2	< 2	< 2
Bis(2-Ethylhexyl)phthalate	3.56	< 1	< 1	1.8	< 1	< 1	NA	< 1	1.2	< 1	< 1	NA	< 1	1.8	< 1
Butylbenzylphthalate	1,250	< 1	< 1	< 1	< 1	< 1	NA	< 1	< 1	< 1	< 1	NA	< 1	< 1	< 1
Carbazole	—	1.2	1.1	< 1	< 1	< 1	NA	< 1	< 1	< 1	< 1	NA	< 1	< 1	< 1
Chrysene	0.0296	< 1	< 1	< 1	< 1	< 1	NA	< 1	< 1	< 1	< 1	NA	< 1	< 1	< 1
Dibenz(a,h)anthracene	0.0296	< 1	< 1	< 1	< 1	< 1	NA	< 1	< 1	< 1	< 1	NA	< 1	< 1	< 1
Dibenzofuran	—	1.4	1.6	< 1	< 1	< 1	NA	< 1	< 1	< 1	< 1	NA	< 1	< 1	< 1
Diethylphthalate	28,400	< 1	< 1	< 1	< 1	< 1	NA	< 1	< 1	< 1	< 1	NA	< 1	< 1	< 1
Dimethylphthalate	72,000	< 1	< 1	< 1	< 1	< 1	NA	< 1	< 1	< 1	< 1	NA	< 1	< 1	< 1
Di-n-Butylphthalate	2,910	< 1	< 1	< 1	< 1	< 1	NA	< 1	< 1	< 1	< 1	NA	< 1	< 1	< 1
Di-n-Octyl phthalate	—	< 1	< 1	< 1	< 1	< 1	NA	< 1	< 1	< 1	< 1	NA	< 1	< 1	< 1
Fluoranthene	90.2	< 1	< 1	< 1	< 1	< 1	NA	< 1	< 1	< 1	< 1	NA	< 1	< 1	< 1
Fluorene	3,460	1.7	2.3	< 1	< 1	< 1	NA	< 1	< 1	< 1	< 1	NA	< 1	< 1	< 1
Hexachlorobenzene	0.000466	< 1	< 1	< 1	< 1	< 1	NA	< 1	< 1	< 1	< 1	NA	< 1	< 1	< 1
Hexachlorobutadiene	29.9	< 2	< 2	< 2	< 2	< 2	NA	< 2	< 2	< 2	< 2	NA	< 2	< 2	< 2
Hexachlorocyclopentadiene	4,180	< 5	< 5	< 5	< 5	< 5	NA	< 5	< 5	< 5	< 5	NA	< 5	< 5	< 5
Hexachloroethane	5.33	< 2	< 2	< 2	< 2	< 2	NA	< 2	< 2	< 2	< 2	NA	< 2	< 2	< 2
Indeno(1,2,3-cd)pyrene	0.0296	< 1	< 1	< 1	< 1	< 1	NA	< 1	< 1	< 1	< 1	NA	< 1	< 1	< 1
Isophorone	600	< 1	< 1	< 1	< 1	< 1	NA	< 1	< 1	< 1	< 1	NA	< 1	< 1	< 1
Naphthalene	9,880	5.1	5.8	< 1	< 1	< 1	NA	< 1	< 1	< 1	< 1	NA	< 1	< 1	< 1
Nitrobenzene	449	< 1	< 1	< 1	< 1	< 1	NA	< 1	< 1	< 1	< 1	NA	< 1	< 1	< 1
N-Nitroso-di-n-propylamine	0.819	< 2	< 2	< 2	< 2	< 2	NA	< 2	< 2	< 2	< 2	NA	< 2	< 2	< 2
N-Nitrosodiphenylamine	9.73	< 1	< 1	< 1	< 1	< 1	NA	< 1	< 1	< 1	< 1	NA	< 1	< 1	< 1
Pentachlorophenol	4.91	< 5	< 5	< 5	< 5	< 5	NA	< 5	< 5	< 5	< 5	NA	< 5	< 5	< 5
Phenanthrene	—	2.4	3.5	< 1	< 1	< 1	NA	< 1	< 1	< 1	< 1	NA	< 1	< 1	< 1
Phenol	1,110,000	< 2	< 2	< 2	< 2	< 2	NA	< 2	< 2	< 2	< 2	NA	< 2	< 2	< 2
Pyrene	2,590	< 1	< 1	< 1	< 1	< 1	NA	< 1	< 1	< 1	< 1	NA	< 1	< 1	< 1
Volatile Organics (EPA Method 8260) (µg/L)															
1,1,1,2-Tetrachloroethane	—	< 1	NA	< 1	NA	NA	NA	NA	< 1	NA	NA	NA	NA	< 1	NA
1,1,1-Trichloroethane	417,000	< 1	NA	< 1	NA	NA	NA	NA	< 1	NA	NA	NA	NA	< 1	NA
1,1,2,2-Tetrachloroethane	6.48	< 1	NA	< 1	NA	NA	NA	NA	< 1	NA	NA	NA	NA	< 1	NA
1,1,2-Trichloroethane	25.3	< 1	NA	< 1	NA	NA	NA	NA	< 1	NA	NA	NA	NA	< 1	NA
1,1,2-Trichlorotrifluoroethane	—	< 2	NA	< 2	NA	NA	NA	NA	< 2	NA	NA	NA	NA	< 2	NA
1,1-Dichloroethane	—	< 1	NA	< 1	NA	NA	NA	NA	< 1	NA	NA	NA	NA	< 1	NA
1,1-Dichloroethene	1.93	< 1	NA	< 1	NA	NA	NA	NA	< 1	NA	NA	NA	NA	< 1	NA
1,1-Dichloropropene	—	< 1	NA	< 1	NA	NA	NA	NA	< 1	NA	NA	NA	NA	< 1	NA
1,2,3-Trichlorobenzene	—	< 5	NA	< 5	NA	NA	NA	NA	< 5	NA	NA	NA	NA	< 5	NA
1,2,3-Trichloropropane	—	< 1	NA	< 1	NA	NA	NA	NA	< 1	NA	NA	NA	NA	< 1	NA
1,2,4-Trichlorobenzene	227	< 5	NA	< 5	NA	NA	NA	NA	< 5	NA	NA	NA	NA	< 5	NA
1,2,4-Trimethylbenzene	—	< 1	NA	< 1	NA	NA	NA	NA	< 1	NA	NA	NA	NA	1	NA
1,2-Dibromo-3-chloropropane	—	< 5	NA	< 5	NA	NA	NA	NA	< 5	NA	NA	NA	NA	< 5	NA
1,2-Dichlorobenzene	4,200	< 1	NA	< 1	NA	NA	NA	NA	< 1	NA	NA	NA	NA	< 1	NA
1,2-Dichloroethane	59.4	< 1	NA	< 1	NA	NA	NA	NA	< 1	NA	NA	NA	NA	< 1	NA
1,2-Dichloropropane	23.2	< 1	NA	< 1	NA	NA	NA	NA	< 1	NA	NA	NA	NA	< 1	NA
1,3,5-Trimethylbenzene	—	< 1	NA	< 1	NA	NA	NA	NA	< 1	NA	NA	NA	NA	< 1	NA
1,3-Dichlorobenzene	2,600	< 1	NA	< 1	NA	NA	NA	NA	< 1	NA	NA	NA	NA	< 1	NA
1,3-Dichloropropane	—	< 1	NA	< 1	NA	NA	NA	NA	< 1	NA	NA	NA	NA	< 1	NA
1,4-Dichlorobenzene	4.86	< 1	NA	< 1	NA	NA	NA	NA	< 1	NA	NA	NA	NA	1.3	NA

Table B-1. Summary of Groundwater Analytical Data Collected During the RI/FS

Parameter	Controlling ARAR	RMW-1		RMW-12D					RMW-13D					RMW-2	
		2/10/99	4/12/99	2/9/99	4/13/99	8/11/99	10/19/99	11/3/99	2/10/99	4/14/99	8/11/99	10/19/99	11/4/99	2/9/99	4/12/99
Volatile Organics (EPA Method 8260) (µg/L)															
2,2-Dichloropropane	—	< 1	NA	< 1	NA	NA	NA	NA	< 1	NA	NA	NA	NA	< 1	NA
2-Butanone	—	< 5	NA	< 5	NA	NA	NA	NA	< 5	NA	NA	NA	NA	< 5	NA
2-Chloroethylvinylether	—	< 5	NA	< 5	NA	NA	NA	NA	< 5	NA	NA	NA	NA	< 5	NA
2-Chlorotoluene	—	< 1	NA	< 1	NA	NA	NA	NA	< 1	NA	NA	NA	NA	< 1	NA
2-Hexanone	—	< 5	NA	< 5	NA	NA	NA	NA	< 5	NA	NA	NA	NA	< 5	NA
4-Chlorotoluene	—	< 1	NA	< 1	NA	NA	NA	NA	< 1	NA	NA	NA	NA	< 1	NA
4-Isopropyltoluene	—	< 1	NA	< 1	NA	NA	NA	NA	< 1	NA	NA	NA	NA	< 1	NA
4-Methyl-2-Pentanone (MIBK)	—	< 5	NA	< 5	NA	NA	NA	NA	< 5	NA	NA	NA	NA	< 5	NA
Acetone	—	< 5	NA	< 5	NA	NA	NA	NA	< 5	NA	NA	NA	NA	< 5	NA
Acrolein	780	< 50	NA	< 50	NA	NA	NA	NA	< 50	NA	NA	NA	NA	< 50	NA
Acrylonitrile	0.4	< 5	NA	< 5	NA	NA	NA	NA	< 5	NA	NA	NA	NA	< 5	NA
Benzene	43	< 1	NA	< 1	NA	NA	NA	NA	< 1	NA	NA	NA	NA	< 1	NA
Bromobenzene	—	< 1	NA	< 1	NA	NA	NA	NA	< 1	NA	NA	NA	NA	< 1	NA
Bromochloromethane	—	< 1	NA	< 1	NA	NA	NA	NA	< 1	NA	NA	NA	NA	< 1	NA
Bromodichloromethane	22	< 1	NA	< 1	NA	NA	NA	NA	< 1	NA	NA	NA	NA	< 1	NA
Bromoethane	—	< 2	NA	< 2	NA	NA	NA	NA	< 2	NA	NA	NA	NA	< 2	NA
Bromoform	219	< 1	NA	< 1	NA	NA	NA	NA	< 1	NA	NA	NA	NA	< 1	NA
Bromomethane	968	< 2	NA	< 2	NA	NA	NA	NA	< 2	NA	NA	NA	NA	< 2	NA
Carbon Disulfide	—	< 1	NA	< 1	NA	NA	NA	NA	< 1	NA	NA	NA	NA	< 1	NA
Carbon Tetrachloride	2.66	< 1	NA	< 1	NA	NA	NA	NA	< 1	NA	NA	NA	NA	< 1	NA
Chlorobenzene	5,030	< 1	NA	< 1	NA	NA	NA	NA	< 1	NA	NA	NA	NA	**9.3**	NA
Chloroethane	—	< 2	NA	< 2	NA	NA	NA	NA	< 2	NA	NA	NA	NA	< 2	NA
Chloroform	283	< 1	NA	< 1	NA	NA	NA	NA	< 1	NA	NA	NA	NA	< 1	NA
Chloromethane	133	< 2	NA	< 2	NA	NA	NA	NA	< 2	NA	NA	NA	NA	< 2	NA
cis-1,2-Dichloroethene	—	< 1	NA	< 1	NA	NA	NA	NA	< 1	NA	NA	NA	NA	< 1	NA
cis-1,3-Dichloropropene	—	< 1	NA	< 1	NA	NA	NA	NA	< 1	NA	NA	NA	NA	< 1	NA
Dibromochloromethane	20.6	< 1	NA	< 1	NA	NA	NA	NA	< 1	NA	NA	NA	NA	< 1	NA
Dibromomethane	—	< 1	NA	< 1	NA	NA	NA	NA	< 1	NA	NA	NA	NA	< 1	NA
Ethylbenzene	6,910	< 1	NA	< 1	NA	NA	NA	NA	< 1	NA	NA	NA	NA	< 1	NA
Ethylene Dibromide	—	< 1	NA	< 1	NA	NA	NA	NA	< 1	NA	NA	NA	NA	< 1	NA
Hexachlorobutadiene	29.9	< 5	NA	< 5	NA	NA	NA	NA	< 5	NA	NA	NA	NA	< 5	NA
Isopropylbenzene	—	< 1	NA	< 1	NA	NA	NA	NA	< 1	NA	NA	NA	NA	< 1	NA
m,p-Xylene	—	< 1	NA	< 1	NA	NA	NA	NA	< 1	NA	NA	NA	NA	**1.8**	NA
Methyl Iodide	—	< 1	NA	< 1	NA	NA	NA	NA	< 1	NA	NA	NA	NA	< 1	NA
Methylene Chloride	1,600	< 2	NA	< 2	NA	NA	NA	NA	< 2	NA	NA	NA	NA	< 2	NA
Naphthalene	9,880	6	NA	< 5	NA	NA	NA	NA	< 5	NA	NA	NA	NA	< 5	NA
n-Butylbenzene	—	< 1	NA	< 1	NA	NA	NA	NA	< 1	NA	NA	NA	NA	< 1	NA
n-Propylbenzene	—	< 1	NA	< 1	NA	NA	NA	NA	< 1	NA	NA	NA	NA	< 1	NA
o-Xylene	—	< 1	NA	< 1	NA	NA	NA	NA	< 1	NA	NA	NA	NA	< 1	NA
sec-Butylbenzene	—	< 1	NA	< 1	NA	NA	NA	NA	< 1	NA	NA	NA	NA	< 1	NA
Styrene	—	< 1	NA	< 1	NA	NA	NA	NA	< 1	NA	NA	NA	NA	< 1	NA
tert-Butylbenzene	—	< 1	NA	< 1	NA	NA	NA	NA	< 1	NA	NA	NA	NA	< 1	NA
Tetrachloroethene	4.15	< 1	NA	< 1	NA	NA	NA	NA	< 1	NA	NA	NA	NA	< 1	NA
Toluene	48,500	< 1	NA	< 1	NA	NA	NA	NA	< 1	NA	NA	NA	NA	< 1	NA
trans-1,2-Dichloroethene	32,800	< 1	NA	< 1	NA	NA	NA	NA	< 1	NA	NA	NA	NA	< 1	NA
trans-1,3-Dichloropropene	—	< 1	NA	< 1	NA	NA	NA	NA	< 1	NA	NA	NA	NA	< 1	NA
trans-1,4-Dichloro-2-butene	—	< 5	NA	< 5	NA	NA	NA	NA	< 1	NA	NA	NA	NA	< 1	NA
Trichloroethene	55.6	< 1	NA	< 1	NA	NA	NA	NA	< 5	NA	NA	NA	NA	< 5	NA
Trichlorofluoromethane	—	< 2	NA	< 2	NA	NA	NA	NA	< 1	NA	NA	NA	NA	< 1	NA
Vinyl Acetate	—	< 5	NA	< 5	NA	NA	NA	NA	< 2	NA	NA	NA	NA	< 2	NA
Vinyl Chloride	2.92	< 2	NA	< 2	NA	NA	NA	NA	< 5	NA	NA	NA	NA	< 5	NA
									< 2	NA	NA	NA	NA	< 2	NA

NOTES:

Detected values are highlighted in bold.

Bold and boxed = detected compound above controlling ARAR..

NA - Indicates compound not analyzed for.

B - Contamination in assoc. method blank.

J - Indicates estimated value.

R - Rejected data.

Table B-1. Summary of Groundwater Analytical Data Collected During the RI/FS

Parameter	Controlling ARAR	RMW-2D 2/9/99	RMW-2D 4/12/99	RMW-3D 2/10/99	RMW-3D 4/13/99	RMW-3D 8/11/99	RMW-3D 10/19/99	RMW-3D 11/4/99	RMW-4B 10/19/99	RMW-6D 2/10/99	RMW-6D 4/14/99	RMW-6D 8/10/99	RMW-7 2/10/99	RMW-7 4/13/99	RMW-7 8/10/99	RMW-7 11/4/99
Conventionals - Geochemical Parameters (mg/L)																
Total Dissolved Solids	—	6,500	5,400	4,500	3,900	3,600	NA	1,800	NA	7,000	8,500	8,000	4,200	2,100	5,100	12,000
Total Suspended Solids	—	3.4	1.8	4.5	< 1	2.7	NA	2.1	NA	3.7	4.4	3.6	1.7	1.9	1.9	5.3
Total Organic Carbon	—	65	64	58	67	72	NA	60	NA	77	88	75	11	15	23	6.4
N-Ammonia (mg-N/L)	—	6.4	8.1	5.9	8.7	7	NA	8.2	NA	4.4	4.5	5	< 0.01	0.11	< 0.05	< 0.1
Nitrate + Nitrite (mg-N/L)	—	< 0.01	0.013	< 0.01	< 0.01	< 0.01	NA	< 0.01	NA	0.024	< 0.05	0.025	0.042	0.033	0.29	1.1
Calcium	—	42	44	46.6	54.3	46	NA	44.3	NA	83.6	89.1	92.8	67.9	46.5	105	247
Chloride	—	2,300	1,900	1,900	1,300	1,200	NA	1,300	NA	2,800	4,000	1,700	1,800	810	2,500	6,900
Iron	—	0.69	0.53	0.59	0.43	0.49	NA	0.42	NA	0.22	0.28	0.39	0.57	1.34	0.61	0.27
Ferrous Iron	—	0.79	1.2	0.42	1.3	0.83	NA	0.76	NA	0.29	0.41	0.82	0.4	1.6	0.68	0.22
Magnesium	—	163	170	163	174	159	NA	154	NA	155	193	245	114	64.3	165	413
Manganese	—	0.039	0.029	0.025	0.017	0.014	NA	0.011	NA	0.132	0.12	0.111	0.017	0.054	0.035	0.02
Sodium	—	NA	NA	NA	NA	1,130	NA	1,130	NA	NA	NA	2,710	NA	NA	1,450	3,260
Sulfate	—	NA	NA	NA	NA	NA	NA	34	NA	NA	NA	NA	NA	NA	NA	920
Sulfide	—	< 0.1	0.05	1.3	< 0.05	0.21	NA	< 0.05	NA	9.5	5.3	0.12	< 0.1	< 0.05	< 0.05	0.22
Alkalinity	—	1,900	1,900	1,600	1,600	1,600	NA	1,400	NA	1,800	1,700	1,700	590	630	280	350
Metals (mg/L)																
Arsenic	0.005	0.002	0.002	0.001	0.001	0.001	NA	< 0.001	NA	0.008	0.006	0.004	0.003	0.004	0.002	< 0.005
Barium	500	0.015	0.012	0.015	0.012	0.011	NA	0.009	NA	0.043	0.065	0.053	0.013	0.01	0.025	0.058
Chromium	162	0.087	0.109	0.079	0.105	0.078	NA	0.071	NA	0.141	0.151	0.114	0.014	0.025	0.007	< 0.005
Hexavalent Chrome	0.05	< 0.06	< 0.11	< 0.1	< 0.11	< 0.01	NA	< 0.06	NA	< 0.1	< 0.01	< 0.01	< 0.1	< 0.06	< 0.01	< 0.01
Copper	0.0031	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	NA	< 0.002	NA	< 0.002	< 0.002	< 0.002	0.005	0.009	0.005	0.005
Lead	0.0081	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	NA	< 0.001	NA	< 0.001	< 0.001	< 0.001	0.002	0.003	0.001	< 0.005
Mercury	0.00005	< 0.0001	< 0.0001	< 0.0001	< 0.0002	< 0.0001	NA	< 0.0001	NA	< 0.0001	< 0.0002	< 0.0001	< 0.0001	< 0.0002	< 0.0001	< 0.0001
Nickel	0.0082	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	NA	< 0.01	NA	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Zinc	0.081	0.007 B	< 0.004	0.013 B	0.09 B	0.014	NA	< 0.006	NA	0.007 B	0.007 B	0.006	0.136	0.009 B	0.008	0.017
Other Contaminants (mg/L)																
Weak Acid Dissoc. Cyanide	0.0028	< 0.005	< 0.005	< 0.005	< 0.005	0.005	< 0.004	< 0.005	< 0.004	< 0.005	0.01	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005
Diesel Range Hydrocarbons	0.5	< 0.25	< 0.25	< 0.25	< 0.25	< 0.25	NA	< 0.25	NA	< 0.25	< 0.25	< 0.25	< 0.25	< 0.25	< 0.25	< 0.25
Semivolatile Organics (EPA Method 8270) (µg/L)																
1,2,4-Trichlorobenzene	227	< 1	< 1	< 1	< 1	< 1	NA	< 1	NA	< 1	< 1	< 1	< 1	< 1	< 1	< 1
1,2-Dichlorobenzene	4,200	< 1	< 1	< 1	< 1	< 1	NA	< 1	NA	< 1	< 1	< 1	< 1	< 1	< 1	< 1
1,3-Dichlorobenzene	2,600	< 1	< 1	< 1	< 1	< 1	NA	< 1	NA	< 1	< 1	< 1	< 1	< 1	< 1	< 1
1,4-Dichlorobenzene	4.86	< 1	< 1	< 1	< 1	< 1	NA	< 1	NA	< 1	< 1	< 1	< 1	< 1	< 1	< 1
2,2'-Oxybis(1-Chloropropane)	—	< 1	< 1	< 1	< 1	< 1	NA	< 1	NA	< 1	< 1	< 1	< 1	< 1	< 1	< 1
2,4,5-Trichlorophenol	—	< 5	< 5	< 5	< 5	< 5	NA	< 5	NA	< 5	< 5	< 5	< 5	< 5	< 5	< 5
2,4,6-Trichlorophenol	3.93	< 5	< 5	< 5	< 5	< 5	NA	< 5	NA	< 5	< 5	< 5	< 5	< 5	< 5	< 5
2,4-Dichlorophenol	191	< 3	< 3	< 3	< 3	< 3	NA	< 3	NA	< 3	< 3	< 3	< 3	< 3	< 3	< 3
2,4-Dimethylphenol	553	< 3	< 3	< 3	< 3	< 3	NA	< 3	NA	< 3	< 3	< 3	< 3	< 3	< 3	< 3
2,4-Dinitrophenol	3,460	< 10	< 10	< 10	< 10	< 10	NA	< 10	NA	< 10	< 10	< 10	< 10	< 10	< 10	< 10
2,4-Dinitrotoluene	9.1	< 5	< 5	< 5	< 5	< 5	NA	< 5	NA	< 5	< 5	< 5	< 5	< 5	< 5	< 5
2,6-Dinitrotoluene	—	< 5	< 5	< 5	< 5	< 5	NA	< 5	NA	< 5	< 5	< 5	< 5	< 5	< 5	< 5
2-Chloronaphthalene	—	< 1	< 1	< 1	< 1	< 1	NA	< 1	NA	< 1	< 1	< 1	< 1	< 1	< 1	< 1
2-Chlorophenol	97	< 1	< 1	< 1	< 1	< 1	NA	< 1	NA	< 1	< 1	< 1	< 1	< 1	< 1	< 1
2-Methylnaphthalene	—	< 1	< 1	< 1	< 1	< 1	NA	< 1	NA	< 1	< 1	< 1	< 1	< 1	< 1	< 1
2-Methylphenol	—	< 2	< 2	< 2	< 2	< 2	NA	< 2	NA	< 2	< 2	< 2	< 2	< 2	< 2	< 2
2-Nitroaniline	—	< 5	< 5	< 5	< 5	< 5	NA	< 5	NA	< 5	< 5	< 5	< 5	< 5	< 5	< 5
2-Nitrophenol	—	< 5	< 5	< 5	< 5	< 5	NA	< 5	NA	< 5	< 5	< 5	< 5	< 5	< 5	< 5
3,3'-Dichlorobenzidine	0.0462	< 5	< 5	< 5	< 5	< 5	NA	< 5	NA	< 5	< 5	< 5	< 5	< 5	< 5	< 5
3-Nitroaniline	—	< 6	< 6	< 6	< 6	< 6	NA	< 6	NA	< 6	< 6	< 6	< 6	< 6	< 6	< 6
4,6-Dinitro-2-Methylphenol	765	< 10	< 10	< 10	< 10	< 10	NA	< 10	NA	< 10	< 10	< 10	< 10	< 10	< 10	< 10
4-Bromophenyl-phenylether	—	< 1	< 1	< 1	< 1	< 1	NA	< 1	NA	< 1	< 1	< 1	< 1	< 1	< 1	< 1
4-Chloro-3-methylphenol	—	< 2	< 2	< 2	< 2	< 2	NA	< 2	NA	< 2	< 2	< 2	< 2	< 2	< 2	< 2
4-Chloroaniline	—	< 3	< 3	< 3	< 3	< 3	NA	< 3	NA	< 3	< 3	< 3	< 3	< 3	< 3	< 3
4-Chlorophenyl-phenylether	—	< 1	< 1	< 1	< 1	< 1	NA	< 1	NA	< 1	< 1	< 1	< 1	< 1	< 1	< 1
4-Methylphenol	—	< 1	< 1	< 1	< 1	< 1	NA	< 1	NA	< 1	< 1	< 1	< 1	< 1	< 1	< 1
4-Nitroaniline	—	< 5	< 5	< 5	< 5	< 5	NA	< 5	NA	< 5	< 5	< 5	< 5	< 5	< 5	< 5
4-Nitrophenol	—	< 5	< 5	< 5	< 5	< 5	NA	< 5	NA	< 5	< 5	< 5	< 5	< 5	< 5	< 5

Table B-1. Summary of Groundwater Analytical Data Collected During the RI/FS

Parameter	Controlling ARAR	RMW-2D 2/9/99	RMW-2D 4/12/99	RMW-3D 2/10/99	RMW-3D 4/13/99	RMW-3D 8/11/99	RMW-3D 10/19/99	RMW-3D 11/4/99	RMW-4B 10/19/99	RMW-6D 2/10/99	RMW-6D 4/14/99	RMW-6D 8/10/99	RMW-7 2/10/99	RMW-7 4/13/99	RMW-7 8/10/99	RMW-7 11/4/99
Semivolatile Organics (EPA Method 8270) (µg/L)																
Acenaphthene	643	< 1	< 1	< 1	< 1	< 1	NA	< 1	NA	< 1	< 1	< 1	< 1	< 1	< 1	< 1
Acenaphthylene	—	< 1	< 1	< 1	< 1	< 1	NA	< 1	NA	< 1	< 1	< 1	< 1	< 1	< 1	< 1
Anthracene	25,900	< 1	< 1	< 1	< 1	< 1	NA	< 1	NA	< 1	< 1	< 1	< 1	< 1	< 1	< 1
Benzo(a)anthracene	0.0296	< 1	< 1	< 1	< 1	< 1	NA	< 1	NA	< 1	< 1	< 1	< 1	< 1	< 1	< 1
Benzo(a)pyrene	0.0296	< 1	< 1	< 1	< 1	< 1	NA	< 1	NA	< 1	< 1	< 1	< 1	< 1	< 1	< 1
Benzo(b)fluoranthene	0.0296	< 1	< 1	< 1	< 1	< 1	NA	< 1	NA	< 1	< 1	< 1	< 1	< 1	< 1	< 1
Benzo(g,h,i)perylene	—	< 1	< 1	< 1	< 1	< 1	NA	< 1	NA	< 1	< 1	< 1	< 1	< 1	< 1	< 1
Benzo(k)fluoranthene	0.0296	< 1	< 1	< 1	< 1	< 1	NA	< 1	NA	< 1	< 1	< 1	< 1	< 1	< 1	< 1
Benzoic Acid	—	< 10	< 10	< 10	< 10	< 10	NA	< 10	NA	< 10	< 10	< 10	< 10	< 10	< 10	< 10
Benzyl Alcohol	—	< 5	< 5	< 5	< 5	< 5	NA	< 5	NA	< 5	< 5	< 5	< 5	< 5	< 5	< 5
Bis(2-Chloroethoxy) Methane	—	< 1	< 1	< 1	< 1	< 1	NA	< 1	NA	< 1	< 1	< 1	< 1	< 1	< 1	< 1
Bis-(2-Chloroethyl) Ether	0.854	< 2	< 2	< 2	< 2	< 2	NA	< 2	NA	< 2	< 2	< 2	< 2	< 2	< 2	< 2
Bis(2-Ethylhexyl)phthalate	3.56	< 1	< 1	**1.4**	**3.3**	< 1	NA	< 1	NA	2	< 1	< 1	< 1	< 1	< 1	< 1
Butylbenzylphthalate	1,250	< 1	< 1	< 1	< 1	< 1	NA	< 1	NA	< 1	< 1	< 1	< 1	< 1	< 1	< 1
Carbazole	—	< 1	< 1	< 1	< 1	< 1	NA	< 1	NA	< 1	< 1	< 1	< 1	< 1	< 1	< 1
Chrysene	0.0296	< 1	< 1	< 1	< 1	< 1	NA	< 1	NA	< 1	< 1	< 1	< 1	< 1	< 1	< 1
Dibenz(a,h)anthracene	0.0296	< 1	< 1	< 1	< 1	< 1	NA	< 1	NA	< 1	< 1	< 1	< 1	< 1	< 1	< 1
Dibenzofuran	—	< 1	< 1	< 1	< 1	< 1	NA	< 1	NA	< 1	< 1	< 1	< 1	< 1	< 1	< 1
Diethylphthalate	28,400	< 1	< 1	< 1	< 1	< 1	NA	< 1	NA	< 1	< 1	< 1	< 1	< 1	< 1	< 1
Dimethylphthalate	72,000	< 1	< 1	< 1	< 1	< 1	NA	< 1	NA	< 1	< 1	< 1	< 1	< 1	< 1	< 1
Di-n-Butylphthalate	2,910	< 1	< 1	< 1	< 1	< 1	NA	< 1	NA	< 1	< 1	< 1	< 1	< 1	< 1	< 1
Di-n-Octyl phthalate	—	< 1	< 1	< 1	< 1	< 1	NA	< 1	NA	< 1	< 1	< 1	< 1	< 1	< 1	< 1
Fluoranthene	90.2	< 1	< 1	< 1	< 1	< 1	NA	< 1	NA	< 1	< 1	< 1	< 1	< 1	< 1	< 1
Fluorene	3,460	< 1	< 1	< 1	< 1	< 1	NA	< 1	NA	< 1	< 1	< 1	< 1	< 1	< 1	< 1
Hexachlorobenzene	0.000466	< 1	< 1	< 1	< 1	< 1	NA	< 1	NA	< 1	< 1	< 1	< 1	< 1	< 1	< 1
Hexachlorobutadiene	29.9	< 2	< 2	< 2	< 2	< 2	NA	< 2	NA	< 2	< 2	< 2	< 2	< 2	< 2	< 2
Hexachlorocyclopentadiene	4,180	< 5	< 5	< 5	< 5	< 5	NA	< 5	NA	< 5	< 5	< 5	< 5	< 5	< 5	< 5
Hexachloroethane	5.33	< 2	< 2	< 2	< 2	< 2	NA	< 2	NA	< 2	< 2	< 2	< 2	< 2	< 2	< 2
Indeno(1,2,3-cd)pyrene	0.0296	< 1	< 1	< 1	< 1	< 1	NA	< 1	NA	< 1	< 1	< 1	< 1	< 1	< 1	< 1
Isophorone	600	< 1	< 1	< 1	< 1	< 1	NA	< 1	NA	< 1	< 1	< 1	< 1	< 1	< 1	< 1
Naphthalene	9,880	< 1	< 1	< 1	< 1	< 1	NA	< 1	NA	< 1	< 1	< 1	< 1	< 1	< 1	< 1
Nitrobenzene	449	< 1	< 1	< 1	< 1	< 1	NA	< 1	NA	< 1	< 1	< 1	< 1	< 1	< 1	< 1
N-Nitroso-di-n-propylamine	0.819	< 2	< 2	< 2	< 2	< 2	NA	< 2	NA	< 2	< 2	< 2	< 2	< 2	< 2	< 2
N-Nitrosodiphenylamine	9.73	< 1	< 1	< 1	< 1	< 1	NA	< 1	NA	< 1	< 1	< 1	< 1	< 1	< 1	< 1
Pentachlorophenol	4.91	< 5	< 5	< 5	< 5	< 5	NA	< 5	NA	< 5	< 5	< 5	< 5	< 5	< 5	< 5
Phenanthrene	—	< 1	< 1	< 1	< 1	< 1	NA	< 1	NA	< 1	< 1	< 1	< 1	< 1	< 1	< 1
Phenol	1,110,000	< 2	< 2	< 2	< 2	< 2	NA	< 2	NA	< 2	< 2	< 2	< 2	< 2	< 2	< 2
Pyrene	2,590	< 1	< 1	< 1	< 1	< 1	NA	< 1	NA	< 1	< 1	< 1	< 1	< 1	< 1	< 1
Volatile Organics (EPA Method 8260) (µg/L)																
1,1,1,2-Tetrachloroethane	—	< 1	NA	< 1	NA	NA	NA	NA	NA	< 1	NA	NA	< 1	NA	NA	NA
1,1,1-Trichloroethane	417,000	< 1	NA	< 1	NA	NA	NA	NA	NA	< 1	NA	NA	< 1	NA	NA	NA
1,1,2,2-Tetrachloroethane	6.48	< 1	NA	< 1	NA	NA	NA	NA	NA	< 1	NA	NA	< 1	NA	NA	NA
1,1,2-Trichloroethane	25.3	< 1	NA	< 1	NA	NA	NA	NA	NA	< 1	NA	NA	< 1	NA	NA	NA
1,1,2-Trichlorotrifluoroethane	—	< 2	NA	< 2	NA	NA	NA	NA	NA	< 2	NA	NA	< 2	NA	NA	NA
1,1-Dichloroethane	—	< 1	NA	< 1	NA	NA	NA	NA	NA	< 1	NA	NA	< 1	NA	NA	NA
1,1-Dichloroethene	1.93	< 1	NA	< 1	NA	NA	NA	NA	NA	< 1	NA	NA	< 1	NA	NA	NA
1,1-Dichloropropene	—	< 1	NA	< 1	NA	NA	NA	NA	NA	< 1	NA	NA	< 1	NA	NA	NA
1,2,3-Trichlorobenzene	—	< 5	NA	< 5	NA	NA	NA	NA	NA	< 5	NA	NA	< 5	NA	NA	NA
1,2,3-Trichloropropane	—	< 1	NA	< 1	NA	NA	NA	NA	NA	< 1	NA	NA	< 1	NA	NA	NA
1,2,4-Trichlorobenzene	227	< 5	NA	< 5	NA	NA	NA	NA	NA	< 5	NA	NA	< 5	NA	NA	NA
1,2,4-Trimethylbenzene	—	< 1	NA	< 1	NA	NA	NA	NA	NA	< 1	NA	NA	< 1	NA	NA	NA
1,2-Dibromo-3-chloropropane	—	< 5	NA	< 5	NA	NA	NA	NA	NA	< 5	NA	NA	< 5	NA	NA	NA
1,2-Dichlorobenzene	4,200	< 1	NA	< 1	NA	NA	NA	NA	NA	< 1	NA	NA	< 1	NA	NA	NA
1,2-Dichloroethane	59.4	< 1	NA	< 1	NA	NA	NA	NA	NA	< 1	NA	NA	< 1	NA	NA	NA
1,2-Dichloropropane	23.2	< 1	NA	< 1	NA	NA	NA	NA	NA	< 1	NA	NA	< 1	NA	NA	NA
1,3,5-Trimethylbenzene	—	< 1	NA	< 1	NA	NA	NA	NA	NA	< 1	NA	NA	< 1	NA	NA	NA
1,3-Dichlorobenzene	2,600	< 1	NA	< 1	NA	NA	NA	NA	NA	< 1	NA	NA	< 1	NA	NA	NA
1,3-Dichloropropane	—	< 1	NA	< 1	NA	NA	NA	NA	NA	< 1	NA	NA	< 1	NA	NA	NA
1,4-Dichlorobenzene	4.86	< 1	NA	< 1	NA	NA	NA	NA	NA	< 1	NA	NA	< 1	NA	NA	NA

Table B-1. Summary of Groundwater Analytical Data Collected During the RI/FS

Parameter	Controlling ARAR	RMW-7D 2/10/99	RMW-7D 4/13/99	RMW-7D 8/10/99	RMW-7D 11/4/99	MW-8(B) 3/9/99	MW-8(B) 4/13/99	RMW-9 2/10/99	RMW-9 3/8/99	RMW-9 4/13/99	RMW-9 4/13/99 Duplicate	RMW-9 8/10/99	RMW-9 11/3/99	Trip Blank 6/30/98	Equip Blank 4/14/99	Field Blank 8/10/99	Equip Blank 11/4/99
Semivolatile Organics (EPA Method 8270) (µg/L)																	
Acenaphthene	643	< 1	< 1	< 1	< 1	NA	< 1	< 1	< 1	< 1	< 1	< 1	< 1	NA	< 1	< 1	< 1
Acenaphthylene	—	< 1	< 1	< 1	< 1	NA	< 1	< 1	< 1	< 1	< 1	< 1	< 1	NA	< 1	< 1	< 1
Anthracene	25,900	< 1	< 1	< 1	< 1	NA	< 1	< 1	< 1	< 1	< 1	< 1	< 1	NA	< 1	< 1	< 1
Benzo(a)anthracene	0.0296	< 1	< 1	< 1	< 1	NA	< 1	1.1	< 1	< 1	< 1	< 1	< 1	NA	< 1	< 1	< 1
Benzo(a)pyrene	0.0296	< 1	< 1	< 1	< 1	NA	< 1	< 1	< 1	< 1	< 1	< 1	< 1	NA	< 1	< 1	< 1
Benzo(b)fluoranthene	0.0296	< 1	< 1	< 1	< 1	NA	< 1	< 1	< 1	< 1	< 1	< 1	< 1	NA	< 1	< 1	< 1
Benzo(g,h,i)perylene	—	< 1	< 1	< 1	< 1	NA	< 1	< 1	< 1	< 1	< 1	< 1	< 1	NA	< 1	< 1	< 1
Benzo(k)fluoranthene	0.0296	< 1	< 1	< 1	< 1	NA	< 1	< 1	< 1	< 1	< 1	< 1	< 1	NA	< 1	< 1	< 1
Benzoic Acid	—	< 10	< 10	< 10	< 10	NA	< 10	< 10	< 10	< 10	< 10	< 10	< 10	NA	< 10	< 10	< 10
Benzyl Alcohol	—	< 5	< 5	< 5	< 5	NA	< 5	< 5	< 5	< 5	< 5	< 5	< 5	NA	< 5	< 5	< 5
Bis(2-Chloroethoxy) Methane	—	< 1	< 1	< 1	< 1	NA	< 1	< 1	< 1	< 1	< 1	< 1	< 1	NA	< 1	< 1	< 1
Bis-(2-Chloroethyl) Ether	0.854	< 2	< 2	< 2	< 2	NA	< 2	< 2	< 2	< 2	< 2	< 2	< 2	NA	< 2	< 2	< 2
Bis(2-Ethylhexyl)phthalate	3.56	8.4	< 1	< 1	< 1	NA	< 1	4.5	< 1	3	< 1	< 1	< 1	NA	< 1	< 1	< 1
Butylbenzylphthalate	1,250	< 1	< 1	< 1	< 1	NA	< 1	< 1	< 1	< 1	< 1	< 1	< 1	NA	< 1	< 1	< 1
Carbazole	—	< 1	< 1	< 1	< 1	NA	< 1	11	< 1	< 1	< 1	< 1	< 1	NA	< 1	< 1	< 1
Chrysene	0.0296	< 1	< 1	< 1	< 1	NA	< 1	1.6	< 1	< 1	< 1	< 1	< 1	NA	< 1	< 1	< 1
Dibenz(a,h)anthracene	0.0296	< 1	< 1	< 1	< 1	NA	< 1	< 1	< 1	< 1	< 1	< 1	< 1	NA	< 1	< 1	< 1
Dibenzofuran	—	< 1	< 1	< 1	< 1	NA	< 1	< 1	< 1	< 1	< 1	< 1	< 1	NA	< 1	< 1	< 1
Diethylphthalate	28,400	< 1	< 1	< 1	< 1	NA	< 1	< 1	< 1	< 1	< 1	< 1	< 1	NA	< 1	< 1	< 1
Dimethylphthalate	72,000	< 1	< 1	< 1	< 1	NA	< 1	< 1	< 1	< 1	< 1	< 1	< 1	NA	< 1	< 1	< 1
Di-n-Butylphthalate	2,910	< 1	< 1	< 1	< 1	NA	< 1	< 1	< 1	< 1	< 1	< 1	< 1	NA	< 1	< 1	< 1
Di-n-Octyl phthalate	—	< 1	< 1	< 1	< 1	NA	< 1	< 1	< 1	< 1	< 1	< 1	< 1	NA	< 1	< 1	< 1
Fluoranthene	90.2	< 1	< 1	< 1	< 1	NA	< 1	5.6	< 1	< 1	< 1	< 1	< 1	NA	< 1	< 1	< 1
Fluorene	3,460	< 1	< 1	< 1	< 1	NA	< 1	3.2	< 1	< 1	< 1	< 1	< 1	NA	< 1	< 1	< 1
Hexachlorobenzene	0.000466	< 1	< 1	< 1	< 1	NA	< 1	< 1	< 1	< 1	< 1	< 1	< 1	NA	< 1	< 1	< 1
Hexachlorobutadiene	29.9	< 2	< 2	< 2	< 2	NA	< 2	< 2	< 2	< 2	< 2	< 2	< 2	NA	< 2	< 2	< 2
Hexachlorocyclopentadiene	4,180	< 5	< 5	< 5	< 5	NA	< 5	< 5	< 5	< 5	< 5	< 5	< 5	NA	< 5	< 5	< 5
Hexachloroethane	5.33	< 2	< 2	< 2	< 2	NA	< 2	< 2	< 2	< 2	< 2	< 2	< 2	NA	< 2	< 2	< 2
Indeno(1,2,3-cd)pyrene	0.0296	< 1	< 1	< 1	< 1	NA	< 1	< 1	< 1	< 1	< 1	< 1	< 1	NA	< 1	< 1	< 1
Isophorone	600	< 1	< 1	< 1	< 1	NA	< 1	< 1	< 1	< 1	< 1	< 1	< 1	NA	< 1	< 1	< 1
Naphthalene	9,880	< 1	< 1	< 1	< 1	NA	< 1	9.5	3.4	2.7	2.6	3.2	3.1	NA	< 1	< 1	< 1
Nitrobenzene	449	< 1	< 1	< 1	< 1	NA	< 1	< 1	< 1	< 1	< 1	< 1	< 1	NA	< 1	< 1	< 1
N-Nitroso-di-n-propylamine	0.819	< 2	< 2	< 2	< 2	NA	< 2	< 2	< 2	< 2	< 2	< 2	< 2	NA	< 2	< 2	< 2
N-Nitrosodiphenylamine	9.73	< 1	< 1	< 1	< 1	NA	< 1	< 1	< 1	< 1	< 1	< 1	< 1	NA	< 1	< 1	< 1
Pentachlorophenol	4.91	< 5	< 5	< 5	< 5	NA	< 5	< 5	< 5	< 5	< 5	< 5	< 5	NA	< 5	< 5	< 5
Phenanthrene	—	< 1	< 1	< 1	< 1	NA	< 1	11	< 1	< 1	< 1	< 1	< 1	NA	< 1	< 1	< 1
Phenol	1,110,000	< 2	< 2	< 2	< 2	NA	< 2	< 2	< 2	< 2	< 2	< 2	< 2	NA	< 2	< 2	< 2
Pyrene	2,590	< 1	< 1	< 1	< 1	NA	< 1	6.6	< 1	< 1	< 1	< 1	< 1	NA	< 1	< 1	< 1
Volatile Organics (EPA Method 8260) (µg/L)																	
1,1,1,2-Tetrachloroethane	—	< 1	NA	NA	NA	< 1	NA	< 1	< 3	NA	NA	NA	NA	< 1	NA	NA	NA
1,1,1-Trichloroethane	417,000	< 1	NA	NA	NA	< 1	NA	< 1	< 3	NA	NA	NA	NA	< 1	NA	NA	NA
1,1,2,2-Tetrachloroethane	6.48	< 1	NA	NA	NA	< 1	NA	< 1	< 3	NA	NA	NA	NA	< 1	NA	NA	NA
1,1,2-Trichloroethane	25.3	< 1	NA	NA	NA	< 1	NA	< 1	< 3	NA	NA	NA	NA	< 1	NA	NA	NA
1,1,2-Trichlorotrifluoroethane	—	< 2	NA	NA	NA	< 5	NA	< 2	< 15	NA	NA	NA	NA	< 2	NA	NA	NA
1,1-Dichloroethane	—	< 1	NA	NA	NA	< 1	NA	< 1	< 3	NA	NA	NA	NA	< 1	NA	NA	NA
1,1-Dichloroethene	1.93	< 1	NA	NA	NA	< 1	NA	< 1	< 3	NA	NA	NA	NA	< 1	NA	NA	NA
1,1-Dichloropropene	—	< 1	NA	NA	NA	< 1	NA	< 1	< 3	NA	NA	NA	NA	< 1	NA	NA	NA
1,2,3-Trichlorobenzene	—	< 5	NA	NA	NA	< 5	NA	< 5	< 15	NA	NA	NA	NA	< 5	NA	NA	NA
1,2,3-Trichloropropane	—	< 1	NA	NA	NA	< 3	NA	< 1	< 9	NA	NA	NA	NA	< 1	NA	NA	NA
1,2,4-Trichlorobenzene	227	< 5	NA	NA	NA	< 5	NA	< 5	< 15	NA	NA	NA	NA	< 5	NA	NA	NA
1,2,4-Trimethylbenzene	—	< 1	NA	NA	NA	< 1	NA	58	< 3	NA	NA	NA	NA	< 1	NA	NA	NA
1,2-Dibromo-3-chloropropane	—	< 5	NA	NA	NA	< 5	NA	< 5	< 15	NA	NA	NA	NA	< 5	NA	NA	NA
1,2-Dichlorobenzene	4,200	< 1	NA	NA	NA	< 1	NA	< 1	< 3	NA	NA	NA	NA	NA	NA	NA	NA
1,2-Dichloroethane	59.4	< 1	NA	NA	NA	< 1	NA	< 1	< 3	NA	NA	NA	NA	< 1	NA	NA	NA
1,2-Dichloropropane	23.2	< 1	NA	NA	NA	< 1	NA	< 1	< 3	NA	NA	NA	NA	< 1	NA	NA	NA
1,3,5-Trimethylbenzene	—	< 1	NA	NA	NA	< 1	NA	18	< 3	NA	NA	NA	NA	< 1	NA	NA	NA
1,3-Dichlorobenzene	2,600	< 1	NA	NA	NA	< 1	NA	< 1	< 3	NA	NA	NA	NA	NA	NA	NA	NA
1,3-Dichloropropane	—	< 1	NA	NA	NA	< 1	NA	< 1	< 3	NA	NA	NA	NA	< 1	NA	NA	NA
1,4-Dichlorobenzene	4.86	< 1	NA	NA	NA	< 1	NA	16	30	NA	NA	NA	NA	NA	NA	NA	NA

Table B-1. Summary of Groundwater Analytical Data Collected During the RI/FS

Parameter	Controlling ARAR	RMW-7D 2/10/99	RMW-7D 4/13/99	RMW-7D 8/10/99	RMW-7D 11/4/99	MW-8(B) 3/9/99	MW-8(B) 4/13/99	RMW-9 2/10/99	RMW-9 3/8/99	RMW-9 4/13/99	RMW-9 4/13/99 Duplicate	RMW-9 8/10/99	RMW-9 11/3/99	Trip Blank 6/30/98	Equip Blank 4/14/99	Field Blank 8/10/99	Equip Blank 11/4/99
Volatile Organics (EPA Method 8260) (µg/L)																	
2,2-Dichloropropane	—	< 1	NA	NA	NA	< 1	NA	< 1	< 3	NA	NA	NA	NA	< 1	NA	NA	NA
2-Butanone	—	< 5	NA	NA	NA	< 5	NA	< 5	< 15	NA	NA	NA	NA	< 5	NA	NA	NA
2-Chloroethylvinylether	—	< 5	NA	NA	NA	< 5	NA	< 5	< 15	NA	NA	NA	NA	< 5	NA	NA	NA
2-Chlorotoluene	—	< 1	NA	NA	NA	< 1	NA	< 1	< 3	NA	NA	NA	NA	< 1	NA	NA	NA
2-Hexanone	—	< 5	NA	NA	NA	< 5	NA	< 5	< 15	NA	NA	NA	NA	< 5	NA	NA	NA
4-Chlorotoluene	—	< 1	NA	NA	NA	< 1	NA	< 1	< 3	NA	NA	NA	NA	< 1	NA	NA	NA
4-Isopropyltoluene	—	< 1	NA	NA	NA	< 1	NA	**8.5**	< 3	NA	NA	NA	NA	< 1	NA	NA	NA
4-Methyl-2-Pentanone (MIBK)	—	< 5	NA	NA	NA	< 5	NA	< 5	< 15	NA	NA	NA	NA	< 5	NA	NA	NA
Acetone	—	< 5	NA	NA	NA	< 10	NA	**9.2**	< 30	NA	NA	NA	NA	< 5	NA	NA	NA
Acrolein	780	< 50	NA	NA	NA	< 50	NA	< 50	< 150	NA	NA	NA	NA	< 50	NA	NA	NA
Acrylonitrile	0.4	< 5	NA	NA	NA	< 10	NA	< 5	< 30	NA	NA	NA	NA	< 5	NA	NA	NA
Benzene	43	< 1	NA	NA	NA	< 1	NA	**4.1**	**4.4**	NA	NA	NA	NA	< 1	NA	NA	NA
Bromobenzene	—	< 1	NA	NA	NA	< 1	NA	< 1	< 3	NA	NA	NA	NA	< 1	NA	NA	NA
Bromochloromethane	—	< 1	NA	NA	NA	< 1	NA	< 1	< 3	NA	NA	NA	NA	< 1	NA	NA	NA
Bromodichloromethane	22	< 1	NA	NA	NA	< 1	NA	< 1	< 3	NA	NA	NA	NA	< 1	NA	NA	NA
Bromoethane	—	< 2	NA	NA	NA	< 2	NA	< 2	< 6	NA	NA	NA	NA	< 2	NA	NA	NA
Bromoform	219	< 1	NA	NA	NA	< 1	NA	< 1	< 3	NA	NA	NA	NA	< 1	NA	NA	NA
Bromomethane	968	< 2	NA	NA	NA	< 2	NA	< 2	< 6	NA	NA	NA	NA	< 2	NA	NA	NA
Carbon Disulfide	—	< 1	NA	NA	NA	< 1	NA	< 1	< 3	NA	NA	NA	NA	< 1	NA	NA	NA
Carbon Tetrachloride	2.66	< 1	NA	NA	NA	< 1	NA	< 1	< 3	NA	NA	NA	NA	< 1	NA	NA	NA
Chlorobenzene	5,030	< 1	NA	NA	NA	< 1	NA	**2.2**	**210**	NA	NA	NA	NA	< 1	NA	NA	NA
Chloroethane	—	< 2	NA	NA	NA	< 2	NA	< 2	< 6	NA	NA	NA	NA	< 2	NA	NA	NA
Chloroform	283	< 1	NA	NA	NA	< 1	NA	< 1	< 3	NA	NA	NA	NA	< 1	NA	NA	NA
Chloromethane	133	< 2	NA	NA	NA	< 2	NA	< 2	< 6	NA	NA	NA	NA	< 2	NA	NA	NA
cis-1,2-Dichloroethene	—	< 1	NA	NA	NA	< 1	NA	< 1	< 3	NA	NA	NA	NA	< 1	NA	NA	NA
cis-1,3-Dichloropropene	—	< 1	NA	NA	NA	< 1	NA	< 1	< 3	NA	NA	NA	NA	< 1	NA	NA	NA
Dibromochloromethane	20.6	< 1	NA	NA	NA	< 1	NA	< 1	< 3	NA	NA	NA	NA	< 1	NA	NA	NA
Dibromomethane	—	< 1	NA	NA	NA	< 1	NA	< 1	< 3	NA	NA	NA	NA	< 1	NA	NA	NA
Ethylbenzene	6,910	< 1	NA	NA	NA	< 1	NA	**70**	< 3	NA	NA	NA	NA	< 1	NA	NA	NA
Ethylene Dibromide	—	< 1	NA	NA	NA	< 1	NA	< 1	< 3	NA	NA	NA	NA	< 1	NA	NA	NA
Hexachlorobutadiene	29.9	< 5	NA	NA	NA	< 5	NA	< 5	< 15	NA	NA	NA	NA	< 5	NA	NA	NA
Isopropylbenzene	—	< 1	NA	NA	NA	< 1	NA	**4.2**	< 3	NA	NA	NA	NA	< 1	NA	NA	NA
m,p-Xylene	—	< 1	NA	NA	NA	< 1	NA	**68**	< 3	NA	NA	NA	NA	< 1	NA	NA	NA
Methyl Iodide	—	< 1	NA	NA	NA	< 1	NA	< 1	< 3	NA	NA	NA	NA	< 1	NA	NA	NA
Methylene Chloride	1,600	< 2	NA	NA	NA	< 2	NA	< 2	< 6	NA	NA	NA	NA	< 2	NA	NA	NA
Naphthalene	9,880	< 5	NA	NA	NA	< 5	NA	**16**	< 15	NA	NA	NA	NA	NA	NA	NA	NA
n-Butylbenzene	—	< 1	NA	NA	NA	< 1	NA	< 2.7	< 3	NA	NA	NA	NA	< 1	NA	NA	NA
n-Propylbenzene	—	< 1	NA	NA	NA	< 1	NA	**5.8**	**3.3**	NA	NA	NA	NA	< 1	NA	NA	NA
o-Xylene	—	< 1	NA	NA	NA	< 1	NA	**47**	< 3	NA	NA	NA	NA	< 1	NA	NA	NA
sec-Butylbenzene	—	< 1	NA	NA	NA	< 1	NA	**1.8**	< 3	NA	NA	NA	NA	< 1	NA	NA	NA
Styrene	—	< 1	NA	NA	NA	< 1	NA	< 1	< 3	NA	NA	NA	NA	< 1	NA	NA	NA
tert-Butylbenzene	—	< 1	NA	NA	NA	< 1	NA	< 1	< 3	NA	NA	NA	NA	< 1	NA	NA	NA
Tetrachloroethene	4.15	< 1	NA	NA	NA	< 1	NA	< 1	< 3	NA	NA	NA	NA	< 1	NA	NA	NA
Toluene	48,500	< 1	NA	NA	NA	< 1	NA	**4.7**	< 3	NA	NA	NA	NA	< 1	NA	NA	NA
trans-1,2-Dichloroethene	32,800	< 1	NA	NA	NA	< 1	NA	< 1	< 3	NA	NA	NA	NA	< 1	NA	NA	NA
trans-1,3-Dichloropropene	—	< 1	NA	NA	NA	< 1	NA	< 1	< 3	NA	NA	NA	NA	< 1	NA	NA	NA
trans-1,4-Dichloro-2-butene	—	< 5	NA	NA	NA	< 5	NA	< 5	< 15	NA	NA	NA	NA	< 5	NA	NA	NA
Trichloroethene	55.6	< 1	NA	NA	NA	< 1	NA	< 1	< 3	NA	NA	NA	NA	< 1	NA	NA	NA
Trichlorofluoromethane	—	< 2	NA	NA	NA	< 2	NA	< 2	< 6	NA	NA	NA	NA	< 2	NA	NA	NA
Vinyl Acetate	—	< 5	NA	NA	NA	< 5	NA	< 5	< 15	NA	NA	NA	NA	< 5	NA	NA	NA
Vinyl Chloride	2.92	< 2	NA	NA	NA	< 2	NA	< 2	< 6	NA	NA	NA	NA	< 2	NA	NA	NA

NOTES:

Detected values are highlighted in **bold**.
Bold and boxed = detected compound above controlling ARAR..
NA - Indicates compound not analyzed for.
B - Contamination in assoc. method blank.
J - Indicates estimated value.
R - Rejected data.

Round 1 Geochemical Parameters

Well Location	Date	Time	DTR	pH	Redox	D.O.	Temp.	Cond.	Turbidity
high tide	02/08/1999	949							
low tide	02/08/1999	1731							
high tide	03/08/1999	812							
low tide	03/08/1999	1520							
Transect A									
RMW-1	03/08/1999	1148							
top			15	6.52	-87	1.38	12.8	3.2	NM
middle			20	6.36	-369	0.71	12.5	3.2	NM
bottom			22	6.27	-416	5.25	12.5	6.1	NM
purge	02/10/1999	1055	15	6.36	-495	0.27	9.3	3.5	10
RMW-2	02/08/1999	1347							
top			11	6.16	-272	2.42	8.8	2.4	NM
middle			17	6.18	-327	0.84	9.8	2.6	NM
bottom			22	6.11	-344	0.57	10.4	2.6	NM
purge	02/09/1999	1050	17	7.17	-352	0.38	9.2	2.4	7.82
RMW-2D	02/08/1999	1343							
top			23	6.86	-293	1.81	10.9	6.8	NM
middle			27	6.92	-323	0.62	12.0	6.8	NM
bottom			33	6.94	-337	0.50	12.7	7.4	NM
purge	02/09/1999	1146	34	7.07	-392	0.26	7.8	7.3	3.3
RMW-3D	02/08/1999	1034							
top			20	6.73	-295	0.96	10.2	4.6	NM
middle			27	6.86	-291	0.56	11.5	6.4	NM
bottom			28	6.90	-338	0.45	12.2	24.9	NM
		1915							
top			22	6.70	-240	1.54	9.0	4.6	NM
middle			27	6.70	-241	0.79	9.8	5.0	NM
bottom			35	6.47	-255	0.60	10.3	4.6	NM
purge	02/10/1999	1309	30	7.05	-439	0.18	10.5	7.5	5.91
Transect B									
RGP-4	02/08/1999	1335							
top			17	5.53	-299	2.64	10.0	2.7	NM
middle			20	5.95	-317	1.23	10.2	2.8	NM
bottom			24.29	6.01	-331	0.76	10.4	2.8	NM
purge									

Round 1 Geochemical Parameters (Continued)

Well Location	Date	Time	DTR	pH	Redox	D.O.	Temp.	Cond.	Turbidity
RGP-3	02/08/1999	1427							
top			14	6.54	-203	2.34	7.8	5.5	NM
middle			22	6.38	-330	0.87	8.5	5.6	NM
bottom			25	6.48	-444	0.61	9.3	4.9	NM
purge	02/09/1999	1244	20	6.48	-397	0.29	7.9	5.6	15.8
MW-98-1(GW)	NM								
top									
middle									
bottom									
purge									
RMW-6D	02/08/1999	830							
top			29	6.90	-344	2.67	9.4	11.6	NM
middle			35	7.09	-366	1.69	10.3	26.9	NM
bottom			37	7.10	-352	0.87	11.4	27.1	NM
purge	02/10/1999	1521	35	7.53	-484	0.17	9.9	4.9	2.73
MW-55(C)	02/08/1999	835							
top			5	6.54	-319	1.75	11.1	1.0	NM
middle			10	6.56	-314	1.28	10.8	1.0	NM
bottom			14	6.44	-319	0.84	10.7	1.1	NM
purge	02/10/1999	1618	9	6.49	-392	0.24	9.0	1.0	6.23
RMW-7	02/08/1999	1007							
top			7	6.37	249	4.73	8.2	8.2	NM
middle			12	6.39	58.8	3.87	8.8	8.4	NM
bottom			19	6.39	20.4	2.49	9.2	8.2	NM
		1945							
top			7	6.70	-92.7	1.21	11.4	6.9	NM
middle			12	6.64	-98.7	0.74	11.3	6.9	NM
bottom			19	6.64	-86.9	0.57	11.2	7.0	NM
purge	02/10/1999	1741	10	6.70	-227	0.54	8.6	6.3	0.57
RMW-7D	02/08/1999	1009							
top			25	7.04	-131	1.08	10.5	24.3	NM
middle			32	7.14	-210	0.60	11.3	24.6	NM
bottom			40	7.03	-252	0.48	12.5	28.6	NM
		1940							
top			25	7.16	13.4	1.88	9.7	23.6	NM
middle			32	7.20	-60	0.76	10.2	23.8	NM
bottom			40	7.16	-135	0.52	11.5	27.4	NM
purge	02/10/1999	1807	35	7.39	-298	0.19	9.9	23.7	7.39

Round 1 Geochemical Parameters (Continued)

Well Location		Date	Time	DTR	pH	Redox	D.O.	Temp.	Cond.	Turbidity
Transect C										
RMW-8		02/08/1999	1322							
	top			14	6.73	-288	2.61	9.7	14.5	NM
	middle			18	6.84	-333	0.91	10.6	14.9	NM
	bottom			23	6.87	-341	0.70	11.4	15.5	NM
	purge									
RMW-9		02/08/1999	1242							
	top			6	6.32	-269	2.37	9.3	1.8	NM
	middle			12	6.34	-288	0.97	9.5	1.8	NM
	bottom			19	6.35	-292	0.69	10.0	1.8	NM
	purge	02/10/1999	1009	13	6.97	-363	0.23	7.8	14.5	99
RMW-10		02/08/1999	1619**							
	top									
	middle			12	6.49	-285	0.20	8.6	1.3	NM
	bottom									
	purge									
MW-4(O)		02/08/1999	1024							
	top			11	6.25	-184	1.74	10.0	2.7	NM
	middle			14	6.25	-202	0.83	10.2	2.7	NM
	bottom			18	6.26	-217	0.64	10.6	3.0	NM
			1925							
	top			11	7.10	-11.1	7.63	9.7	1.9	NM
	middle			14	6.30	-135	2.00	9.9	2.3	NM
	bottom			18	6.27	-166	1.17	10.1	2.6	NM
	purge	02/10/1999	1218	13	6.41	-372	0.24	9.2	2.9	1.79
Transect D										
RGP-1		03/08/1999	1216							
	top			17	5.60	-306	0.52	9.1	0.9	NM
	middle			20	5.68	-312	0.49	9.0	0.9	NM
	bottom			23	5.77	-318	0.50	9.0	1.3	NM
	purge	02/09/1999	1333	18	5.79	-343	0.23	8.5	1.2	0.91
RMW-11			NA							
	top									
	middle									
	bottom									
	purge	03/08/1999	1530	14	6.65	-328	0.30	11.7	7.1	NM

Round 1 Geochemical Parameters (Continued)

Well Location	Date	Time	DTR	pH	Redox	D.O.	Temp.	Cond.	Turbidity
RMW-11D									
top									
middle									
bottom									
purge	03/08/1999	1630	24	6.79	-299	0.29	11.2	10.1	NM
MW-8(B)									
top									
middle									
bottom									
purge	03/08/1999	1355	14	6.75	-259	0.37	12.7	8.9	NM
MW-4(B)	02/08/1999	812							
top			5	6.73	-286	2.62	6.7	1.2	NM
middle			6	6.72	-295	1.83	7.3	1.2	NM
bottom			10.5	6.71	-299	1.33	7.8	1.3	NM
purge	02/09/1999	1425	8	6.80	-341	0.32	8.0	1.3	3.1
RMW-12D	02/08/1999	1120							
top			6	6.67	-286	1.10	9.3	1.4	NM
middle			12	6.69	-309	0.65	9.6	1.4	NM
bottom			19	6.66	-131	0.64	10.2	8.0	NM
purge	02/09/1999	1517	14	6.88	-340	0.22	6.8	1.4	13.9
RMW-13D	02/08/1999	943							
top			20	6.42	-407	0.57	11.2	4.7	NM
middle			22	6.47	-438	0.39	12.8	4.7	NM
bottom			27	6.46	-428	0.46	11.8	4.7	NM
		1846							
top			15	6.62	-182	1.82	8.7	3.4	NM
middle			20	6.45	-222	0.89	9.4	4.5	NM
bottom			28	6.92	-301	0.54	10.8	24.2	NM
purge	02/10/1999	1355	23	6.65	-415	0.21	9.1	4.7	0.89
MW-3(B)	03/08/1999	1022							
top			6	6.48	-103	0.91	10.9	11.8	NM
middle			8	6.44	-92	0.61	10.7	14.3	NM
bottom			13	6.40	-87	0.52	10.4	12.3	NM
		1958							
top			6	6.52	245	7.65	8.3	14.0	NM
middle			8	6.64	241	7.24	8.3	14.1	NM
bottom			13	6.65	230	7.03	8.2	13.8	NM

Round 1 Geochemical Parameters (Continued)

Well Location	Date	Time	DTR	pH	Redox	D.O.	Temp.	Cond.	Turbidity
Other Wells									
Olivine Area									
MW-3(O)	03/08/1999	1403							
top			11	6.76	-236	1.11	11.8	4.3	NM
middle			15	6.80	-251	0.77	11.8	4.5	NM
bottom			20	7.20	-337	0.58	12.0	5.8	NM
purge									
MW-1(O)	02/08/1999	1230							
top			11	7.32	-64.1	9.19	8.1	2.2	NM
middle			15	6.43	-234	1.80	8.6	2.2	NM
bottom			20	6.44	-244	1.00	9.5	3.3	NM
RMW-14	02/08/1999	1316							
top			6	6.37	-10.9	4.90	9.1	0.8	NM
middle			12	6.31	-166	2.07	9.4	0.8	NM
bottom			19	6.34	-171	0.86	9.9	0.8	NM
purge									
RMW-15	02/08/1999	1220							
top			7	7.43	-0.749	7.57	8.1	0.5	NM
middle			12	6.73	-160	2.91	8.5	0.8	NM
bottom			19	6.74	-197	1.75	8.8	0.8	NM
purge									
F Street Alignment Wells									
RMW-16	02/08/1999	755							
top			5	7.12	-262	4.80	6.2	0.4	NM
middle			12	6.71	-266	2.85	6.6	0.6	NM
bottom			19	6.44	-278	1.92	6.8	0.6	NM
purge									
RMW-17	03/08/1999	1335							
top			10	6.00	-276	1.05	12.7	2.1	NM
middle			15	6.05	-292	0.74	12.6	4.1	NM
bottom			18	6.19	-350	0.56	13.0	6.2	NM
purge									
Chestnut Street Colony Wharf Wells									
RMW-18	03/08/1999	1046							
top			7	7.20	-173	1.03	9.5	0.7	NM
middle			11	7.26	-197	0.66	9.3	0.1	NM
bottom			18	7.37	-212	0.58	9.2	0.1	NM
purge									

Round 1 Geochemical Parameters (Continued)

Well Location	Date	Time	DTR	pH	Redox	D.O.	Temp.	Cond.	Turbidity
MW-5(B)	02/08/1999	1141							
top			5.5	6.29	-230	1.00	8.7	1.0	NM
middle			10	6.32	-242	0.77	8.8	1.0	NM
bottom			13	6.33	-250	0.60	9.3	1.0	NM
purge									
MW-12(B)	02/08/1999	1151							
top			1.5	6.19	-193	3.96	7.8	1.2	NM
middle			8	6.15	-238	1.49	8.1	1.6	NM
bottom			12	6.18	-243	0.93	8.6	1.6	NM
purge									
Maple Street BMI Wells									
MW-10(B)	02/08/1999	1117							
top			6	6.41	-60.9	4.35	8.5	1.0	NM
middle			10	6.43	-121	1.03	9.2	1.7	NM
bottom			15	6.50	-218	0.66	9.5	1.7	NM
purge									
Chevron and C-Street Wells									
MW-11A(C)	02/08/1999	843							
top			4	7.06	-215	5.16	8.4	0.3	NM
middle									
bottom									
purge									
MW-50(C)	02/08/1999	1105							
top			8	6.13	-321	1.30	8.6	1.0	NM
middle			11	6.18	-139	0.73	9.0	1.0	NM
bottom			14	6.19	-387	0.91	9.5	1.0	NM
purge									
MW-53(C)	02/08/1999	822							
top			4	6.56	-134	2.46	8.5	0.8	NM
middle			10	6.55	-130	2.26	8.6	1.1	NM
bottom			12.5	6.50	-127	1.65	8.8	1.1	NM
purge									
MW-12A(C)	03/08/1999	912							
top			6	6.65	-331	0.40	14.2	2.0	NM
middle			11	6.56	-348	0.32	13.7	2.0	NM
bottom			14	6.55	-351	0.30	13.2	2.2	NM
		1655							
top			6	6.46	-133	3.28	12.3	1.8	NM
middle			11	6.48	-151	2.15	12.0	1.9	NM
bottom			14	6.49	-211	1.11	12.5	2.0	NM
purge									

Round 1 Geochemical Parameters (Continued)

Well Location	Date	Time	DTR	pH	Redox	D.O.	Temp.	Cond.	Turbidity
G.P. Landfill Area									
RGP-2(W)	02/08/1999	1438							
top			15	7.30	-434	1.00	9.4	1.1	NM
middle			17	7.25	-463	0.67	9.2	1.1	NM
bottom			29	7.23	-474	0.57	9.1	1.1	NM
purge									
RMW-4	02/08/1999	1358							
top			12	6.24	-230	0.88	10.5	0.3	NM
middle			17	6.23	-270	0.59	11.1	1.6	NM
bottom			22	6.03	-287	0.48	11.8	3.5	NM
purge									
RMW-5	02/08/1999	1400							
top			10	6.02	-320	0.84	11.2	2.1	NM
middle			13	6.03	-324	0.57	11.7	2.2	NM
bottom			19	6.05	-346	0.52	12.3	2.2	NM
purge									
Hilton Ave. Bulkhead Well									
RMW-20	03/08/1999	1408							
top			7	6.86	-290	2.10	11.9	4.3	NM
middle			16	6.90	-380	0.28	12.1	4.5	NM
bottom			19	6.95	-381	0.29	12.3	5.0	NM
purge									
Stilling Gauge									
stilling gauge	02/08/1999	800							
top			5	7.20	-297	9.31	6.8	1.9	NM
middle			10	7.31	-263	9.09	6.7	2.8	NM
bottom			15	6.91	-194	8.89	6.6	24.0	NM
	03/08/1999	1031							
top			5	6.48	-93.6	8.74	9.6	2.0	NM
middle			10	6.75	-77	8.77	9.2	11.1	NM
bottom			15	6.96	-92	8.59	8.9	27.7	NM

NOTES:
- ** - Well data only from purge.
- NM - Not measured.
- Cond. - Specific conductance.
- D.O. - Dissolved oxygen.
- DTR - Depth to reading in feet below ground surface.
- Redox - Redox potential.
- Temp. - Temperature.

Second Quarter Geochemical Data

Well I.D.			Time	Depth to Reading (feet bgs)	pH	Redox Potential (mV)	Dissolved Oxygen (mg/L)	Temperature (degrees C)	Electrical Conductivity (mS)
Transect A									
	RMW-1		1605						
		top		15	6.42	-499.80	1.42	12.46	2.99
		middle		20	6.33	-500.45	0.92	12.18	3.81
		bottom		22	6.46	-519.68	0.31	12.85	5.23
	RMW-2		1650						
		top		11	6.40	-452.90	0.70	13.55	2.37
		middle		17	6.16	-448.00	0.23	13.76	2.37
		bottom		22	6.16	-452.70	0.22	13.83	2.37
	RMW-2D		1630						
		top		23	7.13	-353.30	0.62	14.68	6.24
		middle		27	7.14	-365.30	0.28	15.16	6.84
		bottom		33	7.04	-434.30	0.24	15.60	7.66
	RMW-3D								
		low tide	1300						
*4/14/99		top		20	6.23	-168.00	0.65	12.25	4.25
		middle		27	6.09	-321.00	0.45	12.76	5.64
		bottom		28	6.10	-353.00	0.32	13.34	5.69
		high tide	1737						
		top		22	6.31	-127.63	0.40	11.80	4.08
		middle		27	6.10	-234.94	0.24	12.50	5.02
		bottom		35	6.63	-300.78	0.22	13.61	21.59
Transect B									
	RGP-4(W)		1715						
		top		17	6.21	-557.90	0.26	11.62	4.09
		middle		20	6.04	-602.00	0.23	11.60	3.75
		bottom		24.29	5.99	-610.20	0.23	11.55	3.96
	RGP-3(W)		1734						
		top		14	5.96	-410.50	0.30	11.37	6.15
		middle		22	5.99	-414.30	0.26	11.66	6.32
		bottom		25	5.89	-421.10	0.24	11.97	6.35
	MW-98-1(GW)								
			17:50						
		top		12	4.85	-306.70	0.69	10.18	0.01
		middle		14	4.90	-287.20	0.68	10.14	0.68
		bottom		15.8	5.22	-335.80	0.39	10.06	1.32
	RMW-6D								
		low tide	1303						
		top		29	6.36	-181.27	0.46	11.46	4.74
		middle		35	6.20	-344.38	0.25	11.75	5.65
		bottom		37	6.28	-406.69	0.21	13.89	12.10
		high tide	1929						
		top			6.25	-348.43	0.48	11.58	5.52
		middle			6.23	-357.93	0.33	11.73	5.76
		bottom			6.49	-371.78	0.44	14.83	23.83

Second Quarter Geochemical Data

Well I.D.		Time	Depth to Reading (feet bgs)	pH	Redox Potential (mV)	Dissolved Oxygen (mg/L)	Temperature (degrees C)	Electrical Conductivity (mS)
MW-55(C)			Not Measured					
RMW-7								
	low tide	1250						
	top		7	6.20	-198.39	0.88	12.40	2.60
	middle		12	6.23	-233.68	0.42	12.25	2.86
	bottom		19	6.25	-237.99	0.31	12.20	2.87
	high tide	1755						
	top		7	6.18	-151.62	1.27	12.25	2.58
	middle		12	6.22	-158.07	0.80	12.28	2.78
	bottom		19	6.21	-160.47	0.60	12.38	2.81
RMW-7D								
	low tide							
	top		25	7.21	-142.51	4.13	12.80	16.37
	middle		32	6.95	-196.79	0.56	12.88	20.64
	bottom		40	6.70	-252.98	0.27	14.52	25.50
	high tide	1803						
	top		25	6.90	-140.37	2.67	12.35	16.49
	middle		32	6.68	-136.21	0.43	13.67	19.94
	bottom		40	6.62	-233.41	0.24	14.29	24.45
Transect C								
RMW-8		1049						
	top		14	6.49	-337.63	0.34	14.58	14.08
	middle		18	6.51	-349.65	0.25	14.78	14.19
	bottom		23	6.56	-357.40	0.24	14.87	14.31
RMW-9		1530						
	top		6	5.88	-287.23	0.33	11.40	1.69
	middle		12	5.84	-295.86	0.24	11.28	1.69
	bottom		19	5.86	-304.83	0.21	11.55	1.71
RMW-10		1516						
	top		3	5.68	-217.73	0.56	11.66	0.62
	middle		12	5.69	-241.42	0.28	10.71	0.91
	bottom		19	5.70	-250.20	0.24	10.80	0.95
MW-4(O)								
	low tide							
	top		11	6.00	-196.37	0.87	11.73	2.18
	middle		14	6.03	-210.37	0.47	11.60	2.26
	bottom		18	6.06	-256.68	0.25	11.64	2.27
	high tide	1724						
	top		11	5.74	-184.32	0.39	12.07	2.35
	middle		14	5.73	-187.37	0.29	11.93	2.72
	bottom		18	5.74	-234.44	0.26	11.91	2.63
Transect D								
RGP-1		937						
	top		17	5.40	-236.24	0.90	11.41	1.06
	middle		20	5.69	-266.70	0.69	11.13	1.93
	bottom		23	5.75	-282.90	0.55	11.04	2.10
RMW-11		2036						
	top		5	5.78	-246.42	0.88	12.63	3.86
	middle		11	5.85	-276.37	0.29	12.98	5.28
	bottom		18	6.09	-311.43	0.41	13.58	8.86

Second Quarter Geochemical Data

Well I.D.	Time	Depth to Reading (feet bgs)	pH	Redox Potential (mV)	Dissolved Oxygen (mg/L)	Temperature (degrees C)	Electrical Conductivity (mS)
RMW-11D	2022						
top		14	6.10	-164.63	0.55	12.04	1.14
middle		18	6.09	-164.48	0.29	12.00	1.17
bottom		29	6.21	-283.88	0.19	13.55	15.40
MW-8(B)	1705						
top		5	5.81	-255.43	0.42	11.69	1.90
middle		12	6.01	-243.03	0.31	12.29	9.07
bottom		19	6.01	-244.63	0.27	12.80	9.27
MW-4(B)	2110						
top		5	5.97	-335.61	0.21	11.22	1.03
middle		6	6.12	-329.36	0.25	11.38	1.15
bottom		10.5	6.13	-332.22	0.19	11.39	1.16
RMW-12D	1058						
top		6	6.09	-252.91	0.27	11.40	1.17
middle		12	6.15	-268.85	0.21	11.63	1.27
bottom		19	6.15	-274.35	0.21	11.80	1.46
RMW-13D							
low tide	1153						
top		20	6.63	-173.64	0.75	12.66	3.41
middle		22	6.61	-183.25	0.35	12.61	3.43
bottom		27	6.26	-289.45	0.25	13.12	4.30
high tide	1821						
top		15	6.36	-96.96	0.48	12.59	3.40
middle		20	6.36	-103.98	0.28	12.50	3.38
bottom		28	5.99	-246.31	0.21	13.20	4.29
MW-3(B)							
low tide	1211						
top		6	6.24	-178.06	1.13	11.20	3.21
middle		8	6.22	-169.21	0.65	11.06	3.34
bottom		13	6.23	-152.92	0.44	10.95	3.35
high tide	1835						
top		6	5.93	-173.45	0.25	11.38	2.72
middle		8	5.93	-170.09	0.23	11.32	2.69
bottom		13	5.93	-154.71	0.21	11.33	2.84
Other Wells							
Olivine Area							
MW-3(O)							
low tide	1414						
top		11	6.30	-213.20	1.08	12.05	3.61
middle		15	6.31	-265.98	0.27	11.99	4.83
bottom		20	6.49	-313.30	0.24	12.20	5.33
high tide	2010						
top			6.27	-209.38	0.33	11.11	3.84
middle			6.27	-252.83	0.23	11.43	4.50
bottom			6.38	-301.28	0.20	11.85	4.92
MW-1(O)	1433						
top		11	6.02	-224.49	0.44	11.66	2.09
middle		15	6.02	-242.38	0.26	12.34	2.16
bottom		20	6.21	-270.72	0.22	12.79	2.90

Second Quarter Geochemical Data

Well I.D.	Time	Depth to Reading (feet bgs)	pH	Redox Potential (mV)	Dissolved Oxygen (mg/L)	Temperature (degrees C)	Electrical Conductivity (mS)
RMW-14	1605						
top		6	6.03	-63.43	2.18	12.05	0.62
middle		12	5.95	-114.35	0.85	11.60	0.76
bottom		19	5.97	-139.00	0.28	12.11	0.77
RMW-15	1546						
top		7	6.18	-91.60	2.57	11.14	0.78
middle		12	6.19	-131.83	0.77	10.84	1.11
bottom		19	6.20	-155.78	0.94	11.10	1.06
"F" Street Alignment Wells							
RMW-16	1624						
top		5	5.57	-250.66	0.68	10.71	0.61
middle		12	5.58	-265.38	0.32	10.46	0.61
bottom		19	5.59	-273.70	0.24	10.52	0.62
RMW-17	1105						
top		10	5.80	-313.33	0.38	11.78	2.12
middle		15	5.82	-332.33	0.30	12.12	2.51
bottom		18	5.90	-335.73	0.28	13.48	5.91
Chestnut Street Colony Wharf Wells							
RMW-18	2125						
top		7	6.65	-190.54	2.86	9.23	0.56
middle		11	6.89	-235.33	1.88	9.12	0.11
bottom		18	6.76	-215.79	1.48	9.09	0.09
MW-5(B)				Not Measured			
MW-12(B)	1649						
top		1.5	5.76	-233.83	0.51	11.41	1.14
middle		8	5.78	-226.28	0.32	11.18	1.66
bottom		12	5.76	-225.21	0.26	11.24	1.79
Maple Street BMI Wells							
MW-10(B)				Not Measured			
MW-1(B)				Not Measured			
MW-7(B)				Not Measured			
Chevron and "C" Street Wells							
MW-11A(C)				Not Measured			
MW-50(C)							
low tide	1249						
top		8	5.90	-312.69	0.72	11.00	0.53
middle		11	5.84	-324.93	0.25	10.78	0.76
bottom		14	5.82	-315.28	0.35	10.92	0.82
high tide	1905						
top			5.86	-315.36	0.21	10.54	0.56
middle			5.79	-310.21	0.21	10.71	0.80
bottom			5.80	-312.11	0.21	10.76	0.80

Second Quarter Geochemical Data

Well I.D.	Time	Depth to Reading (feet bgs)	pH	Redox Potential (mV)	Dissolved Oxygen (mg/L)	Temperature (degrees C)	Electrical Conductivity (mS)
MW-60(C)							
low tide	1136						
top			6.34	-327.94	0.40	11.18	1.28
middle			6.30	-330.84	0.30	11.02	1.33
bottom			6.29	-337.06	0.25	10.86	1.33
high tide	1848						
top			6.07	-270.19	0.41	10.68	1.19
middle			6.01	-285.64	0.24	10.72	1.36
bottom			6.03	-290.75	0.22	10.74	1.35
MW-53(C)		Not Measured					
MW-12A(C)							
low tide	1240						
top		6	6.10	-215.22	1.51	11.69	0.80
middle		11	6.02	-223.95	0.76	11.06	1.08
bottom		14	6.02	-236.58	0.46	11.00	1.13
high tide	1944						
top		6	5.94	-340.34	0.74	11.35	1.32
middle		11	5.95	-365.86	0.35	11.32	1.37
bottom		14	5.95	-371.78	0.31	11.25	1.36
MW-7A(C)		Not Measured					
G.P. Landfill Area							
RGP-2(W)	1001						
top		15	6.72	-426.33	0.37	9.48	1.10
middle		17	6.63	-432.30	0.27	9.33	1.13
bottom		29	6.60	-434.20	0.25	9.28	1.16
RMW-4	1032						
top		10	5.83	-272.40	0.30	12.41	1.23
middle		13	5.86	-285.87	0.26	12.90	1.36
bottom		19	5.76	-280.30	0.24	14.00	3.36
RMW-5	1016						
top		12	5.62	-311.24	0.94	12.54	1.63
middle		17	5.62	-322.50	0.60	13.10	1.66
bottom		22	5.69	-333.10	0.42	13.40	1.68
Hilton Avenue Bulkhead Well							
RMW-20	1447						
top		7	6.15	-274.92	0.47	12.40	1.14
middle		16	6.17	-289.41	0.26	12.51	1.24
bottom		19	6.19	-299.33	0.21	12.78	1.26
Stilling Gauge							
Stilling Gauge		Not Measured					

Third Quarter Geochemical Data

Well I.D.			Time	Depth to Reading (feet bgs)	pH	Redox Potential (mV)	Dissolved Oxygen (mg/L)	Temperature (degrees C)	Electrical Conductivity (mS)
Transect A									
RMW-3D									
10-Aug	*low tide*		1140						
		top		15	6.66	146.00	0.27	16.30	4.47
		middle		25	6.64	99.00	0.19	15.50	4.44
		bottom		33	7.06	10.50	0.17	15.40	24.30
9-Aug	*high tide*		657						
		top		12	6.71	118.00	0.44	16.60	4.41
		middle		25	6.69	91.20	0.27	15.80	4.41
		bottom		34	7.10	6.99	0.23	15.70	23.10
Transect B									
RMW-6D									
10-Aug	*low tide*		1209						
		top		10	6.85	-129.80	0.26	17.40	5.92
		middle		25	6.81	-133.10	0.24	17.00	5.91
		bottom		35	7.02	-118.80	0.21	16.90	25.00
9-Aug	*high tide*		740						
		top		15	6.80	-49.90	0.39	17.62	5.97
		middle		25	6.80	-71.70	0.23	17.26	6.01
		bottom		35	7.03	-80.00	0.20	17.20	26.50
MW-55(C)									
		top	1225	8	6.41	-38.70	0.34	16.80	0.98
		middle		12	6.39	-46.30	0.27	16.50	0.99
		bottom		13	6.42	-53.00	0.31	16.20	0.99
RMW-7									
10-Sep	*low tide*		1130						
		top		10	6.47	-64.20	0.39	18.10	9.20
		middle		15	6.45	-75.60	0.24	18.00	9.20
		bottom		20	6.56	-117.40	0.22	17.60	9.79
10-Sep	*high tide*		1840						
		top		12	6.33	217.00	1.89	19.30	7.74
		middle		15	6.40	175.00	0.90	18.70	9.07
		bottom		18	6.43	21.80	0.23	17.90	9.24
RMW-7D									
10-Aug	*low tide*		1059						
		top		15	7.23	30.60	0.23	17.50	20.50
		middle		20	7.18	-74.30	0.18	16.10	22.60
		bottom		34	7.19	-99.80	0.17	15.80	23.20
10-Aug	*high tide*		1830						
		top		15	7.31	165.00	0.55	18.20	20.60
		middle		25	7.24	127.00	0.25	17.20	23.00
		bottom		34	7.20	34.00	0.21	16.40	25.00

Third Quarter Geochemical Data

Well I.D.		Time	Depth to Reading (feet bgs)	pH	Redox Potential (mV)	Dissolved Oxygen (mg/L)	Temperature (degrees C)	Electrical Conductivity (mS)
Transect C								
RMW-9		1423						
	top		8	6.39	9.77	0.43	16.60	2.37
	middle		13	6.34	-19.90	0.33	15.60	2.38
	bottom		16	6.31	-27.30	0.34	14.80	3.47
RMW-10		1417						
	top		5	6.43	23.00	0.40	18.80	0.71
	middle		11	6.28	18.30	0.24	17.30	1.42
	bottom		20	6.35	10.80	0.24	14.50	2.71
MW-4(O)								
10-Aug	*low tide*	1140						
	top		15	6.40	72.00	0.28	16.60	1.83
	middle		16	6.37	53.00	0.20	16.10	1.86
	bottom		18	6.36	37.60	0.18	15.60	1.93
9-Aug	*high tide*	1820						
	top		13	6.50	125.00	0.87	17.60	2.13
	middle		16	6.47	93.00	0.28	16.20	2.20
	bottom		18	6.44	76.00	0.26	15.50	2.33
Transect D								
RMW-11								
	top		8	6.56	27.80	0.65	16.70	7.62
	middle		13	6.58	13.80	0.40	15.90	7.48
	bottom		18	6.58	7.00	0.35	15.20	7.44
RMW-11D								
	top		10	6.65	146.00	0.59	17.10	1.43
	middle		20	6.56	59.30	0.31	15.60	9.46
	bottom		29	6.68	13.10	0.29	15.20	19.20
MW-8(B)								
	top		5	Well not accessible				
	middle		12					
	bottom		19					
MW-4(B)		1518						
	top		6	6.36	2.45	0.28	17.60	1.42
	middle		8	6.35	37.90	0.43	17.60	1.42
	bottom		10	6.37	-5.27	0.27	17.30	1.40
RMW-12D		1513						
	top		8	6.73	94.50	0.36	18.60	1.18
	middle		13	6.62	47.60	0.26	16.60	6.51
	bottom		17	6.64	12.40	0.26	15.40	8.45

Third Quarter Geochemical Data

Well I.D.			Time	Depth to Reading (feet bgs)	pH	Redox Potential (mV)	Dissolved Oxygen (mg/L)	Temperature (degrees C)	Electrical Conductivity (mS)
RMW-13D									
	10-Aug	*low tide*	1130						
		top		15	6.64	103.00	0.23	17.60	3.52
		middle		22	6.57	37.70	0.18	16.10	3.98
		bottom		28	6.56	18.30	0.16	15.20	4.06
	9-Aug	*high tide*	1816						
		top		9	6.70	211.00	0.49	22.30	3.60
		middle		15	6.65	44.00	0.21	18.50	3.33
		bottom		28	6.60	-3.30	0.21	16.90	3.90
MW-3(B)									
	10-Aug	*low tide*	1200						
		top		6	6.58	172.00	0.25	17.40	2.79
		middle		8	6.58	172.00	0.20	16.80	2.76
		bottom		13	6.58	172.00	0.21	16.90	2.72
	9-Aug	*high tide*	1825						
		top		6	6.56	173.00	0.26	17.80	3.67
		middle		8	6.53	182.00	0.23	17.20	3.74
		bottom		13	6.52	185.00	0.21	17.00	3.64
Other Wells									
Olivine Area									
MW-3(O)									
	10-Aug	*low tide*	1332						
		top		14	6.97	98.10	0.35	17.40	4.50
		middle		17	6.93	47.50	0.22	16.00	4.43
		bottom		19	7.20	-1.16	0.19	14.70	5.60
	9-Aug	*high tide*	1945						
		top		15	6.90	65.20	0.38	16.50	4.59
		middle		17	7.00	33.30	0.24	14.90	5.17
		bottom		19	7.09	21.50	0.20	14.50	5.13
MW-1(O)			1342						
		top		11	6.65	87.00	0.31	16.70	2.12
		middle		15	6.63	59.60	0.22	15.70	2.09
		bottom		19	6.83	11.60	0.23	14.80	2.82
RMW-14			1433						
		top		9	6.53	123.40	0.42	18.30	0.78
		middle		14	6.40	122.10	0.27	16.80	0.84
		bottom		17	6.43	83.30	0.24	15.70	0.88
"F" Street Alignment Wells									
RMW-16			1445						
		top		9	6.08	37.50	0.40	17.00	0.97
		middle		12	6.01	-6.05	0.41	15.90	0.95
		bottom		18	6.01	-13.80	0.43	14.70	0.93

Third Quarter Geochemical Data

Well I.D.		Time	Depth to Reading (feet bgs)	pH	Redox Potential (mV)	Dissolved Oxygen (mg/L)	Temperature (degrees C)	Electrical Conductivity (mS)
Chestnut Street Colony Wharf Wells								
RMW-18								
	top		10	6.80	112.00	0.45	18.60	2.44
	middle		15	6.70	58.70	0.27	16.30	2.34
	bottom		20	6.65	38.00	0.23	15.40	2.36
MW-5(B)								
	top		7	6.50	45.00	0.44	18.80	1.13
	middle		10	6.46	33.00	0.30	17.90	1.08
	bottom		13	6.46	19.10	0.24	16.43	1.08
MW-12(B)		1503						
	top		5	6.35	70.50	0.39	18.00	1.41
	middle		8	6.30	55.50	0.29	16.70	2.12
	bottom		11	6.29	49.30	0.29	15.80	2.08
Maple Street BMI Wells								
MW-10(B)			6	6.42	116.00	0.36	17.50	2.08
			10	6.43	110.00	0.27	16.50	1.93
			15	6.44	107.00	0.36	16.10	1.93
MW-1(B)					Not Measured			
MW-7(B)					Not Measured			
Chevron and "C" Street Wells								
MW-11A(C)					Not Measured			
MW-50(C)								
10-Aug	*low tide*	1300						
	top		11	6.71	-70.00	0.29	17.00	1.03
	middle		12	6.72	-93.00	0.20	16.00	1.03
	bottom		13	6.67	-117.00	0.18	15.40	1.43
9-Aug	*high tide*	1940						
	top		11	6.80	-86.90	0.77	18.50	1.05
	middle		12	6.70	-105.00	0.26	16.60	1.03
	bottom		13	6.68	-120.00	0.21	15.60	1.42
MW-60(C)								
	low tide		Buried					
	top							
	middle							
	bottom							
	high tide							
	top							
	middle							
	bottom							
MW-53(C)					Not Measured			

Third Quarter Geochemical Data

Well I.D.		Time	Depth to Reading (feet bgs)	pH	Redox Potential (mV)	Dissolved Oxygen (mg/L)	Temperature (degrees C)	Electrical Conductivity (mS)
MW-12A(C)								
10-Aug	*low tide*	1235						
	top		9	6.46	75.90	0.49	17.10	1.25
	middle		15	6.49	50.40	0.25	16.10	1.32
	bottom		20	6.48	15.80	0.19	15.40	1.34
9-Aug	*high tide*	1710						
	top		9	6.62	-15.80	0.93	20.40	1.42
	middle		15	6.54	-42.40	0.27	17.20	1.37
	bottom		20	6.57	-114.00	0.23	15.40	1.31
MW-7A(C)				Not Measured- product in well				
G.P. Landfill Area								
RMW-5								
	top		12	6.01	7.04	0.30	17.60	1.91
	middle		17	6.25	-8.80	0.32	17.20	2.76
	bottom		22	6.36	-21.30	0.34	17.10	3.08
Hilton Avenue Bulkhead Well								
RMW-20		1405						
	top		11	6.86	-15.90	0.31	17.50	3.48
	middle		15	6.81	-42.50	0.20	16.80	4.30
	bottom		17	6.82	-55.50	0.20	15.90	4.50
Stilling Gauge								
Stilling Gauge								
	high tide							
	top		5	6.89	261.20	4.89	18.60	7.58
	middle		10	7.56	262.40	6.03	18.30	30.60
	bottom		15	7.63	232.40	2.88	18.00	29.70

Round 1 Geochemical Parameters

Well Location	Date	Time	DTR	pH	Redox	D.O.	Temp.	Cond.	Turbidity
high tide	02/08/1999	949							
low tide	02/08/1999	1731							
high tide	03/08/1999	812							
low tide	03/08/1999	1520							
Transect A									
RMW-1	03/08/1999	1148							
top			15	6.52	-87	1.38	12.8	3.2	NM
middle			20	6.36	-369	0.71	12.5	3.2	NM
bottom			22	6.27	-416	5.25	12.5	6.1	NM
purge	02/10/1999	1055	15	6.36	-495	0.27	9.3	3.5	10
RMW-2	02/08/1999	1347							
top			11	6.16	-272	2.42	8.8	2.4	NM
middle			17	6.18	-327	0.84	9.8	2.6	NM
bottom			22	6.11	-344	0.57	10.4	2.6	NM
purge	02/09/1999	1050	17	7.17	-352	0.38	9.2	2.4	7.82
RMW-2D	02/08/1999	1343							
top			23	6.86	-293	1.81	10.9	6.8	NM
middle			27	6.92	-323	0.62	12.0	6.8	NM
bottom			33	6.94	-337	0.50	12.7	7.4	NM
purge	02/09/1999	1146	34	7.07	-392	0.26	7.8	7.3	3.3
RMW-3D	02/08/1999	1034							
top			20	6.73	-295	0.96	10.2	4.6	NM
middle			27	6.86	-291	0.56	11.5	6.4	NM
bottom			28	6.90	-338	0.45	12.2	24.9	NM
		1915							
top			22	6.70	-240	1.54	9.0	4.6	NM
middle			27	6.70	-241	0.79	9.8	5.0	NM
bottom			35	6.47	-255	0.60	10.3	4.6	NM
purge	02/10/1999	1309	30	7.05	-439	0.18	10.5	7.5	5.91
Transect B									
RGP-4	02/08/1999	1335							
top			17	5.53	-299	2.64	10.0	2.7	NM
middle			20	5.95	-317	1.23	10.2	2.8	NM
bottom			24.29	6.01	-331	0.76	10.4	2.8	NM
purge									

Round 1 Geochemical Parameters (Continued)

Well Location	Date	Time	DTR	pH	Redox	D.O.	Temp.	Cond.	Turbidity
RGP-3	02/08/1999	1427							
top			14	6.54	-203	2.34	7.8	5.5	NM
middle			22	6.38	-330	0.87	8.5	5.6	NM
bottom			25	6.48	-444	0.61	9.3	4.9	NM
purge	02/09/1999	1244	20	6.48	-397	0.29	7.9	5.6	15.8
MW-98-1(GW)	NM								
top									
middle									
bottom									
purge									
RMW-6D	02/08/1999	830							
top			29	6.90	-344	2.67	9.4	11.6	NM
middle			35	7.09	-366	1.69	10.3	26.9	NM
bottom			37	7.10	-352	0.87	11.4	27.1	NM
purge	02/10/1999	1521	35	7.53	-484	0.17	9.9	4.9	2.73
MW-55(C)	02/08/1999	835							
top			5	6.54	-319	1.75	11.1	1.0	NM
middle			10	6.56	-314	1.28	10.8	1.0	NM
bottom			14	6.44	-319	0.84	10.7	1.1	NM
purge	02/10/1999	1618	9	6.49	-392	0.24	9.0	1.0	6.23
RMW-7	02/08/1999	1007							
top			7	6.37	249	4.73	8.2	8.2	NM
middle			12	6.39	58.8	3.87	8.8	8.4	NM
bottom			19	6.39	20.4	2.49	9.2	8.2	NM
		1945							
top			7	6.70	-92.7	1.21	11.4	6.9	NM
middle			12	6.64	-98.7	0.74	11.3	6.9	NM
bottom			19	6.64	-86.9	0.57	11.2	7.0	NM
purge	02/10/1999	1741	10	6.70	-227	0.54	8.6	6.3	0.57
RMW-7D	02/08/1999	1009							
top			25	7.04	-131	1.08	10.5	24.3	NM
middle			32	7.14	-210	0.60	11.3	24.6	NM
bottom			40	7.03	-252	0.48	12.5	28.6	NM
		1940							
top			25	7.16	13.4	1.88	9.7	23.6	NM
middle			32	7.20	-60	0.76	10.2	23.8	NM
bottom			40	7.16	-135	0.52	11.5	27.4	NM
purge	02/10/1999	1807	35	7.39	-298	0.19	9.9	23.7	7.39

Round 1 Geochemical Parameters (Continued)

Well Location	Date	Time	DTR	pH	Redox	D.O.	Temp.	Cond.	Turbidity
Transect C									
RMW-8	02/08/1999	1322							
top			14	6.73	-288	2.61	9.7	14.5	NM
middle			18	6.84	-333	0.91	10.6	14.9	NM
bottom			23	6.87	-341	0.70	11.4	15.5	NM
purge									
RMW-9	02/08/1999	1242							
top			6	6.32	-269	2.37	9.3	1.8	NM
middle			12	6.34	-288	0.97	9.5	1.8	NM
bottom			19	6.35	-292	0.69	10.0	1.8	NM
purge	02/10/1999	1009	13	6.97	-363	0.23	7.8	14.5	99
RMW-10	02/08/1999	1619**							
top									
middle			12	6.49	-285	0.20	8.6	1.3	NM
bottom									
purge									
MW-4(O)	02/08/1999	1024							
top			11	6.25	-184	1.74	10.0	2.7	NM
middle			14	6.25	-202	0.83	10.2	2.7	NM
bottom			18	6.26	-217	0.64	10.6	3.0	NM
		1925							
top			11	7.10	-11.1	7.63	9.7	1.9	NM
middle			14	6.30	-135	2.00	9.9	2.3	NM
bottom			18	6.27	-166	1.17	10.1	2.6	NM
purge	02/10/1999	1218	13	6.41	-372	0.24	9.2	2.9	1.79
Transect D									
RGP-1	03/08/1999	1216							
top			17	5.60	-306	0.52	9.1	0.9	NM
middle			20	5.68	-312	0.49	9.0	0.9	NM
bottom			23	5.77	-318	0.50	9.0	1.3	NM
purge	02/09/1999	1333	18	5.79	-343	0.23	8.5	1.2	0.91
RMW-11		NA							
top									
middle									
bottom									
purge	03/08/1999	1530	14	6.65	-328	0.30	11.7	7.1	NM

Round 1 Geochemical Parameters (Continued)

Well Location	Date	Time	DTR	pH	Redox	D.O.	Temp.	Cond.	Turbidity
RMW-11D									
top									
middle									
bottom									
purge	03/08/1999	1630	24	6.79	-299	0.29	11.2	10.1	NM
MW-8(B)									
top									
middle									
bottom									
purge	03/08/1999	1355	14	6.75	-259	0.37	12.7	8.9	NM
MW-4(B)	02/08/1999	812							
top			5	6.73	-286	2.62	6.7	1.2	NM
middle			6	6.72	-295	1.83	7.3	1.2	NM
bottom			10.5	6.71	-299	1.33	7.8	1.3	NM
purge	02/09/1999	1425	8	6.80	-341	0.32	8.0	1.3	3.1
RMW-12D	02/08/1999	1120							
top			6	6.67	-286	1.10	9.3	1.4	NM
middle			12	6.69	-309	0.65	9.6	1.4	NM
bottom			19	6.66	-131	0.64	10.2	8.0	NM
purge	02/09/1999	1517	14	6.88	-340	0.22	6.8	1.4	13.9
RMW-13D	02/08/1999	943							
top			20	6.42	-407	0.57	11.2	4.7	NM
middle			22	6.47	-438	0.39	12.8	4.7	NM
bottom			27	6.46	-428	0.46	11.8	4.7	NM
		1846							
top			15	6.62	-182	1.82	8.7	3.4	NM
middle			20	6.45	-222	0.89	9.4	4.5	NM
bottom			28	6.92	-301	0.54	10.8	24.2	NM
purge	02/10/1999	1355	23	6.65	-415	0.21	9.1	4.7	0.89
MW-3(B)	03/08/1999	1022							
top			6	6.48	-103	0.91	10.9	11.8	NM
middle			8	6.44	-92	0.61	10.7	14.3	NM
bottom			13	6.40	-87	0.52	10.4	12.3	NM
		1958							
top			6	6.52	245	7.65	8.3	14.0	NM
middle			8	6.64	241	7.24	8.3	14.1	NM
bottom			13	6.65	230	7.03	8.2	13.8	NM

Round 1 Geochemical Parameters (Continued)

Well Location	Date	Time	DTR	pH	Redox	D.O.	Temp.	Cond.	Turbidity
Other Wells									
Olivine Area									
MW-3(O)	03/08/1999	1403							
top			11	6.76	-236	1.11	11.8	4.3	NM
middle			15	6.80	-251	0.77	11.8	4.5	NM
bottom			20	7.20	-337	0.58	12.0	5.8	NM
purge									
MW-1(O)	02/08/1999	1230							
top			11	7.32	-64.1	9.19	8.1	2.2	NM
middle			15	6.43	-234	1.80	8.6	2.2	NM
bottom			20	6.44	-244	1.00	9.5	3.3	NM
RMW-14	02/08/1999	1316							
top			6	6.37	-10.9	4.90	9.1	0.8	NM
middle			12	6.31	-166	2.07	9.4	0.8	NM
bottom			19	6.34	-171	0.86	9.9	0.8	NM
purge									
RMW-15	02/08/1999	1220							
top			7	7.43	-0.749	7.57	8.1	0.5	NM
middle			12	6.73	-160	2.91	8.5	0.8	NM
bottom			19	6.74	-197	1.75	8.8	0.8	NM
purge									
F Street Alignment Wells									
RMW-16	02/08/1999	755							
top			5	7.12	-262	4.80	6.2	0.4	NM
middle			12	6.71	-266	2.85	6.6	0.6	NM
bottom			19	6.44	-278	1.92	6.8	0.6	NM
purge									
RMW-17	03/08/1999	1335							
top			10	6.00	-276	1.05	12.7	2.1	NM
middle			15	6.05	-292	0.74	12.6	4.1	NM
bottom			18	6.19	-350	0.56	13.0	6.2	NM
purge									
Chestnut Street Colony Wharf Wells									
RMW-18	03/08/1999	1046							
top			7	7.20	-173	1.03	9.5	0.7	NM
middle			11	7.26	-197	0.66	9.3	0.1	NM
bottom			18	7.37	-212	0.58	9.2	0.1	NM
purge									

Round 1 Geochemical Parameters (Continued)

Well Location	Date	Time	DTR	pH	Redox	D.O.	Temp.	Cond.	Turbidity
MW-5(B)	02/08/1999	1141							
top			5.5	6.29	-230	1.00	8.7	1.0	NM
middle			10	6.32	-242	0.77	8.8	1.0	NM
bottom			13	6.33	-250	0.60	9.3	1.0	NM
purge									
MW-12(B)	02/08/1999	1151							
top			1.5	6.19	-193	3.96	7.8	1.2	NM
middle			8	6.15	-238	1.49	8.1	1.6	NM
bottom			12	6.18	-243	0.93	8.6	1.6	NM
purge									
Maple Street BMI Wells									
MW-10(B)	02/08/1999	1117							
top			6	6.41	-60.9	4.35	8.5	1.0	NM
middle			10	6.43	-121	1.03	9.2	1.7	NM
bottom			15	6.50	-218	0.66	9.5	1.7	NM
purge									
Chevron and C-Street Wells									
MW-11A(C)	02/08/1999	843							
top			4	7.06	-215	5.16	8.4	0.3	NM
middle									
bottom									
purge									
MW-50(C)	02/08/1999	1105							
top			8	6.13	-321	1.30	8.6	1.0	NM
middle			11	6.18	-139	0.73	9.0	1.0	NM
bottom			14	6.19	-387	0.91	9.5	1.0	NM
purge									
MW-53(C)	02/08/1999	822							
top			4	6.56	-134	2.46	8.5	0.8	NM
middle			10	6.55	-130	2.26	8.6	1.1	NM
bottom			12.5	6.50	-127	1.65	8.8	1.1	NM
purge									
MW-12A(C)	03/08/1999	912							
top			6	6.65	-331	0.40	14.2	2.0	NM
middle			11	6.56	-348	0.32	13.7	2.0	NM
bottom			14	6.55	-351	0.30	13.2	2.2	NM
		1655							
top			6	6.46	-133	3.28	12.3	1.8	NM
middle			11	6.48	-151	2.15	12.0	1.9	NM
bottom			14	6.49	-211	1.11	12.5	2.0	NM
purge									

Round 1 Geochemical Parameters (Continued)

Well Location	Date	Time	DTR	pH	Redox	D.O.	Temp.	Cond.	Turbidity
G.P. Landfill Area									
RGP-2(W)	02/08/1999	1438							
top			15	7.30	-434	1.00	9.4	1.1	NM
middle			17	7.25	-463	0.67	9.2	1.1	NM
bottom			29	7.23	-474	0.57	9.1	1.1	NM
purge									
RMW-4	02/08/1999	1358							
top			12	6.24	-230	0.88	10.5	0.3	NM
middle			17	6.23	-270	0.59	11.1	1.6	NM
bottom			22	6.03	-287	0.48	11.8	3.5	NM
purge									
RMW-5	02/08/1999	1400							
top			10	6.02	-320	0.84	11.2	2.1	NM
middle			13	6.03	-324	0.57	11.7	2.2	NM
bottom			19	6.05	-346	0.52	12.3	2.2	NM
purge									
Hilton Ave. Bulkhead Well									
RMW-20	03/08/1999	1408							
top			7	6.86	-290	2.10	11.9	4.3	NM
middle			16	6.90	-380	0.28	12.1	4.5	NM
bottom			19	6.95	-381	0.29	12.3	5.0	NM
purge									
Stilling Gauge									
stilling gauge	02/08/1999	800							
top			5	7.20	-297	9.31	6.8	1.9	NM
middle			10	7.31	-263	9.09	6.7	2.8	NM
bottom			15	6.91	-194	8.89	6.6	24.0	NM
	03/08/1999	1031							
top			5	6.48	-93.6	8.74	9.6	2.0	NM
middle			10	6.75	-77	8.77	9.2	11.1	NM
bottom			15	6.96	-92	8.59	8.9	27.7	NM

NOTES:

** - Well data only from purge.
NM - Not measured.
Cond. - Specific conductance.
D.O. - Dissolved oxygen.
DTR - Depth to reading in feet below ground surface.
Redox - Redox potential.
Temp. - Temperature.

Second Quarter Geochemical Data

Well I.D.		Time	Depth to Reading (feet bgs)	pH	Redox Potential (mV)	Dissolved Oxygen (mg/L)	Temperature (degrees C)	Electrical Conductivity (mS)
Transect A								
RMW-1		1605						
	top		15	6.42	-499.80	1.42	12.46	2.99
	middle		20	6.33	-500.45	0.92	12.18	3.81
	bottom		22	6.46	-519.68	0.31	12.85	5.23
RMW-2		1650						
	top		11	6.40	-452.90	0.70	13.55	2.37
	middle		17	6.16	-448.00	0.23	13.76	2.37
	bottom		22	6.16	-452.70	0.22	13.83	2.37
RMW-2D		1630						
	top		23	7.13	-353.30	0.62	14.68	6.24
	middle		27	7.14	-365.30	0.28	15.16	6.84
	bottom		33	7.04	-434.30	0.24	15.60	7.66
RMW-3D								
	low tide	1300						
*4/14/99	top		20	6.23	-168.00	0.65	12.25	4.25
	middle		27	6.09	-321.00	0.45	12.76	5.64
	bottom		28	6.10	-353.00	0.32	13.34	5.69
	high tide	1737						
	top		22	6.31	-127.63	0.40	11.80	4.08
	middle		27	6.10	-234.94	0.24	12.50	5.02
	bottom		35	6.63	-300.78	0.22	13.61	21.59
Transect B								
RGP-4(W)		1715						
	top		17	6.21	-557.90	0.26	11.62	4.09
	middle		20	6.04	-602.00	0.23	11.60	3.75
	bottom		24.29	5.99	-610.20	0.23	11.55	3.96
RGP-3(W)		1734						
	top		14	5.96	-410.50	0.30	11.37	6.15
	middle		22	5.99	-414.30	0.26	11.66	6.32
	bottom		25	5.89	-421.10	0.24	11.97	6.35
MW-98-1(GW)		17:50						
	top		12	4.85	-306.70	0.69	10.18	0.01
	middle		14	4.90	-287.20	0.68	10.14	0.68
	bottom		15.8	5.22	-335.80	0.39	10.06	1.32
RMW-6D								
	low tide	1303						
	top		29	6.36	-181.27	0.46	11.46	4.74
	middle		35	6.20	-344.38	0.25	11.75	5.65
	bottom		37	6.28	-406.69	0.21	13.89	12.10
	high tide	1929						
	top			6.25	-348.43	0.48	11.58	5.52
	middle			6.23	-357.93	0.33	11.73	5.76
	bottom			6.49	-371.78	0.44	14.83	23.83

Second Quarter Geochemical Data

Well I.D.		Time	Depth to Reading (feet bgs)	pH	Redox Potential (mV)	Dissolved Oxygen (mg/L)	Temperature (degrees C)	Electrical Conductivity (mS)
MW-55(C)					Not Measured			
RMW-7								
	low tide	1250						
	top		7	6.20	-198.39	0.88	12.40	2.60
	middle		12	6.23	-233.68	0.42	12.25	2.86
	bottom		19	6.25	-237.99	0.31	12.20	2.87
	high tide	1755						
	top		7	6.18	-151.62	1.27	12.25	2.58
	middle		12	6.22	-158.07	0.80	12.28	2.78
	bottom		19	6.21	-160.47	0.60	12.38	2.81
RMW-7D								
	low tide							
	top		25	7.21	-142.51	4.13	12.80	16.37
	middle		32	6.95	-196.79	0.56	12.88	20.64
	bottom		40	6.70	-252.98	0.27	14.52	25.50
	high tide	1803						
	top		25	6.90	-140.37	2.67	12.35	16.49
	middle		32	6.68	-136.21	0.43	13.67	19.94
	bottom		40	6.62	-233.41	0.24	14.29	24.45
Transect C								
RMW-8		1049						
	top		14	6.49	-337.63	0.34	14.58	14.08
	middle		18	6.51	-349.65	0.25	14.78	14.19
	bottom		23	6.56	-357.40	0.24	14.87	14.31
RMW-9		1530						
	top		6	5.88	-287.23	0.33	11.40	1.69
	middle		12	5.84	-295.86	0.24	11.28	1.69
	bottom		19	5.86	-304.83	0.21	11.55	1.71
RMW-10		1516						
	top		3	5.68	-217.73	0.56	11.66	0.62
	middle		12	5.69	-241.42	0.28	10.71	0.91
	bottom		19	5.70	-250.20	0.24	10.80	0.95
MW-4(O)								
	low tide							
	top		11	6.00	-196.37	0.87	11.73	2.18
	middle		14	6.03	-210.37	0.47	11.60	2.26
	bottom		18	6.06	-256.68	0.25	11.64	2.27
	high tide	1724						
	top		11	5.74	-184.32	0.39	12.07	2.35
	middle		14	5.73	-187.37	0.29	11.93	2.72
	bottom		18	5.74	-234.44	0.26	11.91	2.63
Transect D								
RGP-1		937						
	top		17	5.40	-236.24	0.90	11.41	1.06
	middle		20	5.69	-266.70	0.69	11.13	1.93
	bottom		23	5.75	-282.90	0.55	11.04	2.10
RMW-11		2036						
	top		5	5.78	-246.42	0.88	12.63	3.86
	middle		11	5.85	-276.37	0.29	12.98	5.28
	bottom		18	6.09	-311.43	0.41	13.58	8.86

Second Quarter Geochemical Data

Well I.D.	Time	Depth to Reading (feet bgs)	pH	Redox Potential (mV)	Dissolved Oxygen (mg/L)	Temperature (degrees C)	Electrical Conductivity (mS)
RMW-11D	2022						
top		14	6.10	-164.63	0.55	12.04	1.14
middle		18	6.09	-164.48	0.29	12.00	1.17
bottom		29	6.21	-283.88	0.19	13.55	15.40
MW-8(B)	1705						
top		5	5.81	-255.43	0.42	11.69	1.90
middle		12	6.01	-243.03	0.31	12.29	9.07
bottom		19	6.01	-244.63	0.27	12.80	9.27
MW-4(B)	2110						
top		5	5.97	-335.61	0.21	11.22	1.03
middle		6	6.12	-329.36	0.25	11.38	1.15
bottom		10.5	6.13	-332.22	0.19	11.39	1.16
RMW-12D	1058						
top		6	6.09	-252.91	0.27	11.40	1.17
middle		12	6.15	-268.85	0.21	11.63	1.27
bottom		19	6.15	-274.35	0.21	11.80	1.46
RMW-13D							
low tide	1153						
top		20	6.63	-173.64	0.75	12.66	3.41
middle		22	6.61	-183.25	0.35	12.61	3.43
bottom		27	6.26	-289.45	0.25	13.12	4.30
high tide	1821						
top		15	6.36	-96.96	0.48	12.59	3.40
middle		20	6.36	-103.98	0.28	12.50	3.38
bottom		28	5.99	-246.31	0.21	13.20	4.29
MW-3(B)							
low tide	1211						
top		6	6.24	-178.06	1.13	11.20	3.21
middle		8	6.22	-169.21	0.65	11.06	3.34
bottom		13	6.23	-152.92	0.44	10.95	3.35
high tide	1835						
top		6	5.93	-173.45	0.25	11.38	2.72
middle		8	5.93	-170.09	0.23	11.32	2.69
bottom		13	5.93	-154.71	0.21	11.33	2.84
Other Wells							
Olivine Area							
MW-3(O)							
low tide	1414						
top		11	6.30	-213.20	1.08	12.05	3.61
middle		15	6.31	-265.98	0.27	11.99	4.83
bottom		20	6.49	-313.30	0.24	12.20	5.33
high tide	2010						
top			6.27	-209.38	0.33	11.11	3.84
middle			6.27	-252.83	0.23	11.43	4.50
bottom			6.38	-301.28	0.20	11.85	4.92
MW-1(O)	1433						
top		11	6.02	-224.49	0.44	11.66	2.09
middle		15	6.02	-242.38	0.26	12.34	2.16
bottom		20	6.21	-270.72	0.22	12.79	2.90

Second Quarter Geochemical Data

Well I.D.	Time	Depth to Reading (feet bgs)	pH	Redox Potential (mV)	Dissolved Oxygen (mg/L)	Temperature (degrees C)	Electrical Conductivity (mS)
RMW-14	1605						
top		6	6.03	-63.43	2.18	12.05	0.62
middle		12	5.95	-114.35	0.85	11.60	0.76
bottom		19	5.97	-139.00	0.28	12.11	0.77
RMW-15	1546						
top		7	6.18	-91.60	2.57	11.14	0.78
middle		12	6.19	-131.83	0.77	10.84	1.11
bottom		19	6.20	-155.78	0.94	11.10	1.06
"F" Street Alignment Wells							
RMW-16	1624						
top		5	5.57	-250.66	0.68	10.71	0.61
middle		12	5.58	-265.38	0.32	10.46	0.61
bottom		19	5.59	-273.70	0.24	10.52	0.62
RMW-17	1105						
top		10	5.80	-313.33	0.38	11.78	2.12
middle		15	5.82	-332.33	0.30	12.12	2.51
bottom		18	5.90	-335.73	0.28	13.48	5.91
Chestnut Street Colony Wharf Wells							
RMW-18	2125						
top		7	6.65	-190.54	2.86	9.23	0.56
middle		11	6.89	-235.33	1.88	9.12	0.11
bottom		18	6.76	-215.79	1.48	9.09	0.09
MW-5(B)				Not Measured			
MW-12(B)	1649						
top		1.5	5.76	-233.83	0.51	11.41	1.14
middle		8	5.78	-226.28	0.32	11.18	1.66
bottom		12	5.76	-225.21	0.26	11.24	1.79
Maple Street BMI Wells							
MW-10(B)				Not Measured			
MW-1(B)				Not Measured			
MW-7(B)				Not Measured			
Chevron and "C" Street Wells							
MW-11A(C)				Not Measured			
MW-50(C)							
low tide	1249						
top		8	5.90	-312.69	0.72	11.00	0.53
middle		11	5.84	-324.93	0.25	10.78	0.76
bottom		14	5.82	-315.28	0.35	10.92	0.82
high tide	1905						
top			5.86	-315.36	0.21	10.54	0.56
middle			5.79	-310.21	0.21	10.71	0.80
bottom			5.80	-312.11	0.21	10.76	0.80

Second Quarter Geochemical Data

Well I.D.	Time	Depth to Reading (feet bgs)	pH	Redox Potential (mV)	Dissolved Oxygen (mg/L)	Temperature (degrees C)	Electrical Conductivity (mS)
MW-60(C)							
low tide	1136						
top			6.34	-327.94	0.40	11.18	1.28
middle			6.30	-330.84	0.30	11.02	1.33
bottom			6.29	-337.06	0.25	10.86	1.33
high tide	1848						
top			6.07	-270.19	0.41	10.68	1.19
middle			6.01	-285.64	0.24	10.72	1.36
bottom			6.03	-290.75	0.22	10.74	1.35
MW-53(C)				Not Measured			
MW-12A(C)							
low tide	1240						
top		6	6.10	-215.22	1.51	11.69	0.80
middle		11	6.02	-223.95	0.76	11.06	1.08
bottom		14	6.02	-236.58	0.46	11.00	1.13
high tide	1944						
top		6	5.94	-340.34	0.74	11.35	1.32
middle		11	5.95	-365.86	0.35	11.32	1.37
bottom		14	5.95	-371.78	0.31	11.25	1.36
MW-7A(C)				Not Measured			
G.P. Landfill Area							
RGP-2(W)	1001						
top		15	6.72	-426.33	0.37	9.48	1.10
middle		17	6.63	-432.30	0.27	9.33	1.13
bottom		29	6.60	-434.20	0.25	9.28	1.16
RMW-4	1032						
top		10	5.83	-272.40	0.30	12.41	1.23
middle		13	5.86	-285.87	0.26	12.90	1.36
bottom		19	5.76	-280.30	0.24	14.00	3.36
RMW-5	1016						
top		12	5.62	-311.24	0.94	12.54	1.63
middle		17	5.62	-322.50	0.60	13.10	1.66
bottom		22	5.69	-333.10	0.42	13.40	1.68
Hilton Avenue Bulkhead Well							
RMW-20	1447						
top		7	6.15	-274.92	0.47	12.40	1.14
middle		16	6.17	-289.41	0.26	12.51	1.24
bottom		19	6.19	-299.33	0.21	12.78	1.26
Stilling Gauge							
Stilling Gauge				Not Measured			

Third Quarter Geochemical Data

Well I.D.		Time	Depth to Reading (feet bgs)	pH	Redox Potential (mV)	Dissolved Oxygen (mg/L)	Temperature (degrees C)	Electrical Conductivity (mS)
Transect A								
RMW-3D								
10-Aug	*low tide*	1140						
	top		15	6.66	146.00	0.27	16.30	4.47
	middle		25	6.64	99.00	0.19	15.50	4.44
	bottom		33	7.06	10.50	0.17	15.40	24.30
9-Aug	*high tide*	657						
	top		12	6.71	118.00	0.44	16.60	4.41
	middle		25	6.69	91.20	0.27	15.80	4.41
	bottom		34	7.10	6.99	0.23	15.70	23.10
Transect B								
RMW-6D								
10-Aug	*low tide*	1209						
	top		10	6.85	-129.80	0.26	17.40	5.92
	middle		25	6.81	-133.10	0.24	17.00	5.91
	bottom		35	7.02	-118.80	0.21	16.90	25.00
9-Aug	*high tide*	740						
	top		15	6.80	-49.90	0.39	17.62	5.97
	middle		25	6.80	-71.70	0.23	17.26	6.01
	bottom		35	7.03	-80.00	0.20	17.20	26.50
MW-55(C)								
	top	1225	8	6.41	-38.70	0.34	16.80	0.98
	middle		12	6.39	-46.30	0.27	16.50	0.99
	bottom		13	6.42	-53.00	0.31	16.20	0.99
RMW-7								
10-Sep	*low tide*	1130						
	top		10	6.47	-64.20	0.39	18.10	9.20
	middle		15	6.45	-75.60	0.24	18.00	9.20
	bottom		20	6.56	-117.40	0.22	17.60	9.79
10-Sep	*high tide*	1840						
	top		12	6.33	217.00	1.89	19.30	7.74
	middle		15	6.40	175.00	0.90	18.70	9.07
	bottom		18	6.43	21.80	0.23	17.90	9.24
RMW-7D								
10-Aug	*low tide*	1059						
	top		15	7.23	30.60	0.23	17.50	20.50
	middle		20	7.18	-74.30	0.18	16.10	22.60
	bottom		34	7.19	-99.80	0.17	15.80	23.20
10-Aug	*high tide*	1830						
	top		15	7.31	165.00	0.55	18.20	20.60
	middle		25	7.24	127.00	0.25	17.20	23.00
	bottom		34	7.20	34.00	0.21	16.40	25.00

Third Quarter Geochemical Data

Well I.D.			Time	Depth to Reading (feet bgs)	pH	Redox Potential (mV)	Dissolved Oxygen (mg/L)	Temperature (degrees C)	Electrical Conductivity (mS)
Transect C									
	RMW-9		1423						
		top		8	6.39	9.77	0.43	16.60	2.37
		middle		13	6.34	-19.90	0.33	15.60	2.38
		bottom		16	6.31	-27.30	0.34	14.80	3.47
	RMW-10		1417						
		top		5	6.43	23.00	0.40	18.80	0.71
		middle		11	6.28	18.30	0.24	17.30	1.42
		bottom		20	6.35	10.80	0.24	14.50	2.71
	MW-4(O)								
10-Aug		*low tide*	1140						
		top		15	6.40	72.00	0.28	16.60	1.83
		middle		16	6.37	53.00	0.20	16.10	1.86
		bottom		18	6.36	37.60	0.18	15.60	1.93
9-Aug		*high tide*	1820						
		top		13	6.50	125.00	0.87	17.60	2.13
		middle		16	6.47	93.00	0.28	16.20	2.20
		bottom		18	6.44	76.00	0.26	15.50	2.33
Transect D									
	RMW-11								
		top		8	6.56	27.80	0.65	16.70	7.62
		middle		13	6.58	13.80	0.40	15.90	7.48
		bottom		18	6.58	7.00	0.35	15.20	7.44
	RMW-11D								
		top		10	6.65	146.00	0.59	17.10	1.43
		middle		20	6.56	59.30	0.31	15.60	9.46
		bottom		29	6.68	13.10	0.29	15.20	19.20
	MW-8(B)								
		top		5		Well not accessible			
		middle		12					
		bottom		19					
	MW-4(B)		1518						
		top		6	6.36	2.45	0.28	17.60	1.42
		middle		8	6.35	37.90	0.43	17.60	1.42
		bottom		10	6.37	-5.27	0.27	17.30	1.40
	RMW-12D		1513						
		top		8	6.73	94.50	0.36	18.60	1.18
		middle		13	6.62	47.60	0.26	16.60	6.51
		bottom		17	6.64	12.40	0.26	15.40	8.45

Third Quarter Geochemical Data

Well I.D.		Time	Depth to Reading (feet bgs)	pH	Redox Potential (mV)	Dissolved Oxygen (mg/L)	Temperature (degrees C)	Electrical Conductivity (mS)
RMW-13D								
10-Aug	*low tide*	1130						
	top		15	6.64	103.00	0.23	17.60	3.52
	middle		22	6.57	37.70	0.18	16.10	3.98
	bottom		28	6.56	18.30	0.16	15.20	4.06
9-Aug	*high tide*	1816						
	top		9	6.70	211.00	0.49	22.30	3.60
	middle		15	6.65	44.00	0.21	18.50	3.33
	bottom		28	6.60	-3.30	0.21	16.90	3.90
MW-3(B)								
10-Aug	*low tide*	1200						
	top		6	6.58	172.00	0.25	17.40	2.79
	middle		8	6.58	172.00	0.20	16.80	2.76
	bottom		13	6.58	172.00	0.21	16.90	2.72
9-Aug	*high tide*	1825						
	top		6	6.56	173.00	0.26	17.80	3.67
	middle		8	6.53	182.00	0.23	17.20	3.74
	bottom		13	6.52	185.00	0.21	17.00	3.64
Other Wells								
Olivine Area								
MW-3(O)								
10-Aug	*low tide*	1332						
	top		14	6.97	98.10	0.35	17.40	4.50
	middle		17	6.93	47.50	0.22	16.00	4.43
	bottom		19	7.20	-1.16	0.19	14.70	5.60
9-Aug	*high tide*	1945						
	top		15	6.90	65.20	0.38	16.50	4.59
	middle		17	7.00	33.30	0.24	14.90	5.17
	bottom		19	7.09	21.50	0.20	14.50	5.13
MW-1(O)		1342						
	top		11	6.65	87.00	0.31	16.70	2.12
	middle		15	6.63	59.60	0.22	15.70	2.09
	bottom		19	6.83	11.60	0.23	14.80	2.82
RMW-14		1433						
	top		9	6.53	123.40	0.42	18.30	0.78
	middle		14	6.40	122.10	0.27	16.80	0.84
	bottom		17	6.43	83.30	0.24	15.70	0.88
"F" Street Alignment Wells								
RMW-16		1445						
	top		9	6.08	37.50	0.40	17.00	0.97
	middle		12	6.01	-6.05	0.41	15.90	0.95
	bottom		18	6.01	-13.80	0.43	14.70	0.93

Third Quarter Geochemical Data

Well I.D.		Time	Depth to Reading (feet bgs)	pH	Redox Potential (mV)	Dissolved Oxygen (mg/L)	Temperature (degrees C)	Electrical Conductivity (mS)
Chestnut Street Colony Wharf Wells								
RMW-18								
	top		10	6.80	112.00	0.45	18.60	2.44
	middle		15	6.70	58.70	0.27	16.30	2.34
	bottom		20	6.65	38.00	0.23	15.40	2.36
MW-5(B)								
	top		7	6.50	45.00	0.44	18.80	1.13
	middle		10	6.46	33.00	0.30	17.90	1.08
	bottom		13	6.46	19.10	0.24	16.43	1.08
MW-12(B)		1503						
	top		5	6.35	70.50	0.39	18.00	1.41
	middle		8	6.30	55.50	0.29	16.70	2.12
	bottom		11	6.29	49.30	0.29	15.80	2.08
Maple Street BMI Wells								
MW-10(B)			6	6.42	116.00	0.36	17.50	2.08
			10	6.43	110.00	0.27	16.50	1.93
			15	6.44	107.00	0.36	16.10	1.93
MW-1(B)					Not Measured			
MW-7(B)					Not Measured			
Chevron and "C" Street Wells								
MW-11A(C)					Not Measured			
MW-50(C)								
10-Aug	*low tide*	1300						
	top		11	6.71	-70.00	0.29	17.00	1.03
	middle		12	6.72	-93.00	0.20	16.00	1.03
	bottom		13	6.67	-117.00	0.18	15.40	1.43
9-Aug	*high tide*	1940						
	top		11	6.80	-86.90	0.77	18.50	1.05
	middle		12	6.70	-105.00	0.26	16.60	1.03
	bottom		13	6.68	-120.00	0.21	15.60	1.42
MW-60(C)								
	low tide		Buried					
	top							
	middle							
	bottom							
	high tide							
	top							
	middle							
	bottom							
MW-53(C)					Not Measured			

Third Quarter Geochemical Data

Well I.D.		Time	Depth to Reading (feet bgs)	pH	Redox Potential (mV)	Dissolved Oxygen (mg/L)	Temperature (degrees C)	Electrical Conductivity (mS)
MW-12A(C)								
10-Aug	*low tide*	1235						
	top		9	6.46	75.90	0.49	17.10	1.25
	middle		15	6.49	50.40	0.25	16.10	1.32
	bottom		20	6.48	15.80	0.19	15.40	1.34
9-Aug	*high tide*	1710						
	top		9	6.62	-15.80	0.93	20.40	1.42
	middle		15	6.54	-42.40	0.27	17.20	1.37
	bottom		20	6.57	-114.00	0.23	15.40	1.31
MW-7A(C)			Not Measured- product in well					
G.P. Landfill Area								
RMW-5								
	top		12	6.01	7.04	0.30	17.60	1.91
	middle		17	6.25	-8.80	0.32	17.20	2.76
	bottom		22	6.36	-21.30	0.34	17.10	3.08
Hilton Avenue Bulkhead Well								
RMW-20		1405						
	top		11	6.86	-15.90	0.31	17.50	3.48
	middle		15	6.81	-42.50	0.20	16.80	4.30
	bottom		17	6.82	-55.50	0.20	15.90	4.50
Stilling Gauge								
Stilling Gauge								
	high tide							
	top		5	6.89	261.20	4.89	18.60	7.58
	middle		10	7.56	262.40	6.03	18.30	30.60
	bottom		15	7.63	232.40	2.88	18.00	29.70

C Tidal Study

A tidal study was conducted to determine the influence of tidal fluctuations on groundwater flow patterns and water chemistry at the site as discussed in the Work Plan (RETEC, 1998). A preliminary gauging event was performed prior to the start of the tidal study to identify wells to be evaluated during the tidal study. Pressure transducers were installed in identified tidal study wells to provide continuous water level data over several tidal cycles.

Water level fluctuations in wells can be used to determine tidal efficiency factors that define the degree of tidal influence exhibited in a well. Tidal efficiency is defined as the ratio of groundwater elevation fluctuation in a given well to the fluctuation in sea level elevation (Erskine, 1991). In the presence of homogeneous subsurface conditions, wells nearer a tidally-influenced surface water body will exhibit a tidal fluctuation closer to that observed in the water body and therefore, will have a higher tidal efficiency factor than those wells located farther away. Soil conditions beneath the Roeder Avenue site and adjacent properties consist of sandy, gravelly surface fill, wood waste and refuse underlain by sands, silts, and clay. Tidal efficiencies in wells at the site are controlled by both local soil conditions and distance from Bellingham Bay because of the heterogeneous nature of the subsurface. Therefore, observed tidal efficiencies in monitor wells may not always follow expected trends.

C.1 Preliminary Gauging

A preliminary gauging event was performed prior to the tidal study to identify wells for tidal study testing. Thirty-nine wells across the site, from a variety of depth intervals, were gauged for a 12-hour period on November 4, 1998. These wells are listed on Table C-1. The gauging period lasted one-half of a 24-hour tidal cycle that included a high-high and low-low tide. Water levels in the wells were gauged during this period at approximately 1-hour intervals. Water levels were measured to the nearest hundredth of a foot using a water level meter. Specific conductance, pH, dissolved oxygen, redox potential, and temperature measurements were also collected throughout the gauging period. These parameters were measured in the top, middle, and bottom of the screened section in each well.

Preliminary gauging results were analyzed for tidal influence through calculation of tidal efficiency over the 12-hour period of the preliminary study. Tidal efficiency is defined as the ratio of groundwater elevation fluctuation in a given well to the fluctuation in sea level elevation (Erskine, 1991).

Table C-1 Preliminary Tidal Study Wells

WELL	LOCATION
RMW-3D	Landfill, Transect A
RMW-2	Landfill, Transect A
RMW-2D	Landfill, Transect A
RGP-4W	Landfill, Transect A and B
RMW-7D	South of Landfill, Transect B
RMW-7	South of Landfill, Transect B
RMW-6D	South of Landfill, Transect B
MW-98-1(GW)	Landfill, Transect B
RGP-3(W)	Landfill, Transect B
MW-4(O)	North of Landfill, Transect C
RMW-10	North of Landfill, Transect C
RMW-9	Landfill, Transect C
RMW-8	Landfill, Transect C
RMW-13D	South of Landfill, Transect D
MW-3B	South of Landfill, Transect D
MW-8(B)	South of Landfill, Transect D
RMW-11D	South of Landfill, Transect D
RMW-11	South of Landfill, Transect D
RGP-1	Landfill, Transect D
RGP-2(W)	Landfill
RMW-4	Landfill
RMW-5	Landfill
RMW-16	Landfill
RMW-17	Landfill
RMW-15	North of Landfill
RMW-14	North of Landfill
MW-1(O)	North of Landfill
RMW-20	North of Landfill
MW-1(E)	North of Landfill
MW-3(O)	North of Landfill
MW-10(B)	South of Landfill
MW-12(B)	South of Landfill
MW-5(B)	South of Landfill
RMW-18	South of Landfill
RMW-12D	South of Landfill
MW-4(B)	South of Landfill
MW-7(B)	South of Landfill

Tidal efficiency during the preliminary study was calculated by comparing the maximum water level change in a given well over a 12-hour period to the change in water level in the bay calculated by a software program designed to simulate tidal fluctuations in Bellingham Bay. Tidal efficiencies calculated from the preliminary study are summarized in Table C-2.

A total of 21 wells displayed a tidal efficiency of at least 1 percent and 18 wells had a tidal efficiency of less than 1 percent. Well efficiency values as measured during the preliminary gauging vary from 0.1 to 33.3 percent. Data collected during the preliminary gauging, including hydrographs are provided at the end of this appendix.

Data in Table C-2 show that, in general, wells completed wholly or partially in the refuse had a lower tidal efficiency during the preliminary study than wells that do not screen any portion of the refuse. There are many possible explanations for this result, some of which are discussed in Erskine (1991). Three of the more likely possibilities are the high storage factor of the refuse relative to the Sand or Fill Units, the presence of a downward hydraulic gradient in the landfill proper due to the presence of a groundwater mound in the landfill, and the fact that all wells that screen or partially screen the refuse are screened across the water table. These three possibilities are described in the paragraphs below.

The high storage factor of the refuse means that a greater volume of water must be moved per unit change in pressure head to establish equilibrium with changes in pressure head within the refuse. Less water must be moved per unit change in pressure head in the sands and fill material. The less water movement, the quicker the increase in hydraulic head due to pressure changes. Therefore, the sands and fill respond to tidal caused pressure changes more efficiently (and quickly) than the refuse.

The presence of a downward hydraulic gradient within the landfill also causes a decrease in the tidal efficiency of wells screened partially or entirely in the refuse. Increases in hydraulic head in the refuse due to the influence of tides must be caused by the movement of water from the sands or fill beneath the refuse into the refuse because most of the refuse is above mean sea level and even the mean high tide level. However, the presence of a downward gradient, and hence the downward flow of water tends to neutralize or dampen the upward movement of water due to tidal effects. The damping effect increases from the bottom of the refuse to the level of the water table in the refuse.

The effects on tidal efficiency of screens installed across the water table are described by Erskine (1991). The effects are mostly due to the fact that water

Table C-2 Preliminary Tidal Study Tidal Efficiencies

WELL	LOCATION	APPROXIMATE DISTANCE FROM BAY (feet)	GEOLOGIC UNIT OF SCREEN INTERVAL	SCREENED ACROSS WATER TABLE?	TIDAL EFFICIENCY (percent)
RMW-3D	Landfill, Transect A	80	sand	no	9.0
RMW-2	Landfill, Transect A	220	refuse	yes	0.5
RMW-2D	Landfill, Transect A	230	sand	no	1.1
RGP-4W	Landfill, Transect A and B	670	refuse	yes	0.6
RMW-7D	South of Landfill, Transect B	50	sand	no	33.1
RMW-7	South of Landfill, Transect B	50	fill and sand	yes	14.4
RMW-6D	South of Landfill, Transect B	190	sand	no	28.5
MW-98-1(GW)	Landfill, Transect B	460	refuse	yes	0.7
RGP-3(W)	Landfill, Transect B	580	refuse	yes	0.9
MW-4(O)	North of Landfill, Transect C	30	sand and fill	yes	15.6
RMW-10	North of Landfill, Transect C	270	sand and fill	yes	1.5
RMW-9	Landfill, Transect C	500	refuse and sand	yes	0.4
RMW-8	Landfill, Transect C	780	refuse	yes	1.0
RMW-13D	South of Landfill, Transect D	40	sand (gravel)	no	33.4
MW-3B	South of Landfill, Transect D	40	fill and sand	yes	5.9
MW-8(B)	South of Landfill, Transect D	500	fill and sand	yes	0.9
RMW-11D	South of Landfill, Transect D	520	sand and clay	no	1.2
RMW-11	South of Landfill, Transect D	520	fill and sand	yes	0.5
RGP-1	Landfill, Transect D	770	refuse	yes	0.7
RGP-2(W)	Landfill	700	refuse	yes	2.1
RMW-4	Landfill	320	refuse	yes	0.3
RMW-5	Landfill	500	refuse	yes	0.7
RMW-16	Landfill	850	refuse and sand	yes	0.8
RMW-17	Landfill	840	refuse	yes	0.6
RMW-15	North of Landfill	370	fill and sand	yes	1.0
RMW-14	North of Landfill	550	fill and sand	yes	0.7
MW-1(O)	North of Landfill	220	fill and sand	yes	0.6
RMW-20	North of Landfill	90	fill and sand	yes	0.1
MW-1(E)	North of Landfill	340	fill and sand	yes	4.2
MW-3(O)	North of Landfill	100	sand	yes	1.4
MW-10(B)	South of Landfill	370	fill and sand	yes	5.6
MW-12(B)	South of Landfill	630	fill and sand	yes	2.3
MW-5(B)	South of Landfill	580	fill and sand	yes	2.2
RMW-18	South of Landfill	260	fill and sand	yes	0.8
RMW-12D	South of Landfill	320	sand	no	0.8
MW-4(B)	South of Landfill	300	fill/sand	yes	0.7
MW-7(B)	South of Landfill	550	fill and sand	yes	1.4

table conditions do not fully satisfy the theoretical assumptions of the equations describing the effects of tidal caused pressure waves in confined aquifers. Storage factor considerations described above are also a factor in dampening the effects of tidal fluctuations in wells screened across the water table.

In general, wells closer to the bay had a greater preliminary tidal efficiency than wells further from the bay. For example, eight out of nine wells within 200 feet of the bay had preliminary tidal efficiencies greater than 1 percent. Four out of nine wells between 200 and 400 feet from the bay had preliminary tidal efficiencies greater than 1 percent.

Wells with greater than 1 percent preliminary tidal efficiency were identified for potential tidal study testing in accordance with the Work Plan. One percent efficiency was used as a general criteria to eliminate wells from the tidal study to reduce the effects of measurement error, barometric pressure changes, and random fluctuations of water levels on tidal efficiency calculations. However, a small number of wells with tidal efficiencies between 1 and 2 percent were eliminated from the tidal study because they are located further from the bay than other wells having tidal efficiencies of less than 1 percent. Twenty-three wells were selected for tidal study monitoring based on results of the preliminary gauging, as discussed in the paragraphs below.

C.2 Tidal Study Setup and Operation

Two rounds of tidal studies were completed at the site in November 1998, described in this memo as Round 1 and Round 2. Round 1 was conducted over a 6-day period from November 11 to 16, 1998. Wells monitored during Round 1 had a greater than 1 percent tidal efficiency as determined during the preliminary gauging results and were located along the transects described in Section 2 of the Progress Memo. A total of 13 wells were monitored during Round 1, eight shallow and five deep. The Round 2 tidal study was completed over 4 days from November 17 to 20, 1998. Wells monitored during Round 2 were not included in the preliminary gauging, but were evaluated to provide tidal efficiency data in areas outside the transects. A total of 10 wells were monitored during Round 2. Table C-3 lists the wells monitored during both rounds.

Groundwater elevation measurements were collected concurrently from all monitoring wells at 10-minute intervals using a pressure transducer. One tidal gauging station was also established in the Whatcom Waterway to monitor water levels in Bellingham Bay over the course of the measurement period. The location of the tidal gauging station is shown on Figure 2-1 of the Progress Memo.

Table C-3 Tidal Study Wells

WELL	LOCATION	ROUND	DEPTH	SCREEN INTERVAL
Shallow				
RMW-2	Landfill, Transect A	1	22	7-22
MW-3B	South of Landfill, Transect D	1	14	4-14
MW-4(O)	North of Landfill, Transect C	1	21	8-18
MW-3(O)	North of Landfill	1	20	8-18
MW-1(E)	North of Landfill	1	17	8-16
RMW-10	North of Landfill, Transect C	1	19	4-19
RMW-7	South of Landfill, Transect B	1	19	4-19
MW-55(C)	South of Landfill, Transect B	1	14	4-14
MW-1(B)	South of Landfill	2	14	4-14
MW-10(B)	South of Landfill	2	14	4-14
MW-12(B)	South of Landfill	2	16.5	3-13
MW-12A(C)	South of Landfill	2	14	Unknown
MW-7A(C)	South of Landfill	2	Unknown	Unknown
MW-11A(C)	South of Landfill	2	Unknown	Unknown
MW-50(C)	South of Landfill	2	14	4-14
MW-53(C)	South of Landfill	2	14	4-14
MW-60(C)	South of Landfill	2	14	4-14
MW-10A(C)	South of Landfill	2	Unknown	Unknown
Deep				
RMW-2D	Landfill, Transect A	1	39	29-39
RMW-3D	Landfill, Transect A	1	35	25-35
RMW-6D	South of Landfill, Transect B	1	39	29-39
RMW-7D	South of Landfill, Transect B	1	40	30-40
RMW-13D	South of Landfill, Transect D	1	29	18-28

Salinity Monitoring

Prior to installation of the transducers, salinity measurements were collected from the top of the water column in each well using a field meter. A salinity measurement was also collected from the stilling gauge. The purpose of the salinity monitoring was to obtain water density data for calibration of the transducers during the tidal study.

Water Level Measurement

Thirteen monitor wells were gauged using pressure transducers during the Round 1 tidal study. These pressure transducers have a 5-pounds-per-square-inch (psi) range capable of measuring water levels up to 11 feet above the transducer and have an accuracy of ±0.01 feet. For the stilling gauge, a 15-pounds-per-square-inch pressure transducer with an accuracy of ±0.01 feet was used. Ten monitor wells were gauged with pressure transducers during the Round 2 tidal study. All of the transducers were connected to either single- or multi-channel data loggers. Data loggers were programmed to collect readings at 10-minute intervals from each transducer, and were synchronized to ensure that readings were taken at the same time in each well.

At each location, the pressure transducer was lowered into the well and securely fastened to a stable surface structure for the duration of the monitoring period. The depth to water was measured using an electronic water level indicator from a surveyed reference point at the top of the well riser pipe. The pressure transducers were calibrated to this initial water level measurement. At the end of the data collection period, transducers and data loggers were removed and water level data were transferred to computer disk.

The pressure transducers, cables, and water level meter were decontaminated before and after use in each well. The water level data were converted to the USC&GS MLLW datum prior to analysis.

C.3 Analysis of Tidal Effects

The tidal lag and efficiency of selected wells were analyzed during both rounds of the tidal study. The tidal study was conducted to determine the influence of tidal fluctuations on groundwater flow patterns and water chemistry at the site. Results of the tidal study show that water levels in wells further from the bay (generally >400 feet), especially wells in the refuse show little to no effects from tidal fluctuations. A more detailed discussion of tidal study results is provided in the following paragraphs.

Tidal lag and efficiency were calculated using data from transducers that recorded measurements every 10 minutes during both rounds of the tidal study. Transducer measurements are provided at the end of this appendix. Hydrographs created from reduced transducer data are provided at the end of this appendix. Each hydrograph includes the hydrograph of Bellingham Bay created from data collected from a stilling well installed on a dock adjacent to the bay. The Bellingham Bay hydrograph is provided on each hydrograph for comparison to the monitoring wells.

The maximum tidal fluctuation observed in Bellingham Bay during the first round was 7.98 feet. The maximum tidal fluctuation observed in Bellingham Bay during the second round was 8.90 feet. These values were based on the difference between the high-high and low-low tide water elevations.

Tidal efficiencies for wells at the site are summarized in Figure 4-2 and Table 4-1 of the progress memo. The highest tidal efficiencies were observed along the eastern shoreline in deep wells RMW-7D (43.75 percent) and RMW-13D (41.27 percent), which are located within 90 feet of the shoreline. Inland from the eastern shoreline by 140 feet, a tidal efficiency of approximately 20 percent was observed in well RMW-6D. A tidal efficiency of 20 percent was observed in deep well RMW-3D, located within 90 feet of the western shoreline. No tidal response was observed in deep well RMW-2D, located 150 feet upgradient of well RMW-3D.

In shallow wells, observed tidal efficiencies ranged from 1 percent in well MW-12A(C) to 32.2 percent in well MW-1(B), which is located 30 feet from the eastern shoreline. The highest tidal responses were observed in shallow wells located within 100 feet of the shoreline. No tidal response was observed in shallow wells MW-55(C), RMW-2, RMW-10, MW-1(E), MW-11A(C), MW-10(B), and MW-12(B).

Tidal lag is the difference in time between peak water levels in Bellingham Bay and monitoring wells. Tidal lag can be applied to peak high and peak low water levels. Lag times ranged from 30 minutes to 2.5 hours at both high and low tides (Table 4-1). In the majority of cases, the average lag times observed at high and low tides were equivalent. The shortest lag times (30 minutes) were observed in shallow or deep wells that exhibited the highest tidal efficiencies (i.e., wells RMW-7, RMW-13D, and MW-4(O)).

C.4 Determination of Hydraulic Conductivity Values

Hydraulic conductivity values are estimated using tidal study data and the time lag method of Brown (1963). This method uses an empirical relationship between time lag and distance to the shoreline to estimate hydraulic conductivity by the following equation:

$$K = \left[\frac{x^2 \times S \times t_0}{4\pi \times t_1^2 x\, b}\right]$$

Equation 1 Tidal Lag Method

where:

- x = distance from the well to the shoreline (feet)
- S = specific yield (unitless)
- t_o = tidal period (12 hours)
- t_1 = tidal lag (hours)
- b = saturated aquifer thickness (feet)

Data are multiplied by a factor of 0.008467 to convert from units of ft/hr to cm/s.

Hydraulic conductivity estimates were performed for both shallow and deep wells. A discussion of factors used to evaluate hydraulic conductivity via the time-lag method is provided below.

Distance from Well to Shoreline

The distance from the well to the shoreline used in Equation 1 was the distance in the direction of groundwater flow. These distances were determined using the groundwater flow contours provided in Figures 4-1 of the Progress Memo for shallow and deep wells, respectively. for this purpose, the shoreline was estimated assuming a vertical plane at the shoreline defined by the mean water level in the bay.

Storage Coefficient

A range of storage coefficients based on lithology observed during well installation, were used to estimate hydraulic conductivity. The use of specific yield for a storage coefficient in unconfined aquifers is reasonable for soils that gain or release water from storage rapidly in response to tidal changes. However, at the landfill site soils do not gain or release water from storage rapidly enough to reach equilibrium before the next tidal fluctuation occurs. Therefore, only a percentage of the theoretical volume of water in storage is gained or released per tidal cycle. To account for the delayed storage response, a storage coefficient of

50 percent of the literature specific yield values was used to calculate hydraulic conductivity values.

Tidal Lag

Only wells that exhibiting a clear tidal response pattern (i.e., a lag time of 1 hour or less and readily-discernable lag periods), were used to estimate hydraulic conductivity. A clear tidal response pattern was exhibited in shallow wells MW-3(B), MW-4(O), and MW-60(C), and in deep wells RMW-3D, RMW-7D, and RMW-13D.

Saturated Thickness

Saturated thickness is incorporated into Equation 3-1 to convert the results of the time lag method from transmissivity (ft^2/s) to hydraulic conductivity (ft/s). Because the sand layer in the area tested is not overly thick (40 feet or less), inward flow from the shoreline can be assumed to occur along the full saturated thickness. The saturated thickness was estimated as the difference between the elevation of the base of the sand layer and the 25-hour mean water level in the well.

A summary of estimated hydraulic conductivity values is provided in Table C-4. In shallow wells, conductivity values ranged from 1.7×10^{-1} (MW-4(O)) to 7.3×10^{-2} cm/s (MW-3(B)) using one-half the lower specified yield value from the literature. These values are one to two orders of magnitude greater than values estimated by slug testing. Hydraulic conductivity values of 6.6×10^{-2} cm/s (RMW-7D) and 2.0×10^{-1} cm/s (RMW-13D) were calculated in deep wells. These values are one order of magnitude larger than values estimated using slug test methodology.

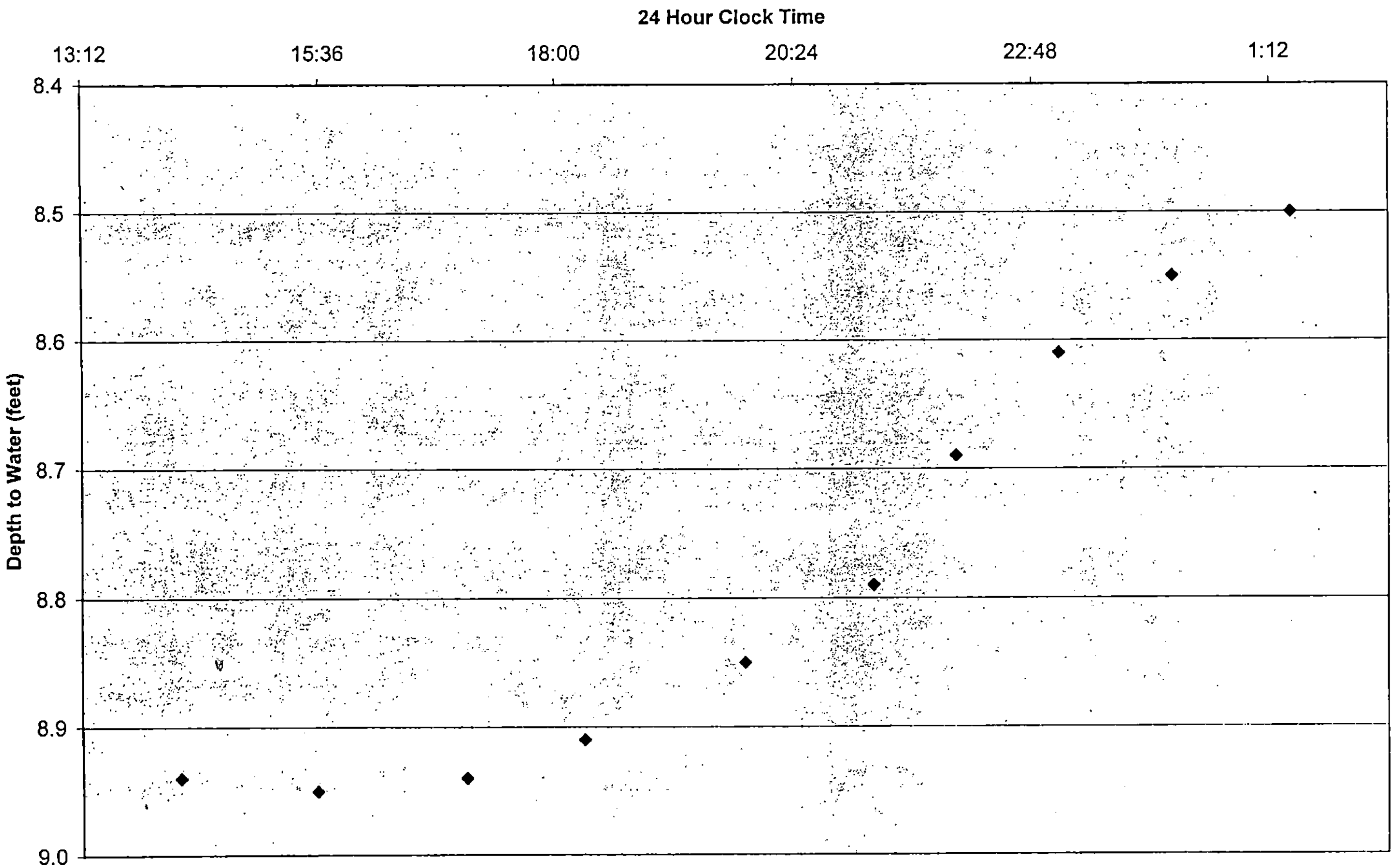
The time- lag method for estimating hydraulic conductivity is sensitive to the specific yield value selected. Because it is not practical to measure specific yield during field testing, estimates from literature must be used. As discussed above, in poorly draining soils only a small fraction of the specific yield may be reached in the aquifer before the tide reverses. Since there is no way of measuring the portion of the specific yield that is reached, the estimates provided by the tidal lag method are assumed to be approximate, and may tend to error on the high side of a conductivity estimate.

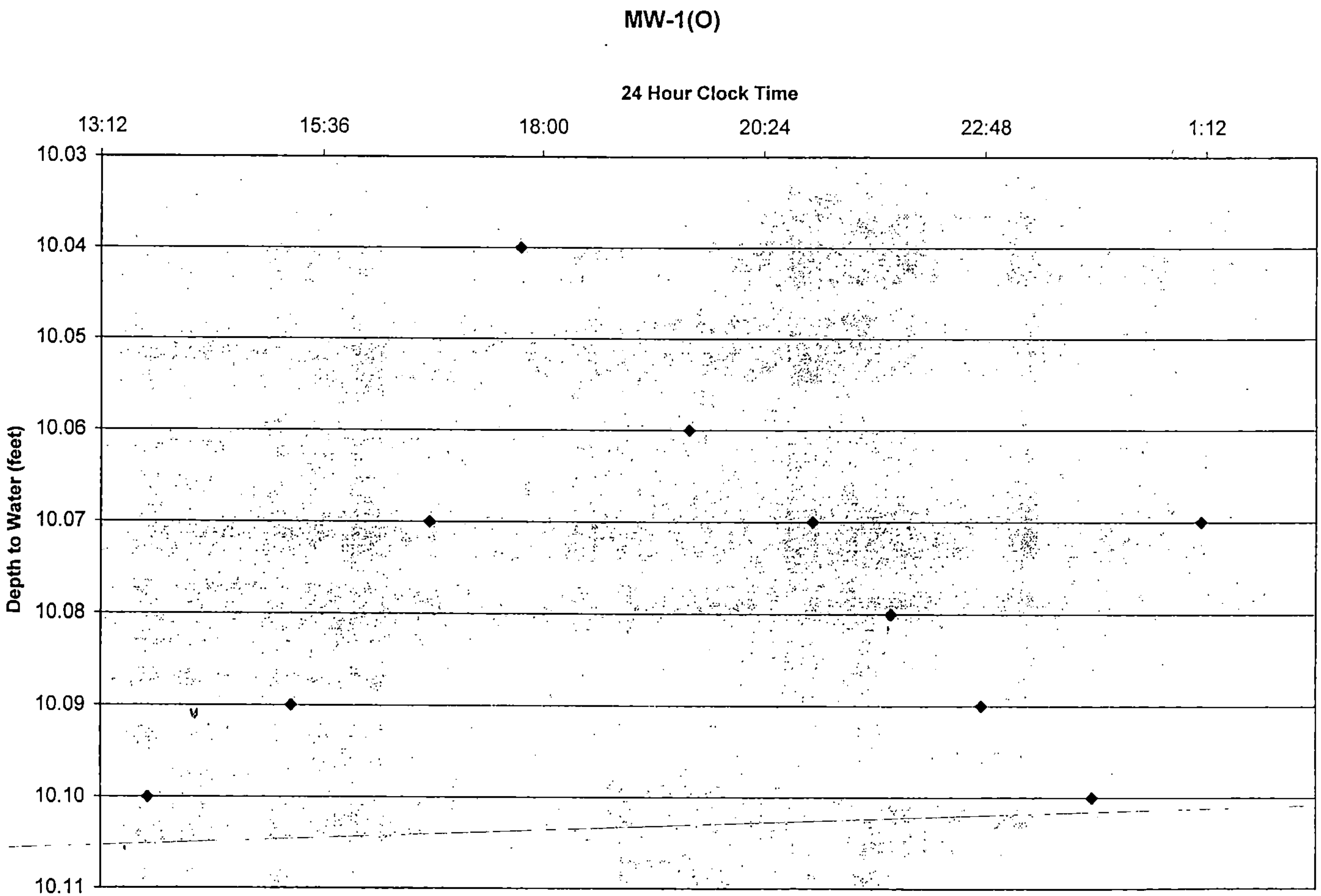
Table C-4 Hydraulic Conductivities From Tidal Study

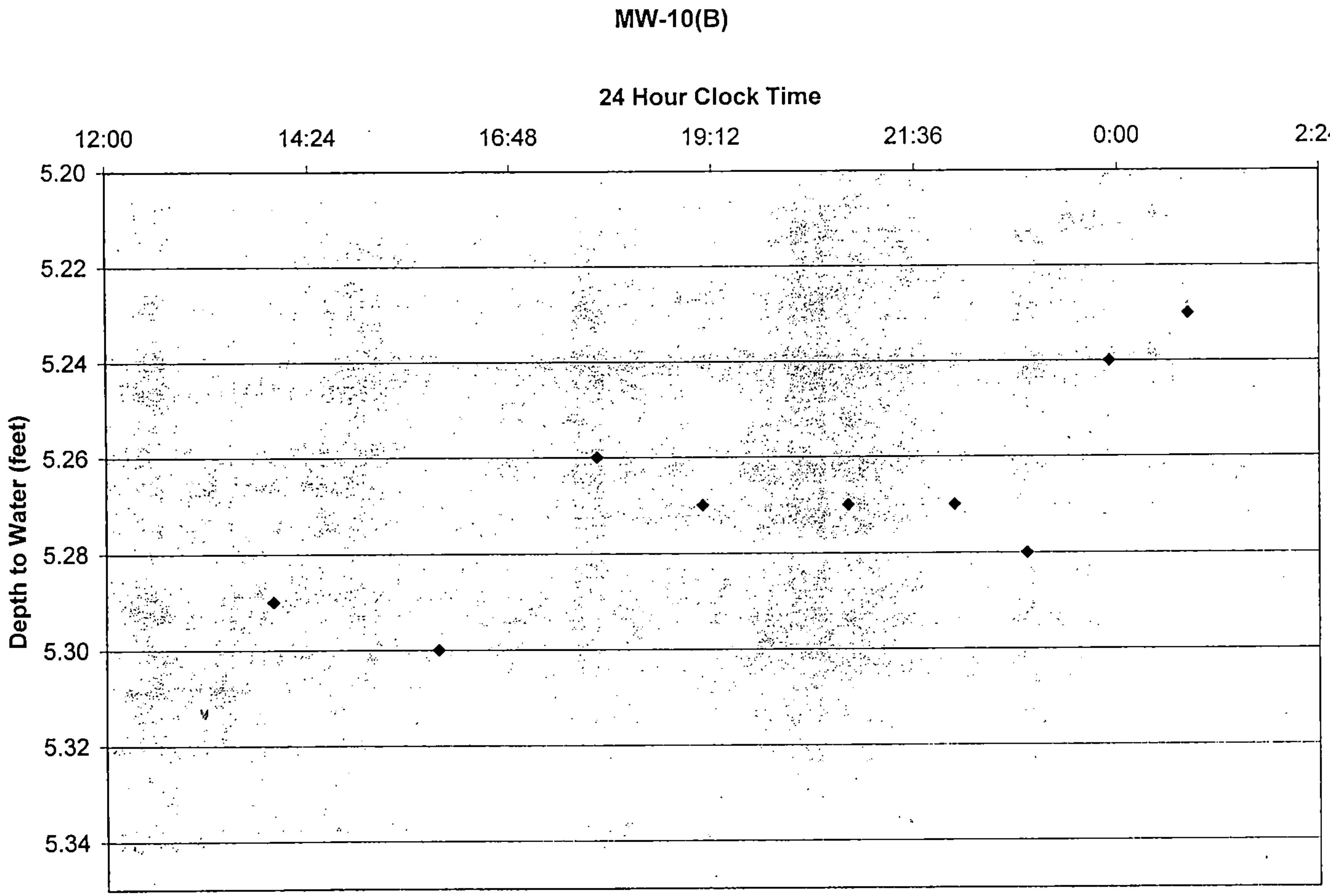
Well	Hydraulic Conductivity (cm/sec) Tidal Lag Method
Shallow	
MW-3(B)	$7.3x10^{-3}$
MW-4(O)	$1.7x10^{-1}$
MW-60(C)	$5.2x10^{-1}$
Deep	
RMW-7D	$6.6x10^{-2}$
RMW-13D	$2.0x10^{-1}$

Hydrographs

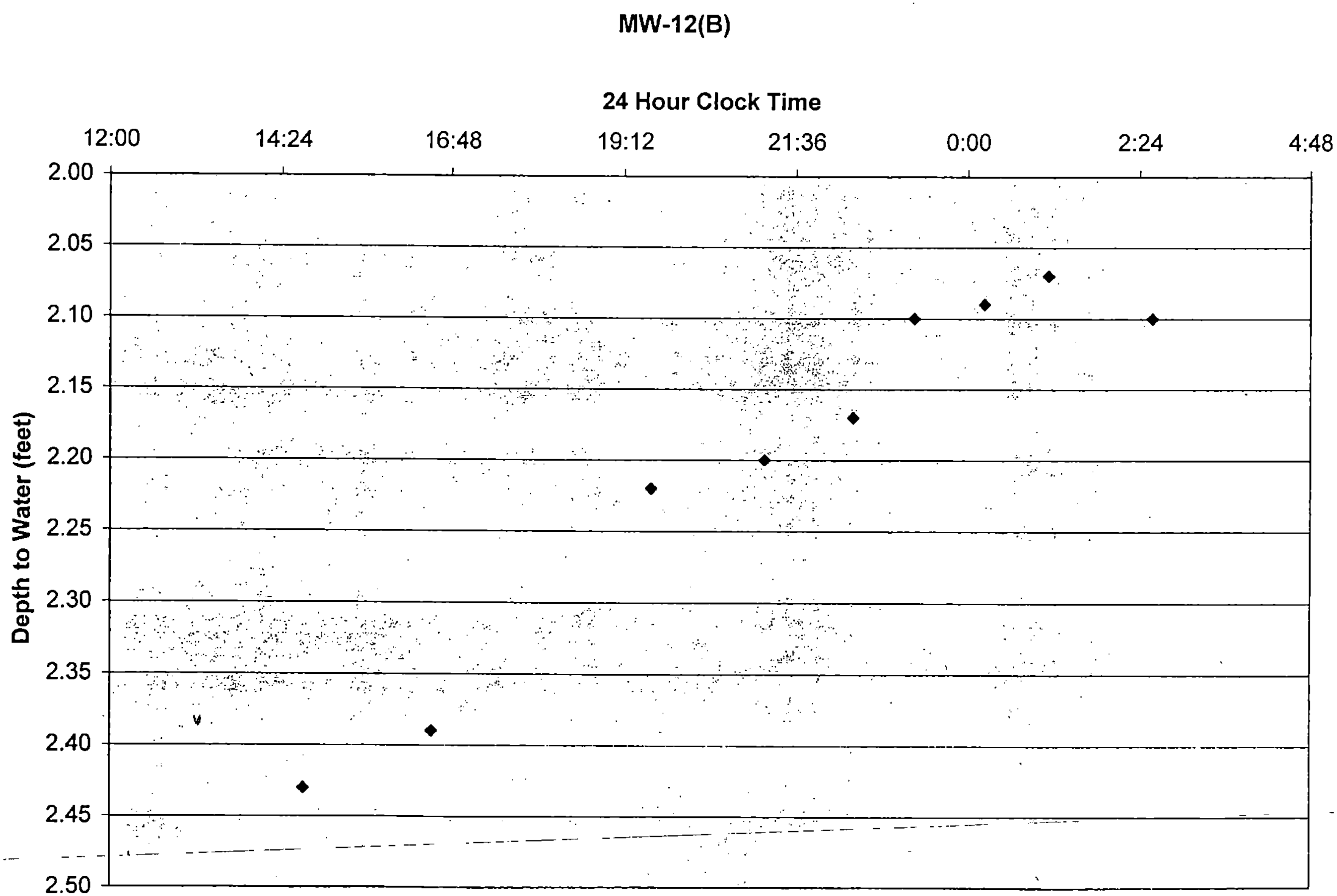
MW-1(E)

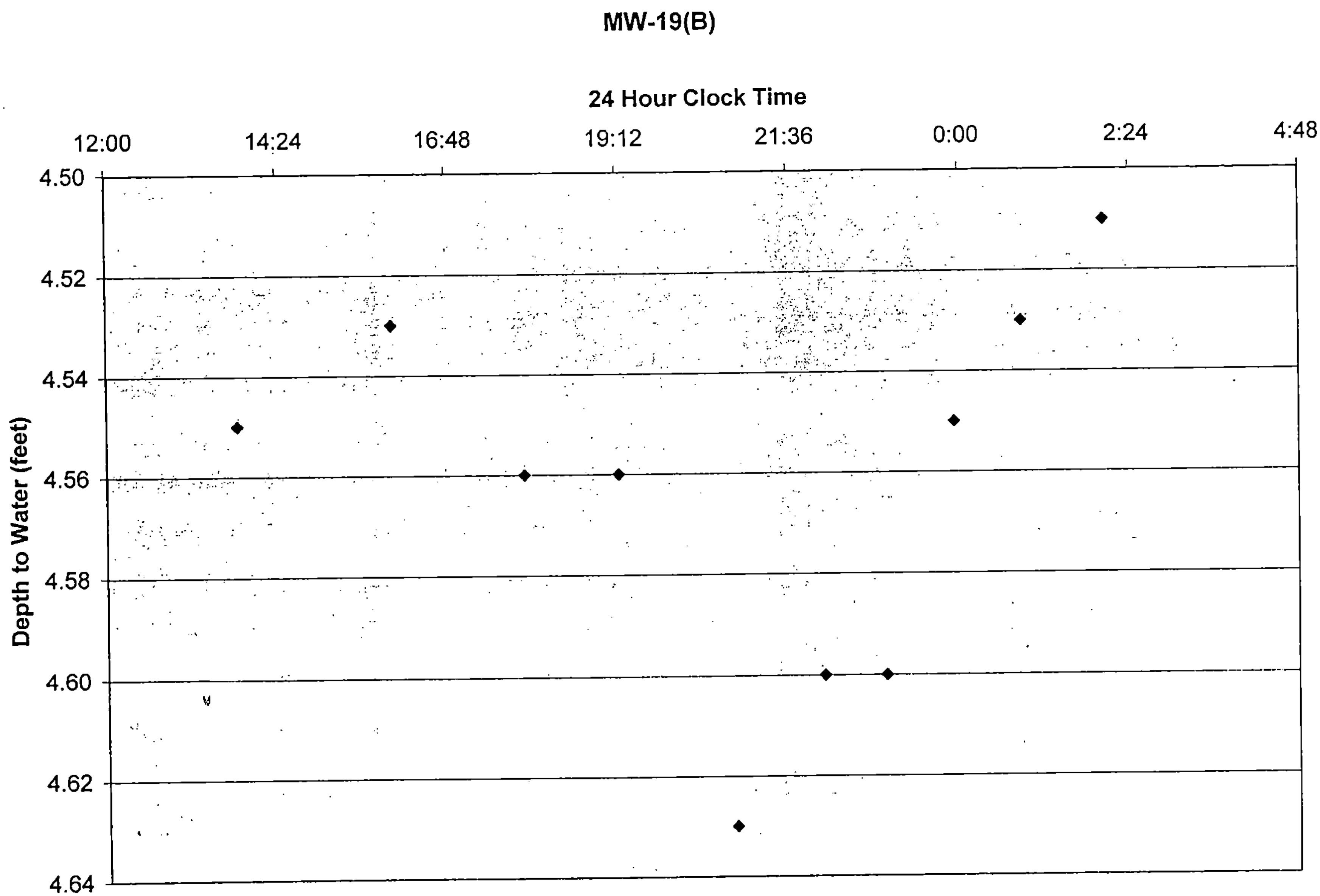

24 Hour Clock Time
13:12
15:36
18:00
20:24
22:48
1:12
Depth to Water (feet)
8.4
8.5
8.6
8.7
8.8
8.9
9.0


MW-1(O)
24 Hour Clock Time
13:12
15:36
18:00
20:24
22:48
1:12
10.03
10.04
10.05
10.06
10.07
10.08
10.09
10.10
10.11
Depth to Water (feet)

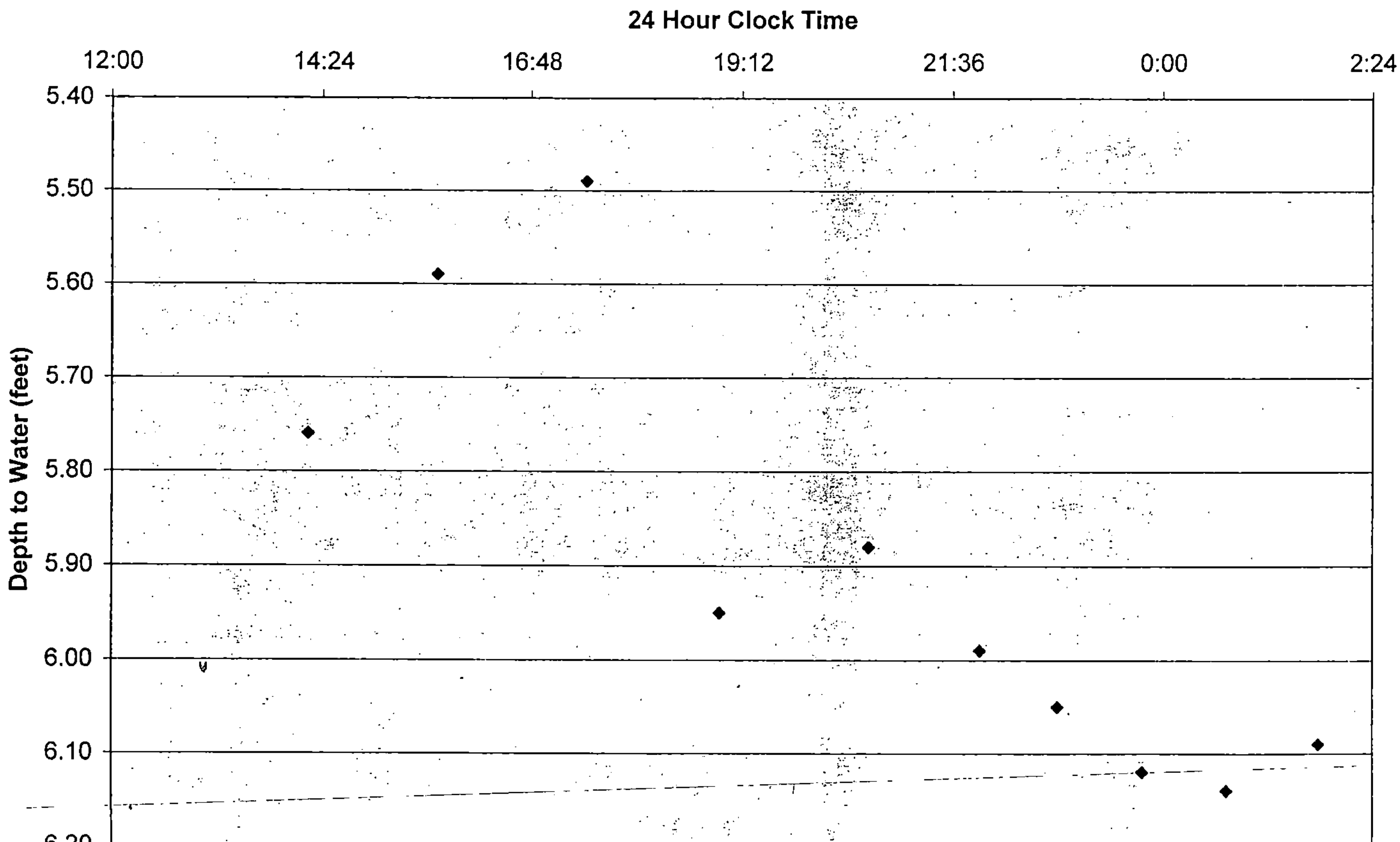


MW-10(B)
24 Hour Clock Time
12:00
14:24
16:48
19:12
21:36
0:00
2:24
Depth to Water (feet)
5.20
5.22
5.24
5.26
5.28
5.30
5.32
5.34

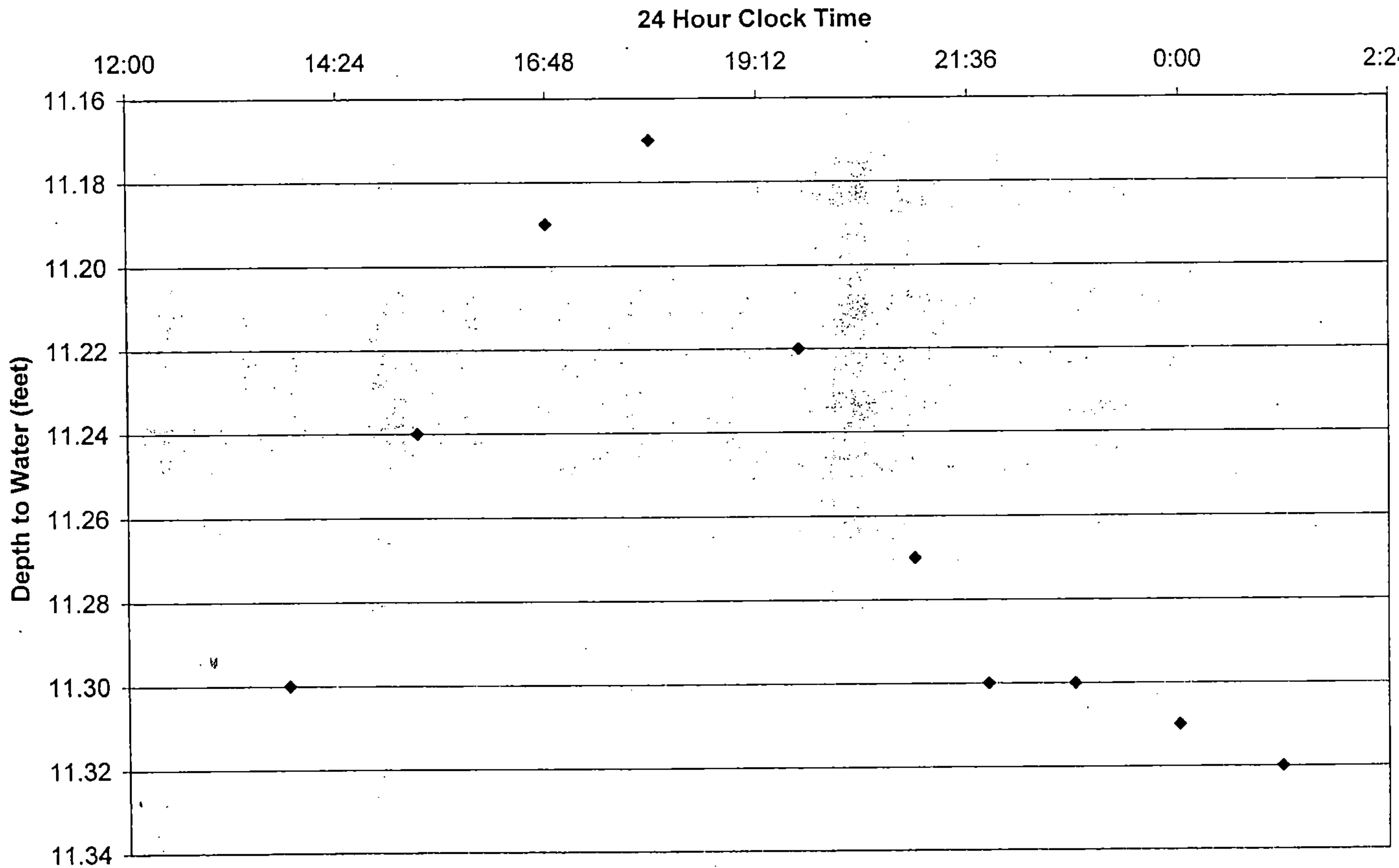

MW-12(B)
24 Hour Clock Time
12:00
14:24
16:48
19:12
21:36
0:00
2:24
4:48
Depth to Water (feet)
2.00
2.05
2.10
2.15
2.20
2.25
2.30
2.35
2.40
2.45
2.50


MW-19(B)
24 Hour Clock Time
12:00
14:24
16:48
19:12
21:36
0:00
2:24
4:48
4.50
4.52
4.54
4.56
4.58
4.60
4.62
4.64
Depth to Water (feet)

MW-3(B)

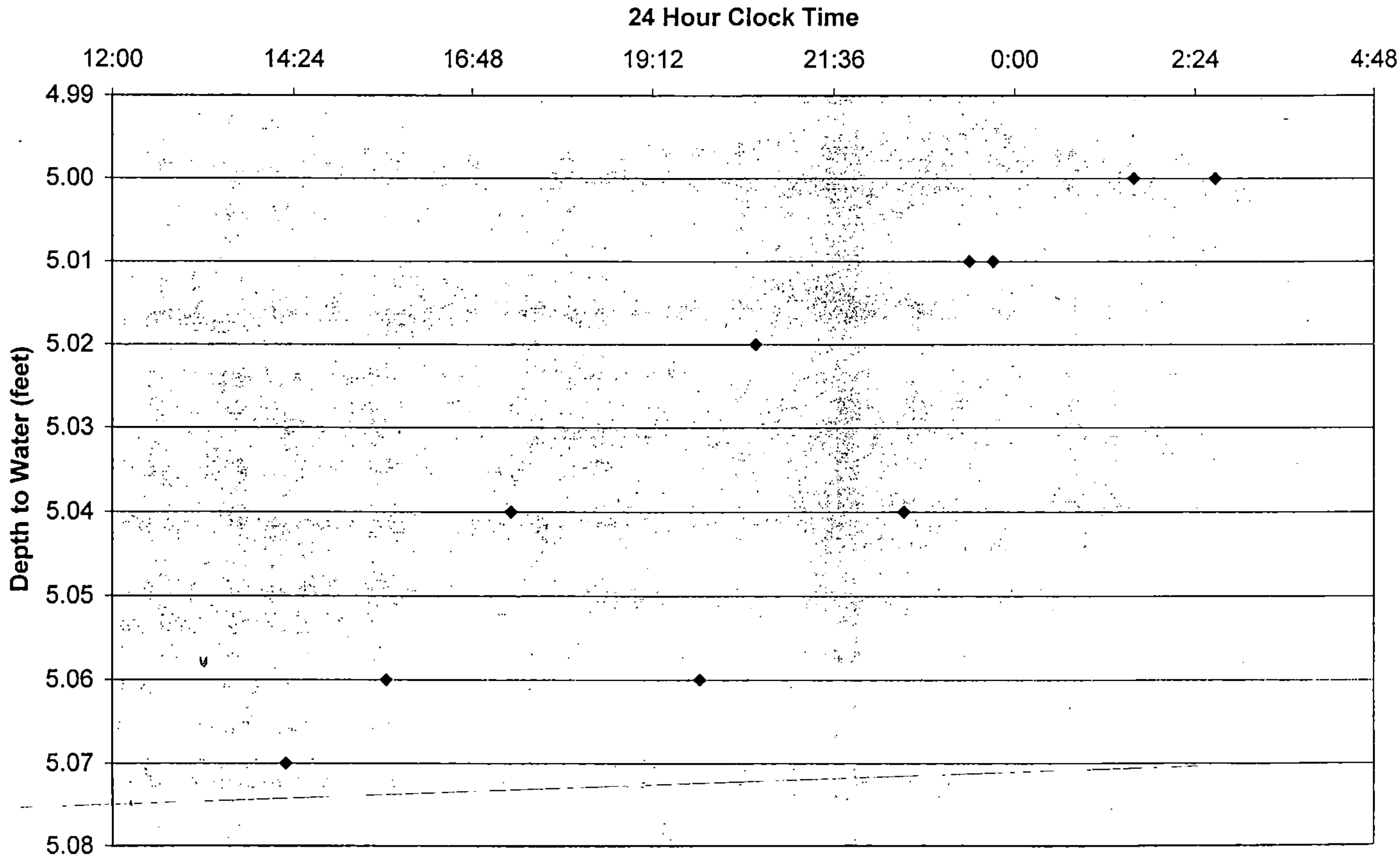

24 Hour Clock Time
12:00
14:24
16:48
19:12
21:36
0:00
2:24
Depth to Water (feet)
5.40
5.50
5.60
5.70
5.80
5.90
6.00
6.10
6.20

MW-3(O)

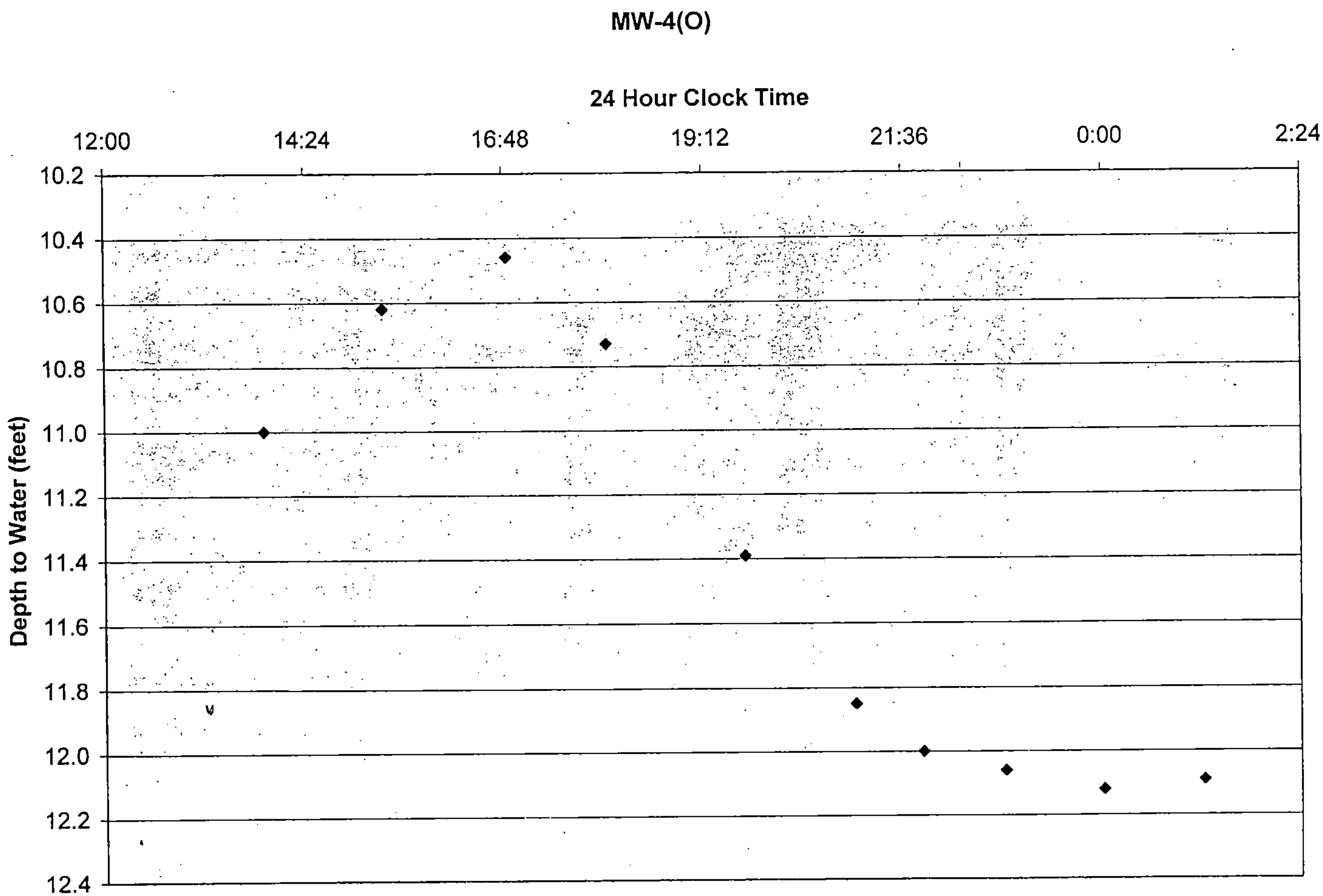


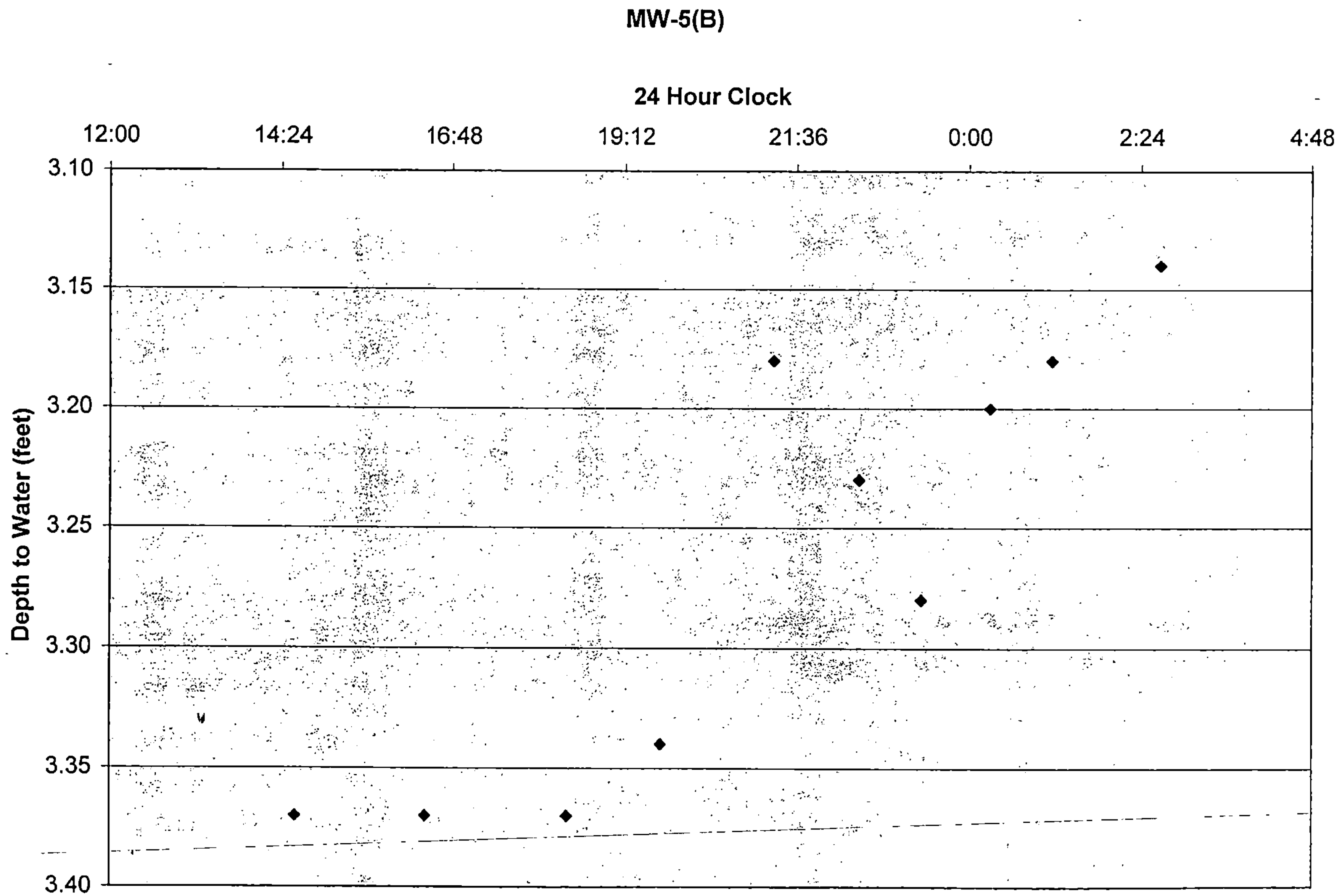
24 Hour Clock Time
12:00
14:24
16:48
19:12
21:36
0:00
2:24
Depth to Water (feet)
11.16
11.18
11.20
11.22
11.24
11.26
11.28
11.30
11.32
11.34

MW-4(B)

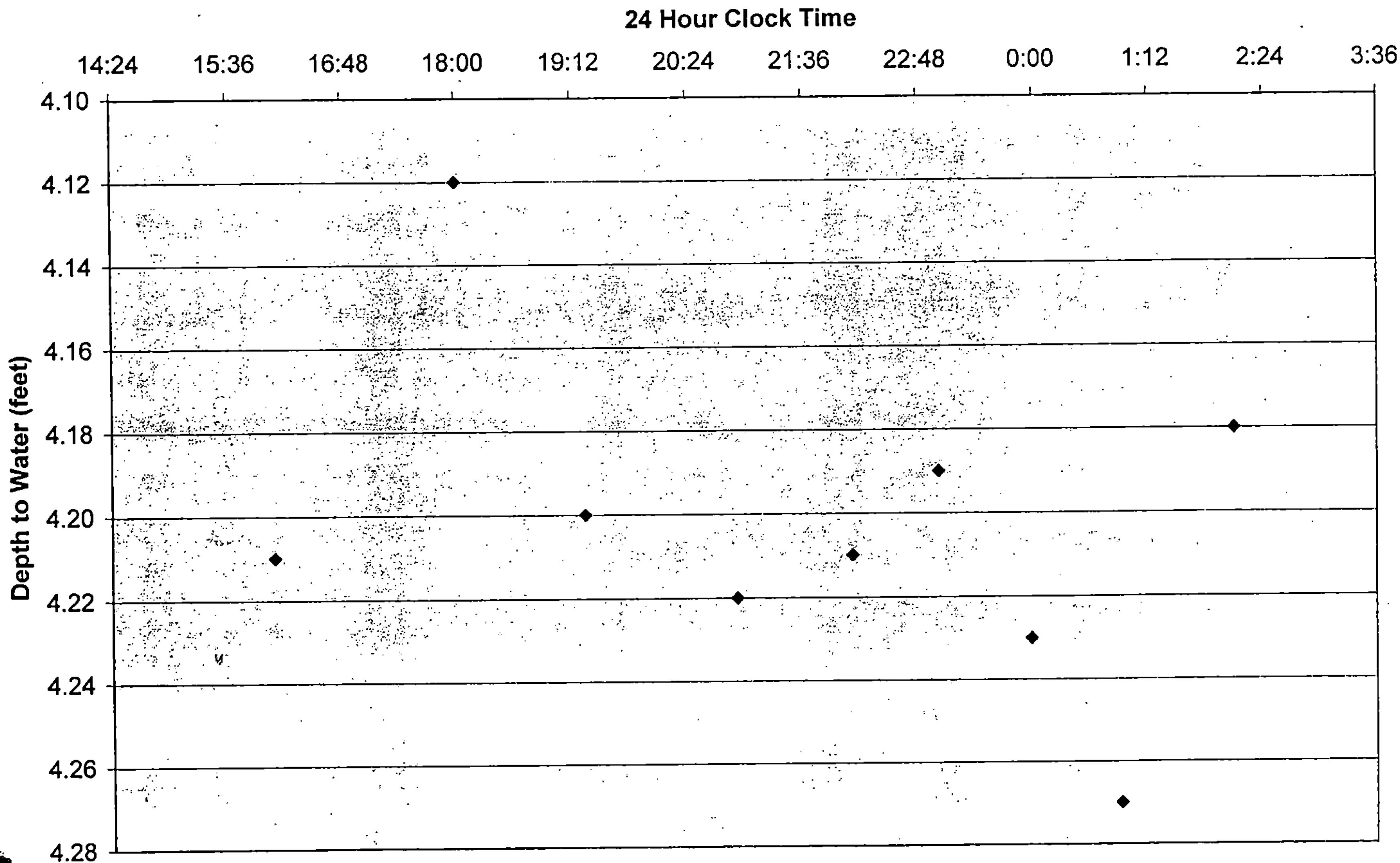


24 Hour Clock Time
12:00
14:24
16:48
19:12
21:36
0:00
2:24
4:48
Depth to Water (feet)
4.99
5.00
5.01
5.02
5.03
5.04
5.05
5.06
5.07
5.08

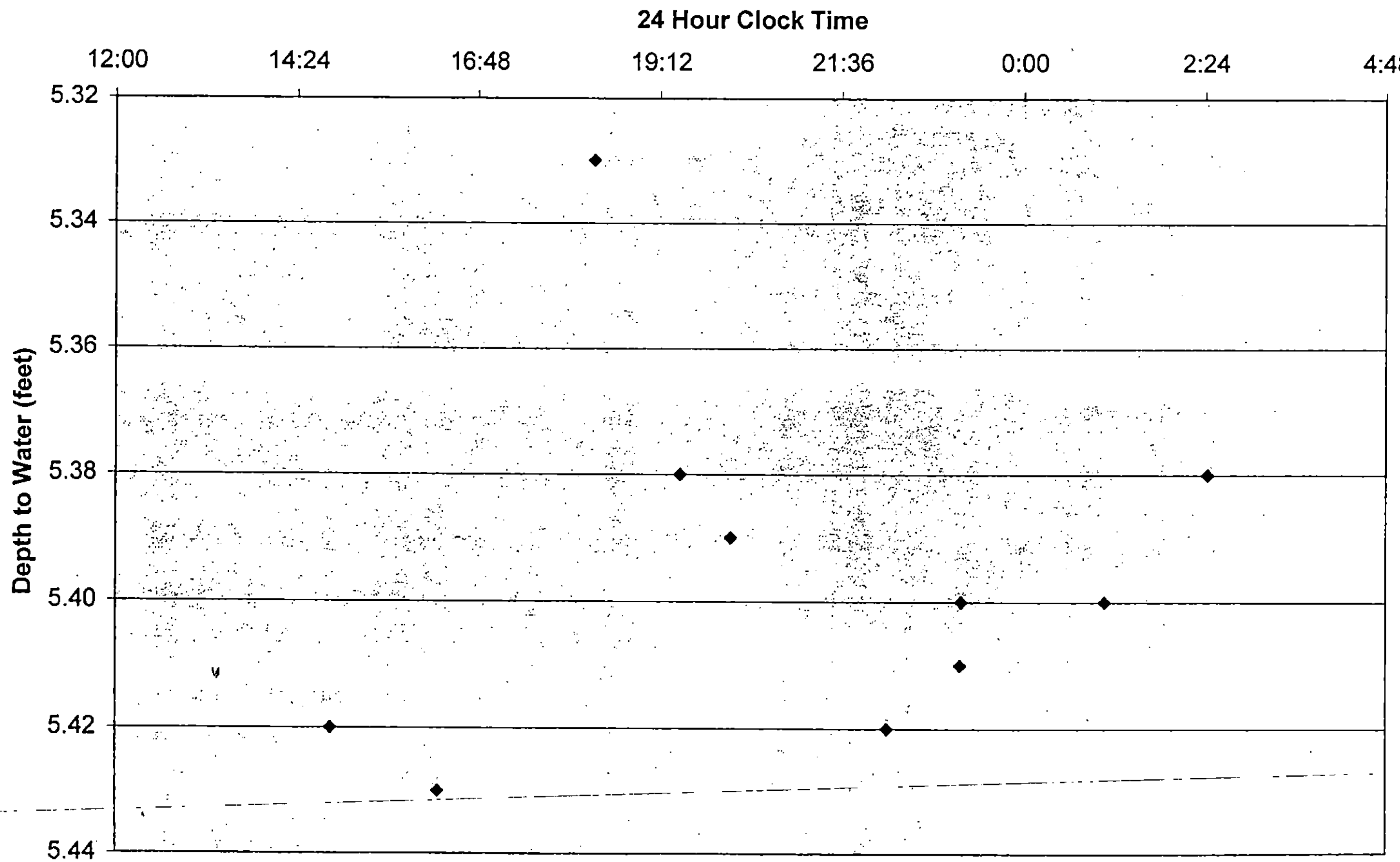

MW-4(O)
24 Hour Clock Time
12:00
14:24
16:48
19:12
21:36
0:00
2:24
Depth to Water (feet)
10.2
10.4
10.6
10.8
11.0
11.2
11.4
11.6
11.8
12.0
12.2
12.4


MW-5(B)
24 Hour Clock
12:00
14:24
16:48
19:12
21:36
0:00
2:24
4:48
Depth to Water (feet)
3.10
3.15
3.20
3.25
3.30
3.35
3.40

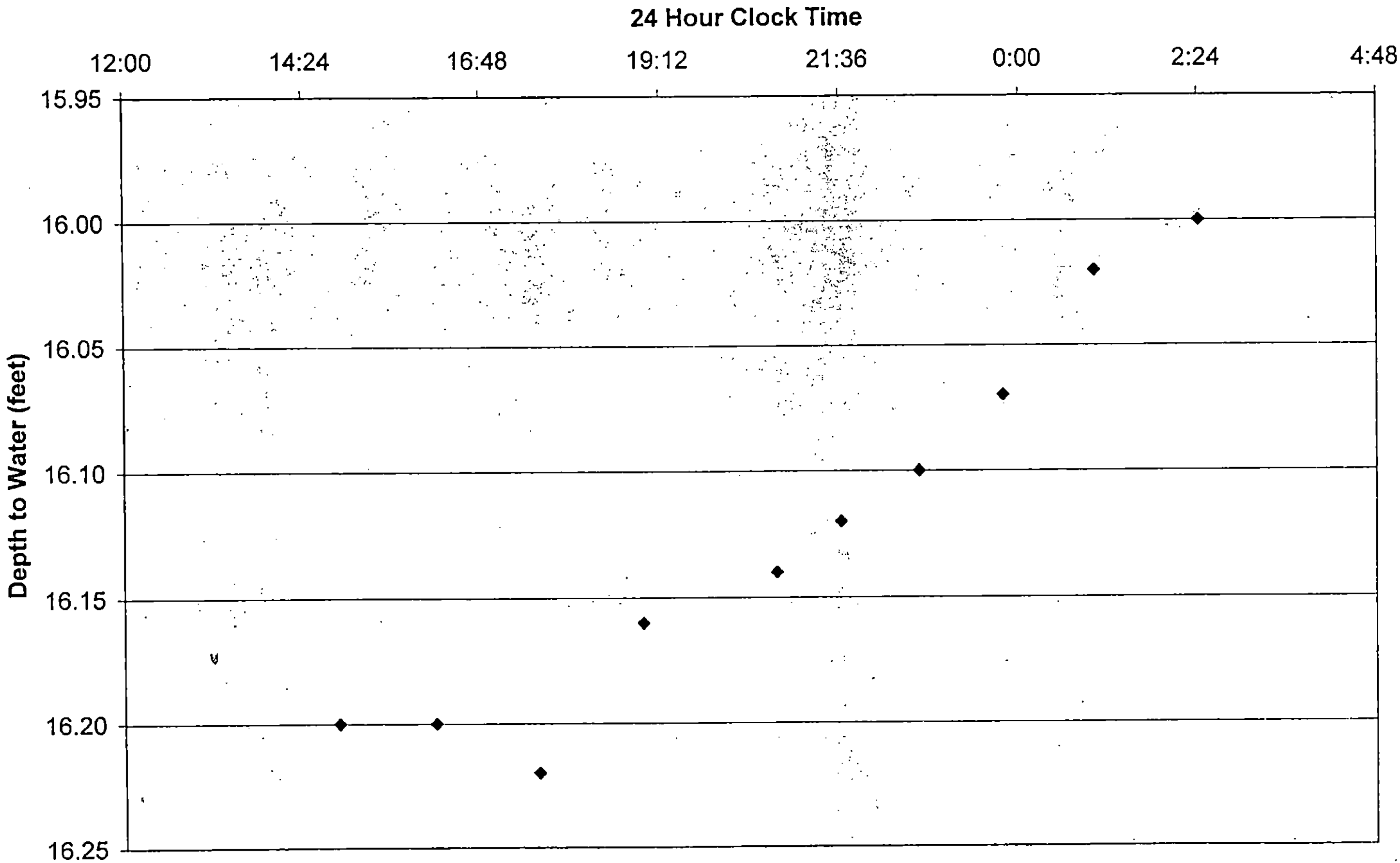
MW-7(B)

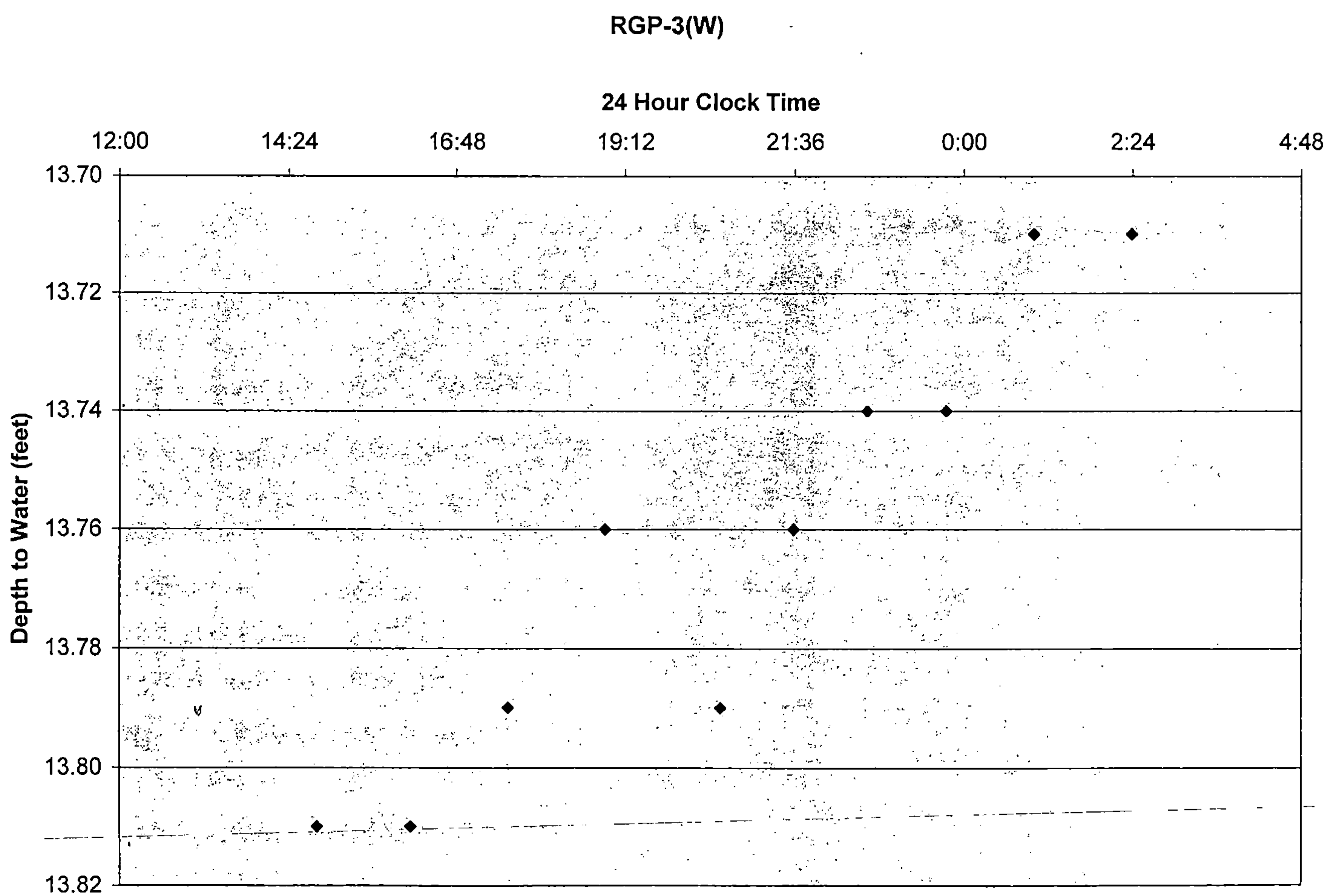

24 Hour Clock Time
14:24
15:36
16:48
18:00
19:12
20:24
21:36
22:48
0:00
1:12
2:24
3:36
Depth to Water (feet)
4.10
4.12
4.14
4.16
4.18
4.20
4.22
4.24
4.26
4.28

MW-8(B)

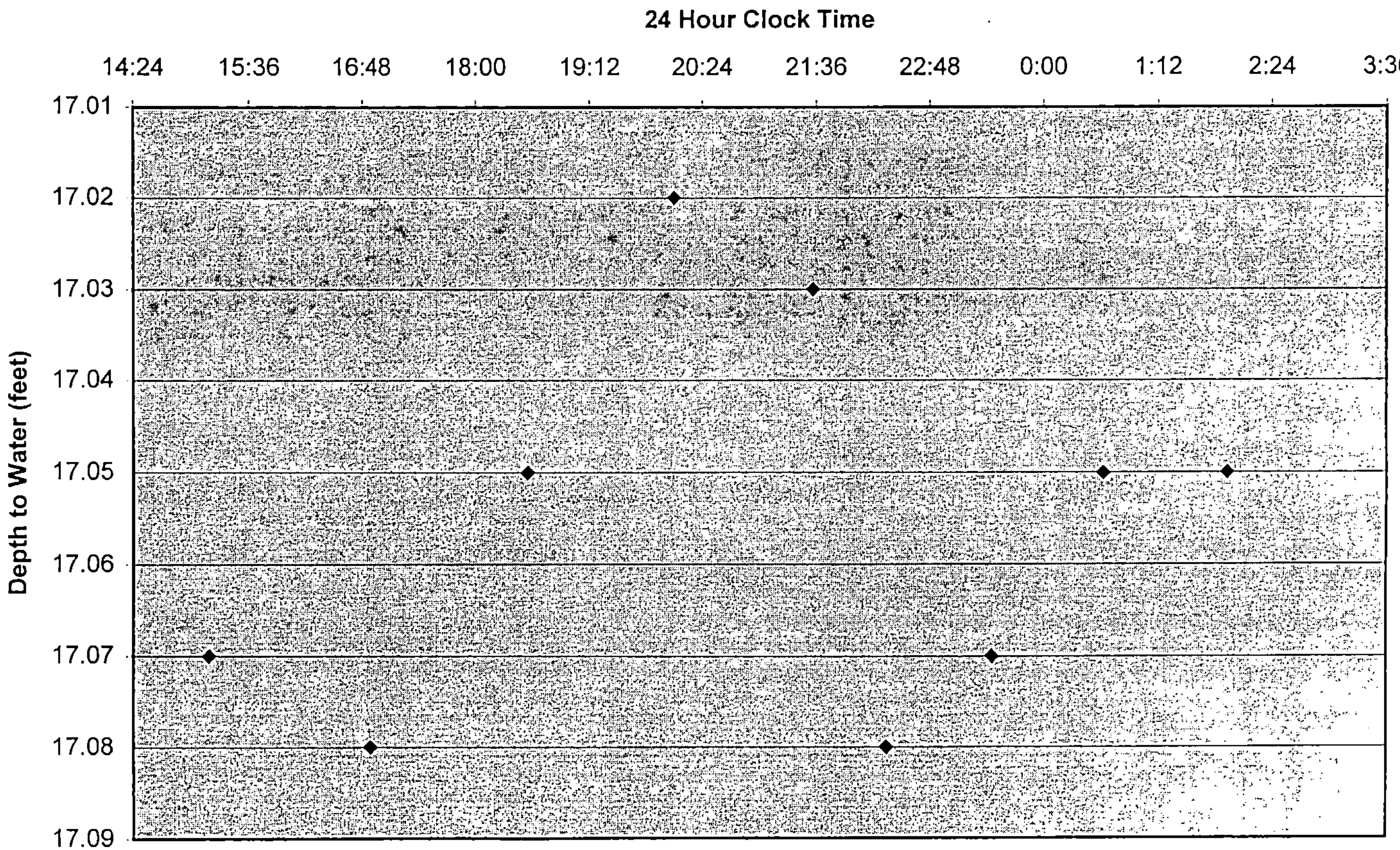

24 Hour Clock Time
12:00
14:24
16:48
19:12
21:36
0:00
2:24
4:48
Depth to Water (feet)
5.32
5.34
5.36
5.38
5.40
5.42
5.44

RGP-2W

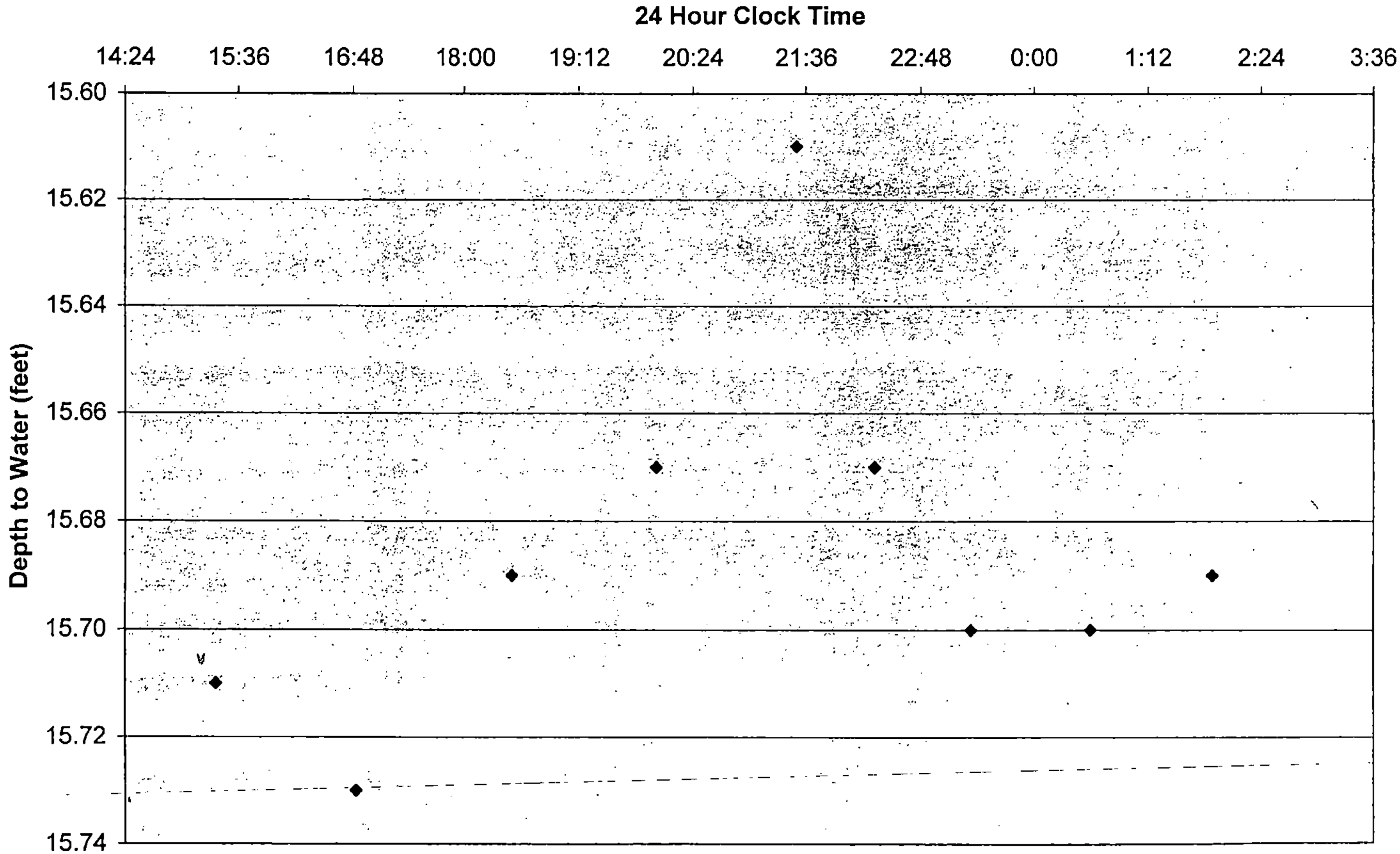

24 Hour Clock Time
12:00
14:24
16:48
19:12
21:36
0:00
2:24
4:48
Depth to Water (feet)
15.95
16.00
16.05
16.10
16.15
16.20
16.25


RGP-3(W)
24 Hour Clock Time
12:00
14:24
16:48
19:12
21:36
0:00
2:24
4:48
Depth to Water (feet)
13.70
13.72
13.74
13.76
13.78
13.80
13.82

RGP-4(W)

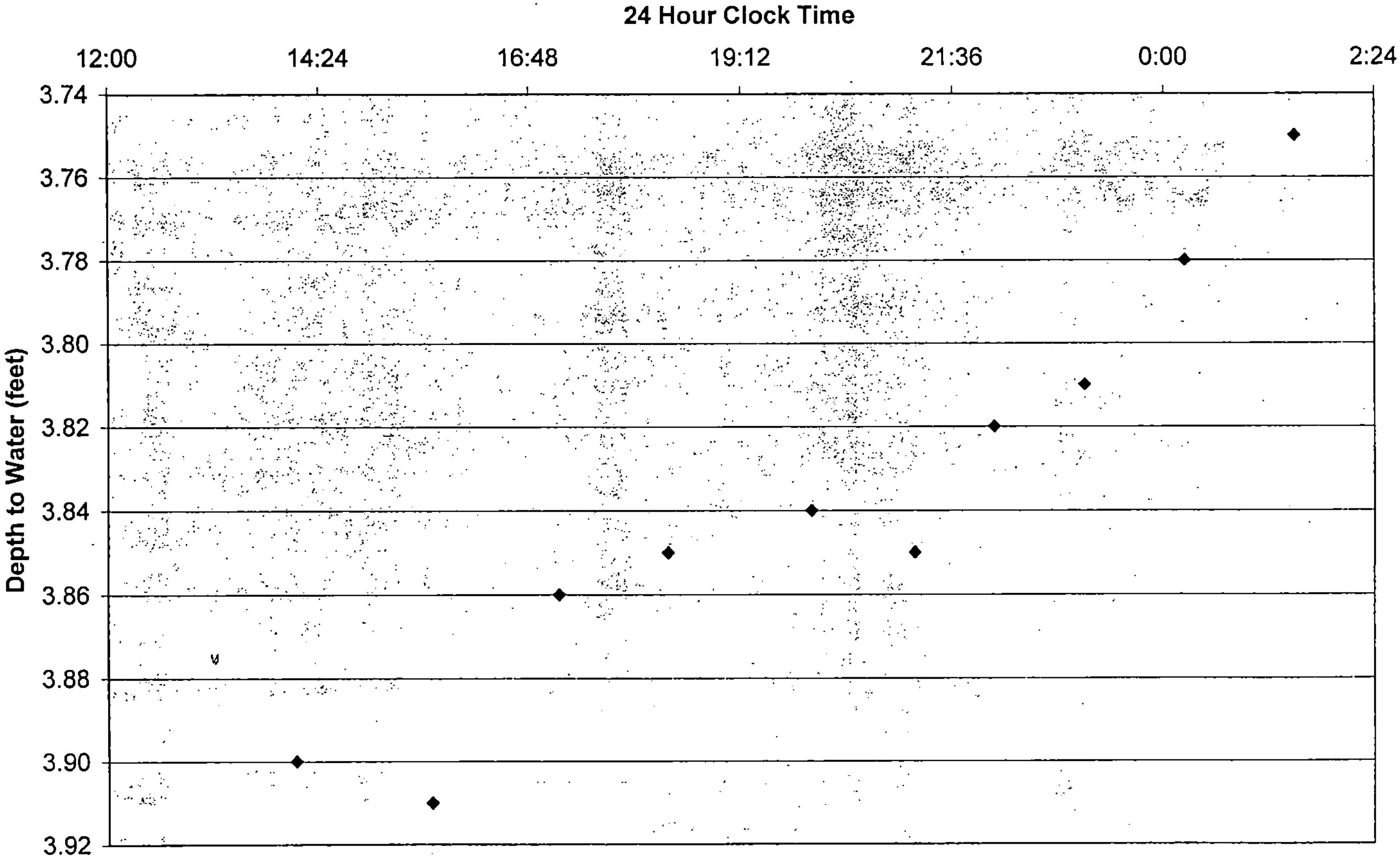

24 Hour Clock Time
14:24
15:36
16:48
18:00
19:12
20:24
21:36
22:48
0:00
1:12
2:24
3:36
Depth to Water (feet)
17.01
17.02
17.03
17.04
17.05
17.06
17.07
17.08
17.09

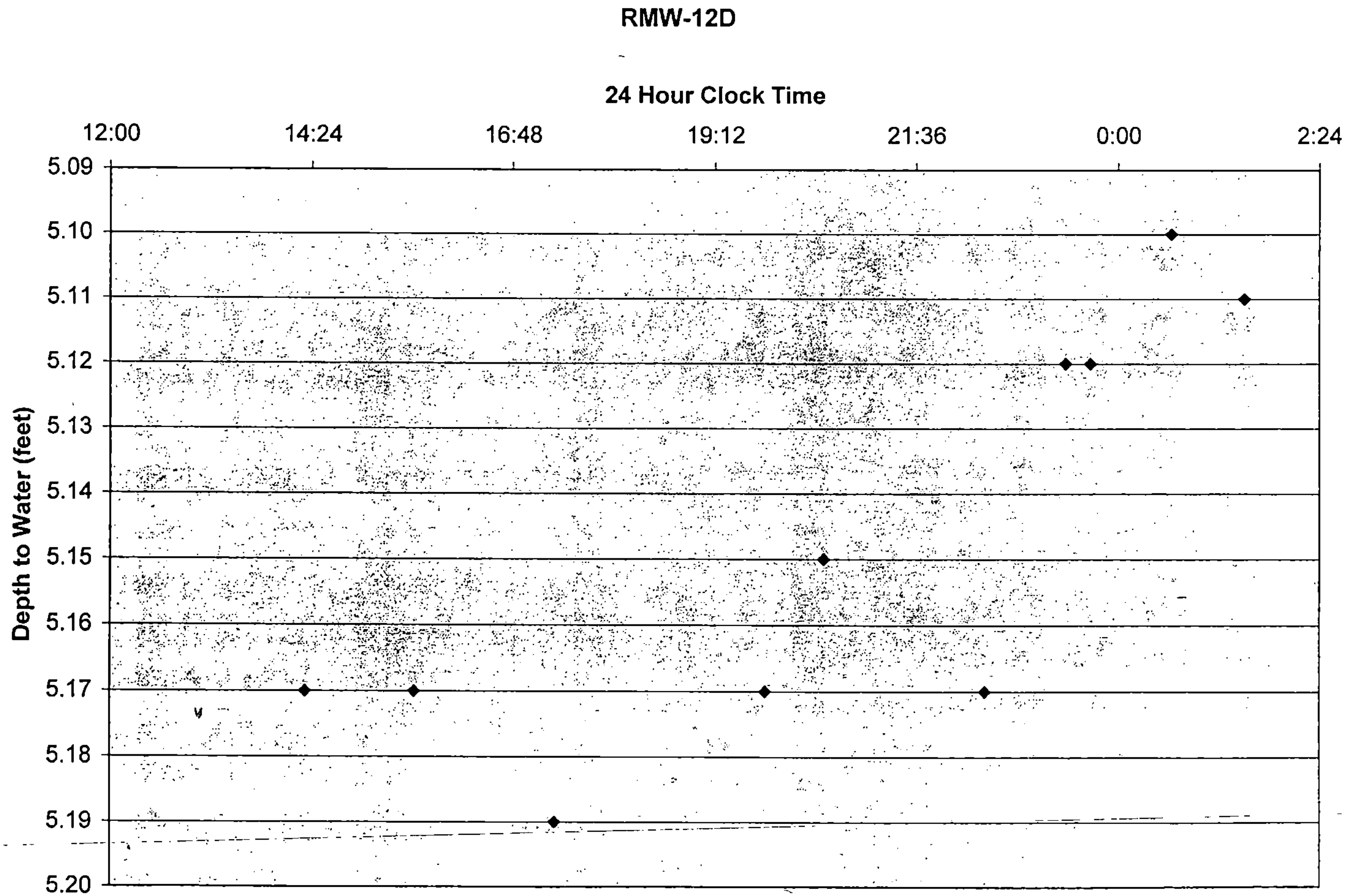
RMW-1



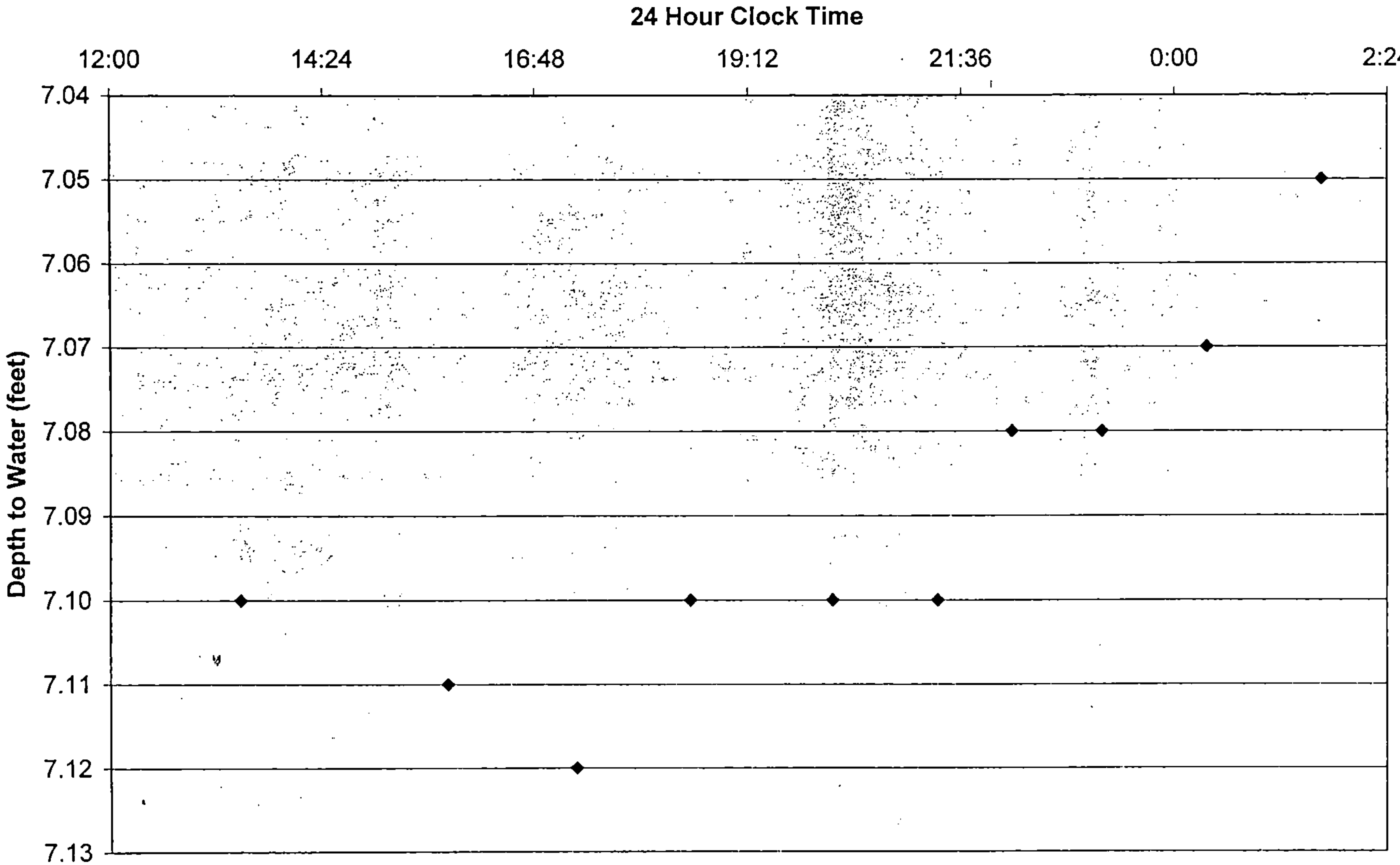
24 Hour Clock Time
14:24
15:36
16:48
18:00
19:12
20:24
21:36
22:48
0:00
1:12
2:24
3:36
Depth to Water (feet)
15.60
15.62
15.64
15.66
15.68
15.70
15.72
15.74

RMW-10


24 Hour Clock Time
12:00
14:24
16:48
19:12
21:36
0:00
2:24
Depth to Water (feet)
3.74
3.76
3.78
3.80
3.82
3.84
3.86
3.88
3.90
3.92

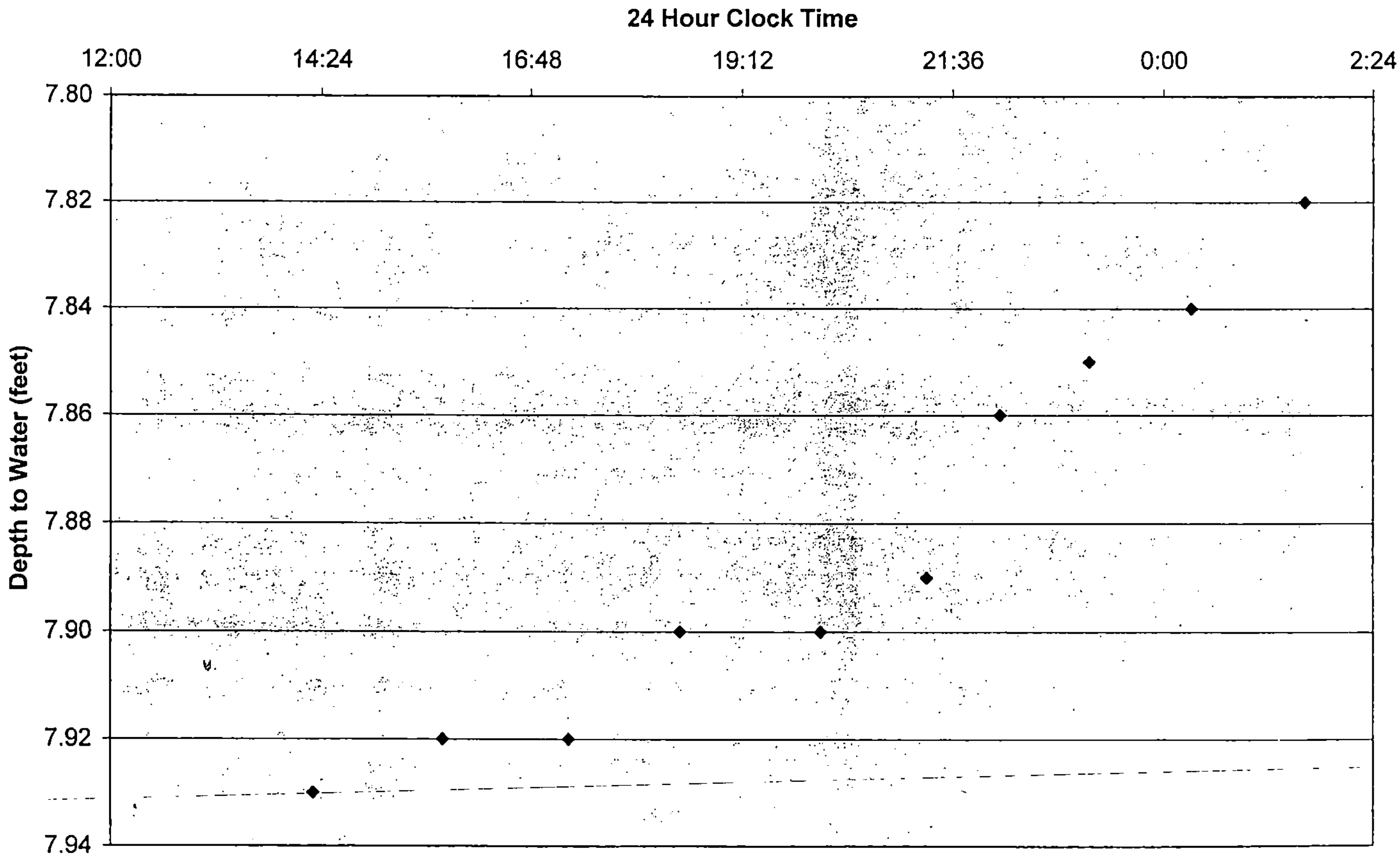

RMW-12D
24 Hour Clock Time
12:00
14:24
16:48
19:12
21:36
0:00
2:24
Depth to Water (feet)
5.09
5.10
5.11
5.12
5.13
5.14
5.15
5.16
5.17
5.18
5.19
5.20

RMW-14

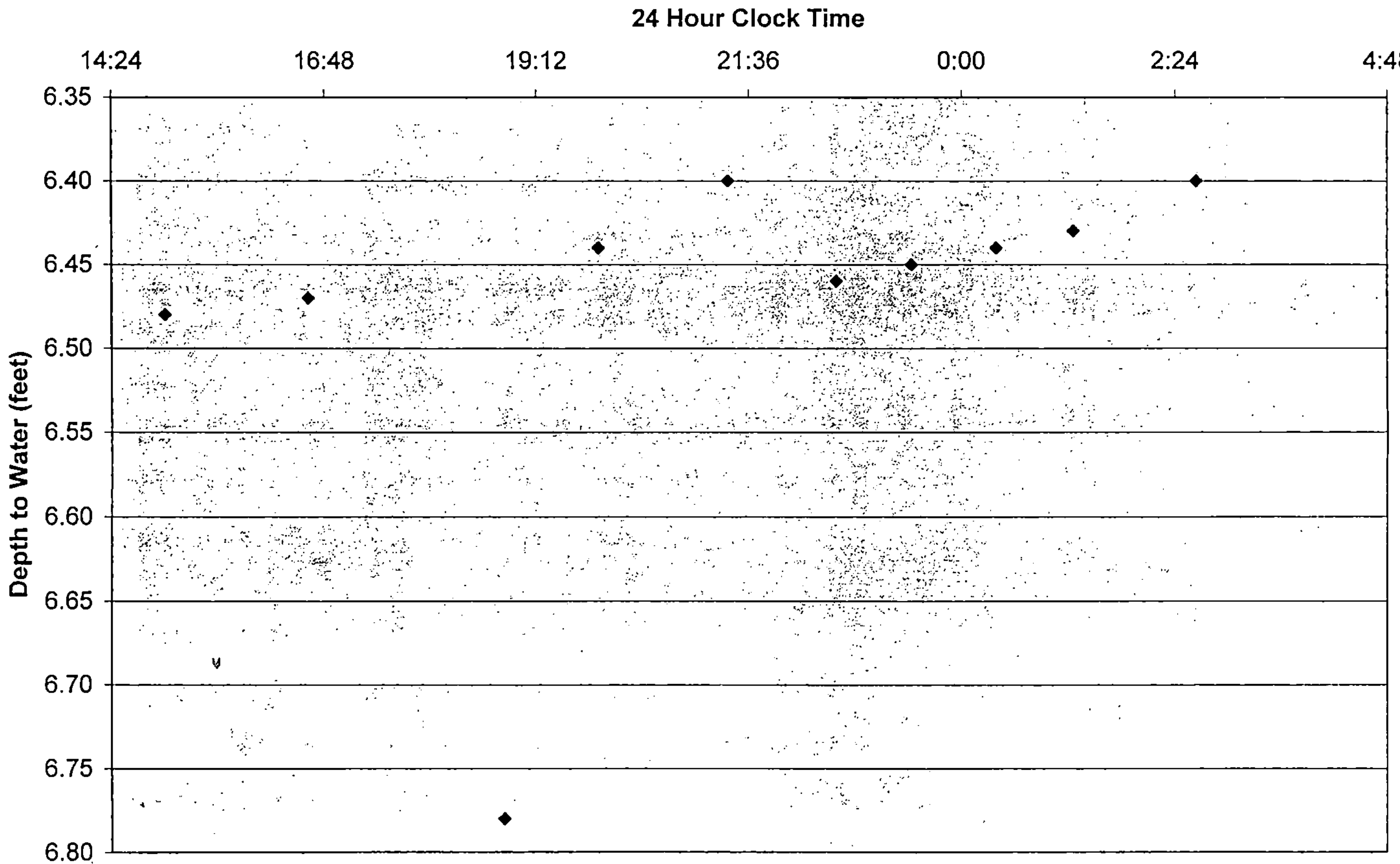


24 Hour Clock Time
12:00
14:24
16:48
19:12
21:36
0:00
2:24
7.04
7.05
7.06
7.07
7.08
7.09
7.10
7.11
7.12
7.13
Depth to Water (feet)

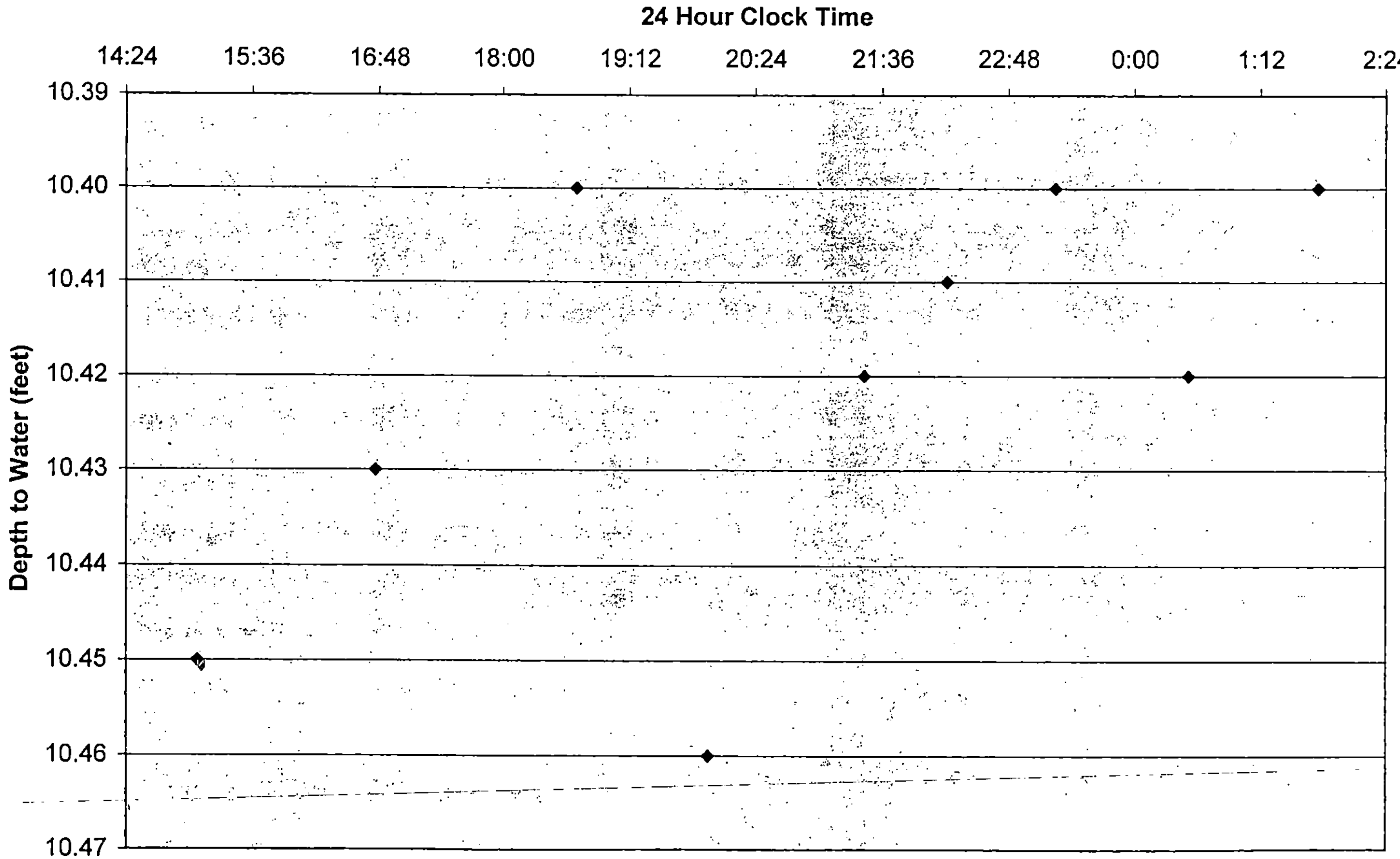
RMW-15

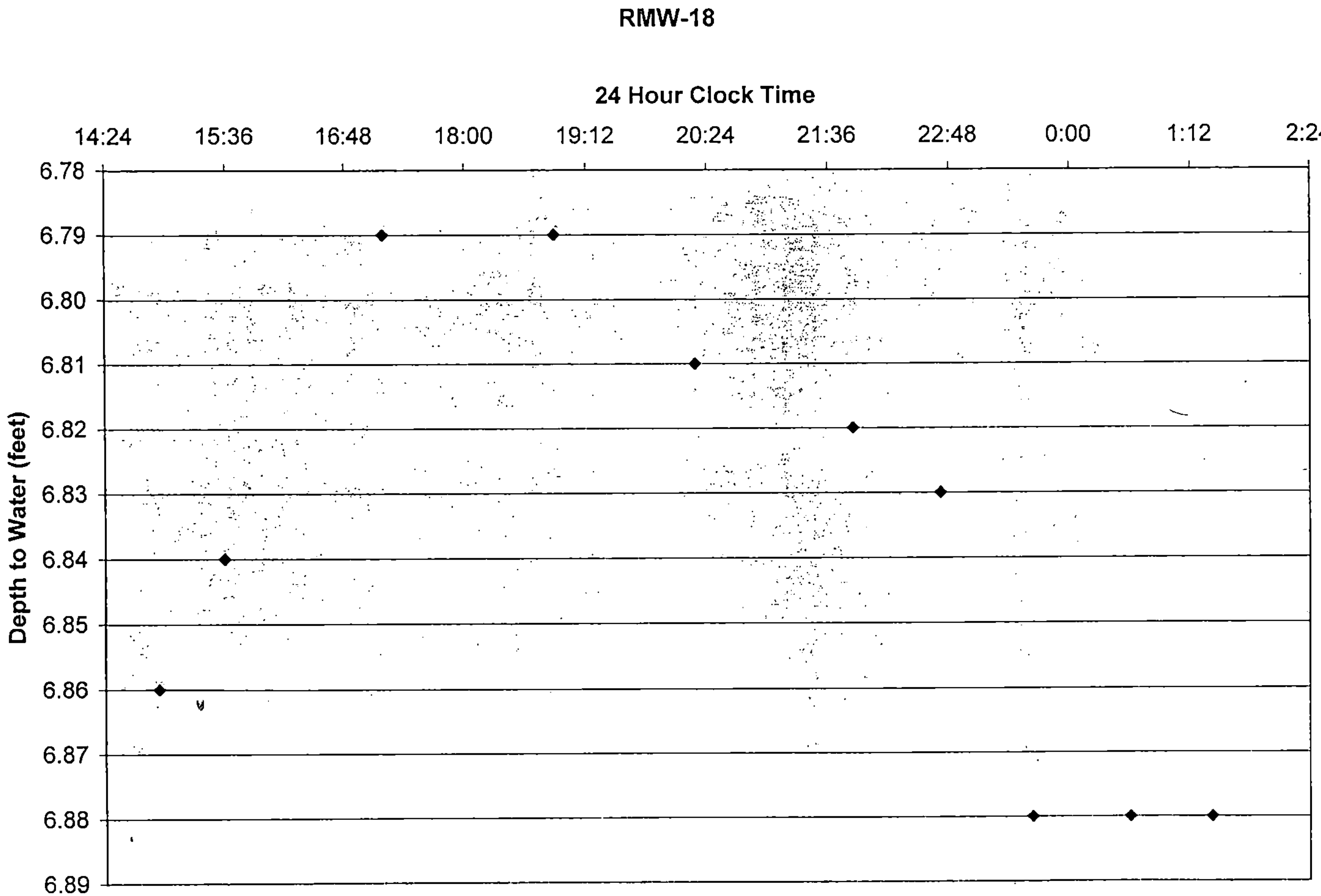

24 Hour Clock Time
12:00
14:24
16:48
19:12
21:36
0:00
2:24
Depth to Water (feet)
7.80
7.82
7.84
7.86
7.88
7.90
7.92
7.94

RMW-16

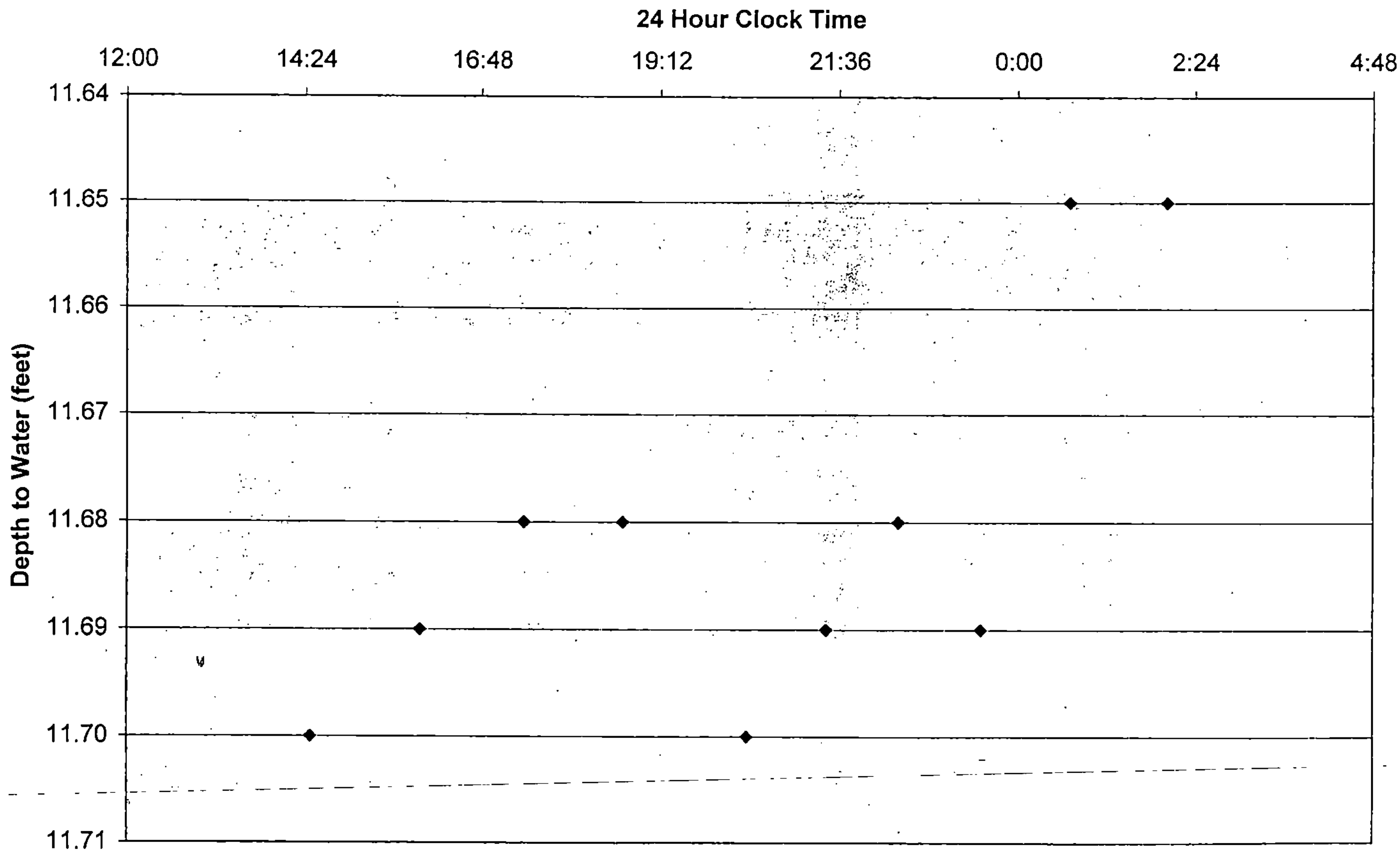

24 Hour Clock Time
14:24
16:48
19:12
21:36
0:00
2:24
4:48
Depth to Water (feet)
6.35
6.40
6.45
6.50
6.55
6.60
6.65
6.70
6.75
6.80

RMW-17

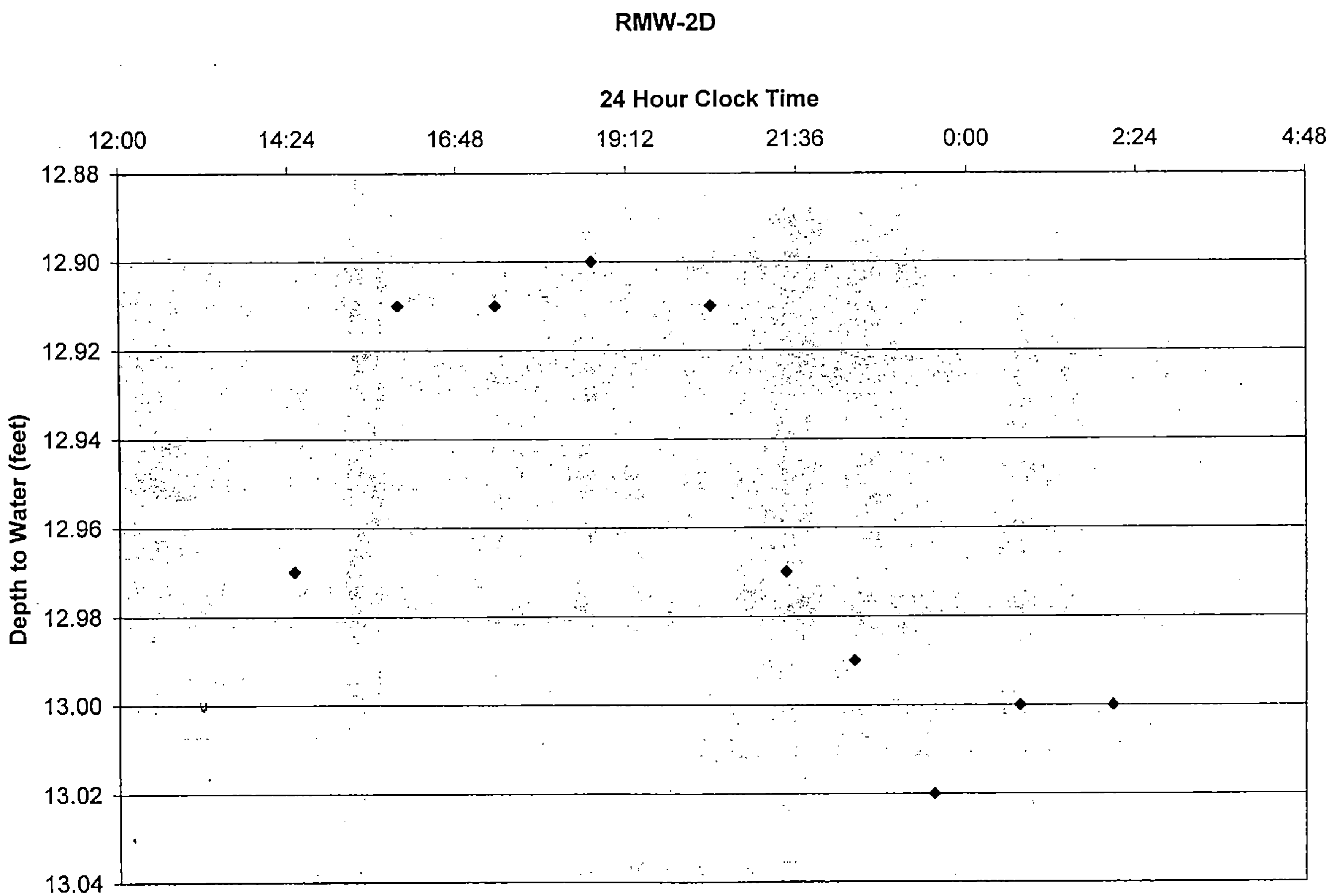

24 Hour Clock Time
14:24
15:36
16:48
18:00
19:12
20:24
21:36
22:48
0:00
1:12
2:24
Depth to Water (feet)
10.39
10.40
10.41
10.42
10.43
10.44
10.45
10.46
10.47

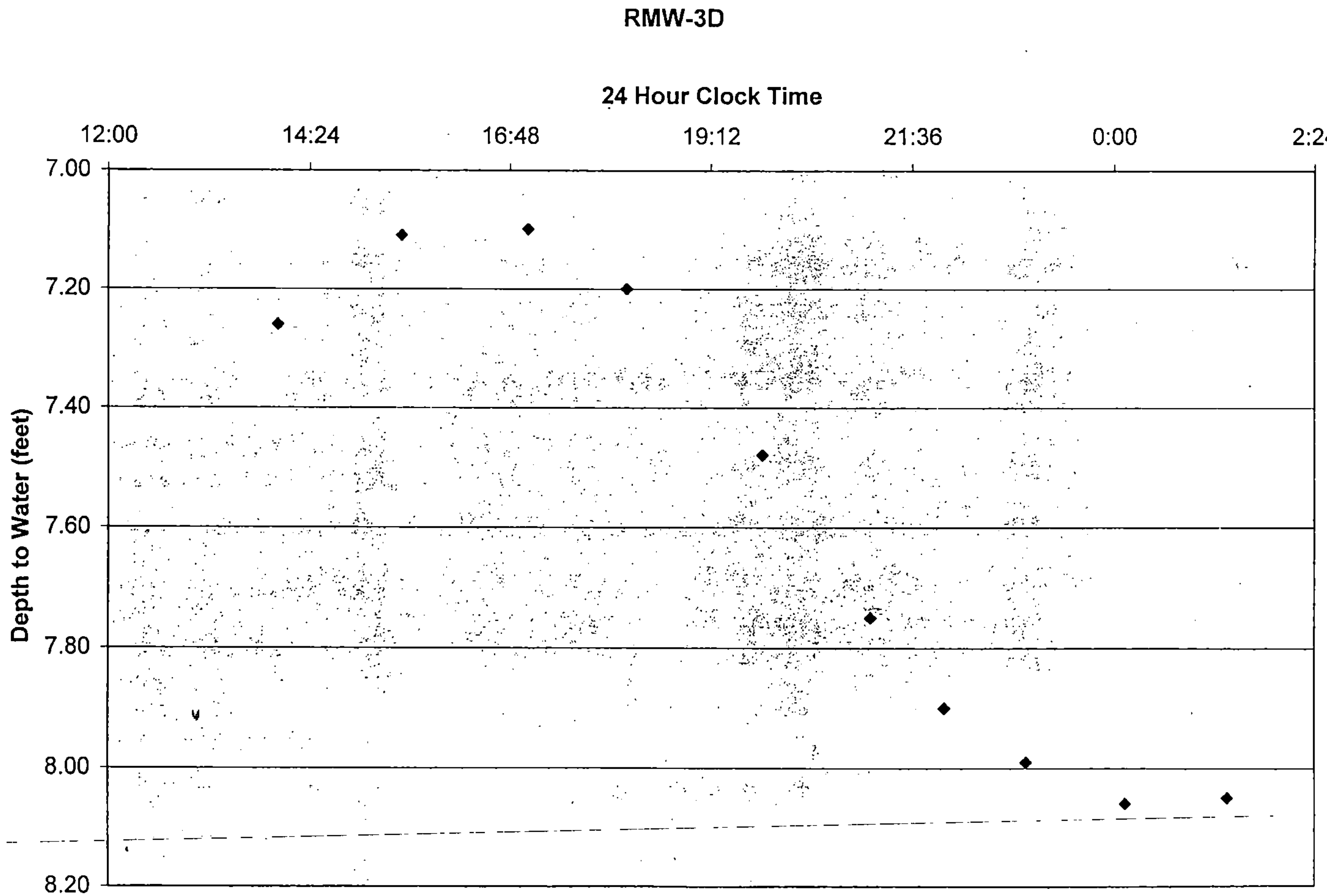

RMW-18
24 Hour Clock Time
14:24
15:36
16:48
18:00
19:12
20:24
21:36
22:48
0:00
1:12
2:24
Depth to Water (feet)
6.78
6.79
6.80
6.81
6.82
6.83
6.84
6.85
6.86
6.87
6.88
6.89

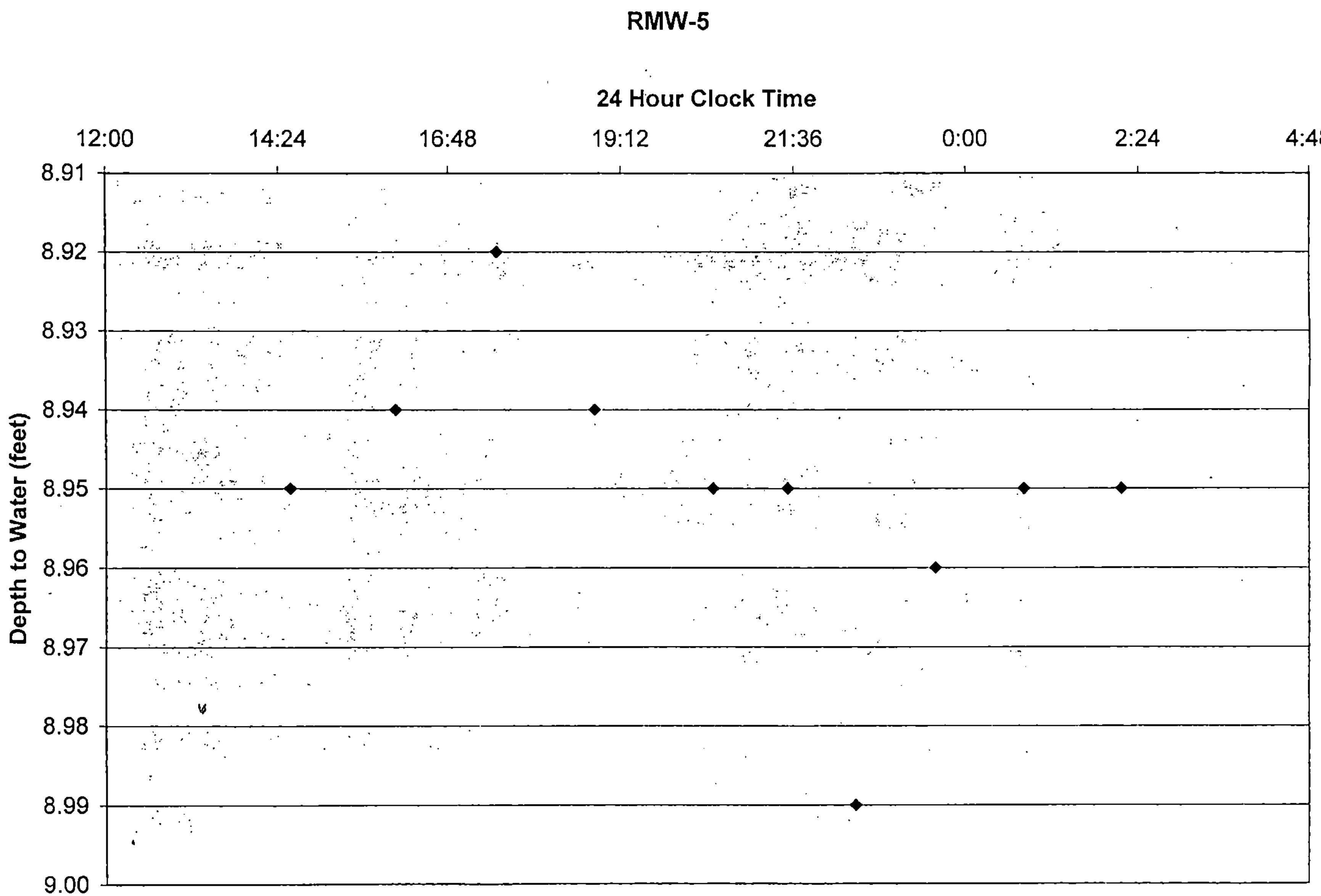
RMW-2



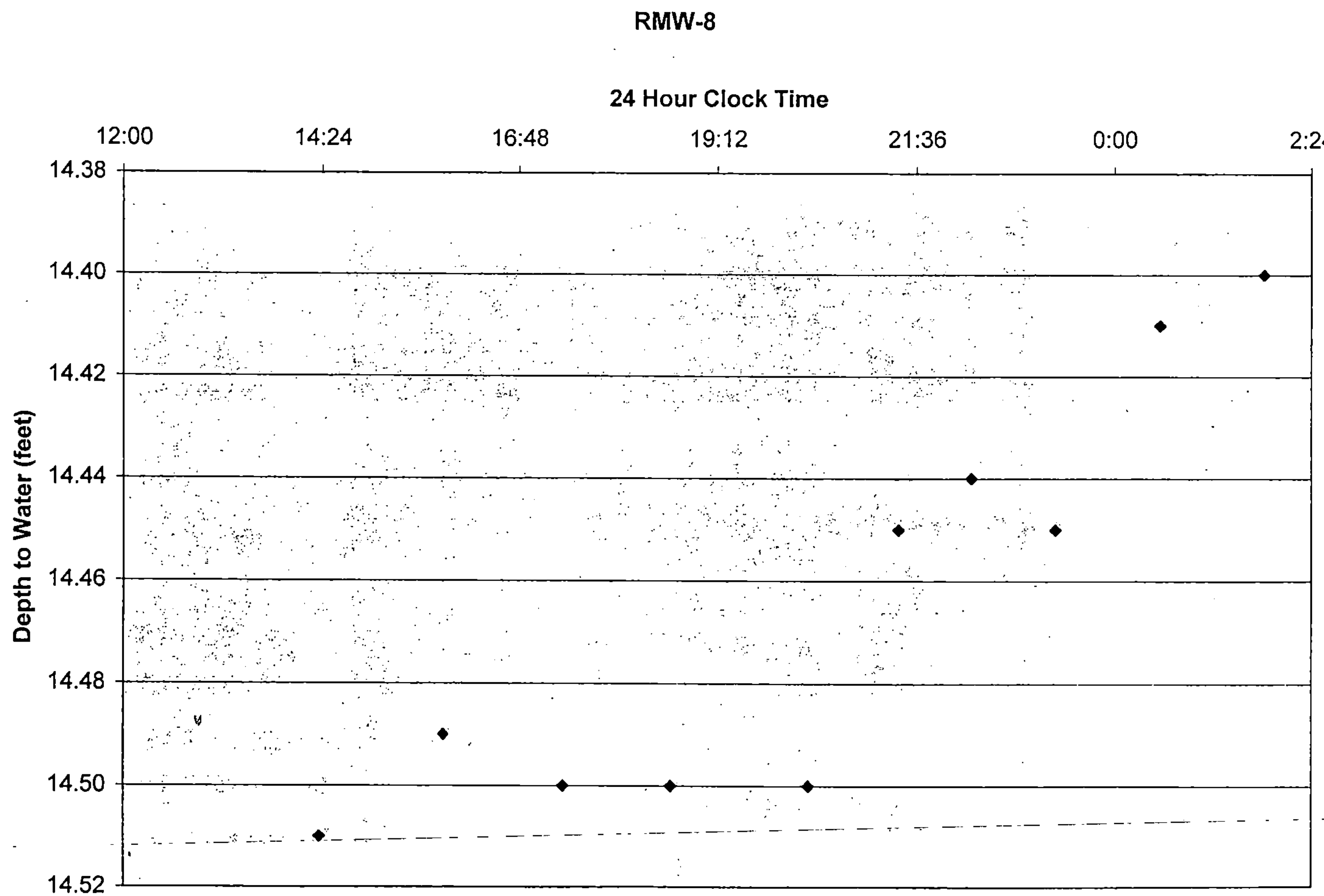
24 Hour Clock Time
12:00
14:24
16:48
19:12
21:36
0:00
2:24
4:48
Depth to Water (feet)
11.64
11.65
11.66
11.67
11.68
11.69
11.70
11.71

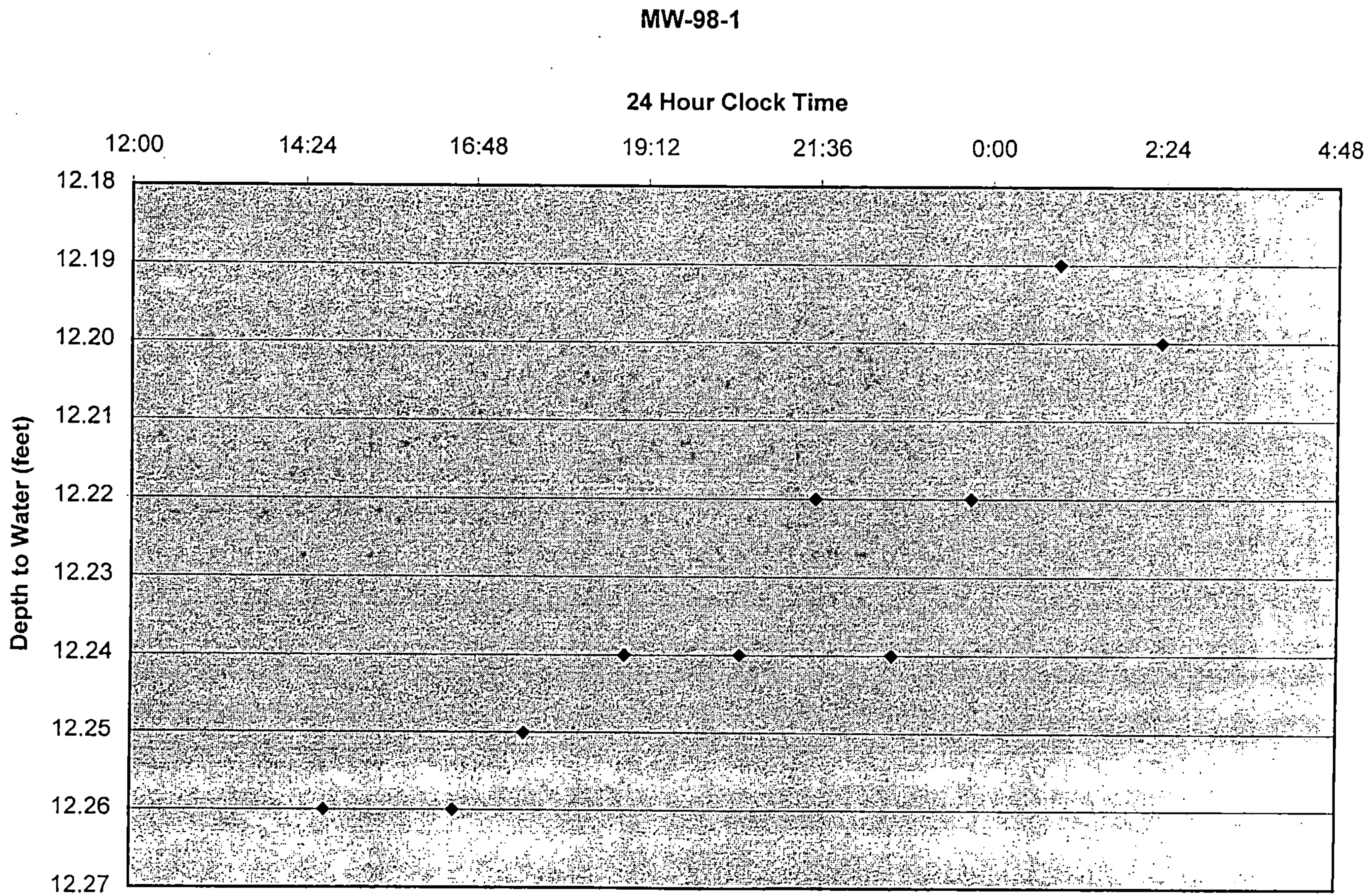

RMW-2D
24 Hour Clock Time
12:00
14:24
16:48
19:12
21:36
0:00
2:24
4:48
Depth to Water (feet)
12.88
12.90
12.92
12.94
12.96
12.98
13.00
13.02
13.04

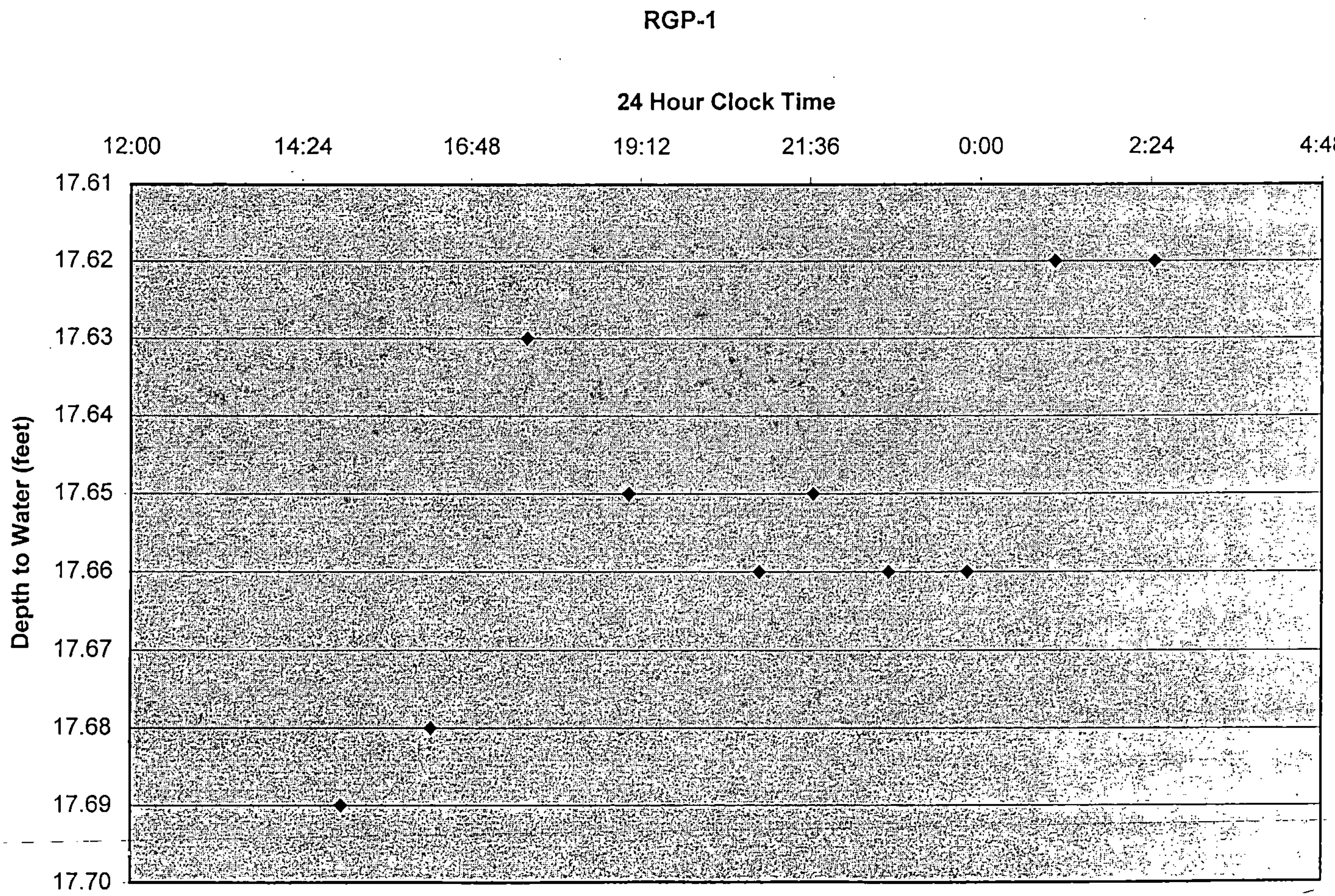

RMW-3D
24 Hour Clock Time
12:00
14:24
16:48
19:12
21:36
0:00
2:24
Depth to Water (feet)
7.00
7.20
7.40
7.60
7.80
8.00
8.20



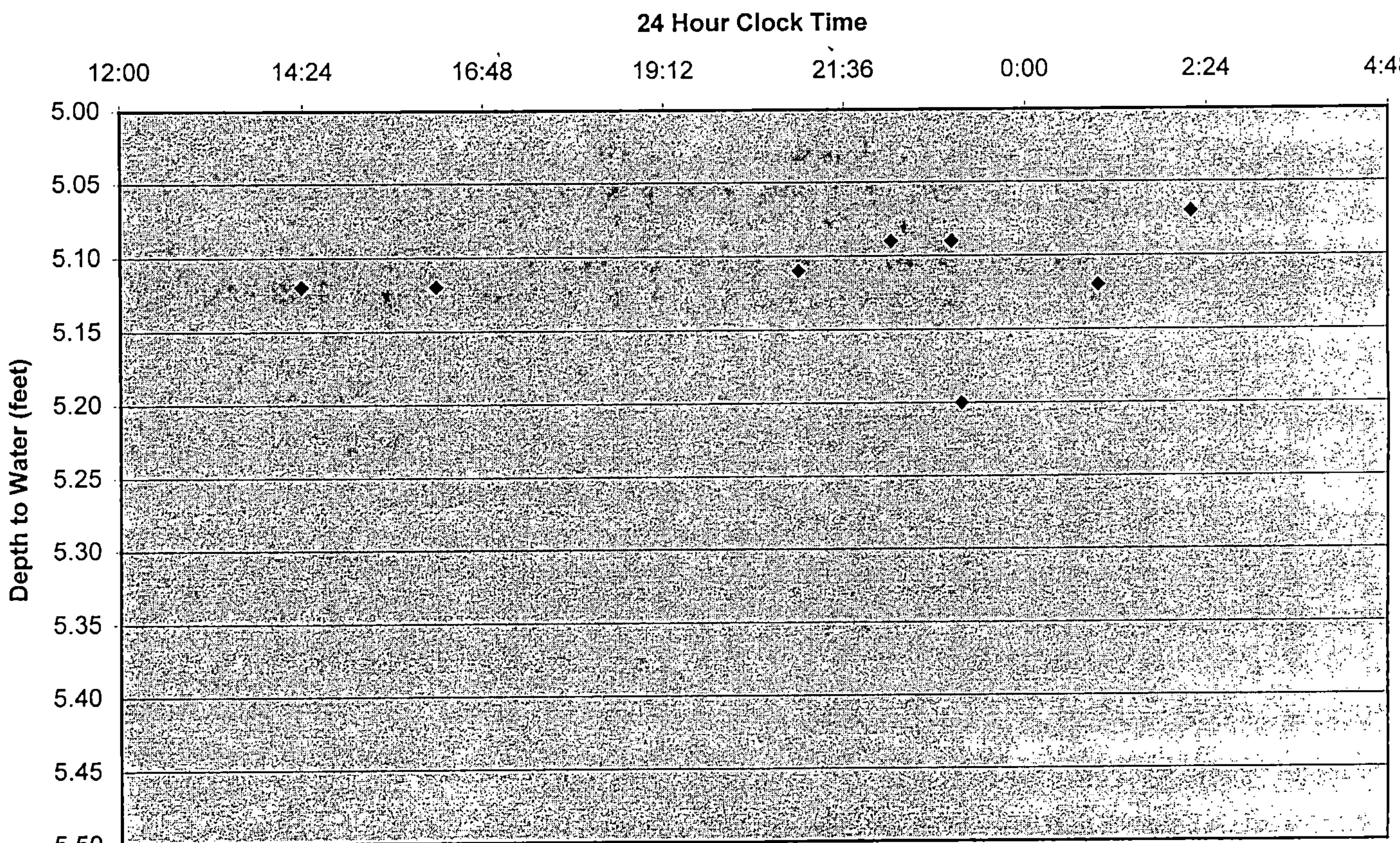
RMW-5
24 Hour Clock Time
12:00
14:24
16:48
19:12
21:36
0:00
2:24
4:48
Depth to Water (feet)
8.91
8.92
8.93
8.94
8.95
8.96
8.97
8.98
8.99
9.00


RMW-8
24 Hour Clock Time
12:00
14:24
16:48
19:12
21:36
0:00
2:24
Depth to Water (feet)
14.38
14.40
14.42
14.44
14.46
14.48
14.50
14.52


MW-98-1
24 Hour Clock Time
12:00
14:24
16:48
19:12
21:36
0:00
2:24
4:48
Depth to Water (feet)
12.18
12.19
12.20
12.21
12.22
12.23
12.24
12.25
12.26
12.27

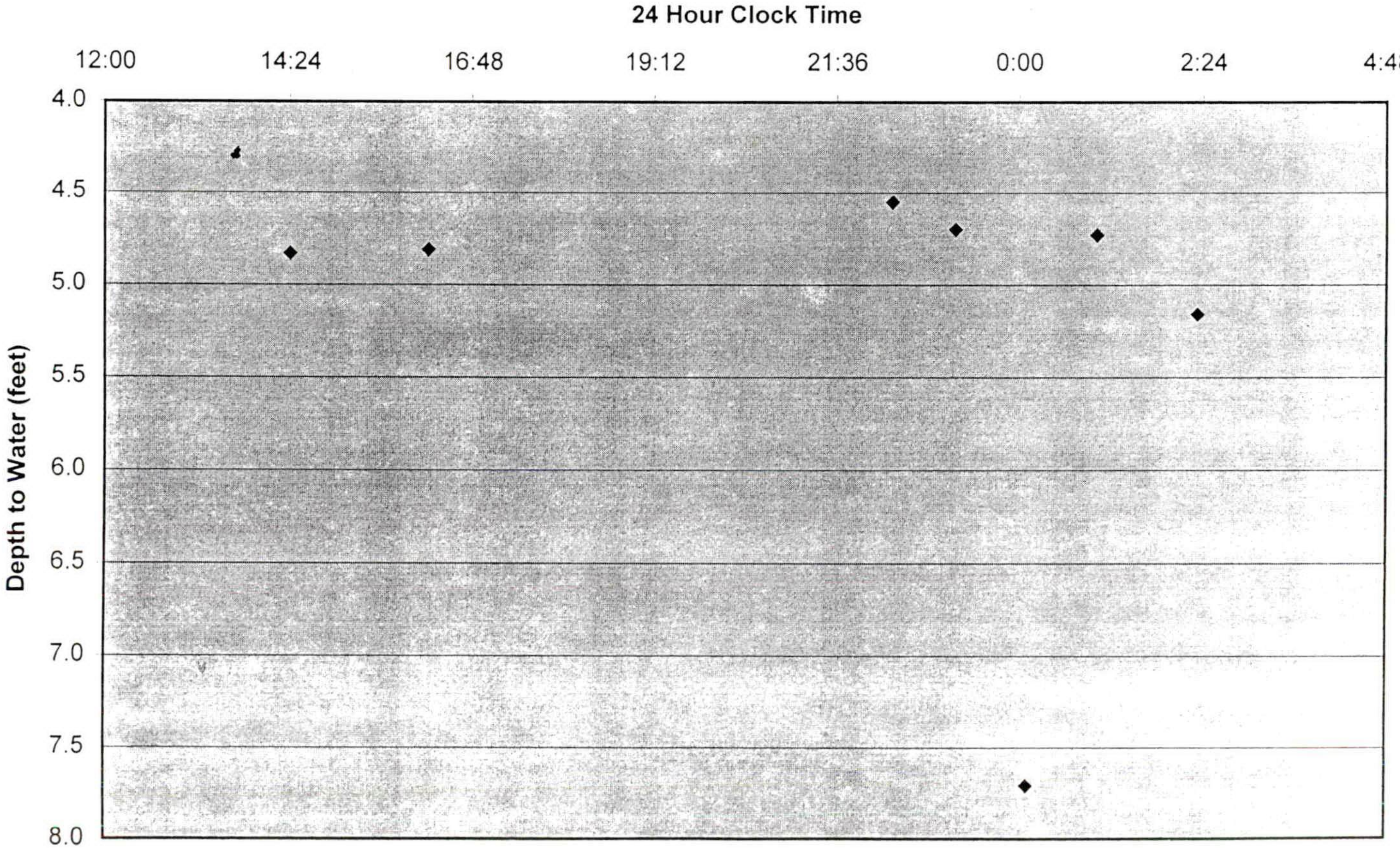

RGP-1
24 Hour Clock Time
12:00
14:24
16:48
19:12
21:36
0:00
2:24
4:48
Depth to Water (feet)
17.61
17.62
17.63
17.64
17.65
17.66
17.67
17.68
17.69
17.70

RMW-11

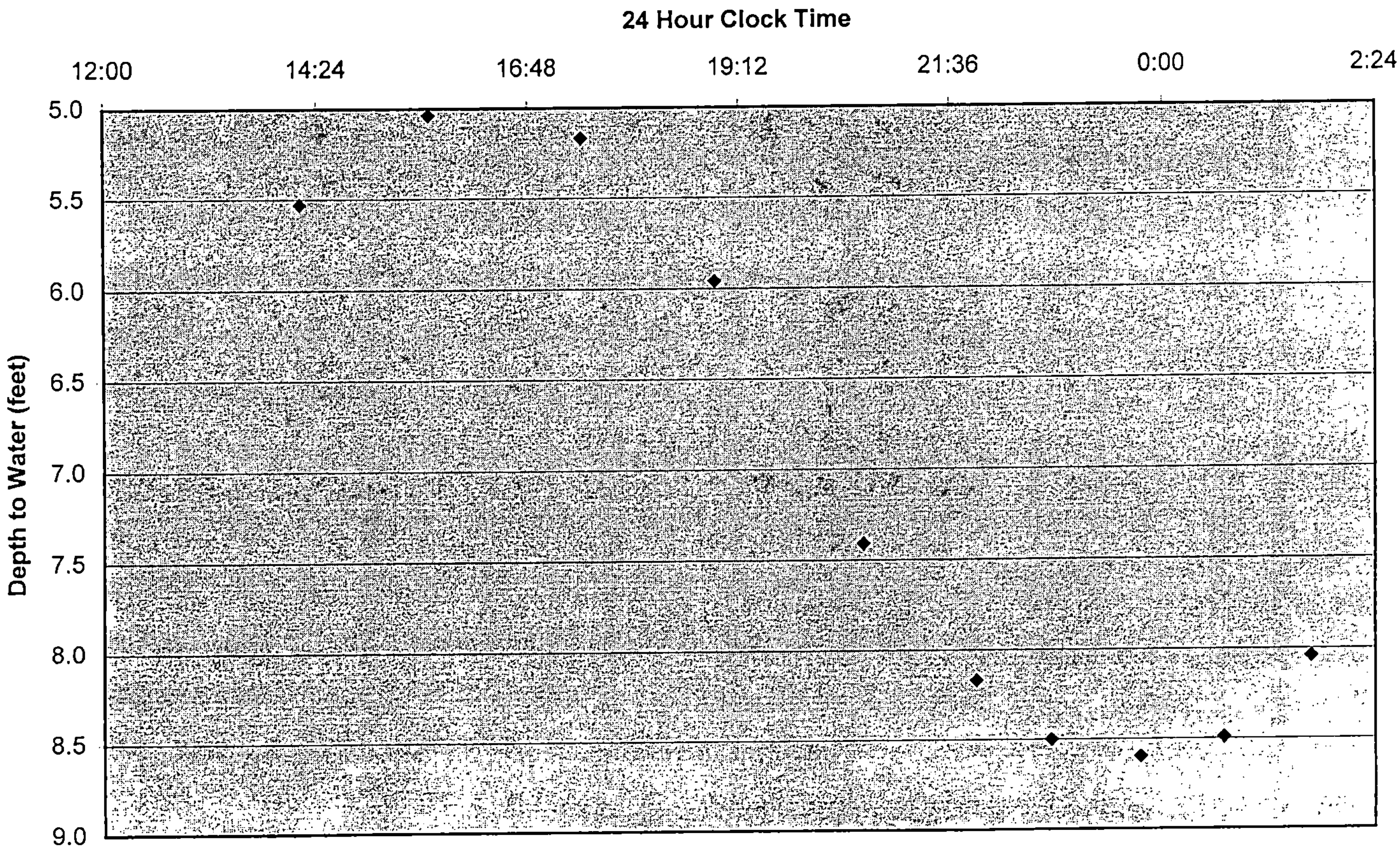


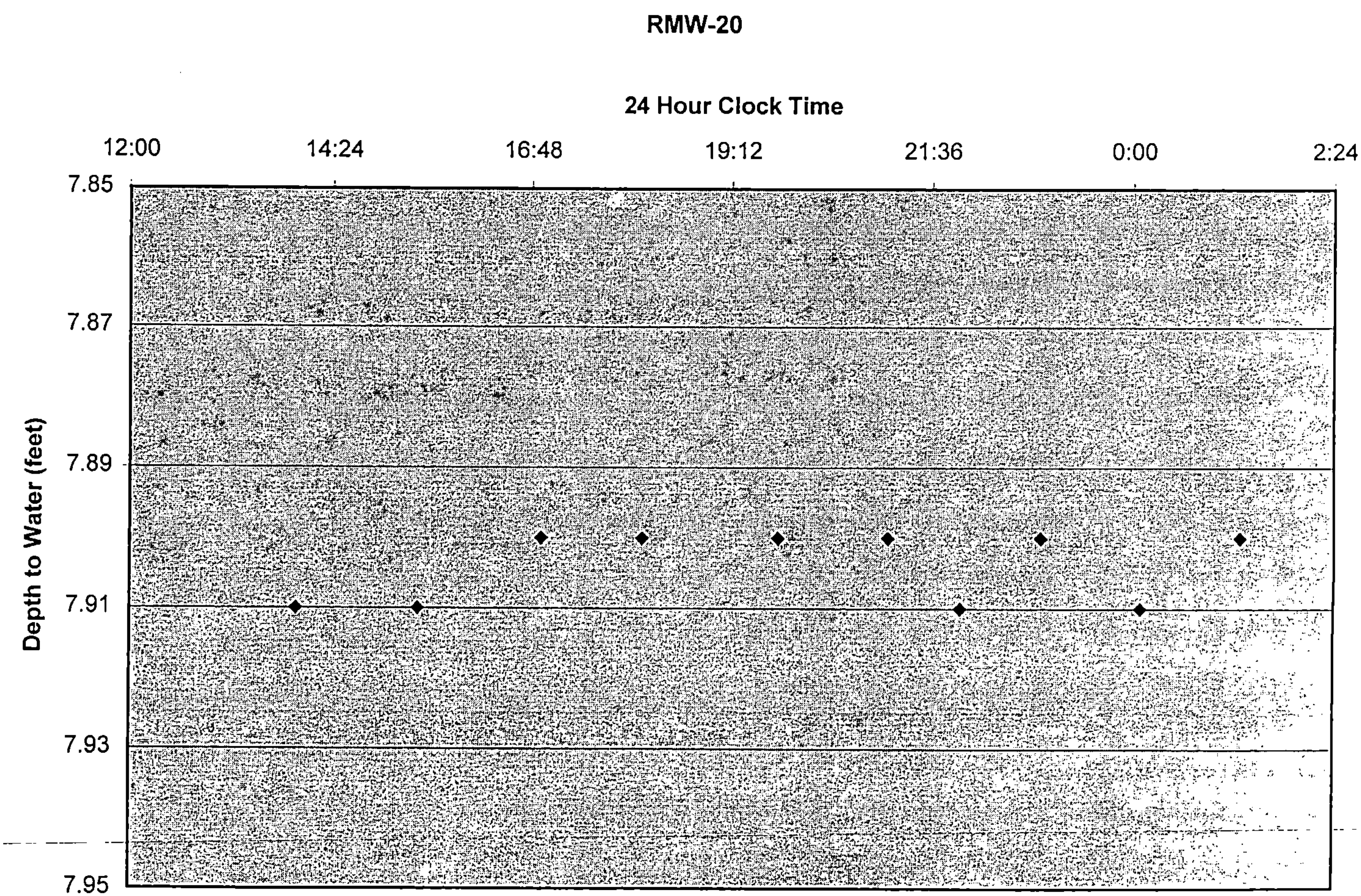
24 Hour Clock Time
12:00
14:24
16:48
19:12
21:36
0:00
2:24
4:48
Depth to Water (feet)
5.00
5.05
5.10
5.15
5.20
5.25
5.30
5.35
5.40
5.45
5.50

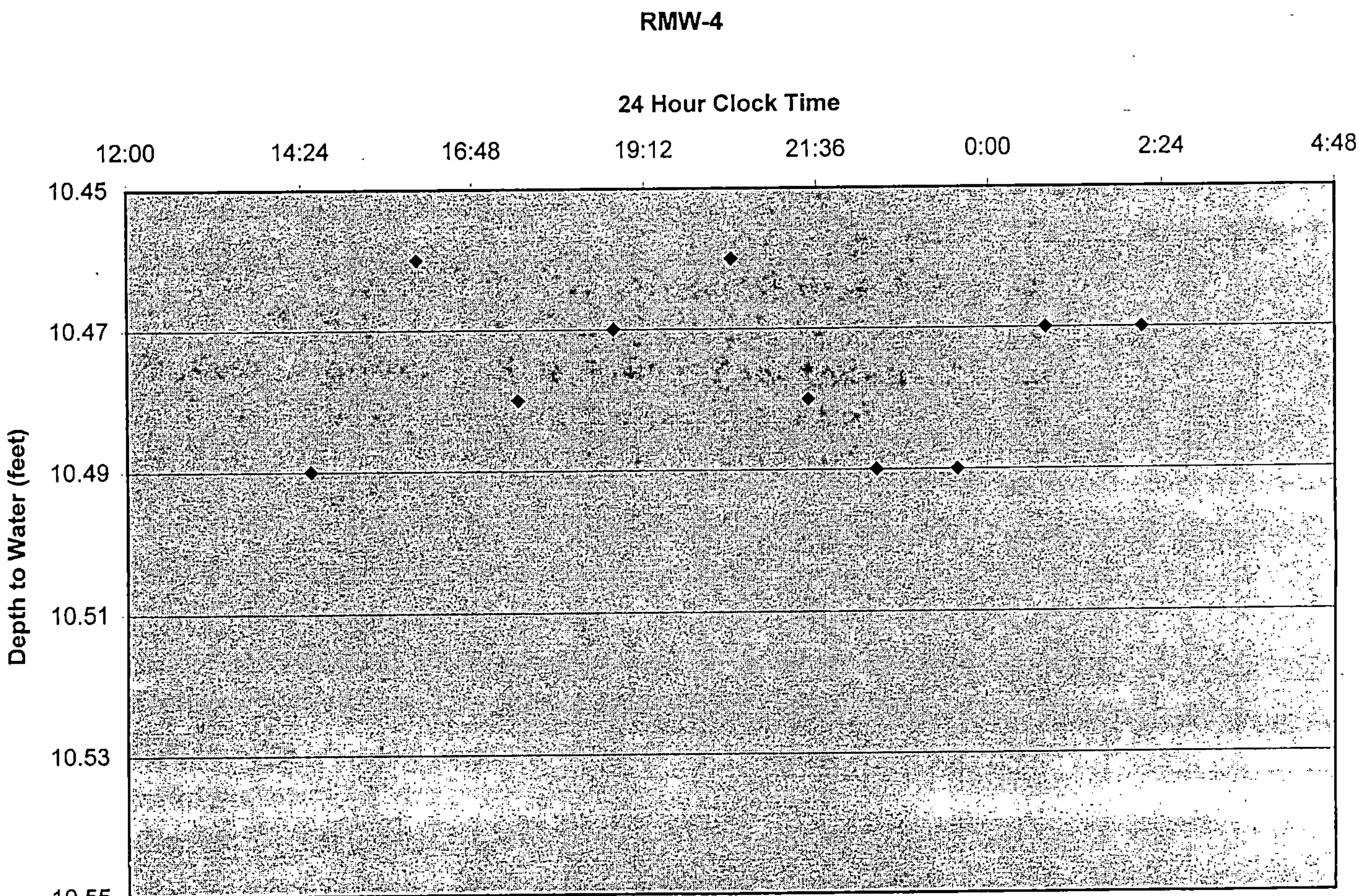
RMW-11D

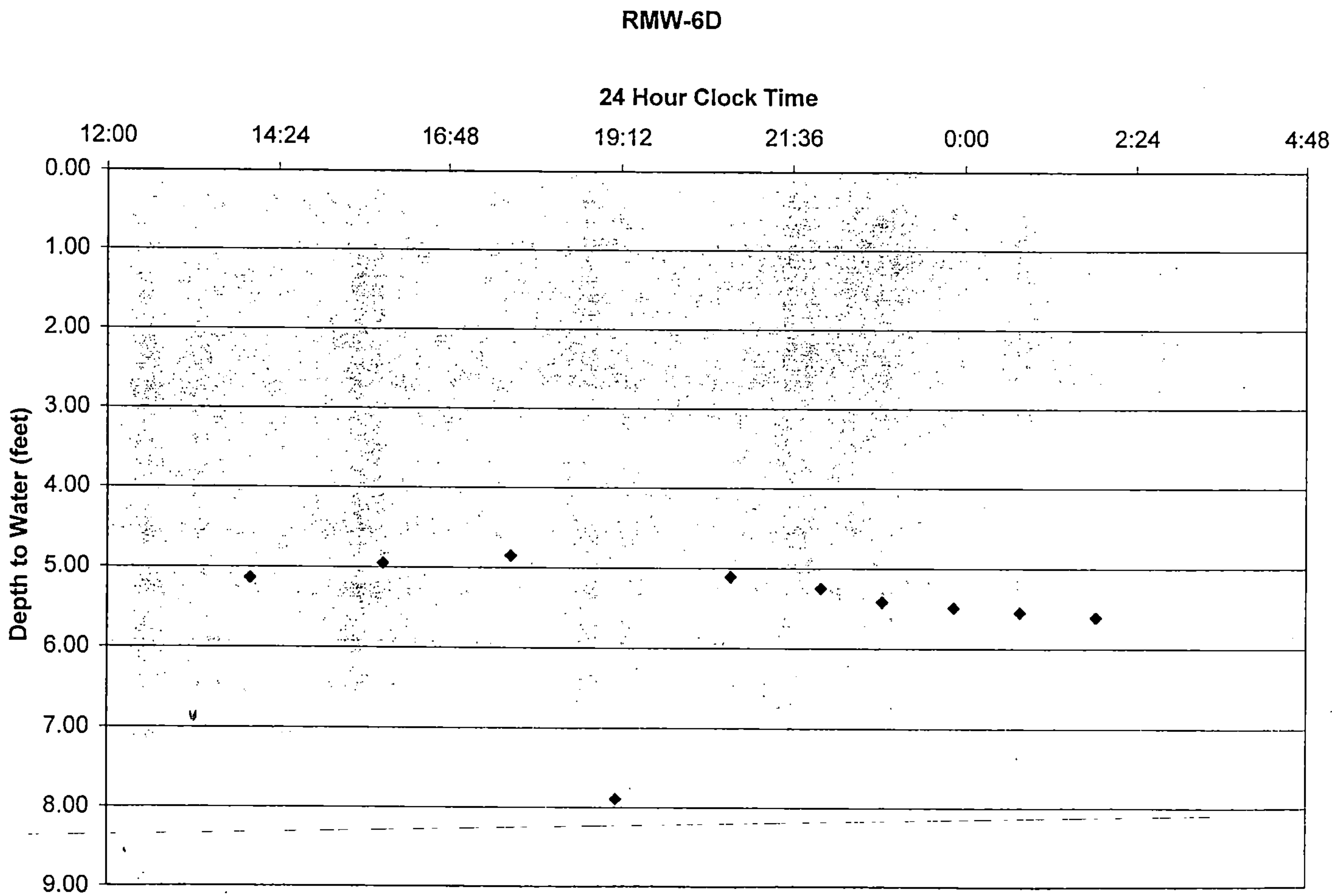

24 Hour Clock Time
12:00
14:24
16:48
19:12
21:36
0:00
2:24
4:48
4.0
4.5
5.0
5.5
6.0
6.5
7.0
7.5
8.0
Depth to Water (feet)

RMW-13D

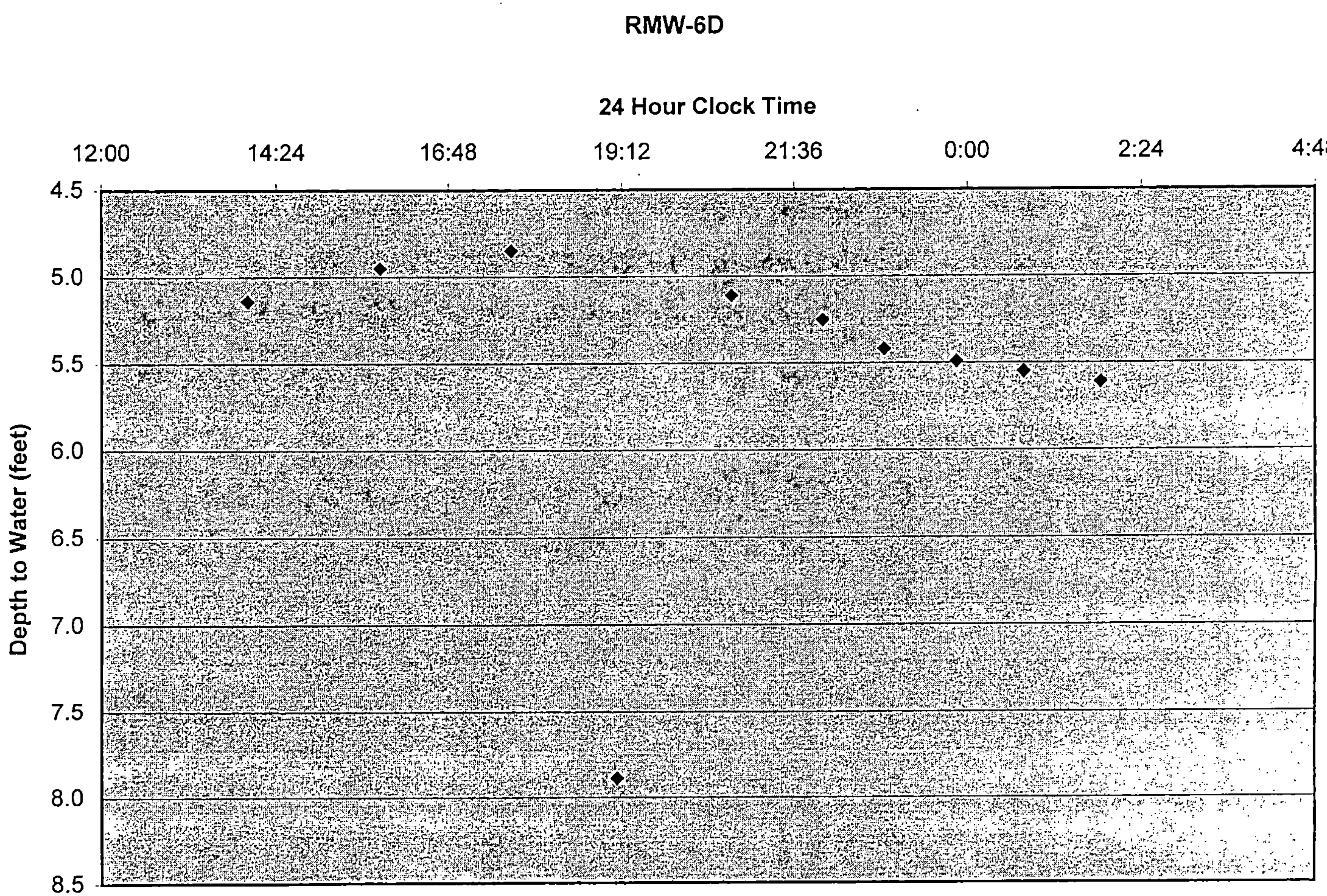

24 Hour Clock Time
12:00
14:24
16:48
19:12
21:36
0:00
2:24
5.0
5.5
6.0
6.5
7.0
7.5
8.0
8.5
9.0
Depth to Water (feet)


RMW-20
24 Hour Clock Time
12:00
14:24
16:48
19:12
21:36
0:00
2:24
7.85
7.87
7.89
7.91
7.93
7.95
Depth to Water (feet)

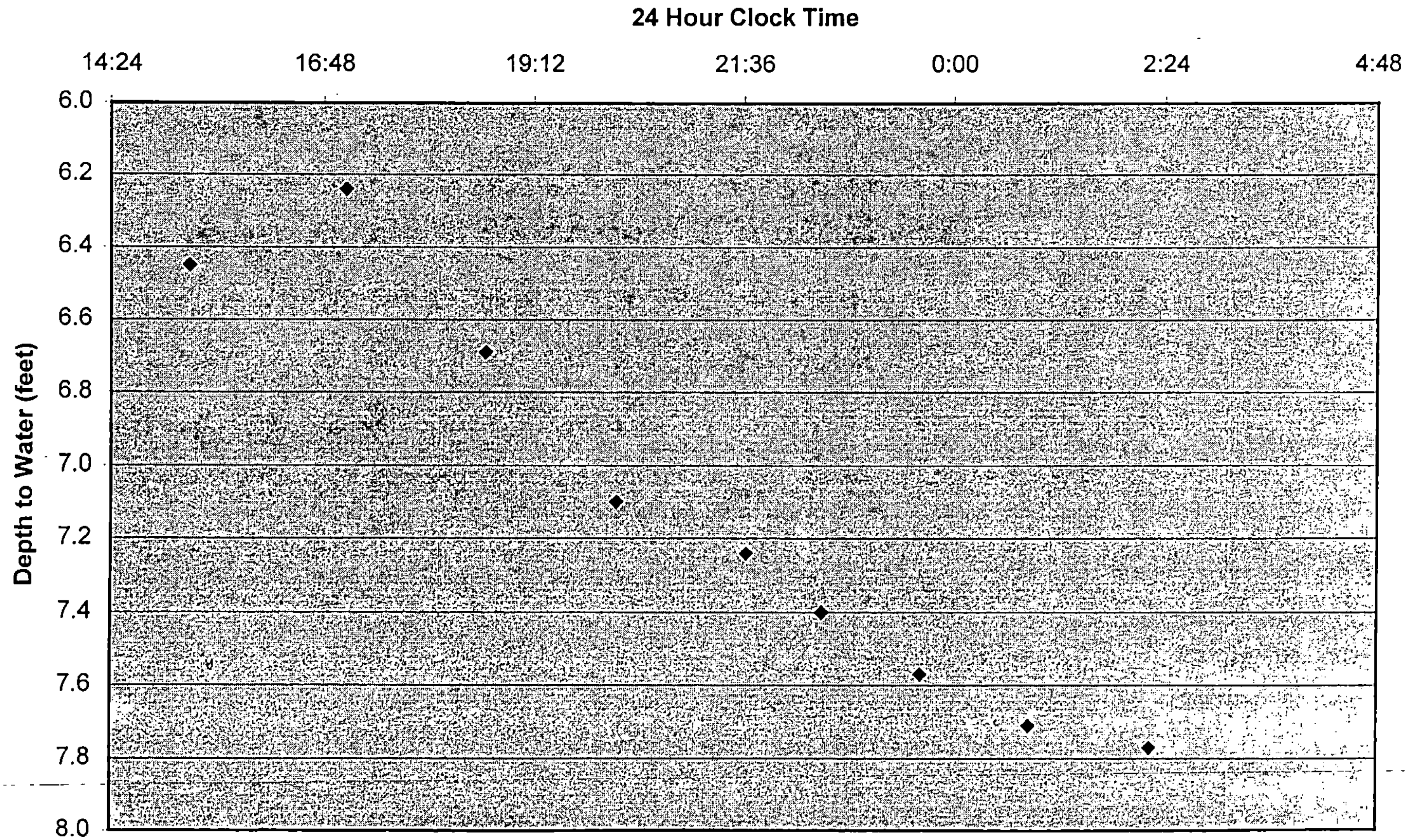

RMW-4
24 Hour Clock Time
12:00
14:24
16:48
19:12
21:36
0:00
2:24
4:48
10.45
10.47
10.49
10.51
10.53
10.55
Depth to Water (feet)



RMW-6D
24 Hour Clock Time
12:00
14:24
16:48
19:12
21:36
0:00
2:24
4:48
Depth to Water (feet)
0.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00

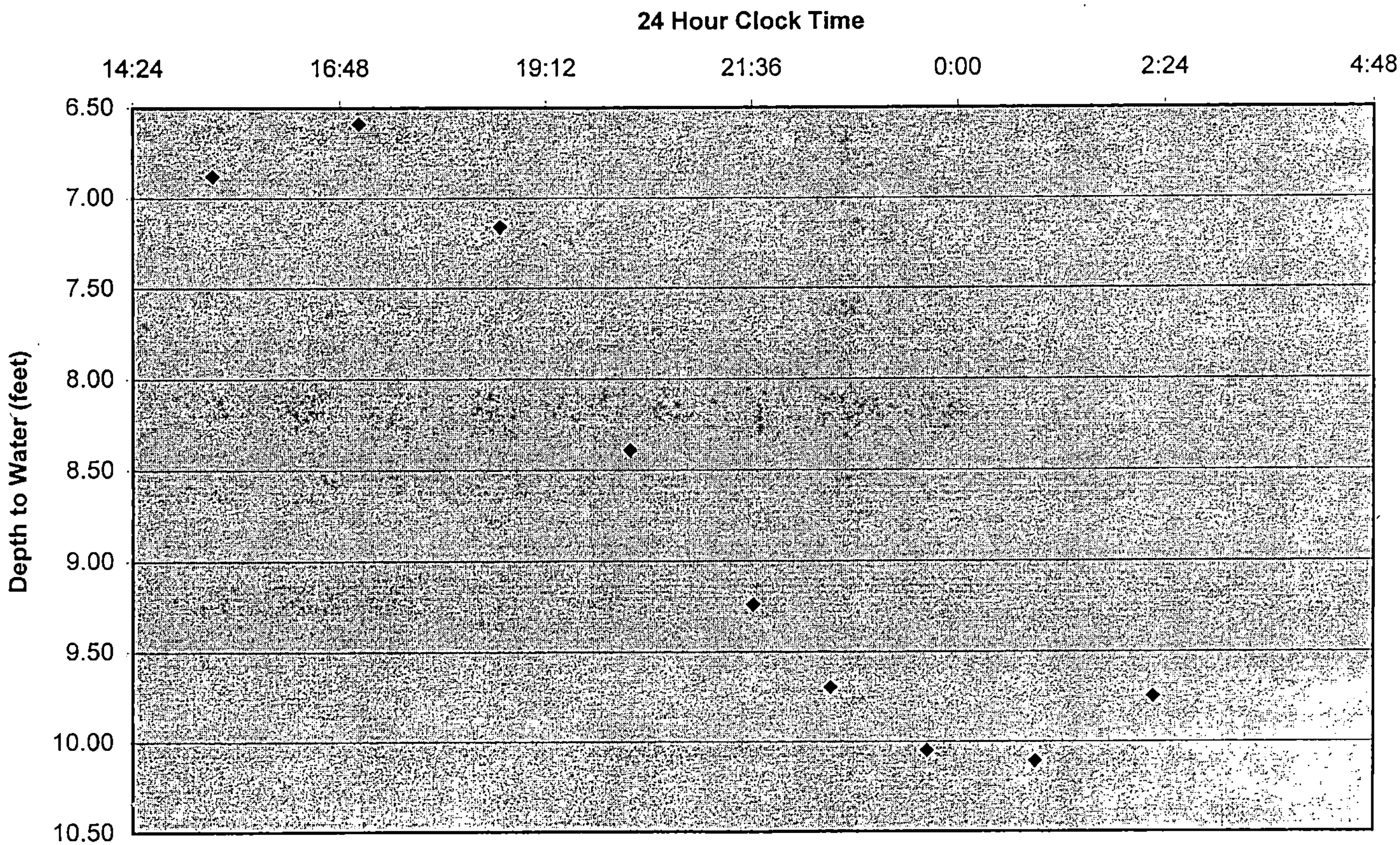

RMW-6D
24 Hour Clock Time
12:00
14:24
16:48
19:12
21:36
0:00
2:24
4:48
Depth to Water (feet)
4.5
5.0
5.5
6.0
6.5
7.0
7.5
8.0
8.5

RMW-7

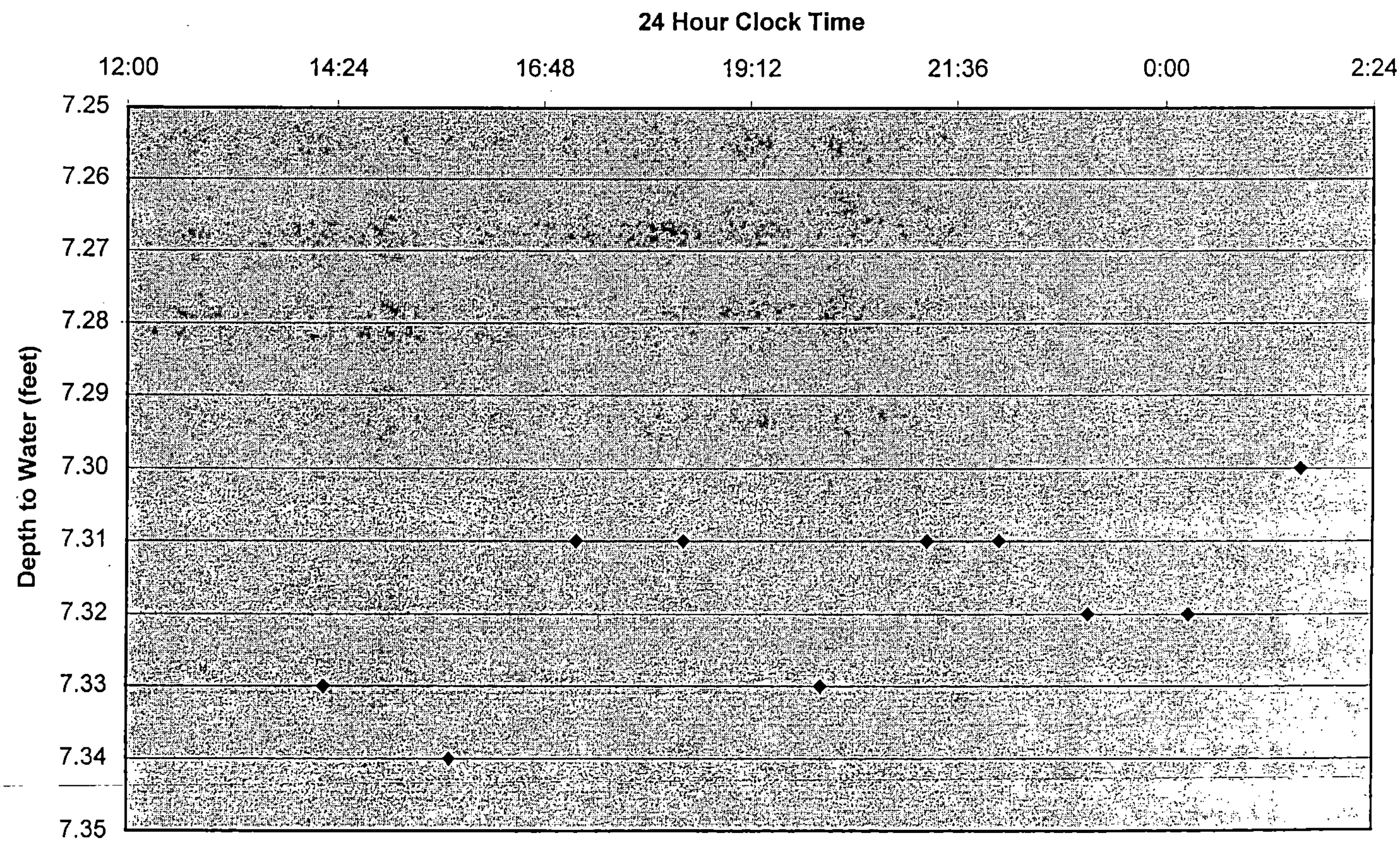


24 Hour Clock Time
14:24
16:48
19:12
21:36
0:00
2:24
4:48
Depth to Water (feet)
6.0
6.2
6.4
6.6
6.8
7.0
7.2
7.4
7.6
7.8
8.0

RMW-7D

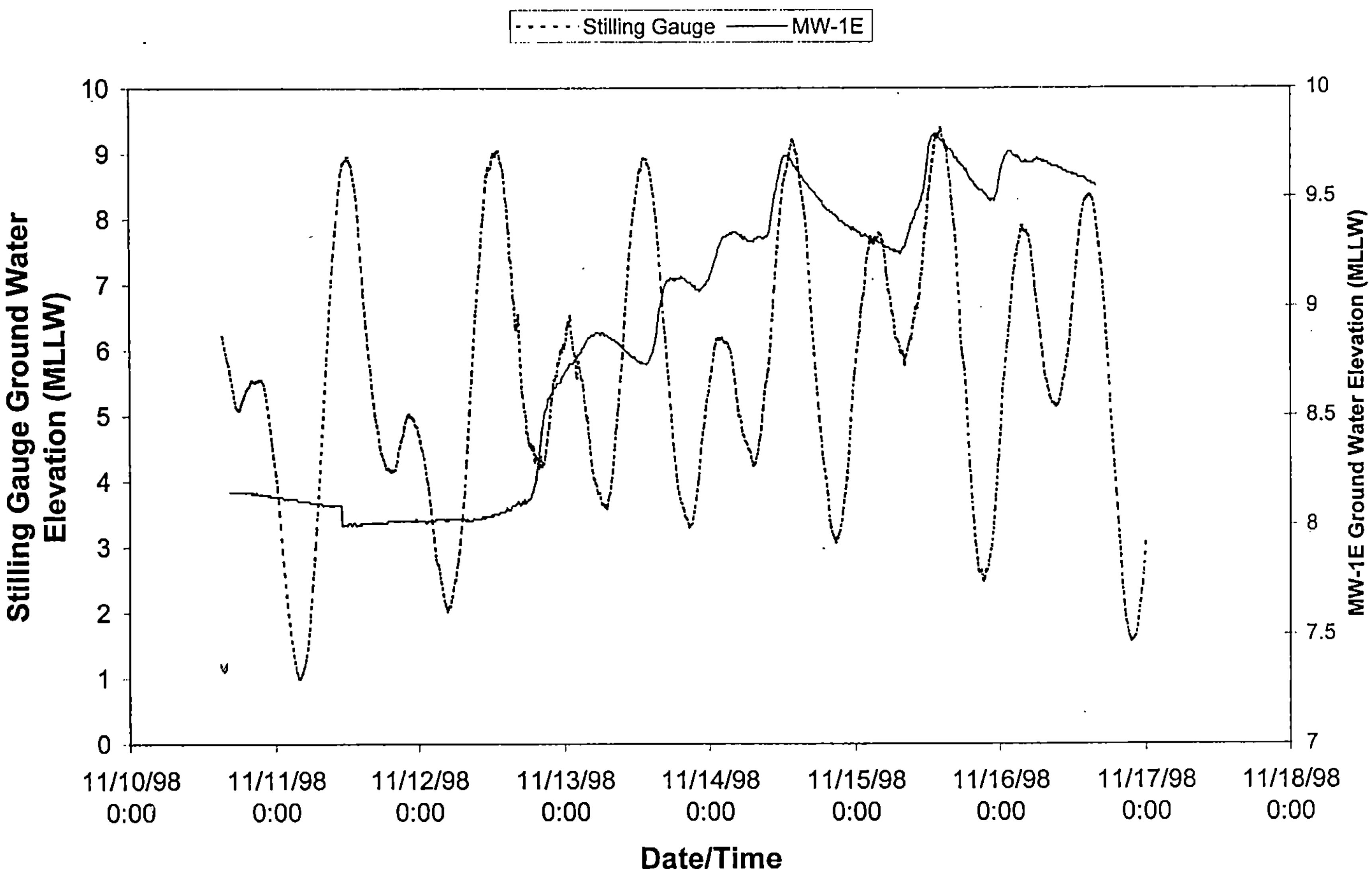

24 Hour Clock Time
14:24
16:48
19:12
21:36
0:00
2:24
4:48
6.50
7.00
7.50
8.00
8.50
9.00
9.50
10.00
10.50
Depth to Water (feet)

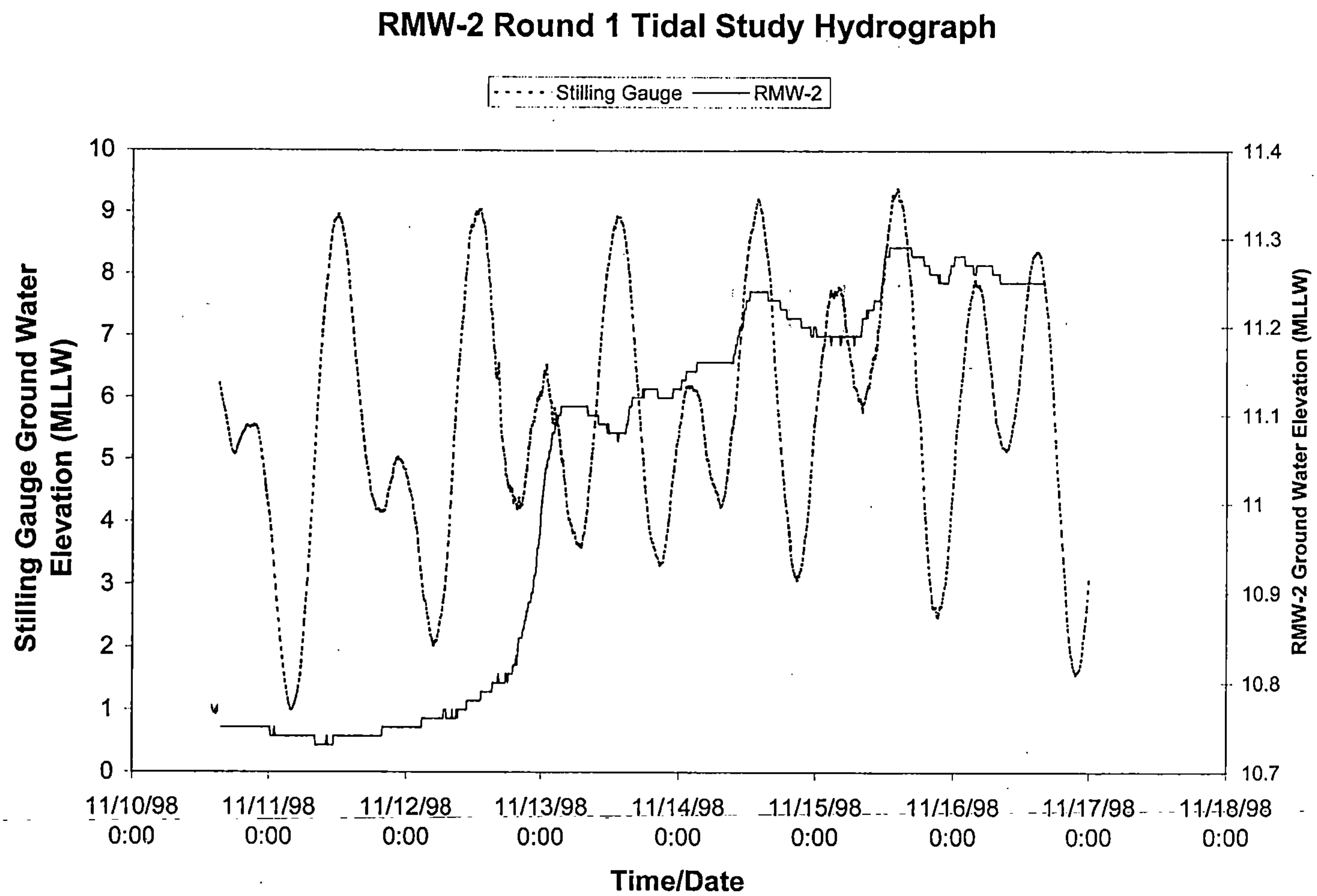
RMW-9


24 Hour Clock Time
12:00
14:24
16:48
19:12
21:36
0:00
2:24
Depth to Water (feet)
7.25
7.26
7.27
7.28
7.29
7.30
7.31
7.32
7.33
7.34
7.35

Round 1 Tidal Study Hydrographs

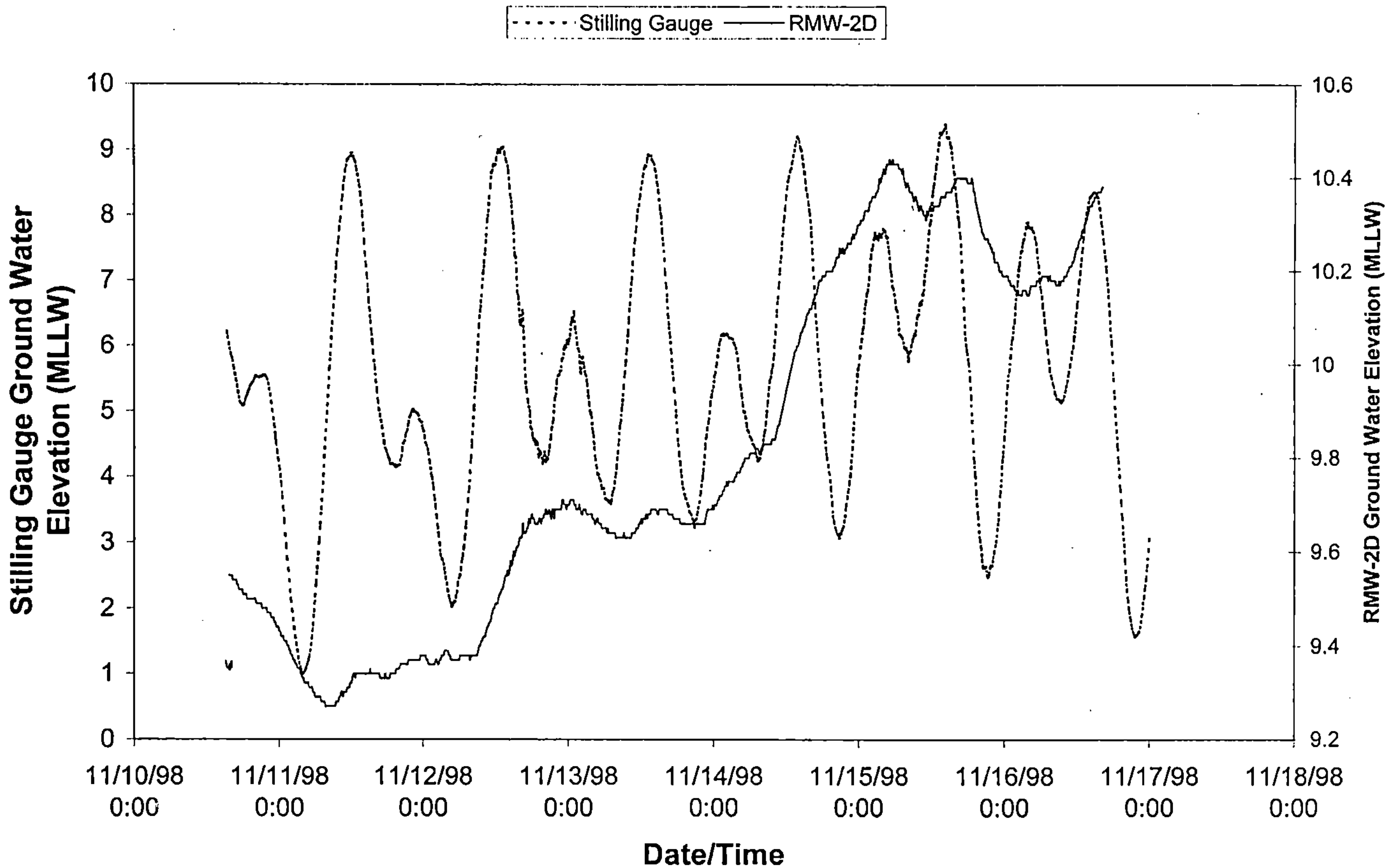
MW-1E Round 1 Tidal Study Hydrograph

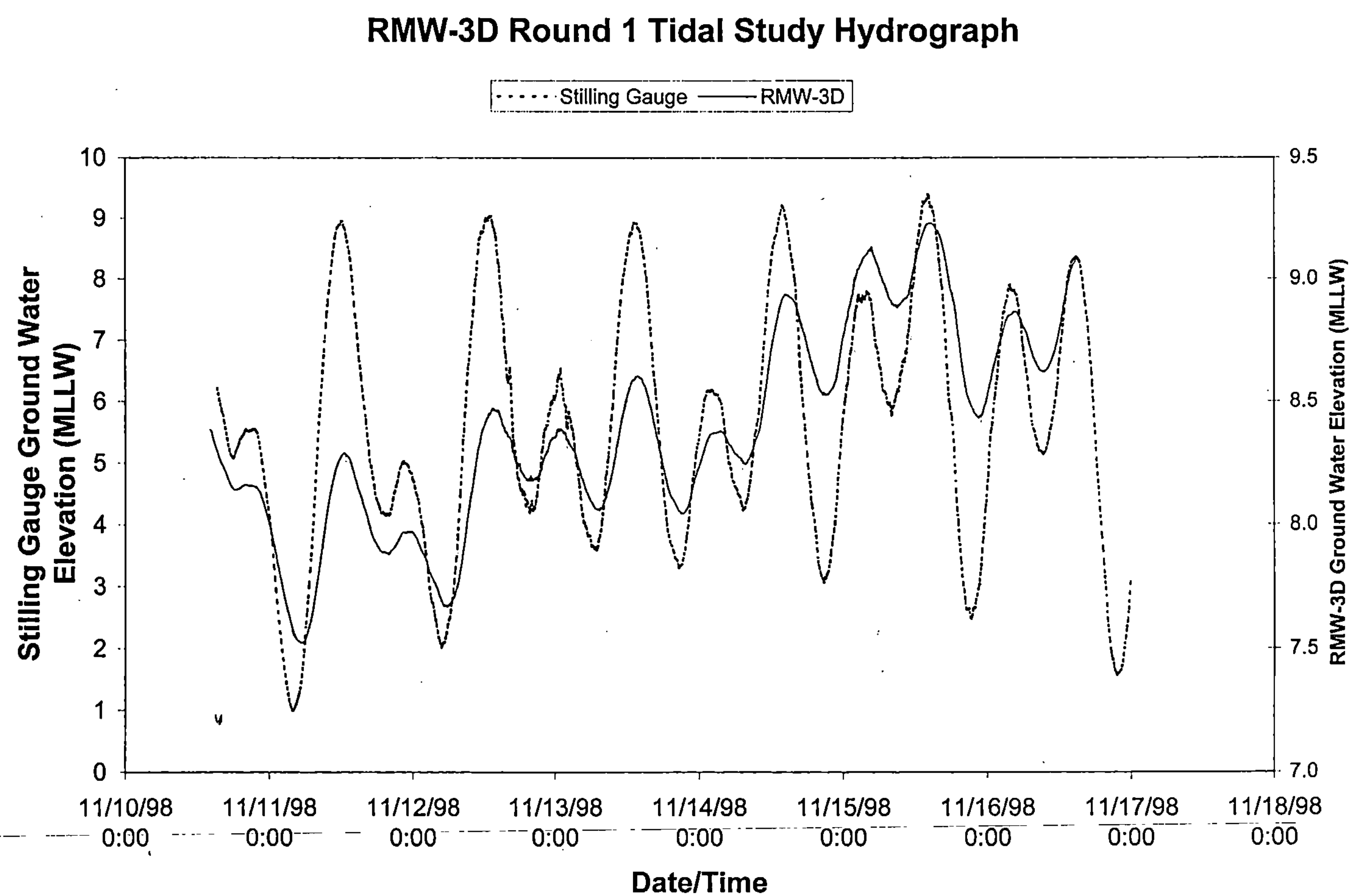


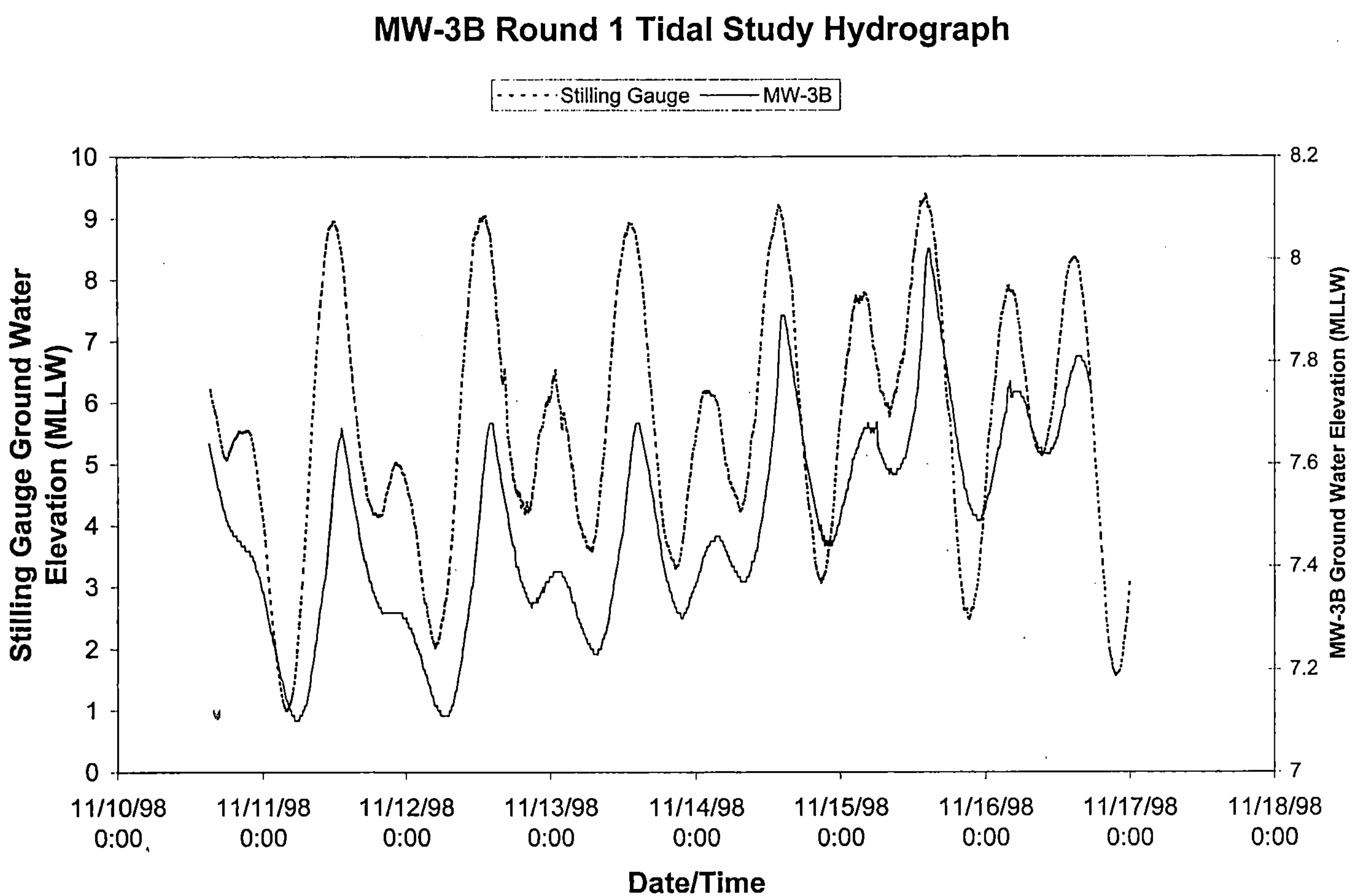


RMW-2 Round 1 Tidal Study Hydrograph
Stilling Gauge
RMW-2
Stilling Gauge Ground Water Elevation (MLLW)
RMW-2 Ground Water Elevation (MLLW)
10
9
8
7
6
5
4
3
2
1
0
11.4
11.3
11.2
11.1
11
10.9
10.8
10.7
11/10/98 0:00
11/11/98 0:00
11/12/98 0:00
11/13/98 0:00
11/14/98 0:00
11/15/98 0:00
11/16/98 0:00
11/17/98 0:00
11/18/98 0:00
Time/Date

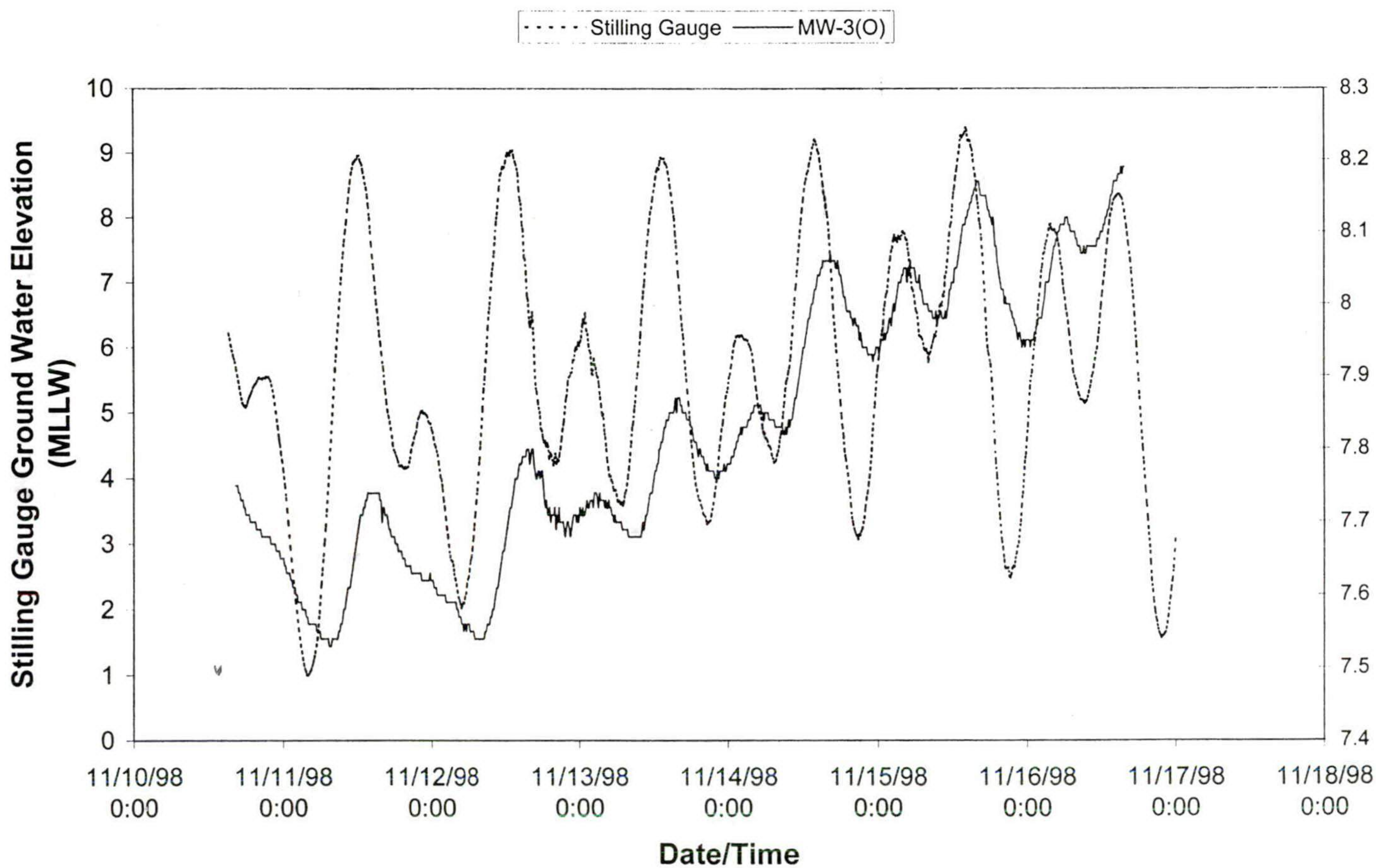
RMW-2D Round 1 Tidal Study Hydrograph



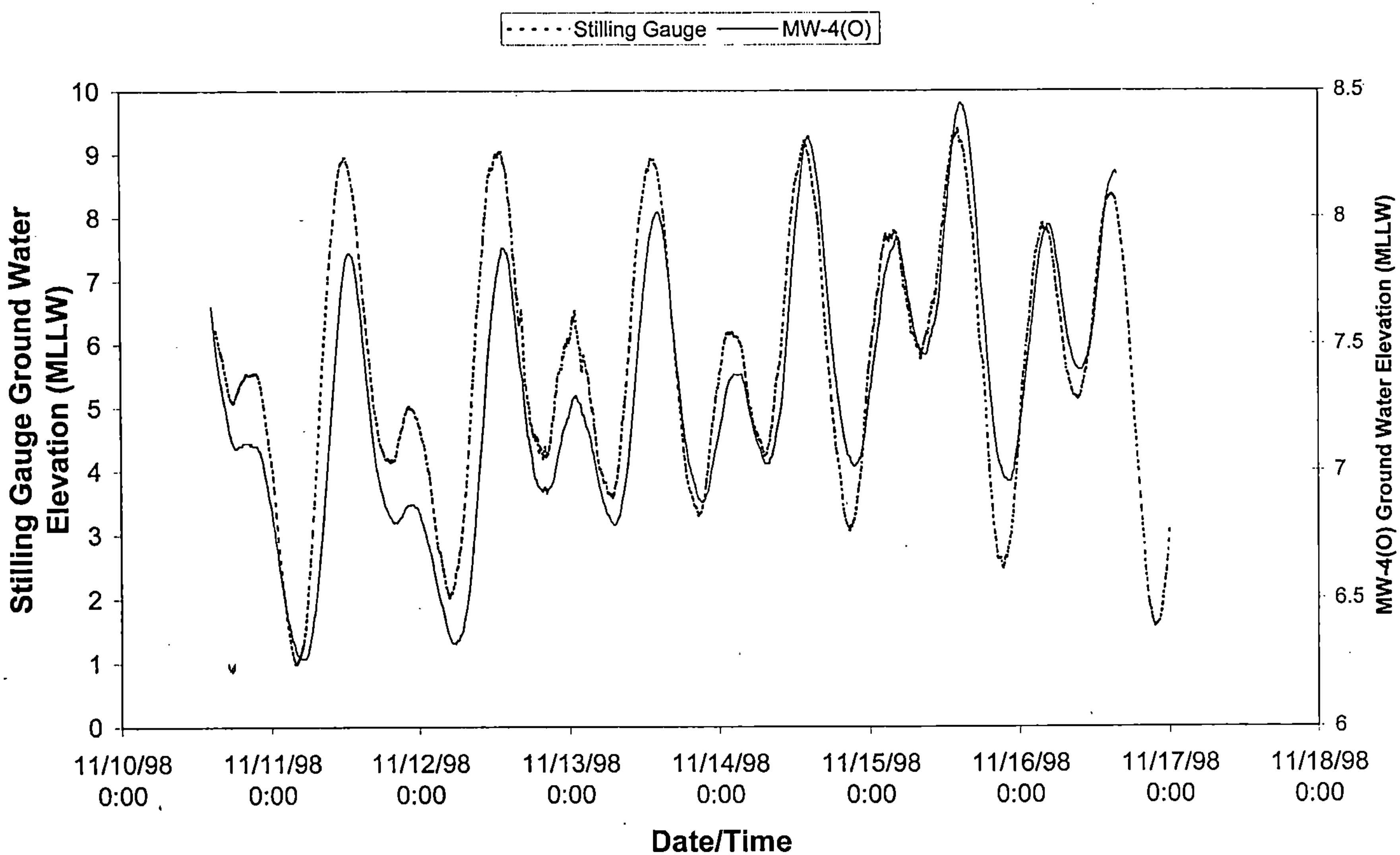

RMW-3D Round 1 Tidal Study Hydrograph
Stilling Gauge
RMW-3D
Stilling Gauge Ground Water Elevation (MLLW)
RMW-3D Ground Water Elevation (MLLW)
0
1
2
3
4
5
6
7
8
9
10
7.0
7.5
8.0
8.5
9.0
9.5
11/10/98 0:00
11/11/98 0:00
11/12/98 0:00
11/13/98 0:00
11/14/98 0:00
11/15/98 0:00
11/16/98 0:00
11/17/98 0:00
11/18/98 0:00
Date/Time

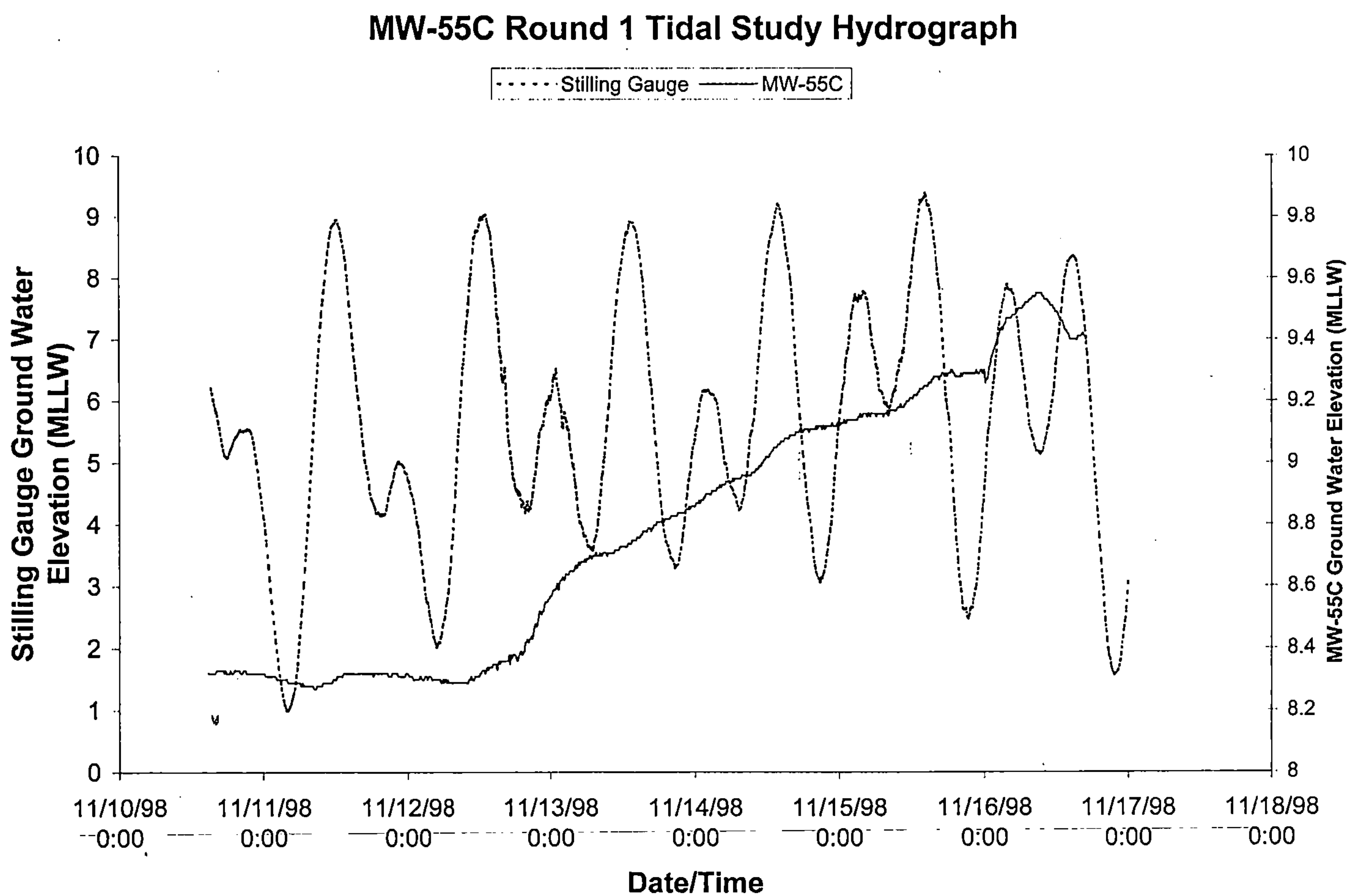

MW-3B Round 1 Tidal Study Hydrograph
Stilling Gauge
MW-3B
Stilling Gauge Ground Water Elevation (MLLW)
MW-3B Ground Water Elevation (MLLW)
10
9
8
7
6
5
4
3
2
1
0
8.2
8
7.8
7.6
7.4
7.2
7
11/10/98 0:00
11/11/98 0:00
11/12/98 0:00
11/13/98 0:00
11/14/98 0:00
11/15/98 0:00
11/16/98 0:00
11/17/98 0:00
11/18/98 0:00
Date/Time

MW-3(O) Round 1 Tidal Study Hydrograph



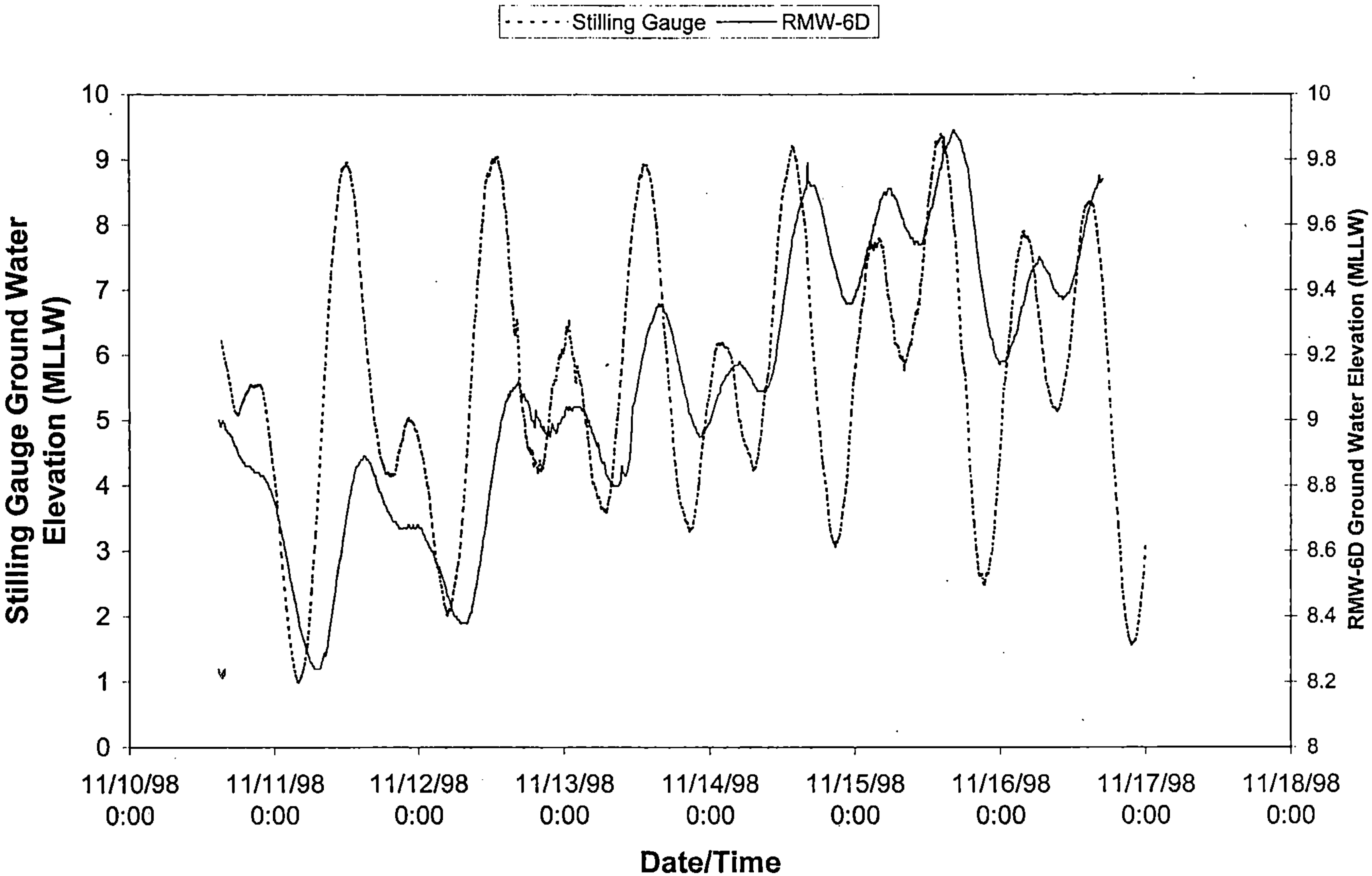
MW-4(O) Round 1 Tidal Study Hydrograph



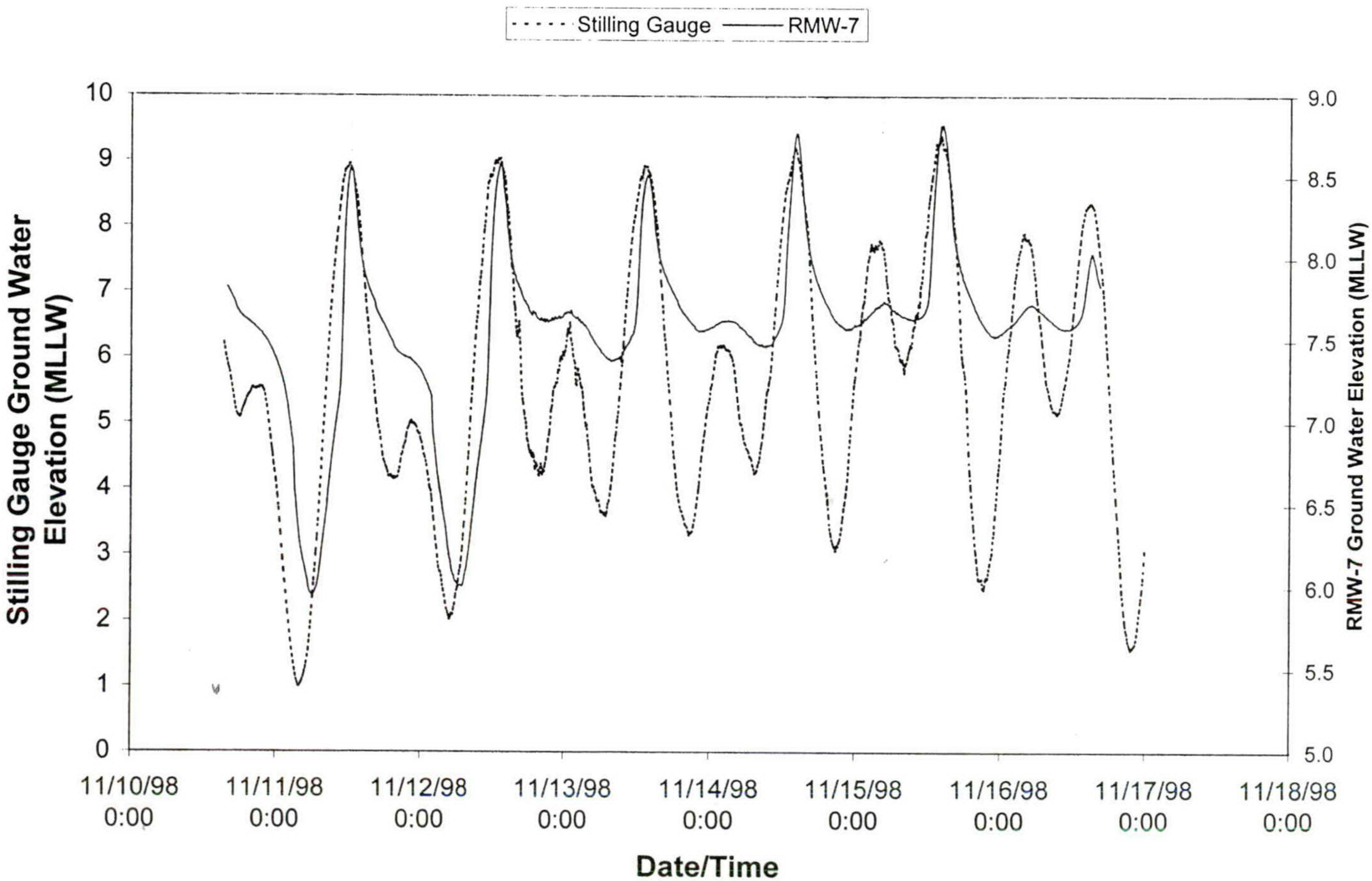


MW-55C Round 1 Tidal Study Hydrograph
Stilling Gauge
MW-55C
Stilling Gauge Ground Water Elevation (MLLW)
MW-55C Ground Water Elevation (MLLW)
0
1
2
3
4
5
6
7
8
9
10
8
8.2
8.4
8.6
8.8
9
9.2
9.4
9.6
9.8
10
11/10/98 0:00
11/11/98 0:00
11/12/98 0:00
11/13/98 0:00
11/14/98 0:00
11/15/98 0:00
11/16/98 0:00
11/17/98 0:00
11/18/98 0:00
Date/Time

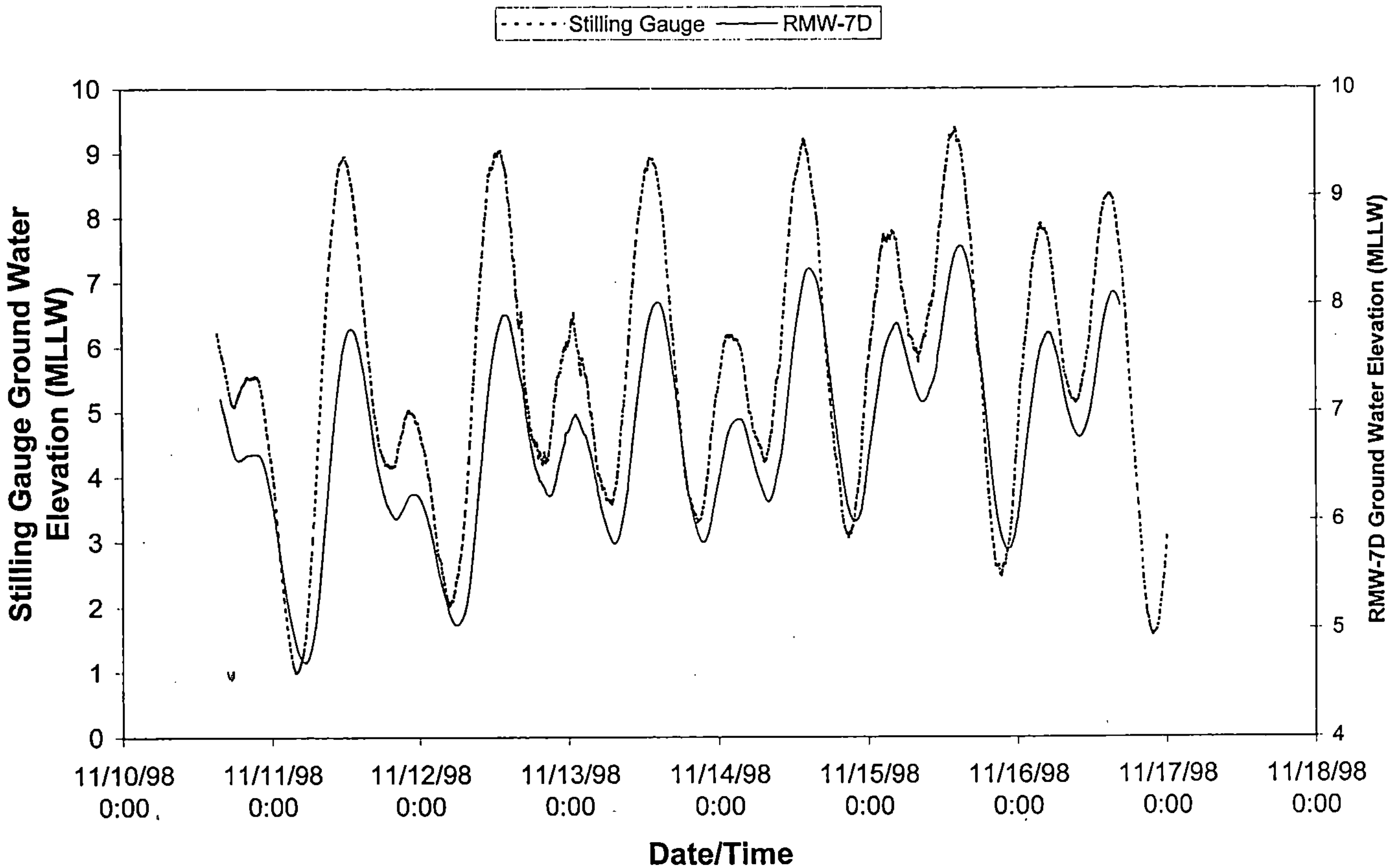
RMW-6D Round 1 Tidal Study Hydrograph

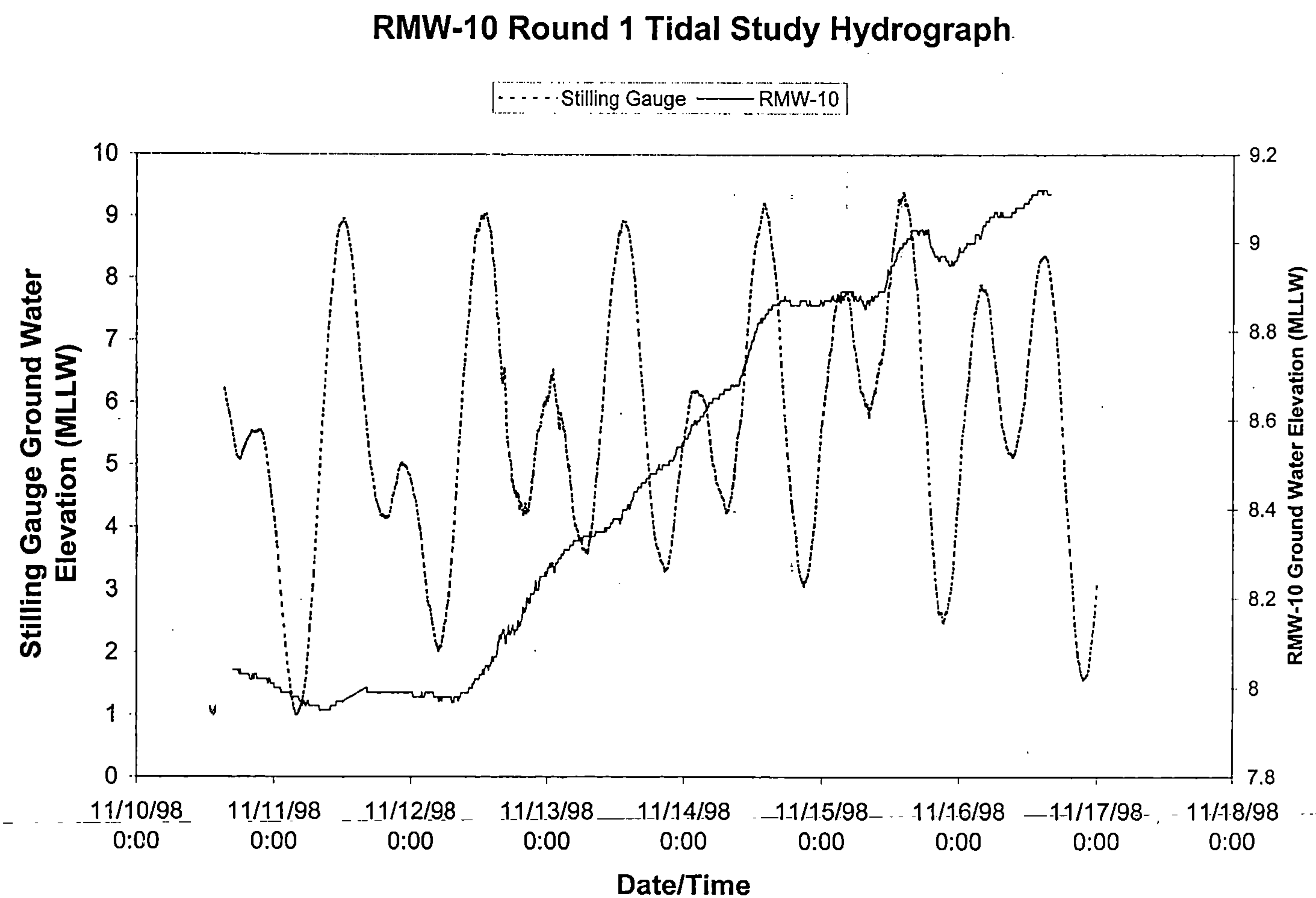


RMW-7 Round 1 Tidal Study Hydrograph

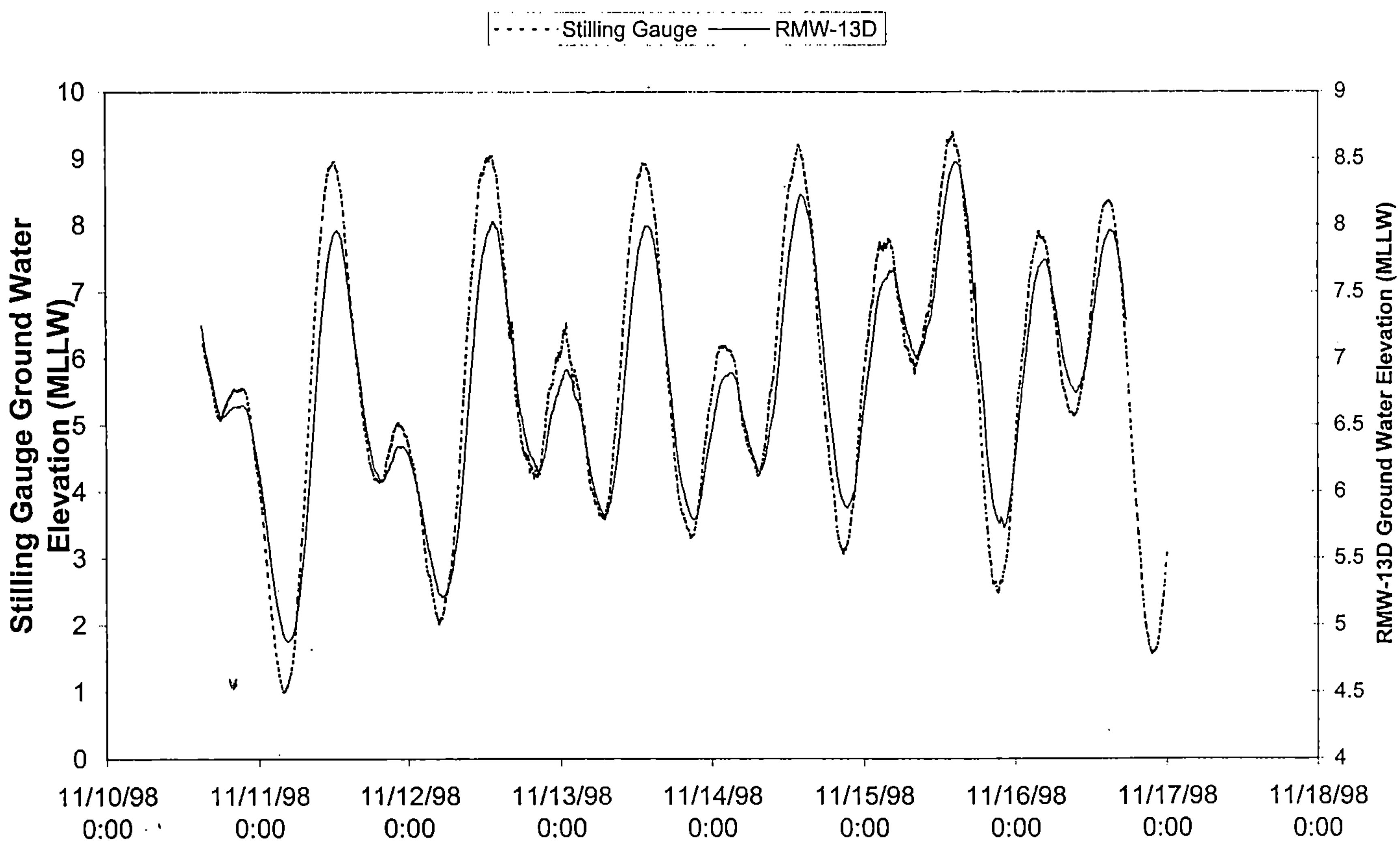


RMW-7D Round 1 Tidal Study Hydrograph

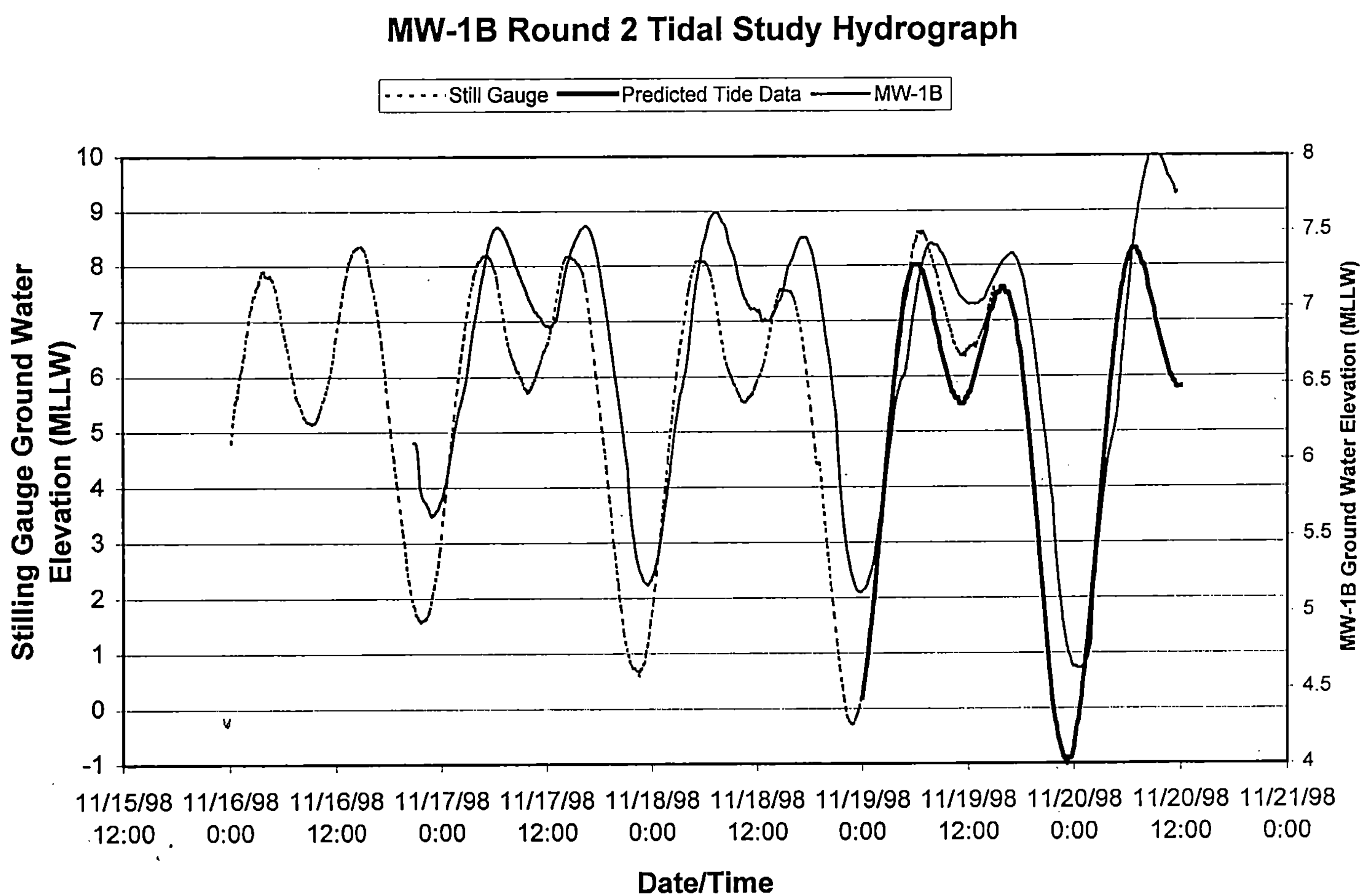


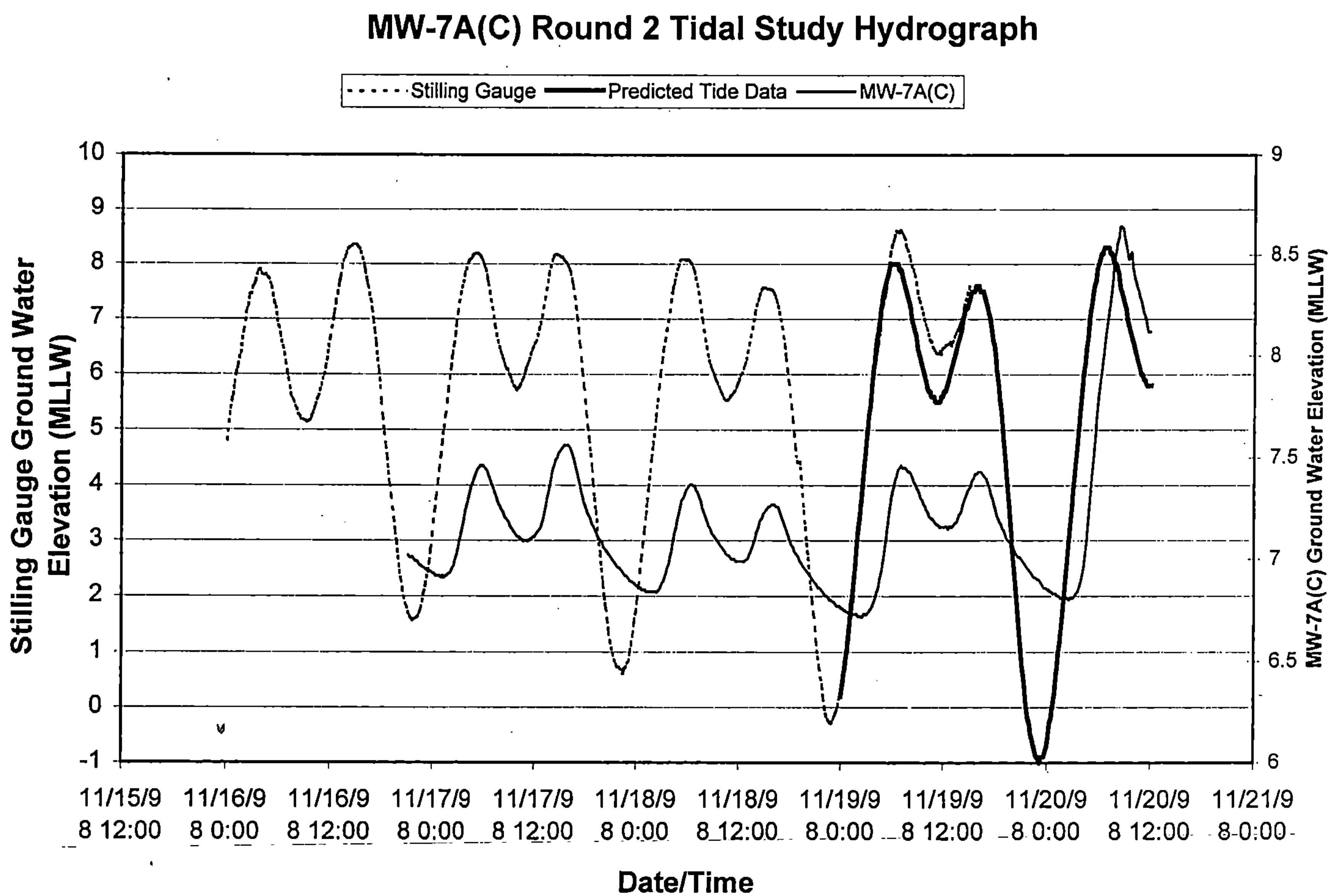

RMW-10 Round 1 Tidal Study Hydrograph
Stilling Gauge
RMW-10
Stilling Gauge Ground Water Elevation (MLLW)
RMW-10 Ground Water Elevation (MLLW)
0
1
2
3
4
5
6
7
8
9
10
7.8
8
8.2
8.4
8.6
8.8
9
9.2
11/10/98 0:00
11/11/98 0:00
11/12/98 0:00
11/13/98 0:00
11/14/98 0:00
11/15/98 0:00
11/16/98 0:00
11/17/98 0:00
11/18/98 0:00
Date/Time

RMW-13D Round 1 Tidal Study Hydrograph

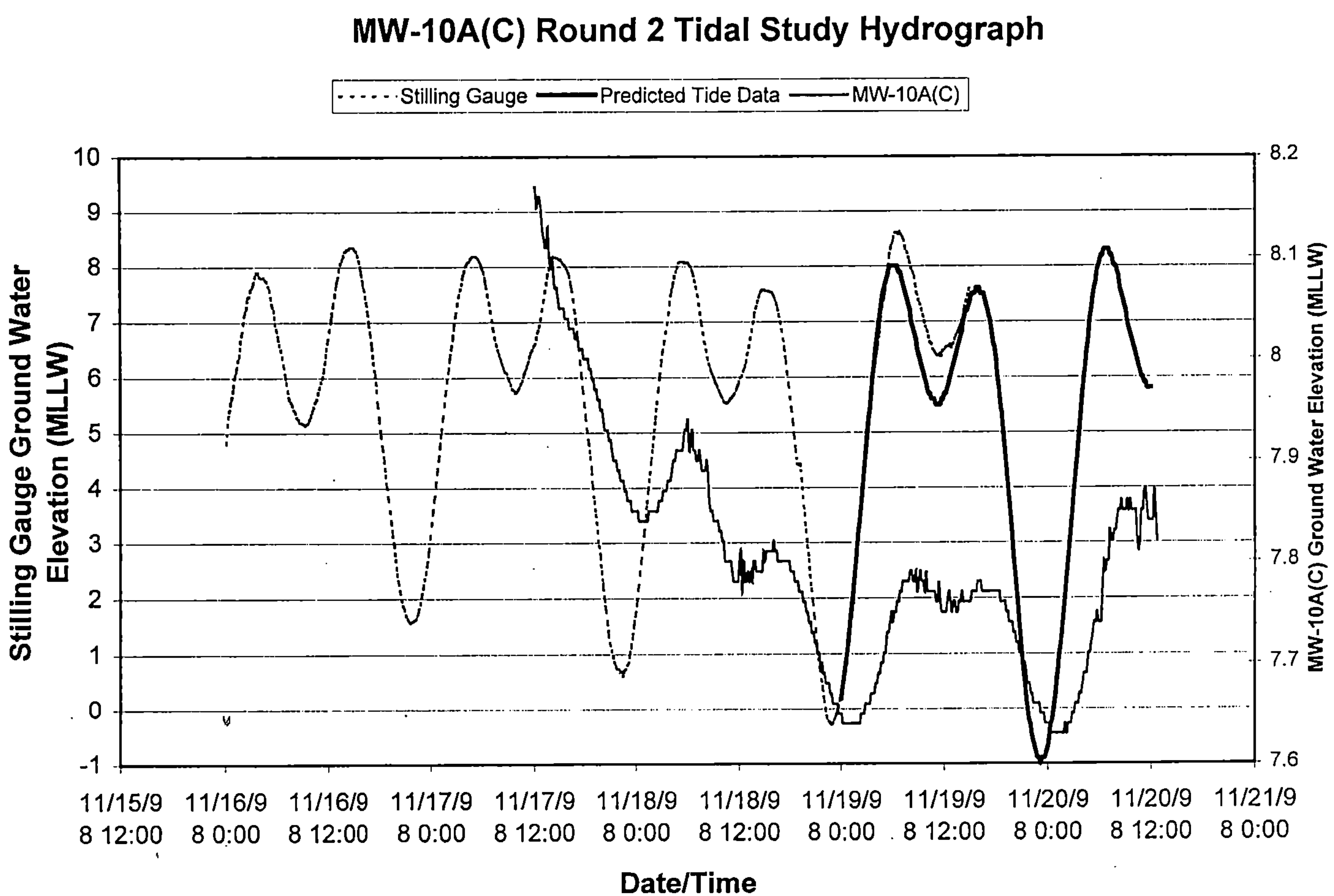


Round 2 Tidal Study Hydrographs

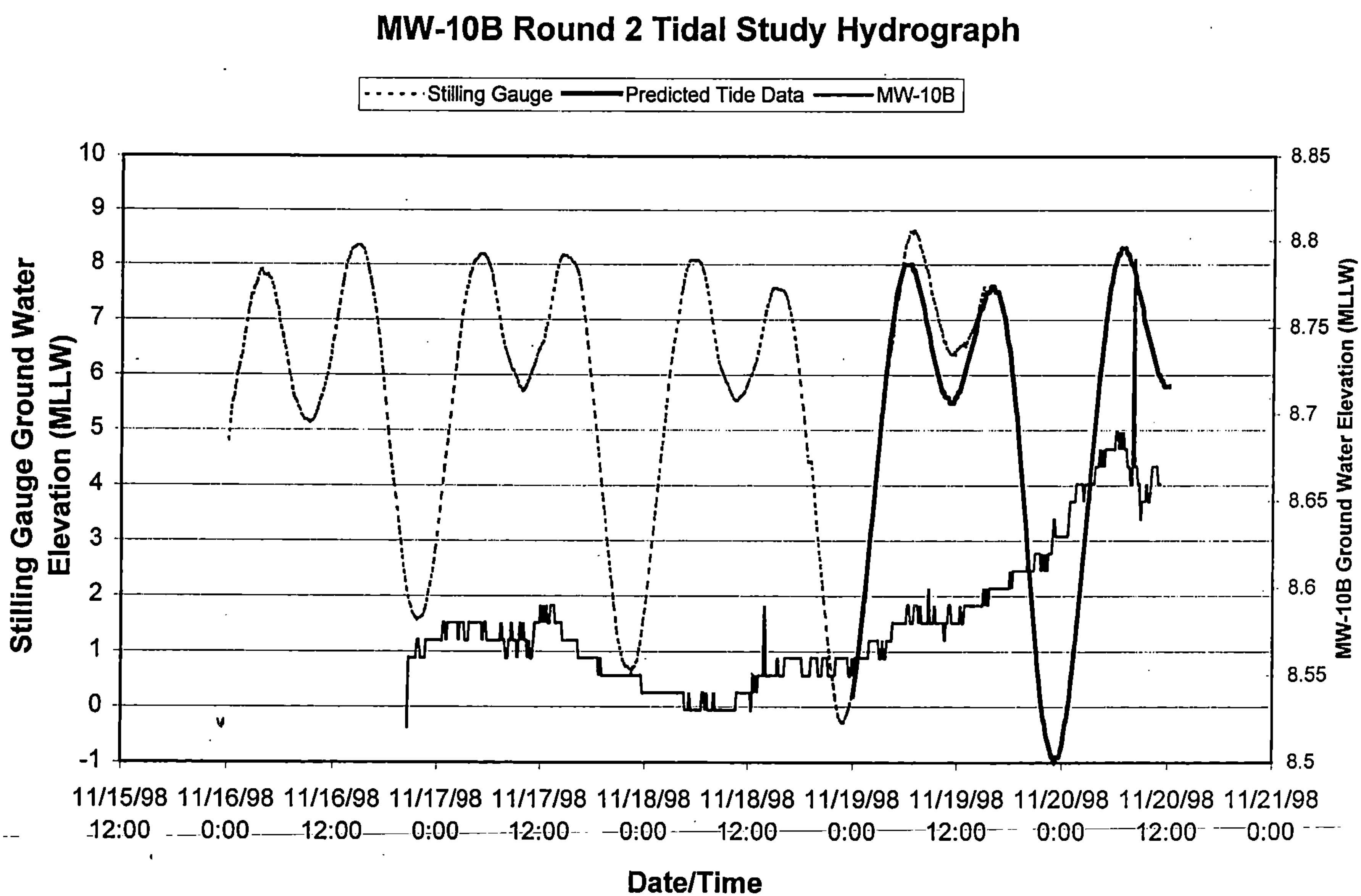

MW-1B Round 2 Tidal Study Hydrograph
Still Gauge
Predicted Tide Data
MW-1B
Stilling Gauge Ground Water Elevation (MLLW)
MW-1B Ground Water Elevation (MLLW)
10
9
8
7
6
5
4
3
2
1
0
-1
8
7.5
7
6.5
6
5.5
5
4.5
4
11/15/98 12:00
11/16/98 0:00
11/16/98 12:00
11/17/98 0:00
11/17/98 12:00
11/18/98 0:00
11/18/98 12:00
11/19/98 0:00
11/19/98 12:00
11/20/98 0:00
11/20/98 12:00
11/21/98 0:00
Date/Time



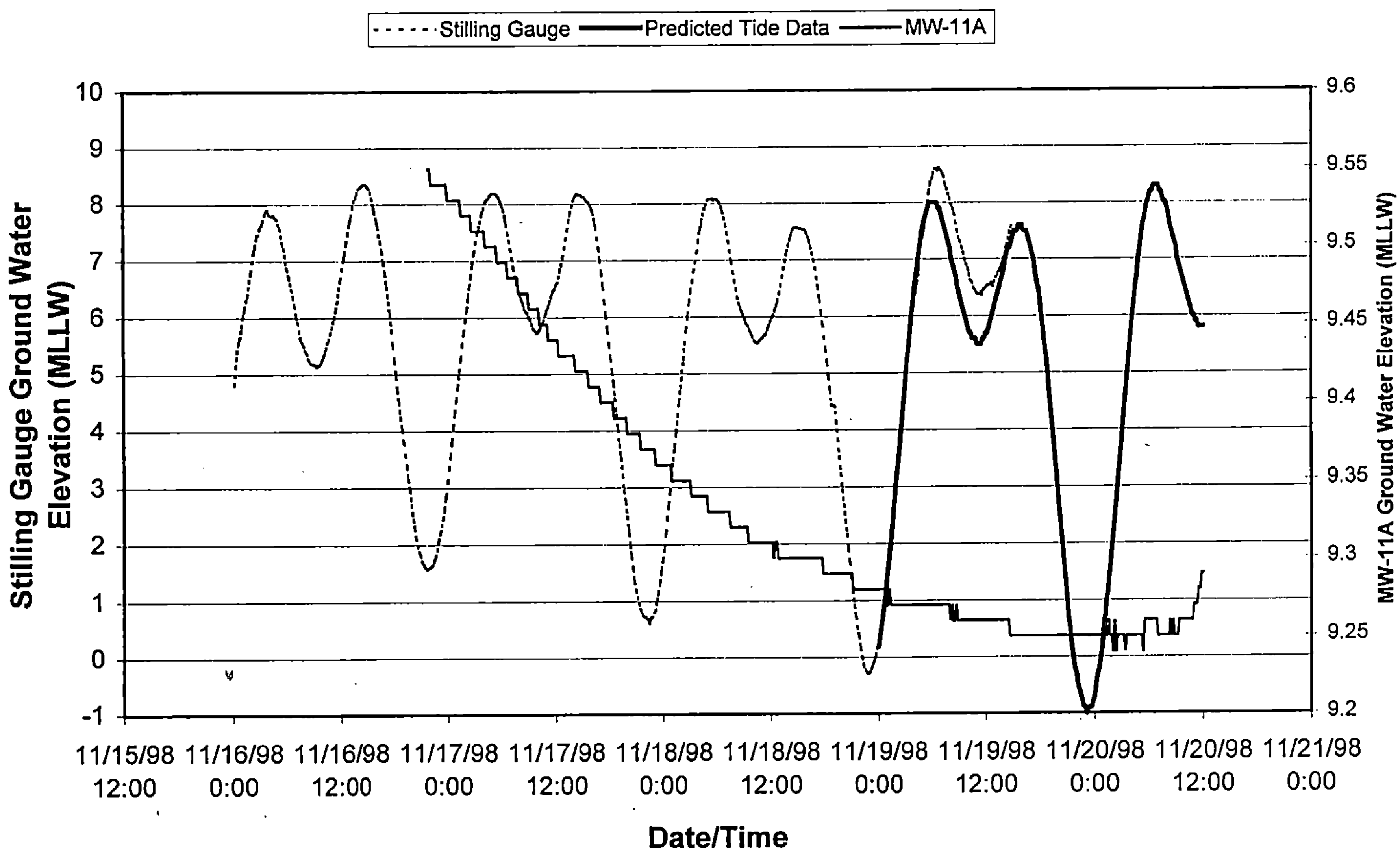
MW-7A(C) Round 2 Tidal Study Hydrograph
Stilling Gauge
Predicted Tide Data
MW-7A(C)
Stilling Gauge Ground Water Elevation (MLLW)
MW-7A(C) Ground Water Elevation (MLLW)
10
9
8
7
6
5
4
3
2
1
0
-1
8.5
8
7.5
7
6.5
6
11/15/9 8 12:00
11/16/9 8 0:00
11/16/9 8 12:00
11/17/9 8 0:00
11/17/9 8 12:00
11/18/9 8 0:00
11/18/9 8 12:00
11/19/9 8 0:00
11/19/9 8 12:00
11/20/9 8 0:00
11/20/9 8 12:00
11/21/9 8 0:00
Date/Time

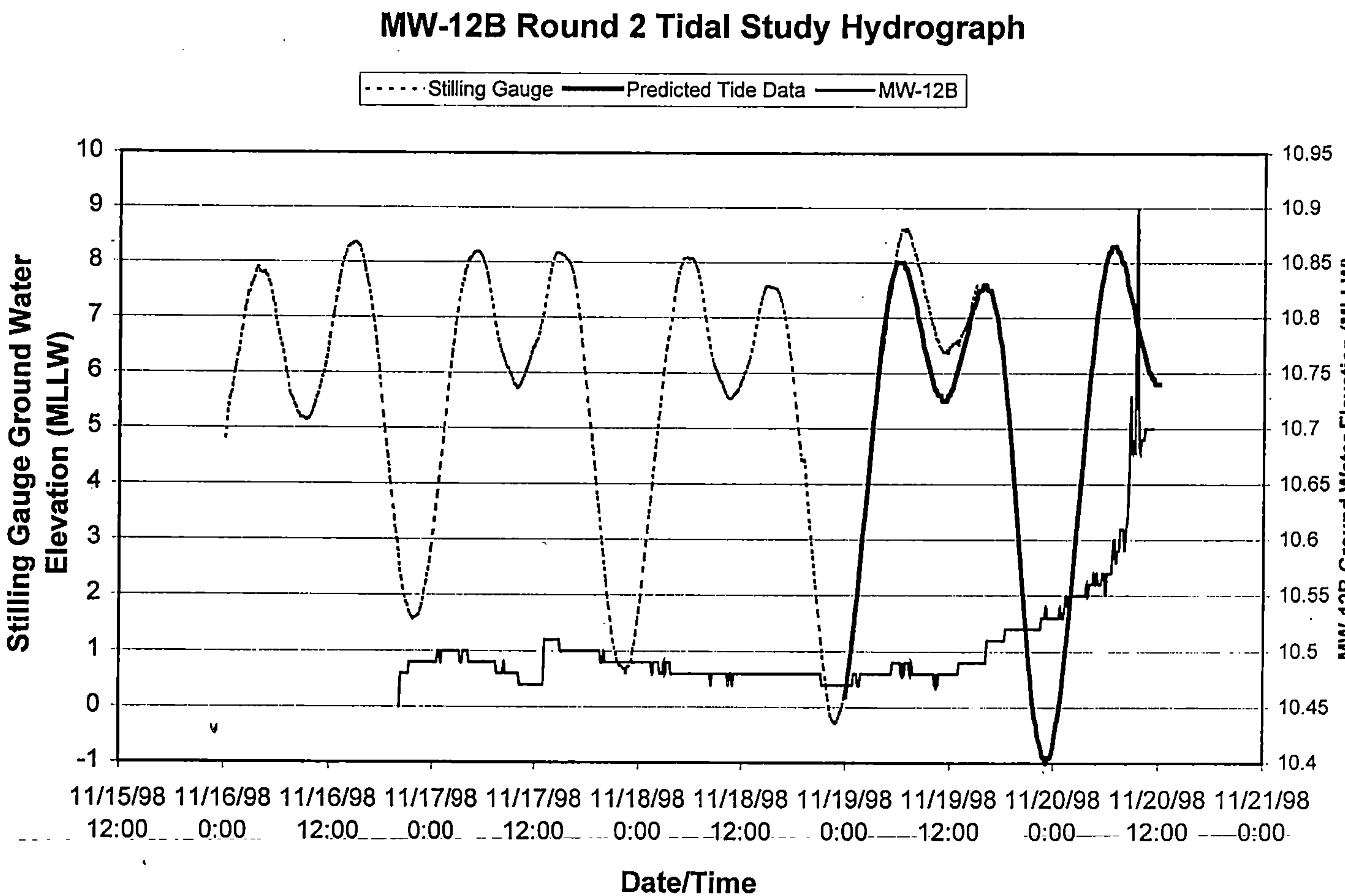


MW-10A(C) Round 2 Tidal Study Hydrograph
Stilling Gauge
Predicted Tide Data
MW-10A(C)
Stilling Gauge Ground Water Elevation (MLLW)
MW-10A(C) Ground Water Elevation (MLLW)
10
9
8
7
6
5
4
3
2
1
0
-1
8.2
8.1
8
7.9
7.8
7.7
7.6
11/15/9 8 12:00
11/16/9 8 0:00
11/16/9 8 12:00
11/17/9 8 0:00
11/17/9 8 12:00
11/18/9 8 0:00
11/18/9 8 12:00
11/19/9 8 0:00
11/19/9 8 12:00
11/20/9 8 0:00
11/20/9 8 12:00
11/21/9 8 0:00
Date/Time


MW-10B Round 2 Tidal Study Hydrograph
Stilling Gauge
Predicted Tide Data
MW-10B
Stilling Gauge Ground Water Elevation (MLLW)
MW-10B Ground Water Elevation (MLLW)
10
9
8
7
6
5
4
3
2
1
0
-1
8.85
8.8
8.75
8.7
8.65
8.6
8.55
8.5
11/15/98 12:00
11/16/98 0:00
11/16/98 12:00
11/17/98 0:00
11/17/98 12:00
11/18/98 0:00
11/18/98 12:00
11/19/98 0:00
11/19/98 12:00
11/20/98 0:00
11/20/98 12:00
11/21/98 0:00
Date/Time

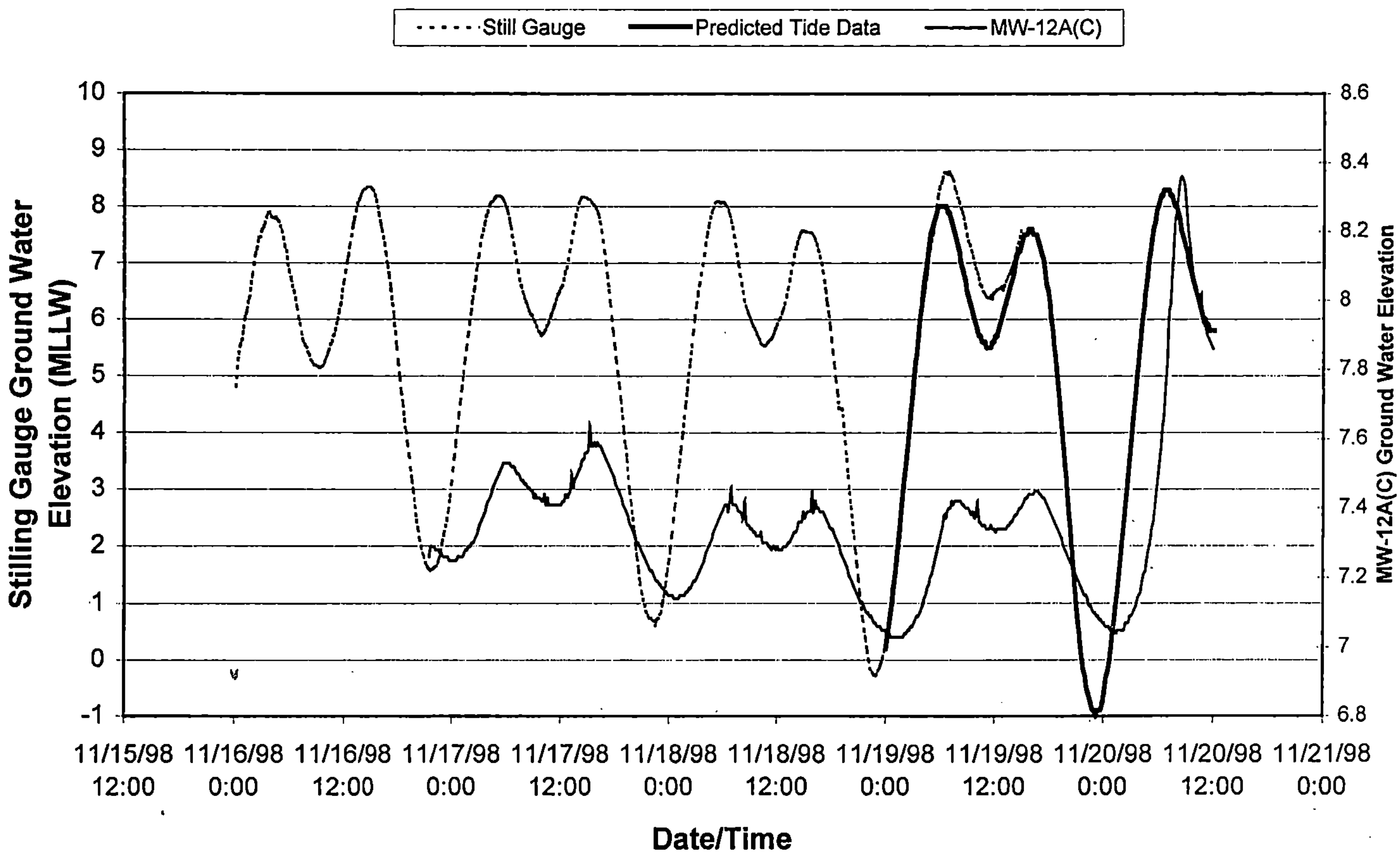
MW-11A Round 2 Tidal Study Hydrograph

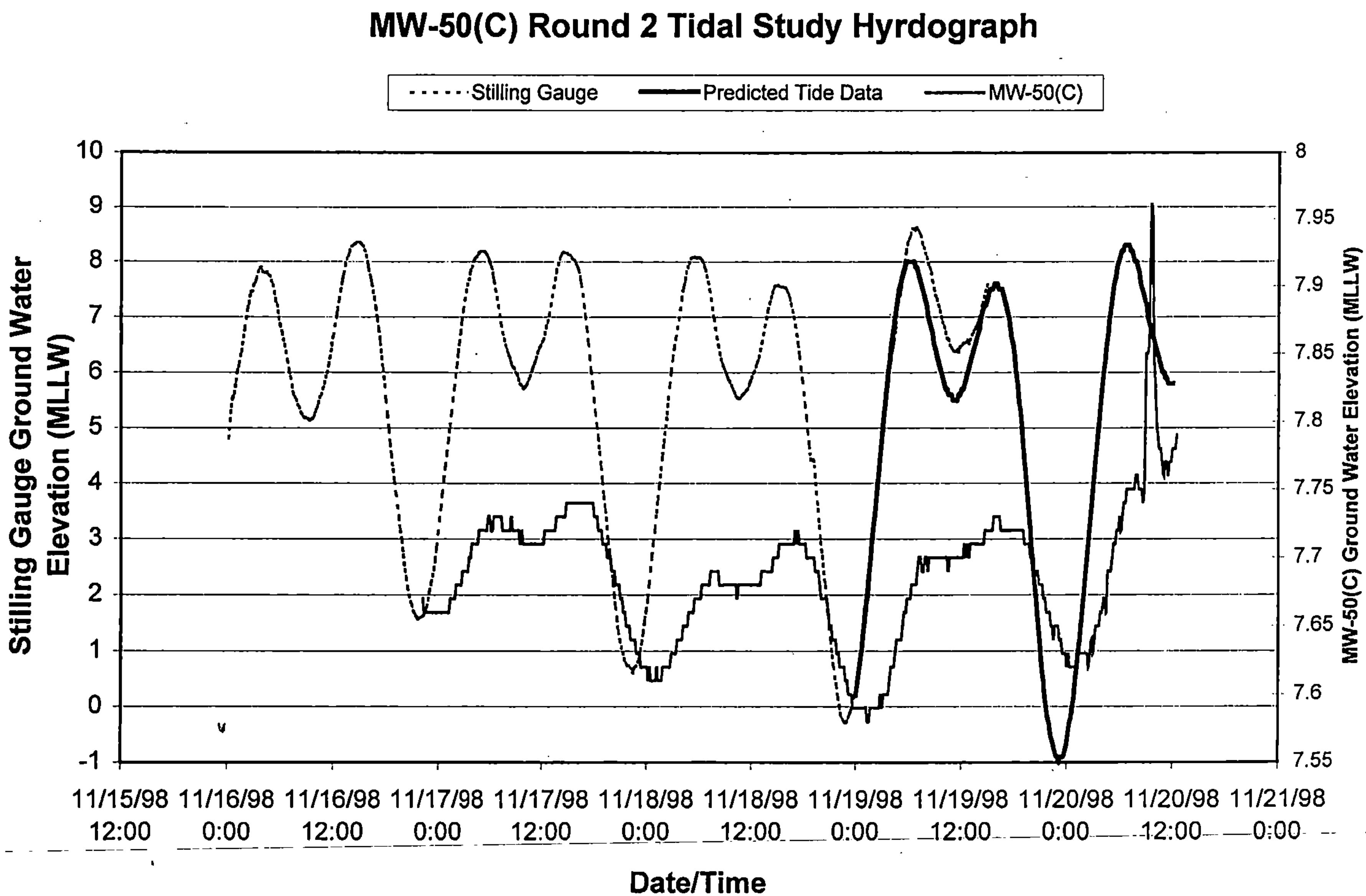


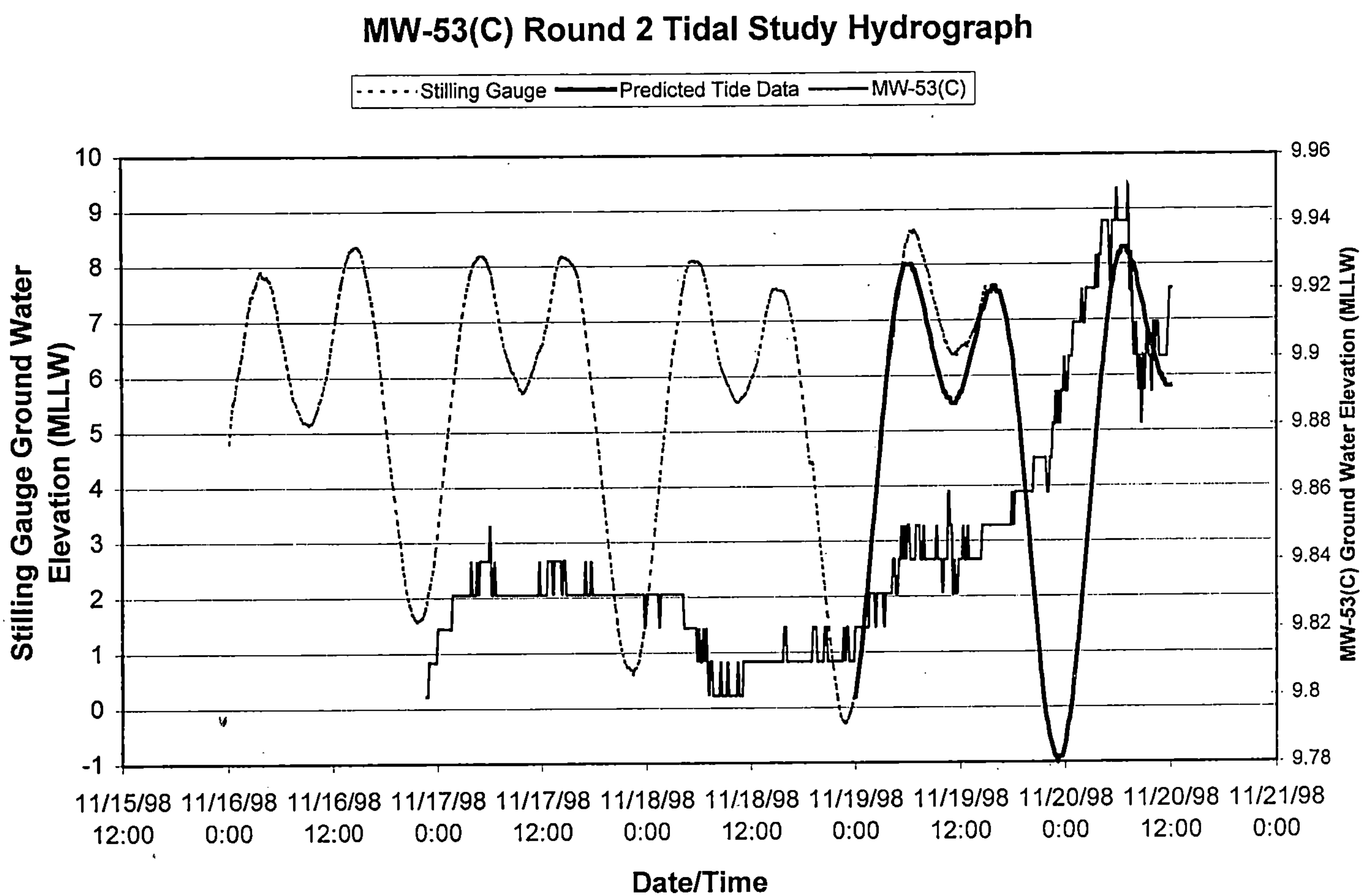


MW-12B Round 2 Tidal Study Hydrograph
Stilling Gauge
Predicted Tide Data
MW-12B
10
9
8
7
6
5
4
3
2
1
0
-1
Stilling Gauge Ground Water Elevation (MLLW)
10.95
10.9
10.85
10.8
10.75
10.7
10.65
10.6
10.55
10.5
10.45
10.4
MW-12B Ground Water Elevation (MLLW)
11/15/98 12:00
11/16/98 0:00
11/16/98 12:00
11/17/98 0:00
11/17/98 12:00
11/18/98 0:00
11/18/98 12:00
11/19/98 0:00
11/19/98 12:00
11/20/98 0:00
11/20/98 12:00
11/21/98 0:00
Date/Time

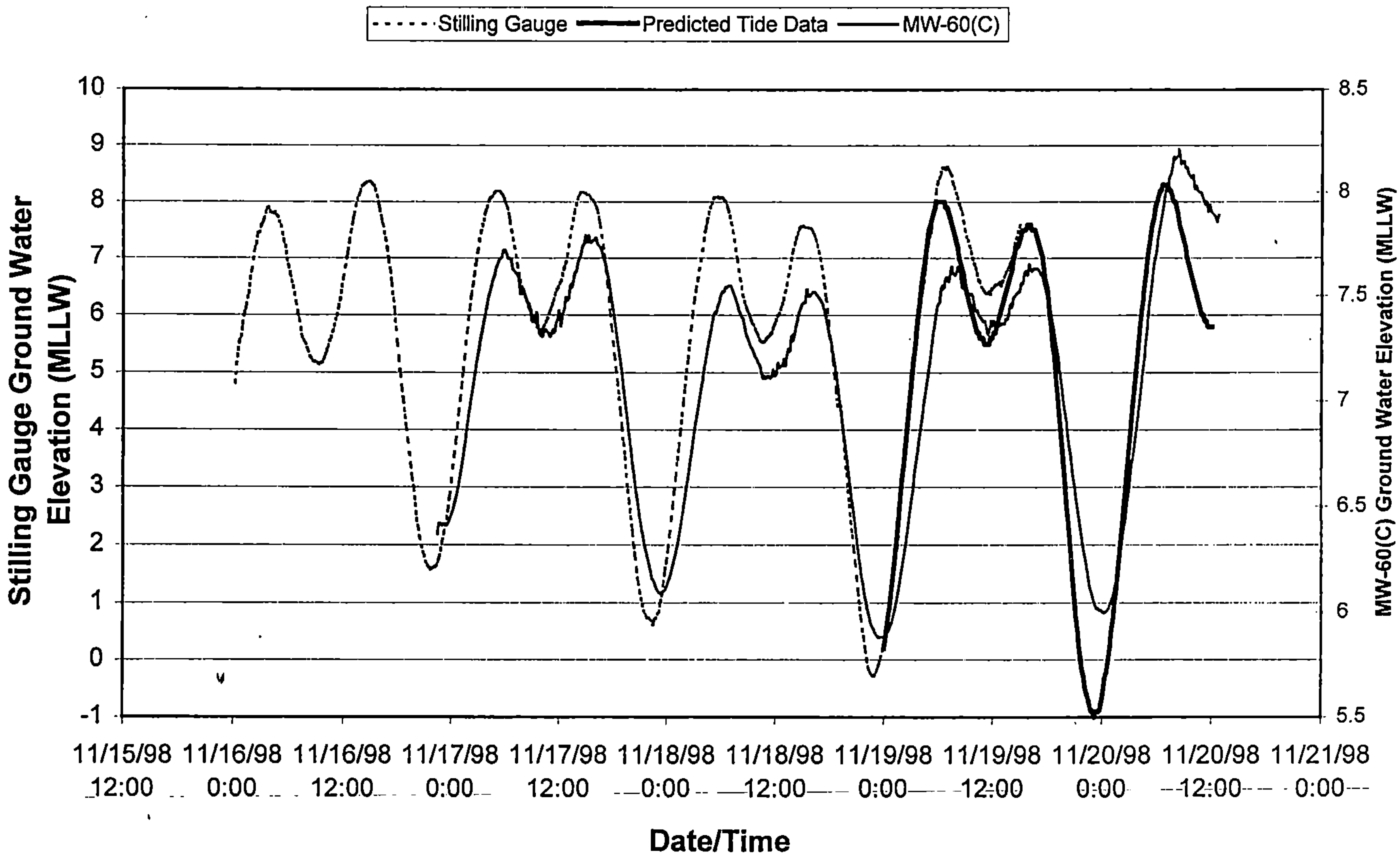
MW-12A(C) Round 2 Tidal Study Hydrograph




MW-50(C) Round 2 Tidal Study Hyrdograph
Stilling Gauge
Predicted Tide Data
MW-50(C)
Stilling Gauge Ground Water Elevation (MLLW)
MW-50(C) Ground Water Elevation (MLLW)
10
9
8
7
6
5
4
3
2
1
0
-1
8
7.95
7.9
7.85
7.8
7.75
7.7
7.65
7.6
7.55
11/15/98 12:00
11/16/98 0:00
11/16/98 12:00
11/17/98 0:00
11/17/98 12:00
11/18/98 0:00
11/18/98 12:00
11/19/98 0:00
11/19/98 12:00
11/20/98 0:00
11/20/98 12:00
11/21/98 0:00
Date/Time


MW-53(C) Round 2 Tidal Study Hydrograph
Stilling Gauge
Predicted Tide Data
MW-53(C)
Stilling Gauge Ground Water Elevation (MLLW)
MW-53(C) Ground Water Elevation (MLLW)
10
9
8
7
6
5
4
3
2
1
0
-1
9.96
9.94
9.92
9.9
9.88
9.86
9.84
9.82
9.8
9.78
11/15/98 12:00
11/16/98 0:00
11/16/98 12:00
11/17/98 0:00
11/17/98 12:00
11/18/98 0:00
11/18/98 12:00
11/19/98 0:00
11/19/98 12:00
11/20/98 0:00
11/20/98 12:00
11/21/98 0:00
Date/Time

MW-60(C) Round 2 Tidal Study Hydrograph



Slug Test Plots

Slug Test Methods and Data

Slug tests were performed on 25 monitoring wells to estimate hydraulic conductivity in the shallow and deep portions of the aquifer. Refer to Table B-1 for a list of wells tested. Most of the wells were slug tested by removing 1.4 quarts of water with a disposable bailer and measuring the rise in head with time. Some wells were slug tested using a prefabricated PVC slug displacing 2 feet of water in the well casing and measuring the rise or fall in head with time. Rising head slug tests were performed on all wells slug tested using a bailer or the prefabricated PVC. Falling head slug tests were performed on selected monitor wells screened below the water table.

Slug Test Data Analysis

All slug tests are analyzed using the method of Bouwer and Rice (1976) (BR). The Bouwer and Rice method can be used to estimate hydraulic conductivity in unconfined aquifers if the following assumptions are met:

- Unconfined aquifer of infinite extent
- The aquifer is homogeneous and isotropic
- The water table is nearly horizontal over the area influenced by the test
- The head is lowered or raised instantaneously and drawdown around the well is negligible
- The well partially or fully penetrates the saturated thickness of the aquifer
- The well diameter is finite
- Flow to the well is in a steady state

Recorded values of head displacement are plotted on an arithmetic axis versus the corresponding time values plotted on a logarithmic axis. A straight line is fitted through the earlier time data and a point is chosen from the straight line. The values of head and time from the chosen point are noted and used to calculate hydraulic conductivity from the following equation:

$$K = \frac{r_c^2 \ln(R_e \div r_w)}{2l} \frac{1}{t} \ln \frac{h_0}{h_t}$$

where:

K = hydraulic conductivity (length/time)
r_c = well casing radius
R_e = radial distance from well over which the head change is dissipated in the aquifer
r_w = borehole radius or radius of aquifer disturbed by drilling
l = length of screen
t = time since start of slug test
h_0 = head displacement at time zero, the instant of slug injection or withdrawal
h_t = head displacement at time t

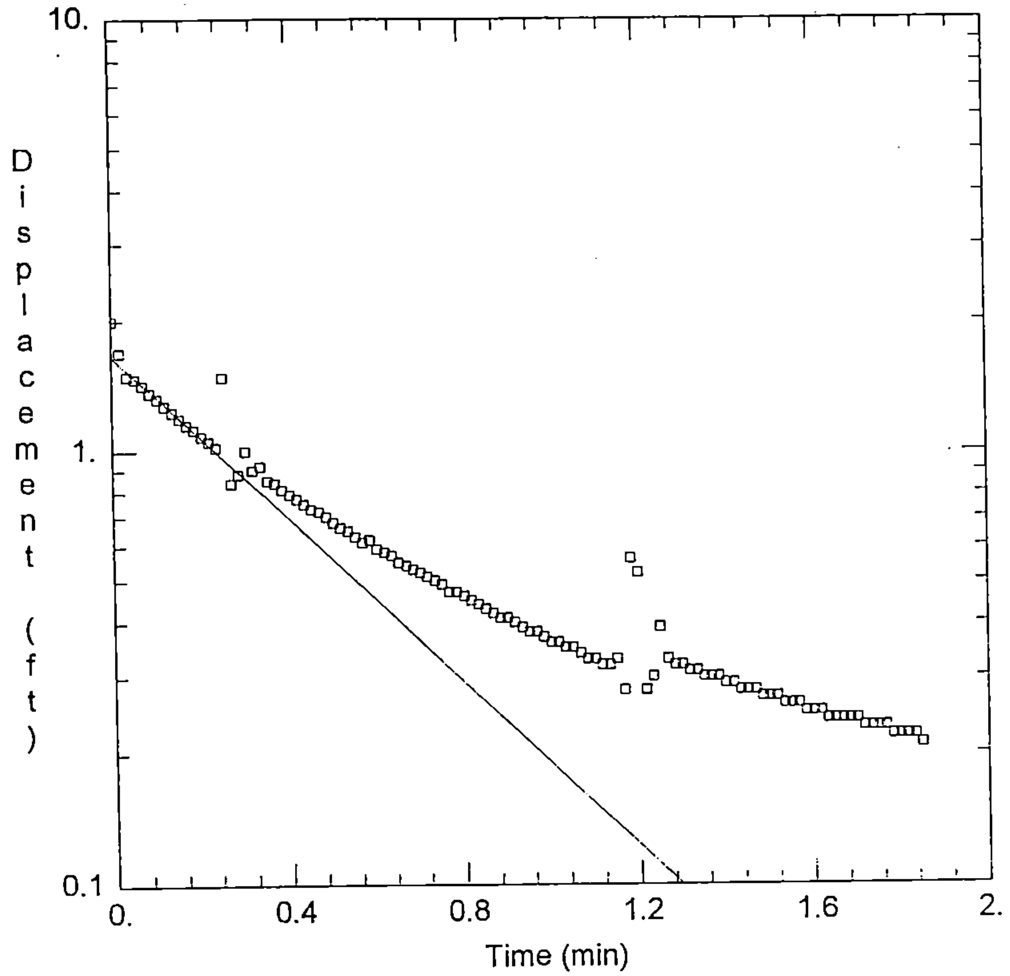
The value of $\ln(R_e \div r_w)$ is dependent on the well and aquifer geometry. Bouwer and Rice (1976) and Kruseman and DeRidder (1994) describe how $\ln(R_e \div r_w)$ is determined.

Hydraulic conductivity values estimated using the BR method were calculated using the software program AQTESOLV for Windows (reference). The program is an aquifer test analysis program which can analyze data and calculate hydraulic conductivity values using the method of BR. The program calculates a best fit regression line which is used to calculate the hydraulic conductivity value. A manual best fit line can also be used. The program user provides inputs such as screen length, aquifer thickness, and initial head displacement.

Slug test plots of displacement versus time are provided at the end of this appendix. The plots also include best fit straight lines and calculated hydraulic conductivities.

Slug Test Wells

Well
Transect A-Shallow
RMW-1
RMW-2
Transect A-Deep
RMW-2D
RMW-3D
Transect B - Shallow
MW-55(C)
RMW-7
Transect B - Deep
RMW-6D
RMW-7D
Transect C
RMW-10
RMW-8
RMW-9
MW-4(O)
Transect D -Shallow
RMW-11
MW-3(B)
MW-4(B)
Transect D - Deep
RMW-13D
RMW-11D
RMW-12D
Other
RMW-4
RMW-5
RMW-14
RMW-15
RMW-16
RMW-17
RMW-18



RMW-2 WITHDRAWAL SLUG TEST

Data Set: D:\AQTEWIN\RMW2OUT.AQT
Date: 03/30/99
Time: 13:18:12

PROJECT INFORMATION

Company: ThermoRetec
Test Location: Roeder Ave.
Test Well: RMW-2
Test Date: 3/8/99

AQUIFER DATA

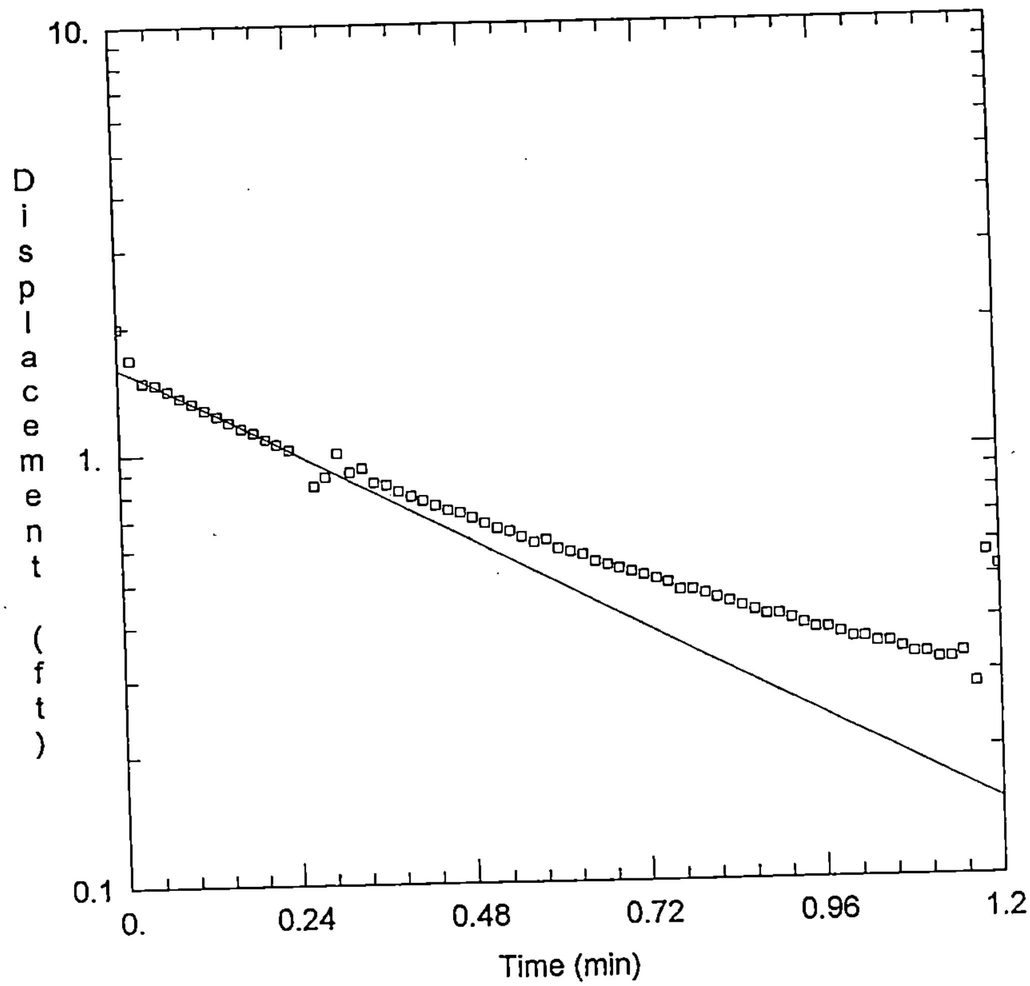
Saturated Thickness: 31. ft
Anisotropy Ratio (Kz/Kr): 1.

WELL DATA

Initial Displacement: 2. ft
Casing Radius: 0.083 ft
Screen Length: 12.73 ft
Water Column Height: 12.73 ft
Wellbore Radius: 0.42 ft
Gravel Pack Porosity: 0.3

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice
K = 0.005518 cm/sec
y0 = 1.655 ft



RMW-2D INJECTION SLUG TEST

Data Set: D:\AQTEWIN\RMW2DOUT.AQT
Date: 03/30/99
Time: 17:06:12

PROJECT INFORMATION

Company: ThermoRetec
Test Location: Roeder Ave.
Test Well: RMW-2D
Test Date: 3/8/99

AQUIFER DATA

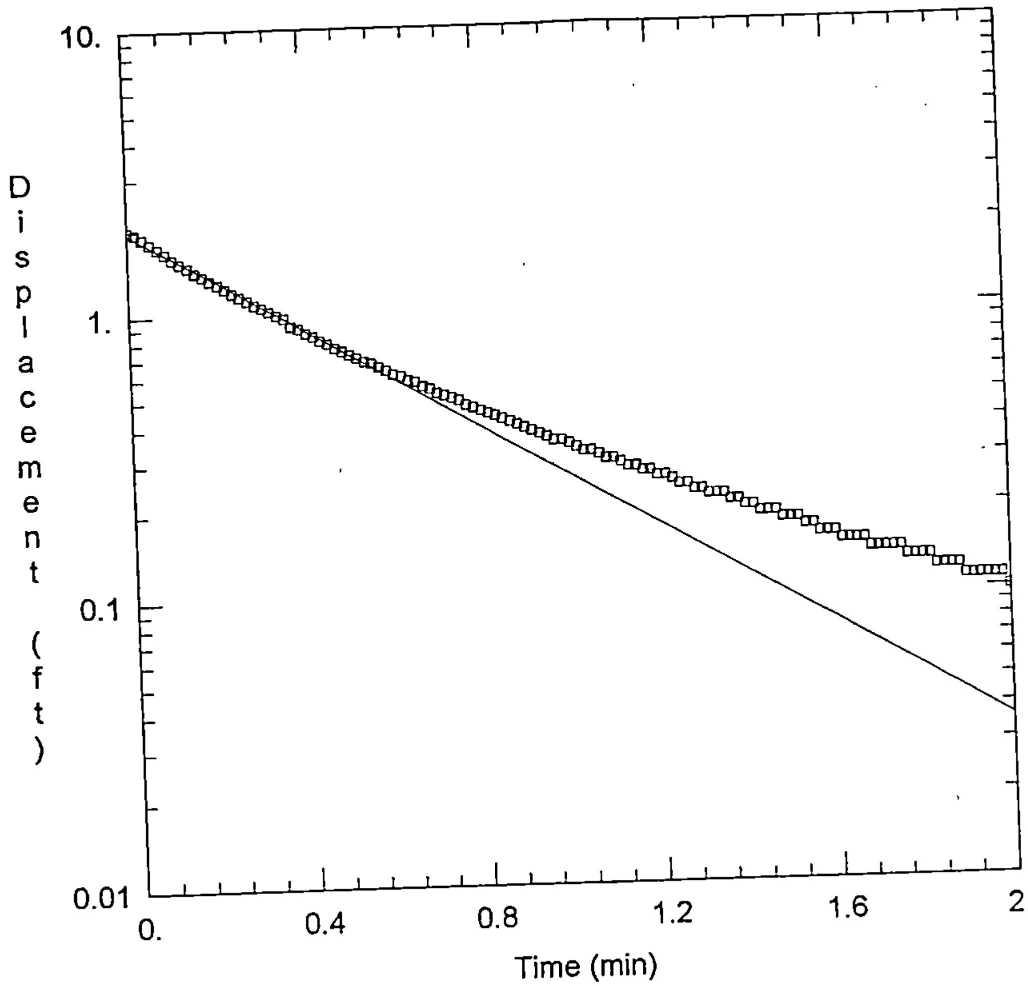
Saturated Thickness: 31. ft
Anisotropy Ratio (Kz/Kr): 1.

WELL DATA

Initial Displacement: 2. ft
Casing Radius: 0.083 ft
Screen Length: 10. ft
Water Column Height: 26.61 ft
Wellbore Radius: 0.42 ft
Gravel Pack Porosity: 0.3

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice
K = 0.007322 cm/sec
y0 = 1.606 ft



RMW-2D WITHDRAWAL SLUG TEST

Data Set: D:\AQTEWIN\RMW2DOUT.AQT
Date: 03/30/99
Time: 17:23:56

PROJECT INFORMATION

Company: ThermoRetec
Test Location: Roeder Ave.
Test Well: RMW-2D
Test Date: 3/8/99

AQUIFER DATA

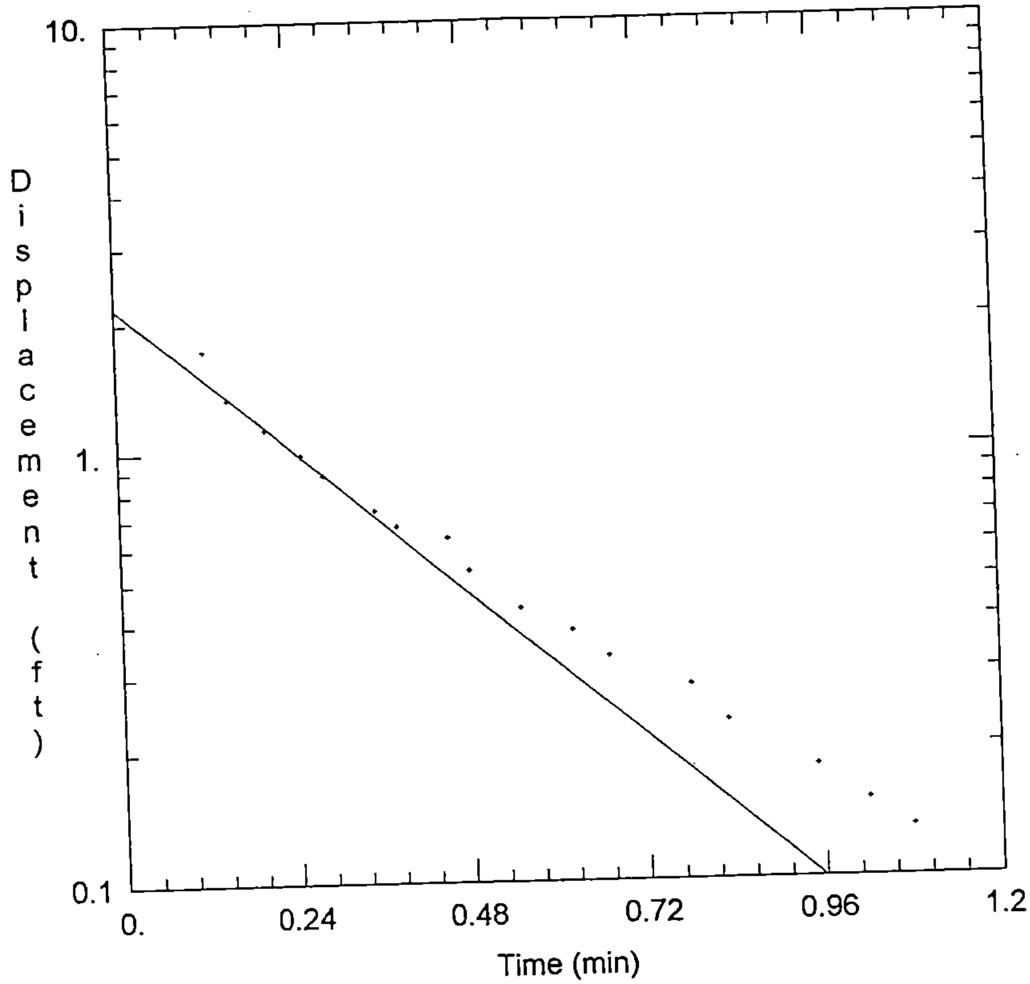
Saturated Thickness: 31. ft
Anisotropy Ratio (Kz/Kr): 1.

WELL DATA

Initial Displacement: 2. ft
Casing Radius: 0.083 ft
Screen Length: 10. ft
Water Column Height: 26.61 ft
Wellbore Radius: 0.42 ft
Gravel Pack Porosity: 0.3

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice
K = 0.007421 cm/sec
y0 = 1.958 ft



RMW-3D WITHDRAWAL SLUG TEST

Data Set: D:\AQTEWIN\DATA\RMW3D.AQT
Date: 04/07/99
Time: 10:26:49

PROJECT INFORMATION

Company: ThermoRetec
Test Location: Roeder Ave.
Test Well: RMW-3D

AQUIFER DATA

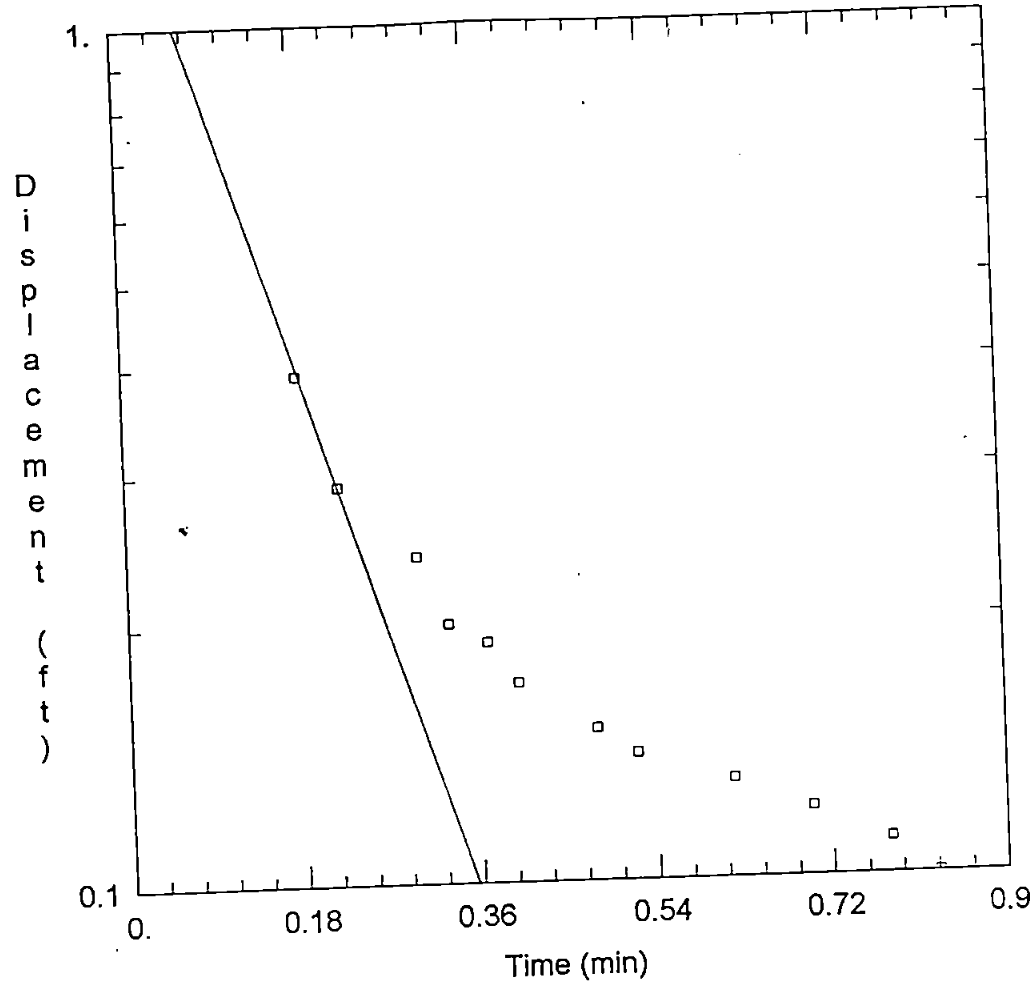
Saturated Thickness: 29. ft
Anisotropy Ratio (Kz/Kr): 1.

WELL DATA

Initial Displacement: 2.15 ft
Casing Radius: 0.083 ft
Screen Length: 10. ft
Water Column Height: 28.73 ft
Wellbore Radius: 0.42 ft
Gravel Pack Porosity: 0.3

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice
K = 0.01355 cm/sec
y0 = 2.178 ft



MW-55C

Data Set: D:\AQTEWIN\DATA\MW-55C.AQT
Date: 04/06/99
Time: 11:27:59

PROJECT INFORMATION

Test Well: RMW-6D

AQUIFER DATA

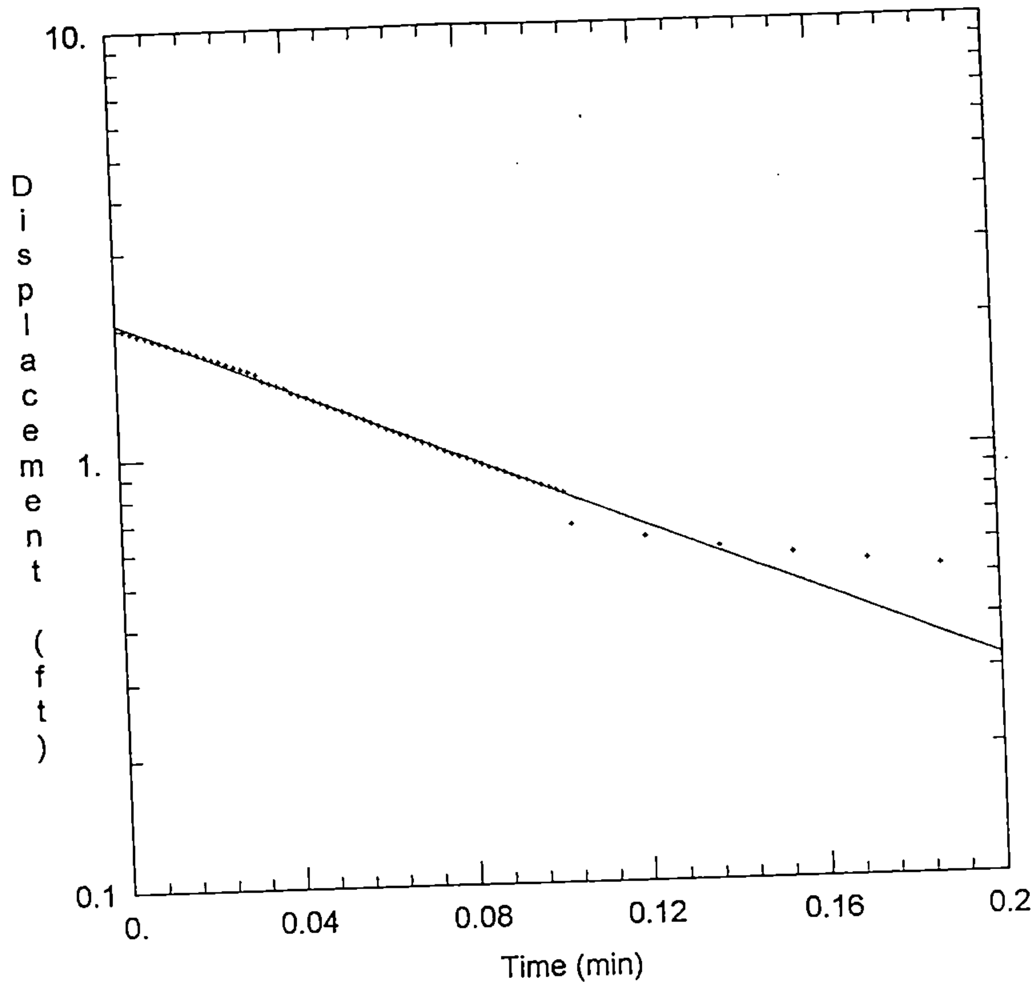
Saturated Thickness: 35. ft
Anisotropy Ratio (Kz/Kr): 1.

WELL DATA

Initial Displacement: 2.15 ft
Casing Radius: 0.083 ft
Screen Length: 9.79 ft
Water Column Height: 9.79 ft
Wellbore Radius: 0.42 ft
Gravel Pack Porosity: 0.3

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice
K = 0.02345 cm/sec
y0 = 1.67 ft



RMW-7 WITHDRAWAL SLUG TEST

Data Set: D:\AQTEWIN\DATA\RMW7DIN.AQT
Date: 04/01/99 Time: 17:06:31

PROJECT INFORMATION

Company: ThermoRetec
Test Location: Roeder Ave.
Test Well: RMW-7
Test Date: 3/9/99

AQUIFER DATA

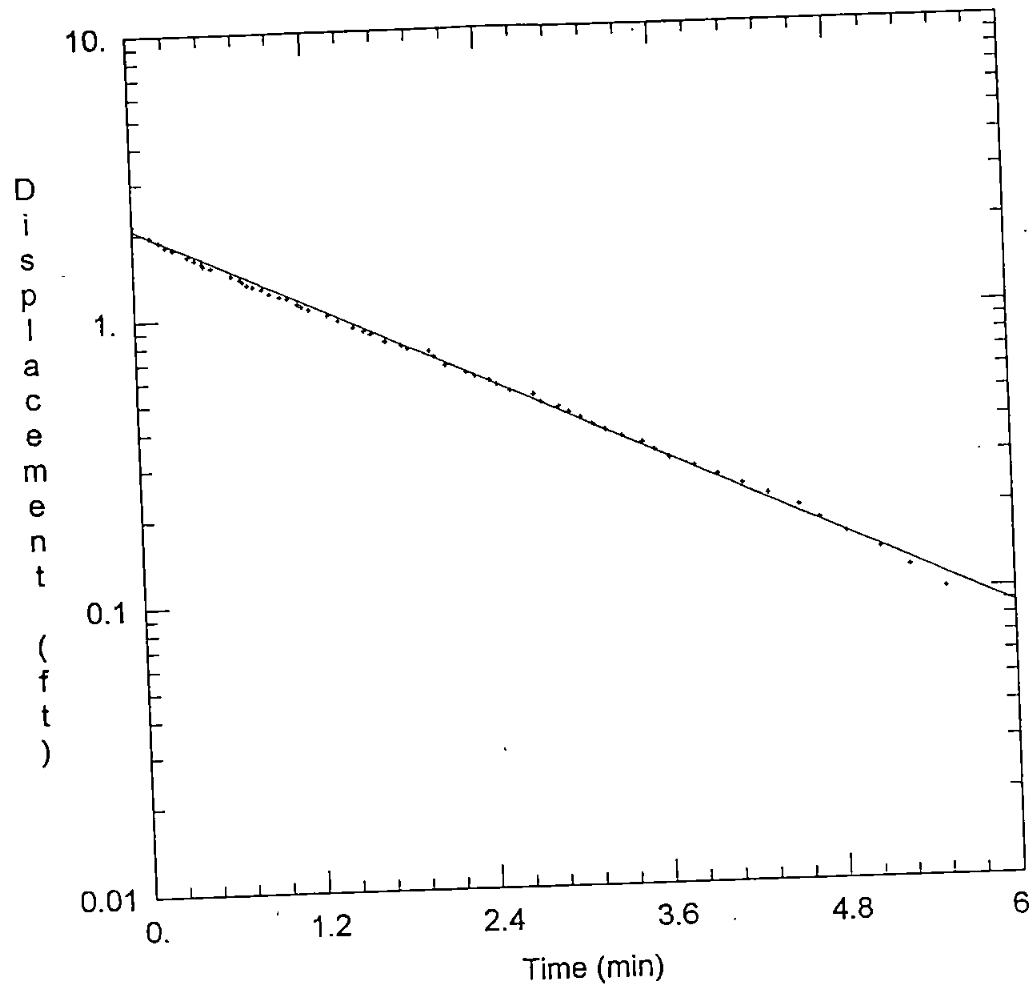
Saturated Thickness: 30.13 ft
Anisotropy Ratio (Kz/Kr): 1.

WELL DATA

Initial Displacement: 2. ft
Casing Radius: 0.083 ft
Screen Length: 11.98 ft
Water Column Height: 11.98 ft
Wellbore Radius: 0.42 ft
Gravel Pack Porosity: 0.3

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice
K = 0.02461 cm/sec
y0 = 2.061 ft



RMW-6D WITHDRAWAL SLUG TEST

Data Set: D:\AQTEWIN\DATA\RMW6D.AQT
Date: 04/07/99
Time: 10:02:03

PROJECT INFORMATION

Company: ThermoRetec
Test Location: Roeder Ave.
Test Well: RMW-6D

AQUIFER DATA

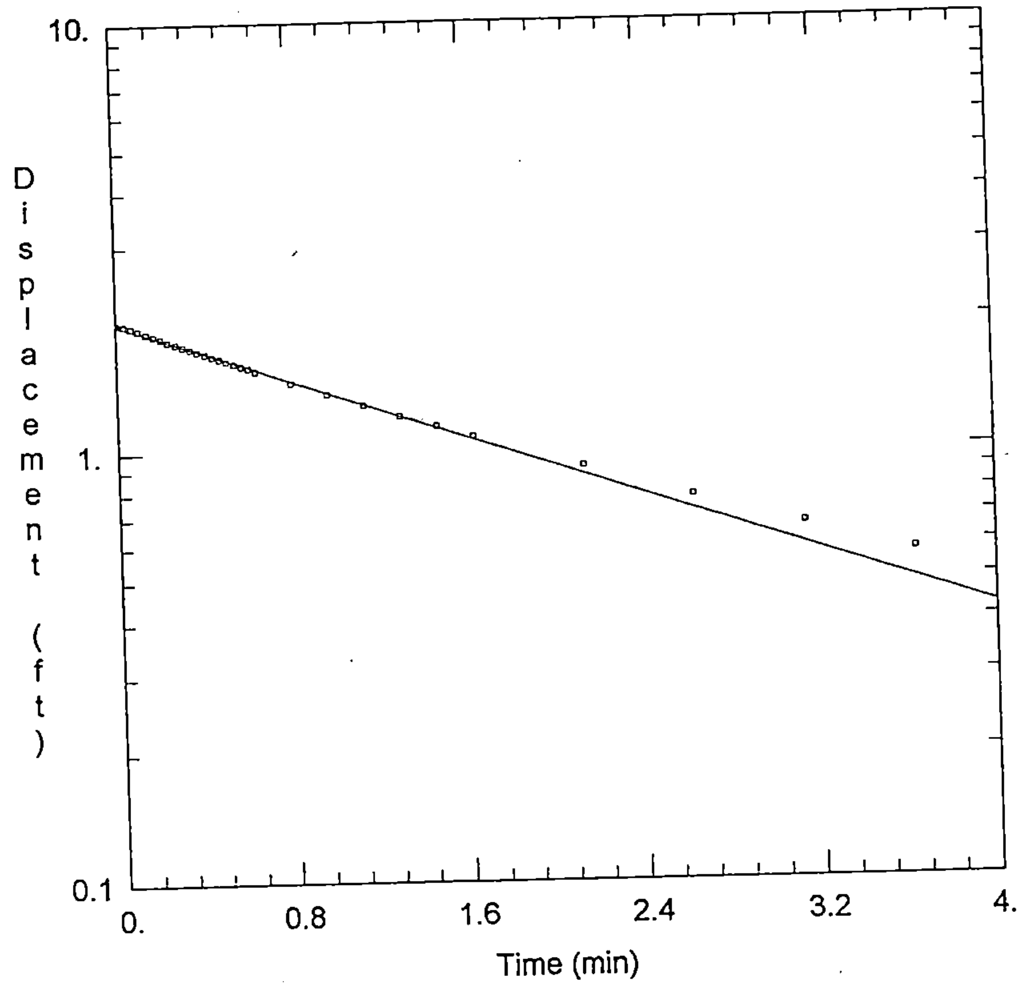
Saturated Thickness: 35. ft
Anisotropy Ratio (Kz/Kr): 1.

WELL DATA

Initial Displacement: 2.15 ft
Casing Radius: 0.083 ft
Screen Length: 10. ft
Water Column Height: 34.27 ft
Wellbore Radius: 0.42 ft
Gravel Pack Porosity: 0.3

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice
K = 0.002189 cm/sec
y0 = 2.072 ft



RMW-7D INJECTION SLUG TEST

Data Set: D:\AQTEWIN\DATA\RMW8OUT.AQT
Date: 04/01/99 Time: 13:30:23

PROJECT INFORMATION

Company: ThermoRetec
Test Location: Roeder Ave.
Test Well: RMW-7D
Test Date: 3/9/99

AQUIFER DATA

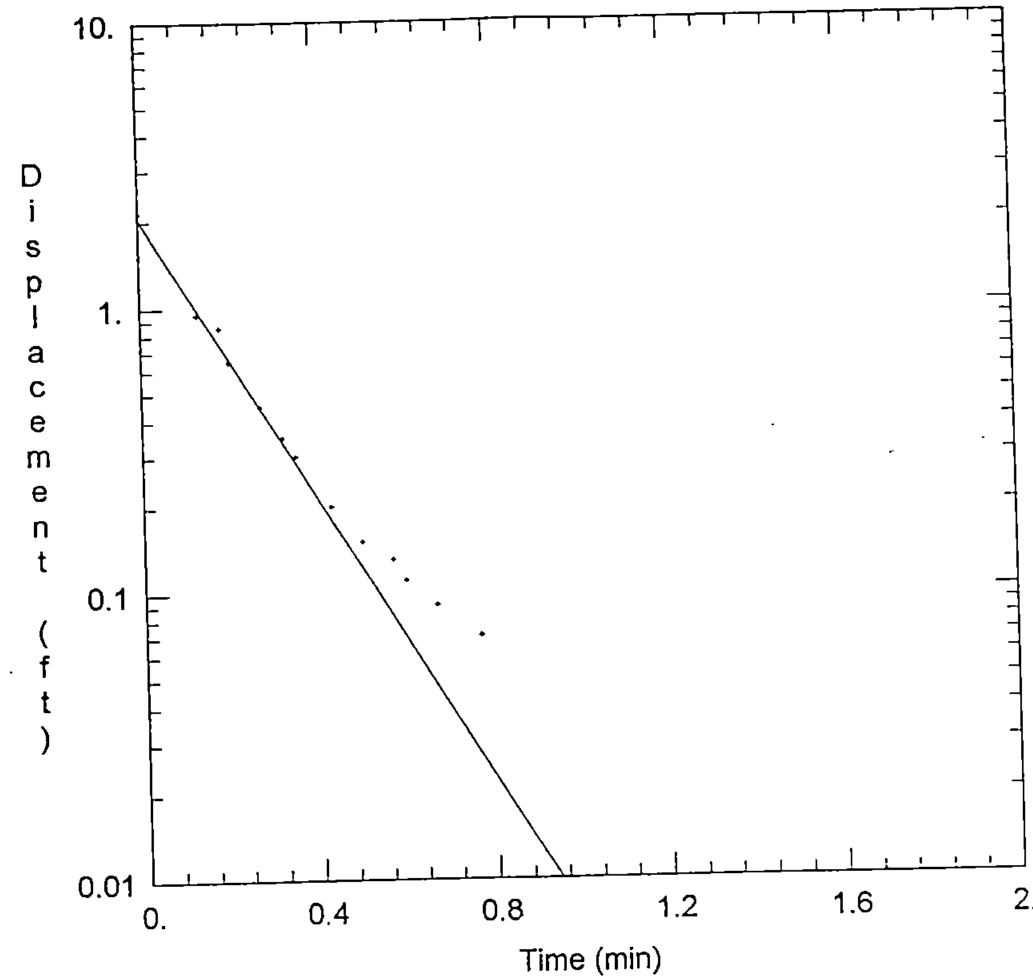
Saturated Thickness: 30.13 ft
Anisotropy Ratio (Kz/Kr): 1.

WELL DATA

Initial Displacement: 2. ft
Casing Radius: 0.083 ft
Screen Length: 10. ft
Water Column Height: 30.13 ft
Wellbore Radius: 0.42 ft
Gravel Pack Porosity: 0.3

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice
K = 0.001705 cm/sec
y0 = 1.991 ft



RMW-10 WITHDRAWAL SLUG TEST

Data Set: D:\AQTEWIN\DATA\RMW10.AQT
Date: 04/07/99 Time: 09:39:55

PROJECT INFORMATION

Company: ThermoRetec
Test Location: Roeder Ave.
Test Well: RMW-10

AQUIFER DATA

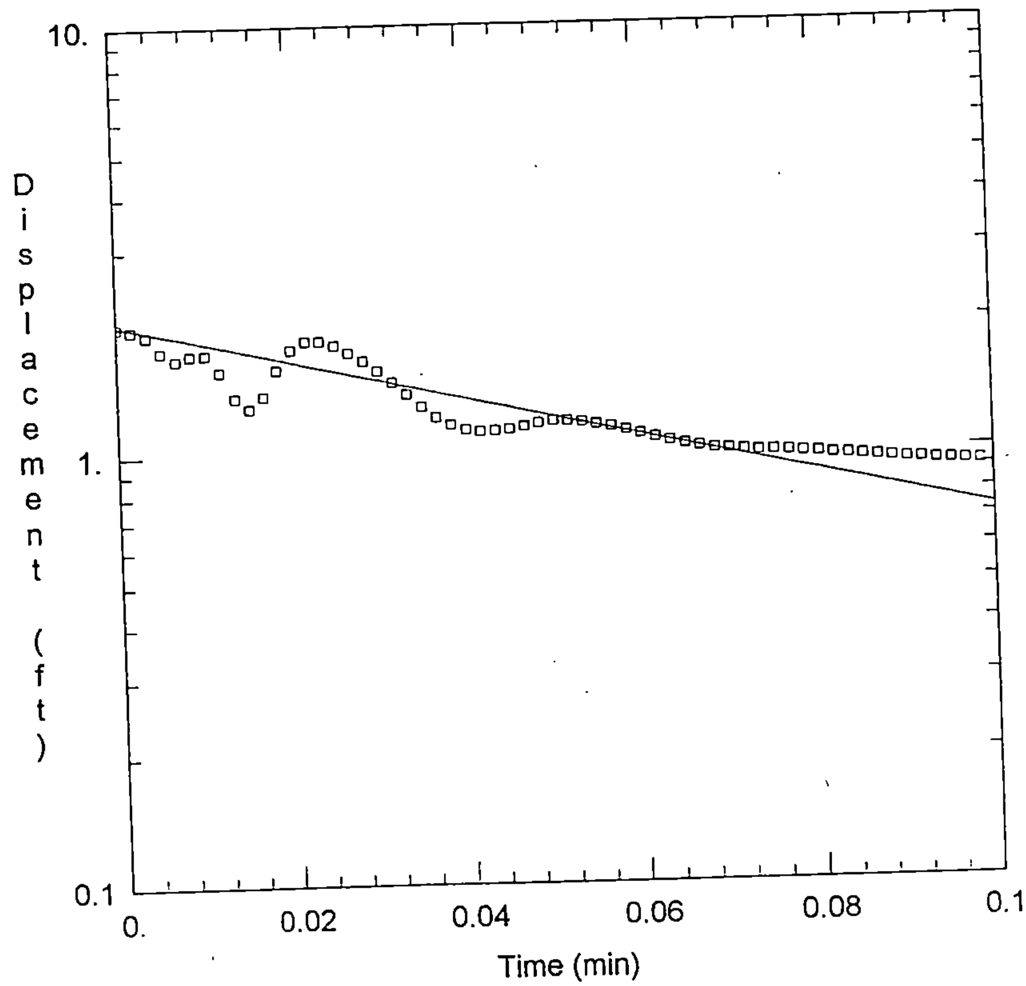
Saturated Thickness: 16.55 ft
Anisotropy Ratio (Kz/Kr): 1.

WELL DATA

Initial Displacement: 2.15 ft
Casing Radius: 0.083 ft
Screen Length: 15. ft
Water Column Height: 16.55 ft
Wellbore Radius: 0.42 ft
Gravel Pack Porosity: 0.3

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice
K = 0.01536 cm/sec
y0 = 2.054 ft



RMW-8 WITHDRAWAL SLUG TEST

Data Set: D:\AQTEWIN\DATA\RMW4OUT.AQT
Date: 03/31/99 Time: 10:47:28

PROJECT INFORMATION

Company: ThermoRetec
Test Location: Roeder Ave.
Test Well: RMW-8
Test Date: 3/8/99

AQUIFER DATA

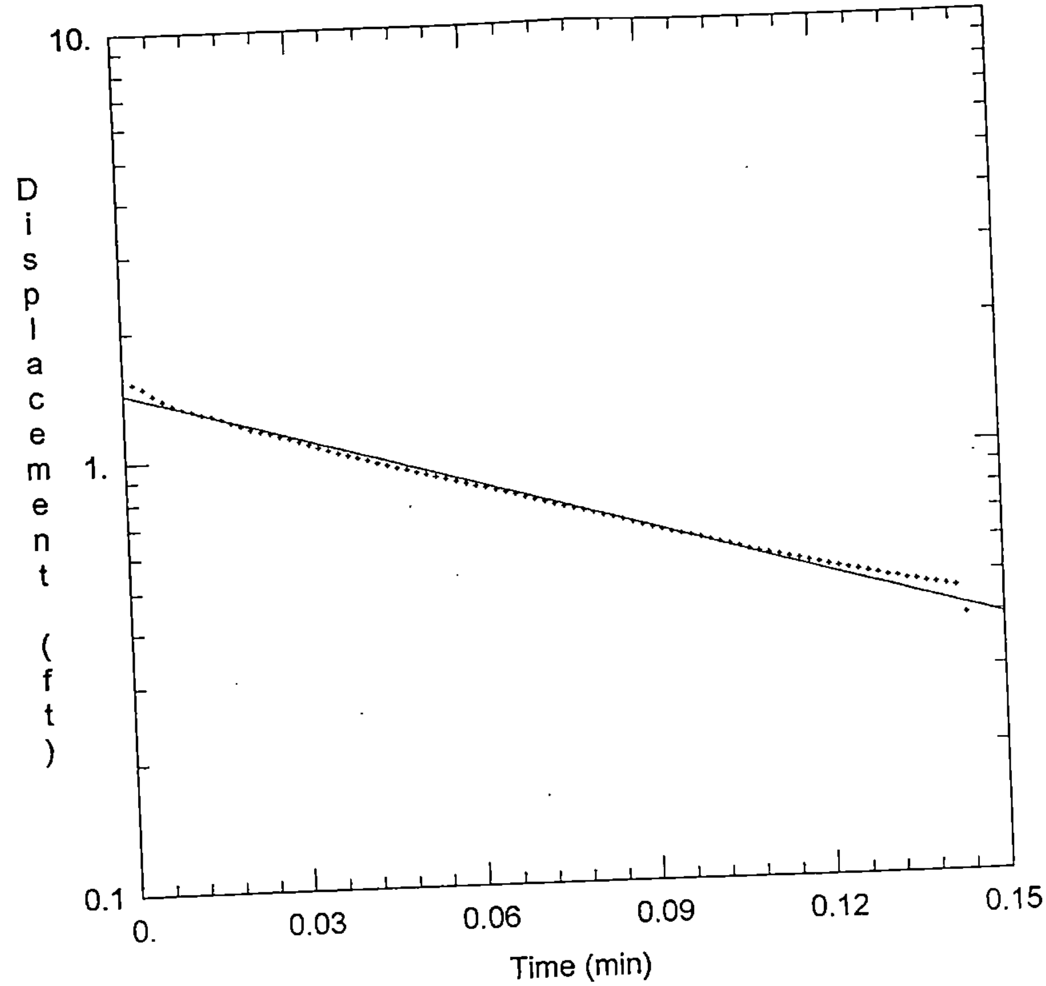
Saturated Thickness: 26. ft
Anisotropy Ratio (Kz/Kr): 1.

WELL DATA

Initial Displacement: 2. ft
Casing Radius: 0.083 ft
Screen Length: 12.79 ft
Water Column Height: 12.79 ft
Wellbore Radius: 0.42 ft
Gravel Pack Porosity: 0.3

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice
K = 0.02622 cm/sec
y0 = 2.023 ft



RMW-9 WITHDRAWAL SLUG TEST

Data Set: D:\AQTEWIN\DATA\RMW9OUT.AQT
Date: 04/07/99 Time: 09:21:28

PROJECT INFORMATION

Company: ThermoRetec
Test Location: Roeder Ave.
Test Well: RMW-9
Test Date: 3/9/99

AQUIFER DATA

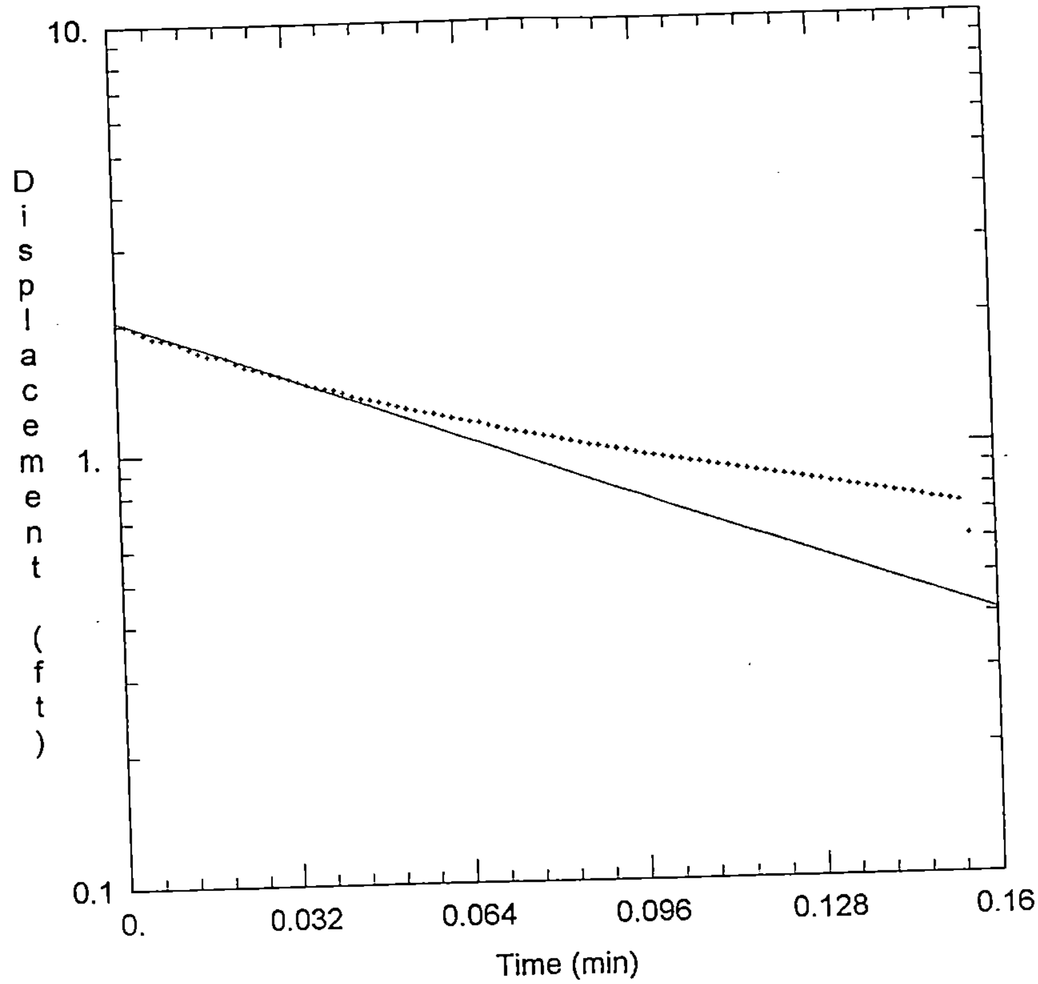
Saturated Thickness: 17. ft
Anisotropy Ratio (Kz/Kr): 1.

WELL DATA

Initial Displacement: 2. ft
Casing Radius: 0.083 ft
Screen Length: 14.18 ft
Water Column Height: 14.18 ft
Wellbore Radius: 0.42 ft
Gravel Pack Porosity: 0.3

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice
K = 0.02173 cm/sec
y0 = 1.443 ft



MW-4(O) WITHDRAWAL SLUG TEST

Data Set: D:\AQTEWIN\DATA\MW4OUT.AQT
Date: 04/06/99 Time: 09:49:30

PROJECT INFORMATION

Company: ThermoRetec
Test Location: Roeder Ave.
Test Well: MW-4(O)
Test Date: 3/9/99

AQUIFER DATA

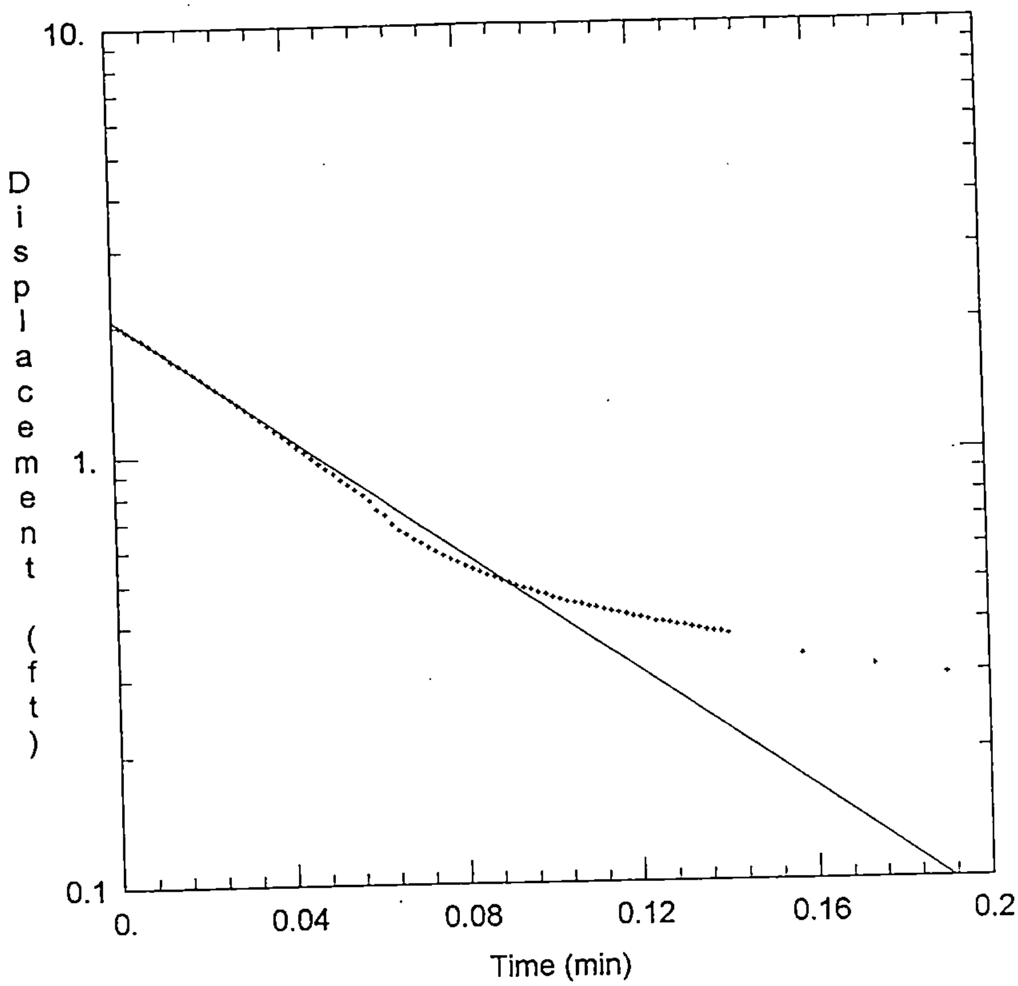
Saturated Thickness: 17. ft
Anisotropy Ratio (Kz/Kr): 1.

WELL DATA

Initial Displacement: 2. ft
Casing Radius: 0.083 ft
Screen Length: 10.48 ft
Water Column Height: 10.48 ft
Wellbore Radius: 0.42 ft
Gravel Pack Porosity: 0.3

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice
K = 0.02982 cm/sec
y0 = 2.044 ft



MW-3B WITHDRAWAL SLUG TEST

Data Set: D:\AQTEWIN\DATA\MW3O.AQT
Date: 04/06/99 Time: 09:50:18

PROJECT INFORMATION

Company: ThermoRetec
Test Location: Roeder Ave.
Test Well: MW-3B
Test Date: 3/9/99

AQUIFER DATA

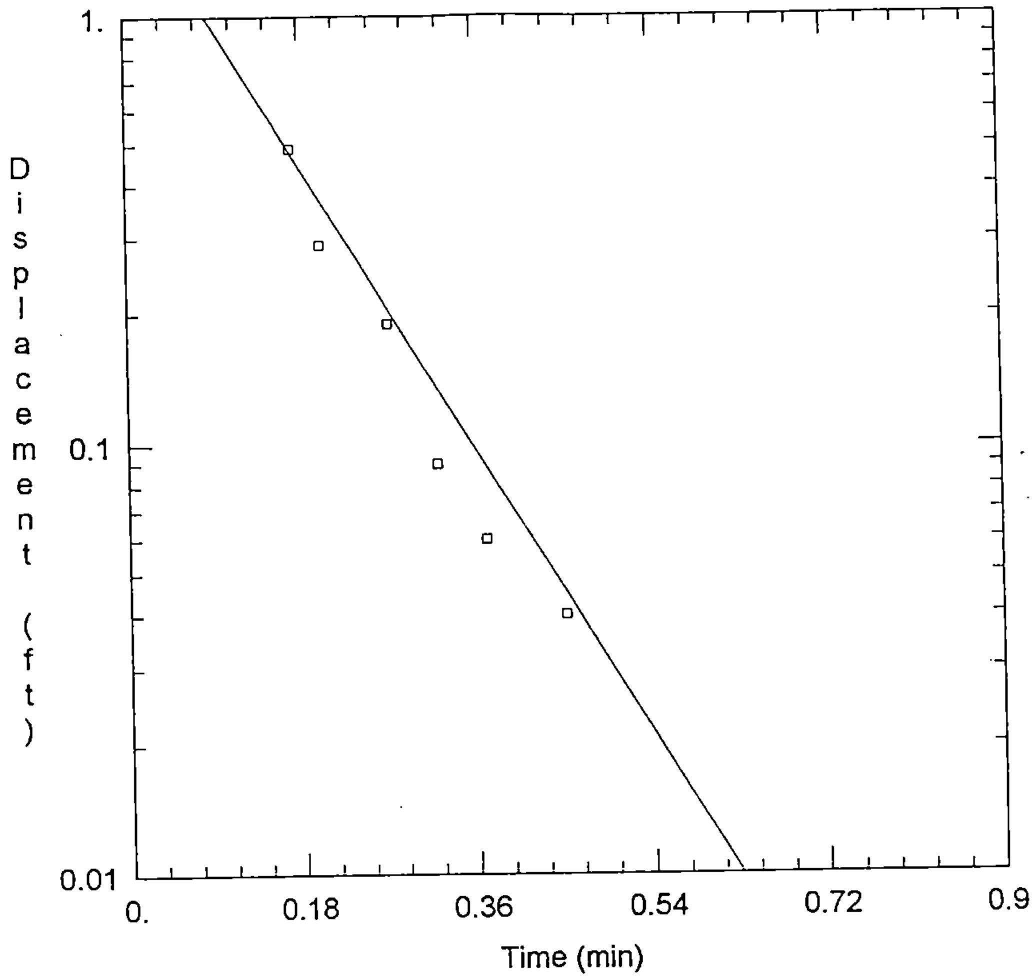
Saturated Thickness: 20.57 ft
Anisotropy Ratio (Kz/Kr): 1.

WELL DATA

Initial Displacement: 2. ft
Casing Radius: 0.083 ft
Screen Length: 7.65 ft
Water Column Height: 7.65 ft
Wellbore Radius: 0.42 ft
Gravel Pack Porosity: 0.3

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice
K = 0.05466 cm/sec
y0 = 2.066 ft



MW-4B

Data Set: D:\AQTEWIN\DATA\MW-4B.AQT
Date: 04/06/99 Time: 11:29:20

PROJECT INFORMATION

Test Well: MW-4B

AQUIFER DATA

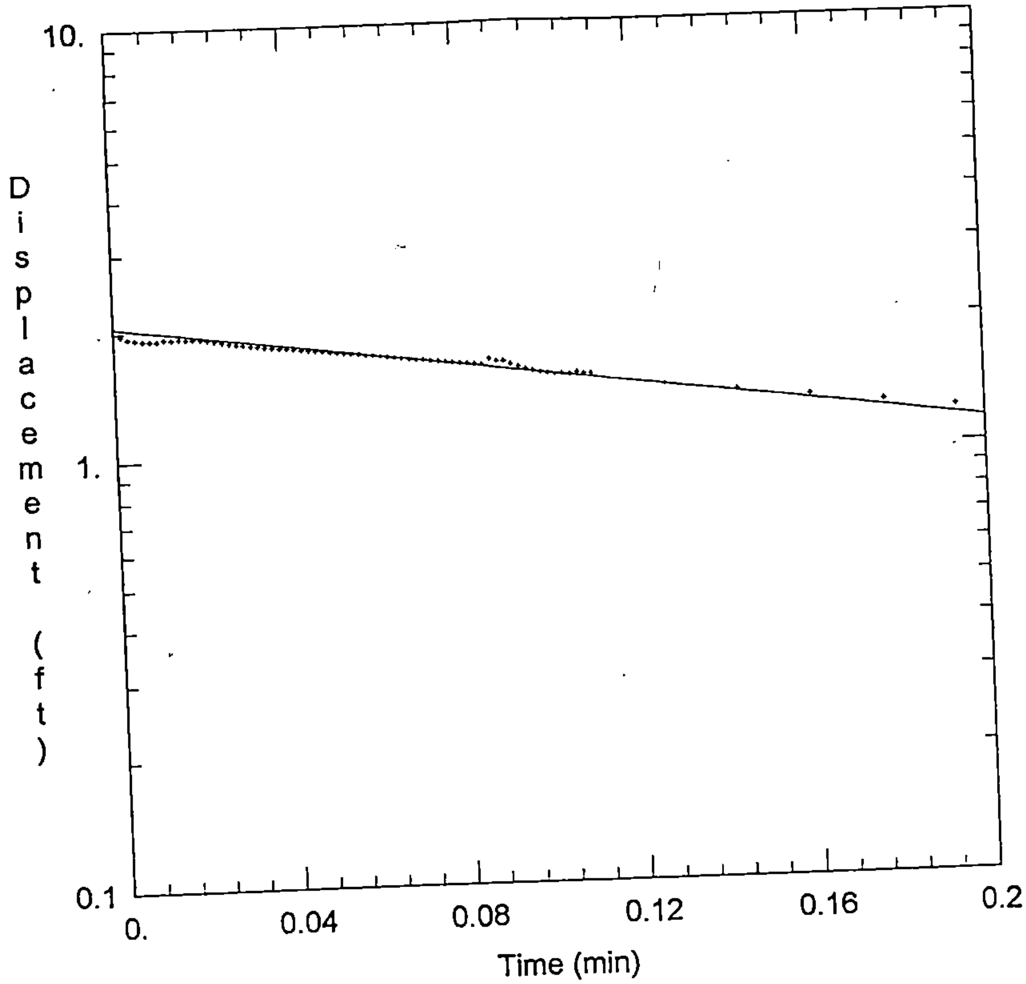
Saturated Thickness: 15. ft Anisotropy Ratio (Kz/Kr): 1.

WELL DATA

Initial Displacement: 2.15 ft
Casing Radius: 0.083 ft
Screen Length: 6.41 ft
Water Column Height: 6.41 ft
Wellbore Radius: 0.42 ft
Gravel Pack Porosity: 0.3

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice
K = 0.0324 cm/sec
y0 = 2.026 ft



RMW-13D INJECTION SLUG TEST

Data Set: D:\AQTEWIN\DATA\RMW13DIN.AQT
Date: 04/06/99
Time: 09:49:54

PROJECT INFORMATION

Company: ThermoRetec
Test Location: Roeder Ave.
Test Well: RMW-13D
Test Date: 3/9/99

AQUIFER DATA

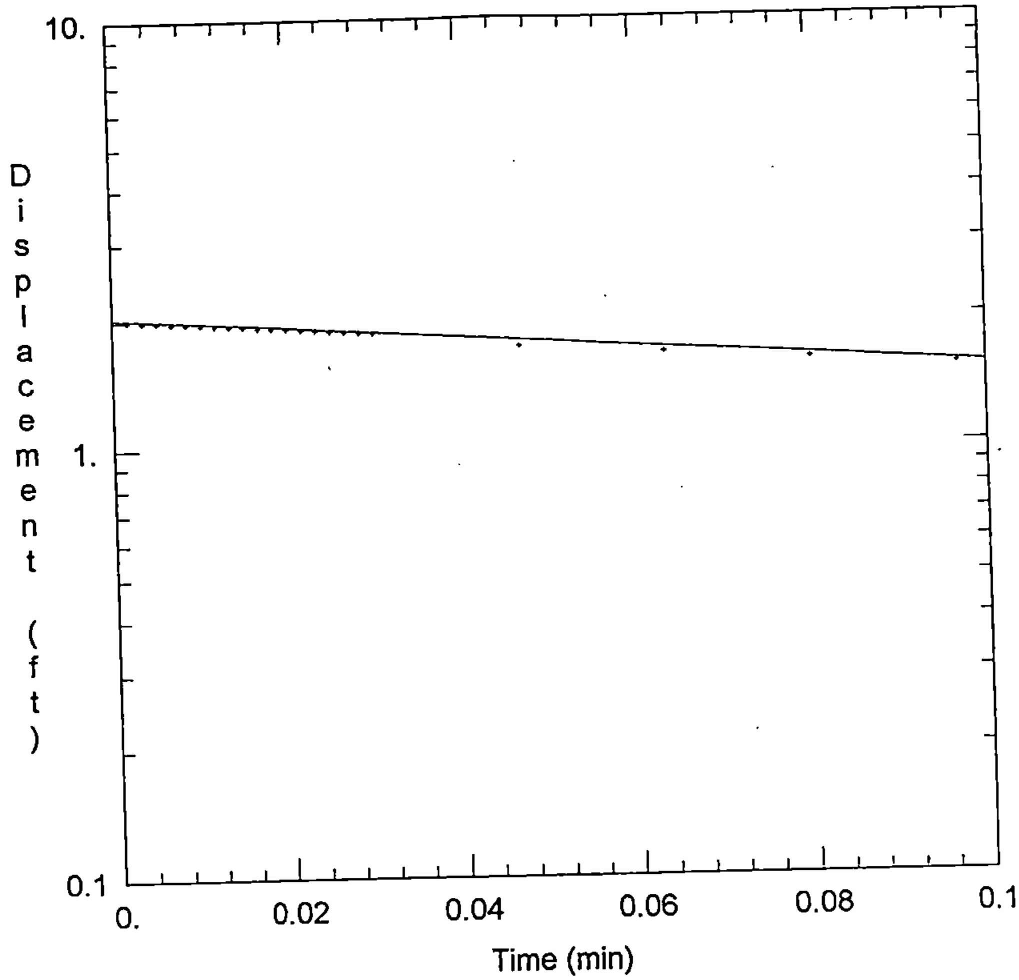
Saturated Thickness: 20.57 ft
Anisotropy Ratio (Kz/Kr): 1.

WELL DATA

Initial Displacement: 2. ft
Casing Radius: 0.083 ft
Screen Length: 10. ft
Water Column Height: 20.57 ft
Wellbore Radius: 0.42 ft
Gravel Pack Porosity: 0.3

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice
K = 0.01221 cm/sec
y0 = 2.056 ft



RMW-13D WITHDRAWAL SLUG TEST

Data Set: D:\AQTEWIN\DATA\RMW13DO.AQT
Date: 04/06/99 Time: 09:50:04

PROJECT INFORMATION

Company: ThermoRetec
Test Location: Roeder Ave.
Test Well: RMW-13D
Test Date: 3/9/99

AQUIFER DATA

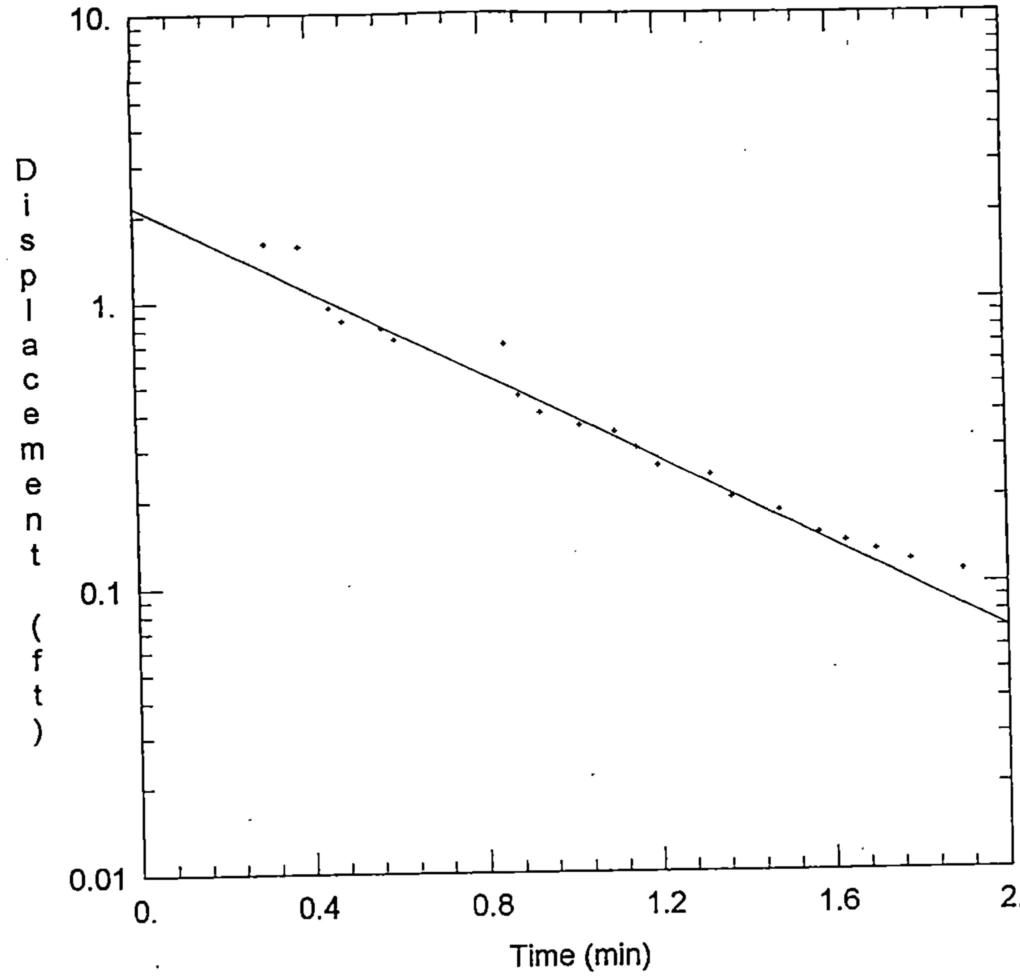
Saturated Thickness: 20.57 ft
Anisotropy Ratio (Kz/Kr): 1.

WELL DATA

Initial Displacement: 2. ft
Casing Radius: 0.083 ft
Screen Length: 10. ft
Water Column Height: 20.57 ft
Wellbore Radius: 0.42 ft
Gravel Pack Porosity: 0.3

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice
K = 0.01163 cm/sec
y0 = 2.031 ft



RMW-11D WITHDRAWAL SLUG TEST

Data Set: A:\RMW11D.AQT
Date: 04/07/99 Time: 09:25:58

PROJECT INFORMATION

Company: ThermoRetec
Test Location: Roeder Ave.
Test Well: RMW-11D

AQUIFER DATA

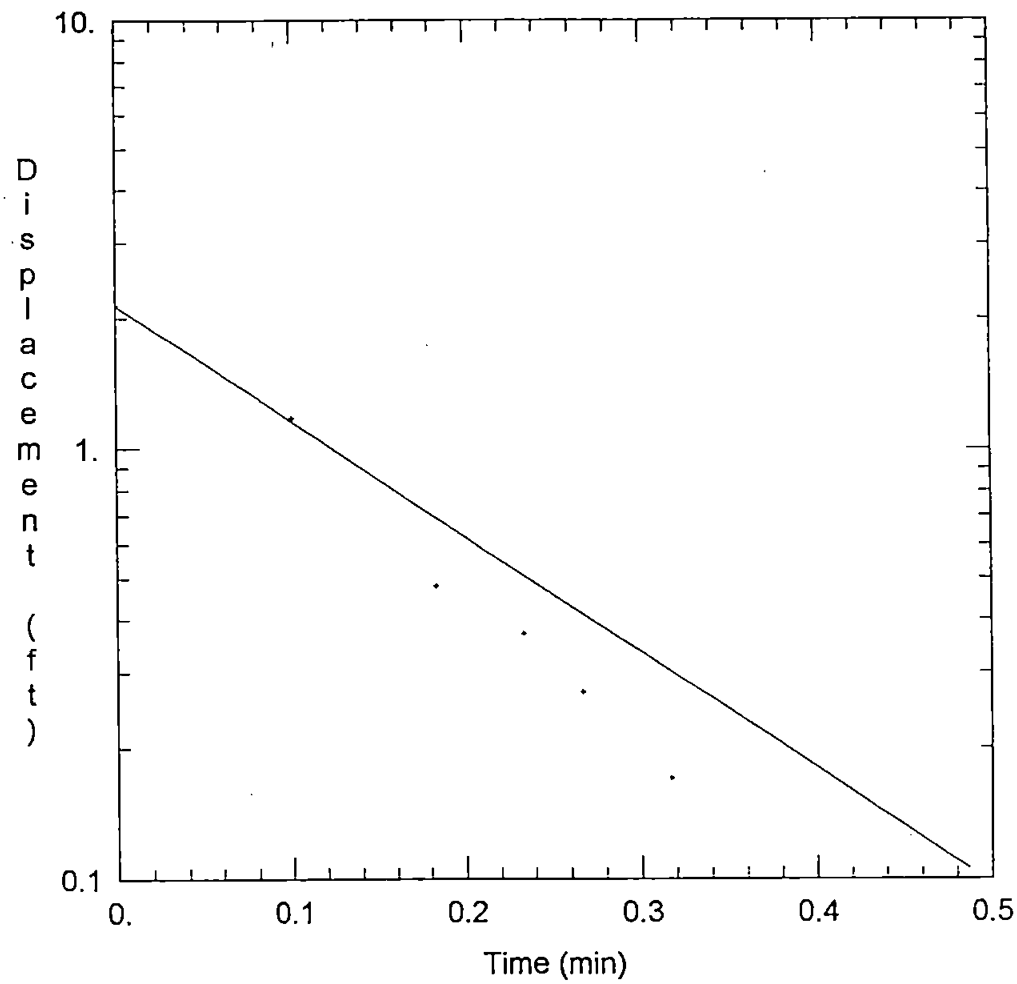
Saturated Thickness: 26. ft
Anisotropy Ratio (Kz/Kr): 1.

WELL DATA

Initial Displacement: 2. ft
Casing Radius: 0.083 ft
Screen Length: 10. ft
Water Column Height: 24.75 ft
Wellbore Radius: 0.42 ft
Gravel Pack Porosity: 0.3

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice
K = 0.006599 cm/sec
y0 = 2.154 ft



RMW-12D WITHDRAWAL SLUG TEST

Data Set: D:\AQTEWIN\DATA\RMW12D.AQT
Date: 04/07/99 Time: 10:16:45

PROJECT INFORMATION

Company: ThermoRetec
Test Location: Roeder Ave.
Test Well: RMW-12D

AQUIFER DATA

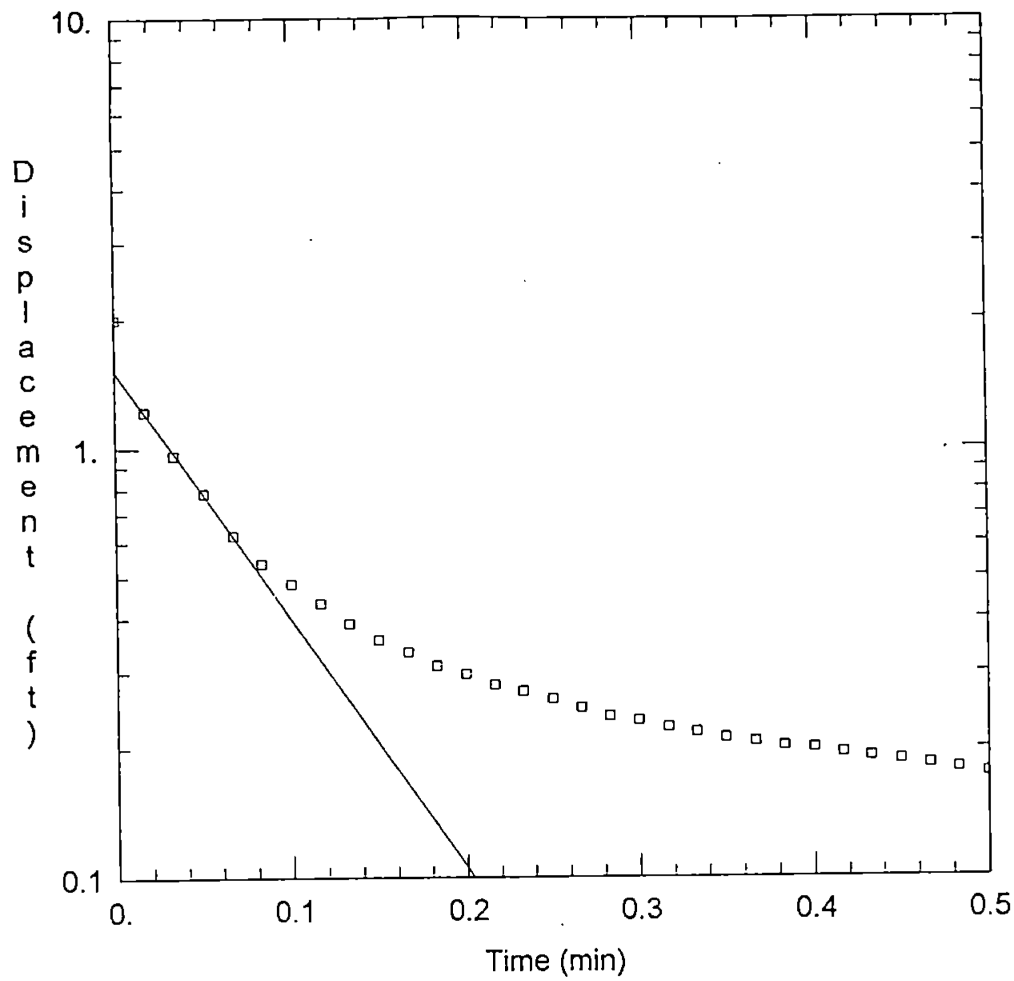
Saturated Thickness: 16. ft
Anisotropy Ratio (Kz/Kr): 1.

WELL DATA

Initial Displacement: 2.15 ft
Casing Radius: 0.083 ft
Screen Length: 10. ft
Water Column Height: 13.97 ft
Wellbore Radius: 0.42 ft
Gravel Pack Porosity: 0.3

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice
K = 0.02097 cm/sec
y0 = 2.141 ft



RMW-4 WITHDRAWAL SLUG TEST

Data Set: D:\AQTEWIN\DATA\RMW4OUT.AQT
Date: 03/31/99 Time: 08:56:05

PROJECT INFORMATION

Company: ThermoRetec
Test Location: Roeder Ave.
Test Well: RMW-4
Test Date: 3/8/99

AQUIFER DATA

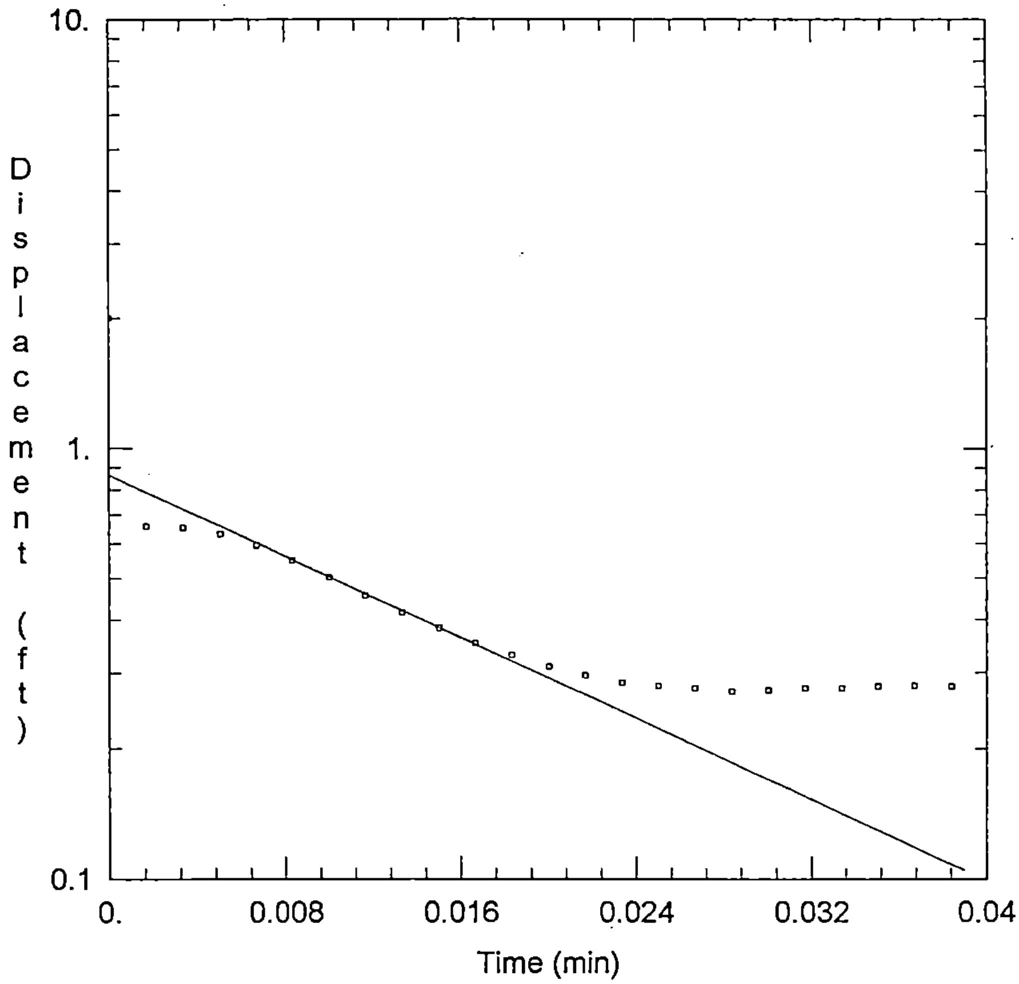
Saturated Thickness: 31. ft Anisotropy Ratio (Kz/Kr): 1.

WELL DATA

Initial Displacement: 2. ft
Casing Radius: 0.083 ft
Screen Length: 13.88 ft
Water Column Height: 13.88 ft
Wellbore Radius: 0.42 ft
Gravel Pack Porosity: 0.3

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice
K = 0.03219 cm/sec
y0 = 1.515 ft



RMW-5 WITHDRAWAL SLUG TEST

Data Set: D:\AQTEWIN\DATA\RMW5OUT.AQT
Date: 04/01/99 Time: 15:49:05

PROJECT INFORMATION

Company: ThermoRetec
Test Location: Roeder Ave.
Test Well: RMW-5
Test Date: 3/9/99

AQUIFER DATA

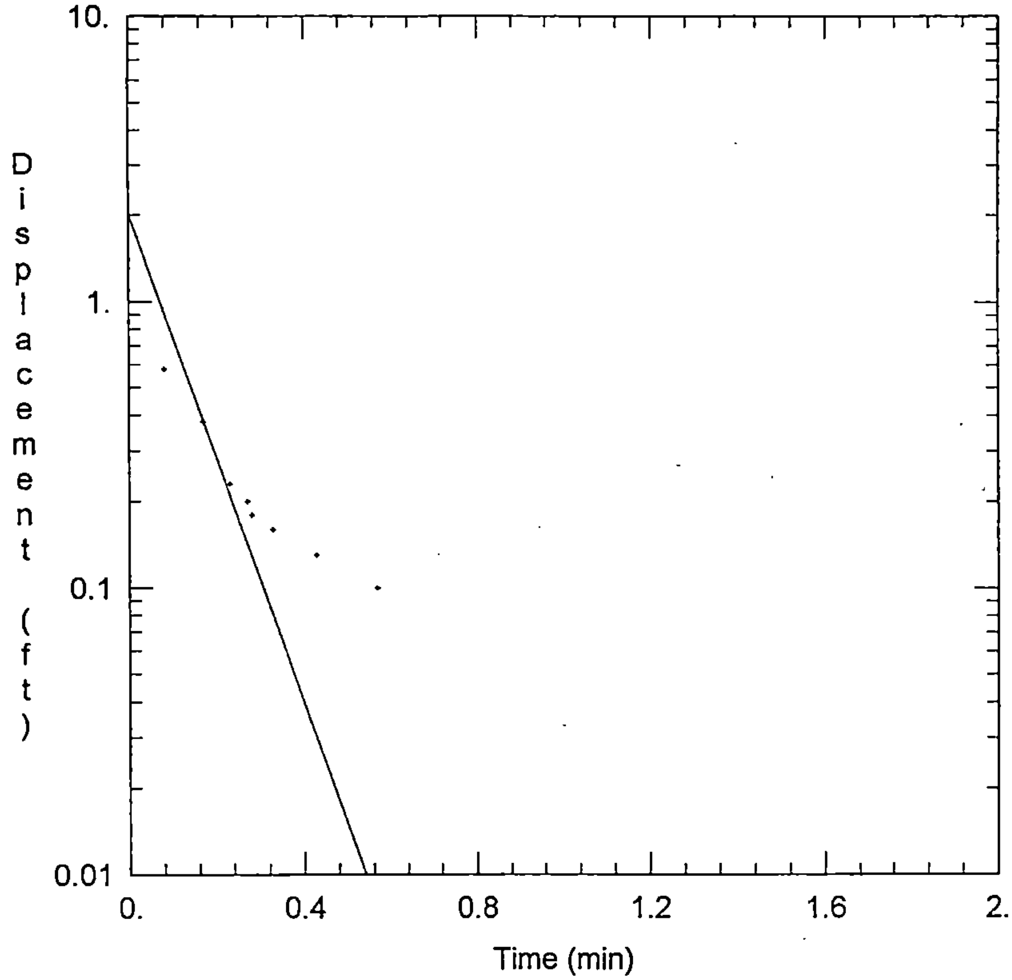
Saturated Thickness: 31. ft
Anisotropy Ratio (Kz/Kr): 1.

WELL DATA

Initial Displacement: 2. ft
Casing Radius: 0.083 ft
Screen Length: 11.77 ft
Water Column Height: 11.77 ft
Wellbore Radius: 0.42 ft
Gravel Pack Porosity: 0.3

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice
K = 0.1443 cm/sec
y0 = 0.8652 ft



RMW-14 WITHDRAWAL SLUG TEST

Data Set: A:\RMW14.AQT
Date: 04/07/99 Time: 09:25:11

PROJECT INFORMATION

Company: ThermoRetec
Test Location: Roeder Ave.
Test Well: RMW-14

AQUIFER DATA

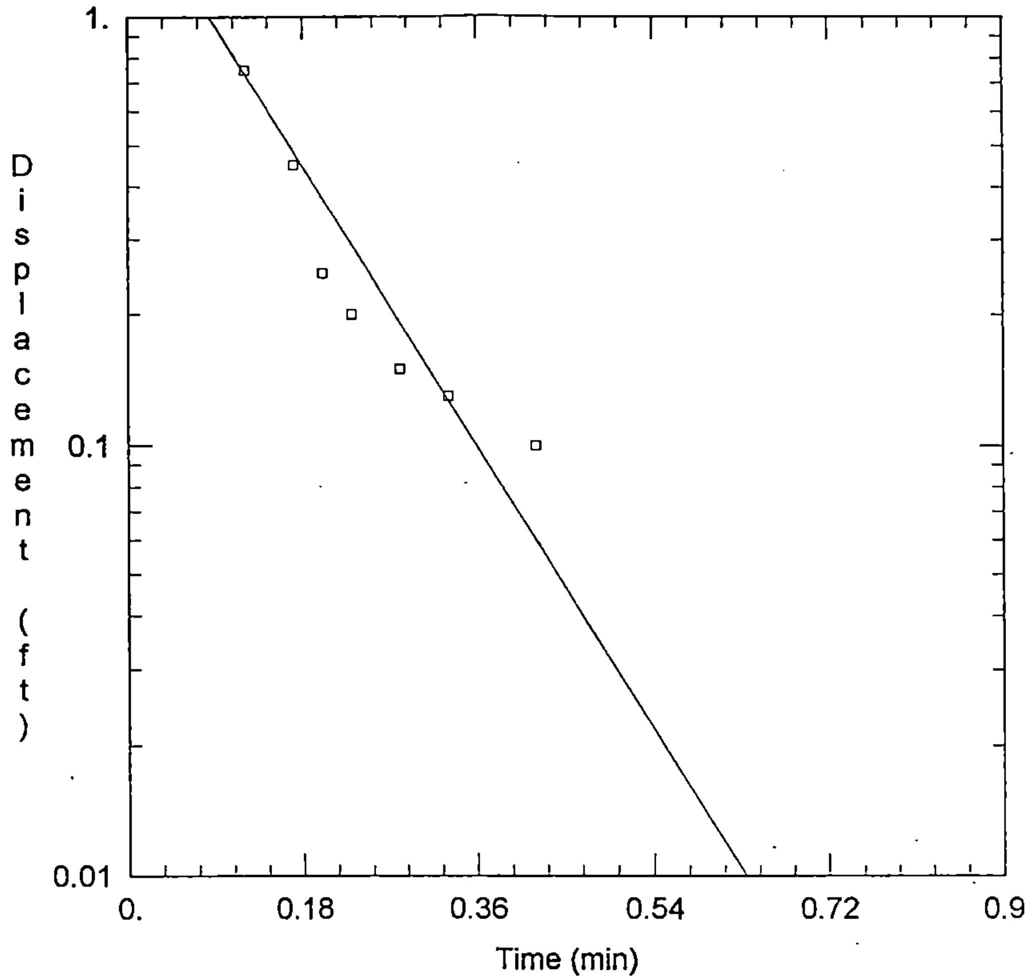
Saturated Thickness: 25. ft
Anisotropy Ratio (Kz/Kr): 1.

WELL DATA

Initial Displacement: 2. ft
Casing Radius: 0.083 ft
Screen Length: 14.08 ft
Water Column Height: 14.08 ft
Wellbore Radius: 0.42 ft
Gravel Pack Porosity: 0.3

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice
K = 0.02372 cm/sec
y0 = 2.005 ft



RMW-18

Data Set: D:\AQTEWIN\DATA\RMW18.AQT
Date: 04/06/99 Time: 13:28:29

PROJECT INFORMATION

Test Well: RMW-18

AQUIFER DATA

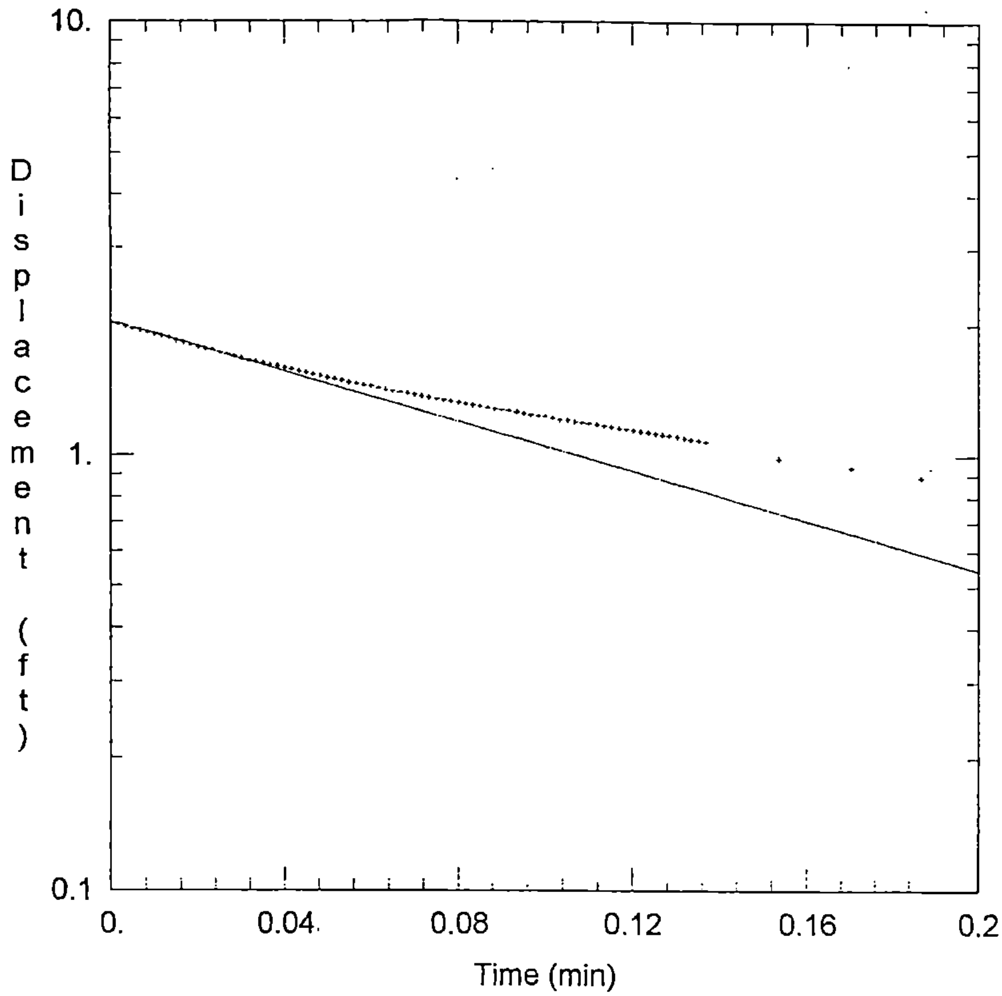
Saturated Thickness: 15. ft Anisotropy Ratio (Kz/Kr): 1.

WELL DATA

Initial Displacement: 2.15 ft
Casing Radius: 0.083 ft
Screen Length: 11.1 ft
Water Column Height: 11.1 ft
Wellbore Radius: 0.42 ft
Gravel Pack Porosity: 0.3

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice
K = 0.02422 cm/sec
y0 = 2.003 ft



MW-8B WITHDRAWAL SLUG TEST

Data Set: A:\MW8B.AQT
Date: 04/05/99 Time: 13:15:25

PROJECT INFORMATION

Company: ThermoRetec
Test Location: Roeder Ave.
Test Well: MW-8B
Test Date: 3/9/99

AQUIFER DATA

Saturated Thickness: 20.55 ft Anisotropy Ratio (Kz/Kr): 1.

WELL DATA

Initial Displacement: 2. ft Water Column Height: 15.55 ft
Casing Radius: 0.083 ft Wellbore Radius: 0.42 ft
Screen Length: 15. ft Gravel Pack Porosity: 0.3

SOLUTION

Aquifer Model: Unconfined K = 0.01578 cm/sec
Solution Method: Bouwer-Rice y0 = 2.03 ft

ThermoRetec

MODELED SHORELINE

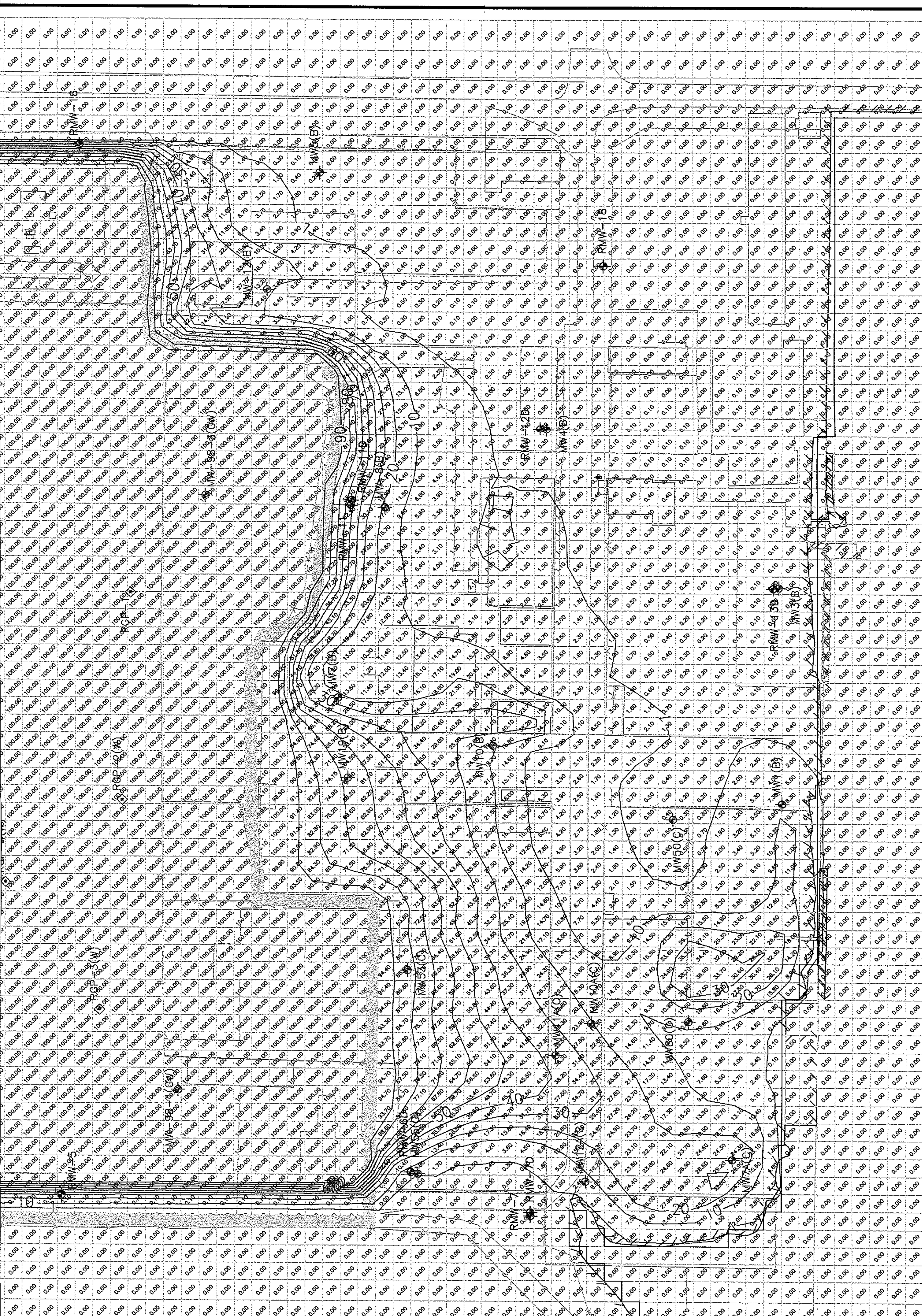
—90— MODEL-PREDICTED "LEACHATE" CONCENTRATION CONTOURS FOR LAYER 2 CELLS

0.00 LAYER 2 MODEL GRID AND PREDICTED "LEACHATE" CONCENTRATION

NOTE: SEE APPENDICES
MODEL LAYER O

50 0

1"=100'



FOR ADDITIONAL
UTPUT

100

ROEDER AVENUE LANDFILL RI/FS

PORTB-03809-710

DATE: 12/15/00 | DRWN: N.S. | FILE: 3809s131

DEVELOPMENT BASELINE SCENARIO
YEAR 2035 CONCENTRATIONS
LAYER 1

MODELED SHORELINE

MODEL-PREDICTED "LEACHATE" CONCENTRATION CONTOURS FOR LAYER 2 CELLS

LAYER 2 MODEL GRID AND PREDICTED "LEACHATE" CONCENTRATION

ThermoRetec

NOTE: SEE APPENDICES
MODEL LAYER OU

50 0

1"=100'

... FOR ADDITIONAL ...TPUT

100

ROEDER AVENUE LANDFILL RI/FS

PORTB-03809-710

DATE: 12/15/00 | DRWN: N.S. | FILE: 3809s132

DEVELOPMENT BASELINE SCENARIO
YEAR 2035 CONCENTRATIONS
LAYER 3

MODELED SHORELINE

—90— MODEL-PREDICTED "LEACHATE" CONCENTRATION CONTOURS FOR LAYER 2 CELLS

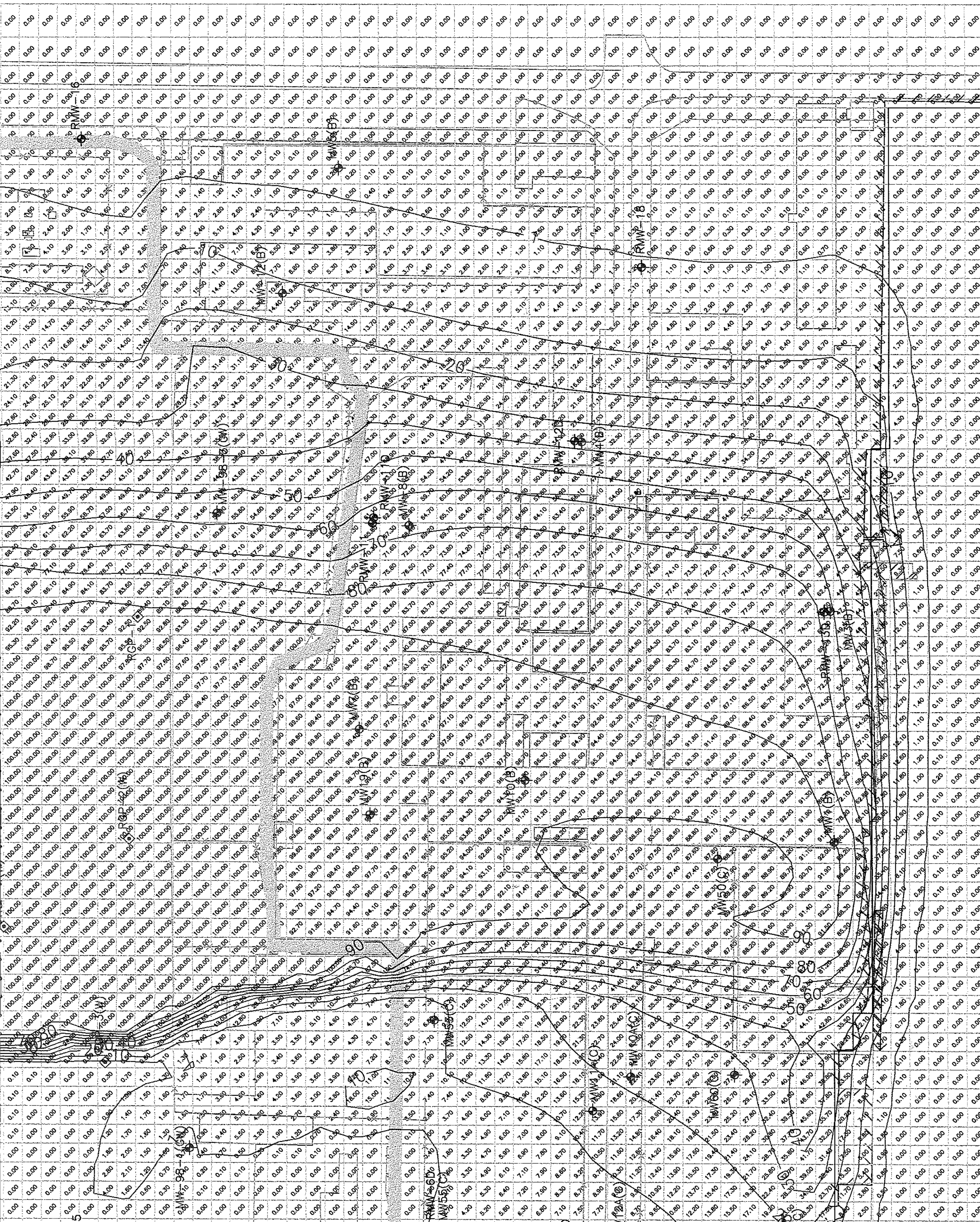
LAYER 2 MODEL GRID AND PREDICTED "LEACHATE" CONCENTRATION

NOTE: SEE APPENDICES
MODEL LAYER O

50 0

1"=100'

ThermoRetec



FOR ADDITIONAL
UTPUT

100

ROEDER AVENUE LANDFILL RI/FS

PORTB-03809-710

DATE: 12/15/00 | DRWN: N.S. | FILE: 3809s133

DEVELOPMENT BASELINE SCENARIO
YEAR 2035 CONCENTRATIONS
LAYER 4

ThermoRetec

MODELED SHORELINE

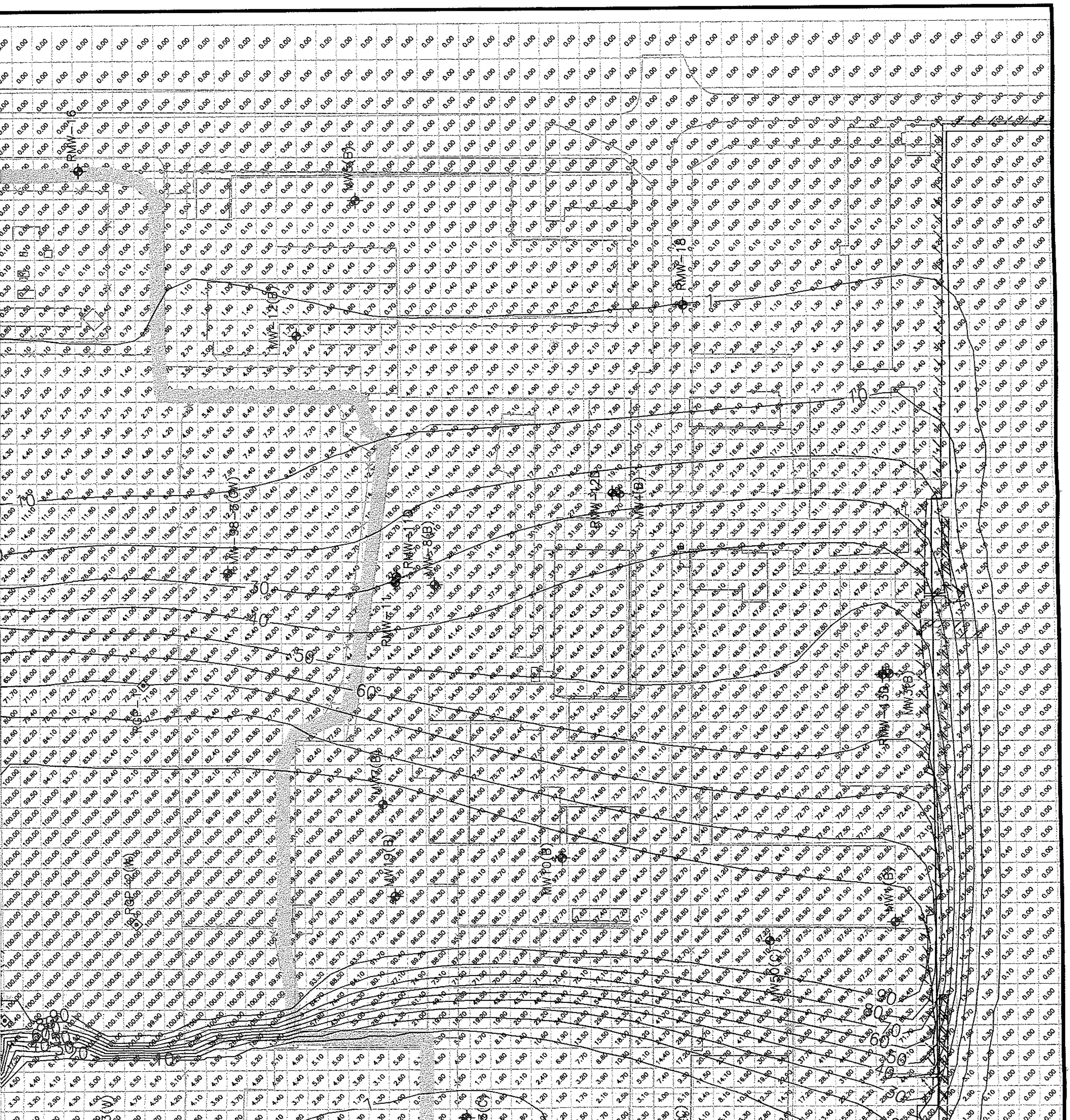
—90— MODEL-PREDICTED "LEACHATE" CONCENTRATION CONTOURS FOR LAYER 2 CELLS

0.00 LAYER 2 MODEL GRID AND PREDICTED "LEACHATE" CONCENTRATION

NOTE: SEE APPENDICES
MODEL LAYER O

50 0

1"=100'



FOR ADDITIONAL
UTPUT

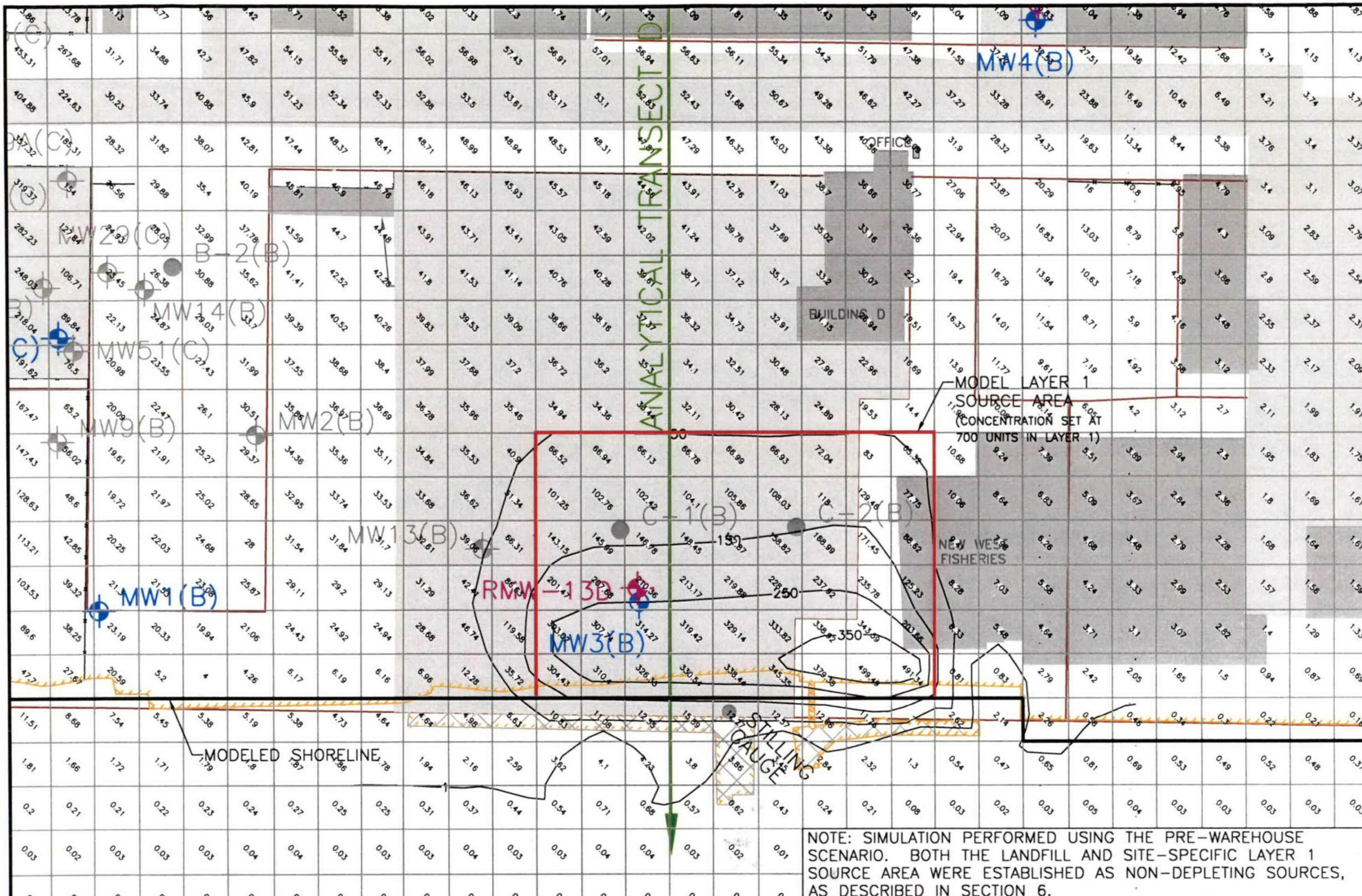
100

ROEDER AVENUE LANDFILL RI/FS

PORTB-03809-710

DATE: 12/15/00 | DRWN: N.S. | FILE: 3809s134

DEVELOPMENT BASELINE SCENARIO
YEAR 2035 CONCENTRATIONS
LAYER 5



RETEC

ROEDER AVENUE LANDFILL RI/FS

PORTB-03809-710

SIMULATION OF MULTI-SOURCE SOLUTE INTERACTIONS AT THE BMI/COLONY WHARF SITE

DATE: 08/27/01	DRWN: N.J.S./SEA	FILE: 3809S221	LAYOUT: ANSI_AI-LJ

```
*******************************************************
*                                                     *
*      INTERNATIONAL GROUND WATER MODELING CENTER     *
*                                                     *
*              S O L U T E   version 3.0              *
*                                                     *
*       ANALYTICAL MODELS FOR SOLUTE TRANSPORT        *
*                                                     *
*******************************************************
```

Model: ONEd-1

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PROJECT.......... = rgp3 lf_sl
USER NAME....... =
DATE............ = 08-22-2001
DATA FILE....... =
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INPUT DATA:

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GROUNDWATER (SEEPAGE) VELOCITY =  185 [ft/y]
LONGITUDINAL DISPERSIVITY..... =  20 [ft]
RETARDATION FACTOR............ =  1155
INITIAL CONCENTRATION......... =  0 [mg/l]
CONCENTRATION AT SOURCE....... =  .64 [mg/l]
DISTANCE INCREMENT............ =  20 [ft]
NUMBER OF DISTANCE INCREMENTS. =  41
NUMBER OF TIME PERIODS........ =  1
    1  TIME................... =  1500 [y]
DURATION OF SOLUTE PULSE...... =  1500 [y]
HALF-LIFE (0 if no decay)..... =  .11 [y]
DECAY CONSTANT (lambda)....... = .6301D+01 [1/y]
```

CONCENTRATION C [mg/l]

DISTANCE [ft]	1 TIME 1500.00 [y]
0.0000	6.4000E-01
20.0000	4.0201E-01
40.0000	2.5251E-01
60.0000	1.5861E-01
80.0000	9.9629E-02
100.0000	6.2579E-02
120.0000	3.9306E-02
140.0000	2.4686E-02
160.0000	1.5502E-02
180.0000	9.7324E-03
200.0000	6.1070E-03
220.0000	3.8288E-03
240.0000	2.3970E-03
260.0000	1.4973E-03
280.0000	9.3211E-04
300.0000	5.7745E-04
320.0000	3.5535E-04

340.0000	2.1676E-04
360.0000	1.3075E-04
380.0000	7.7797E-05
400.0000	4.5539E-05
420.0000	2.6158E-05
440.0000	1.4707E-05
460.0000	0.0000E+00
480.0000	0.0000E+00
500.0000	0.0000E+00
520.0000	0.0000E+00
540.0000	0.0000E+00
560.0000	0.0000E+00
580.0000	0.0000E+00
600.0000	0.0000E+00
620.0000	0.0000E+00
640.0000	0.0000E+00
660.0000	0.0000E+00
680.0000	0.0000E+00
700.0000	0.0000E+00
720.0000	0.0000E+00
740.0000	0.0000E+00
760.0000	0.0000E+00
780.0000	0.0000E+00
800.0000	0.0000E+00
820.0000	0.0000E+00

Alternative A: Controlled Development, Institutional Controls & Monitoring

Probable Environmental Liabilities	Quantity	Units	Unit Cost	Probable Costs (Net Present Value)		
STORMWATER MANAGEMENT FOR LANDFILL AREA						
Stormwater drainage infrastructure necessary to support enhanced drainage in landfill areas is assumed to be provided by the City as part of area-wide redevelopment activities. These costs are not itemized in the RI/FS.						
MANAGEMENT OF LANDFILL METHANE						$1,052,040
Capital Costs					$ 876,700	
In-Building Monitoring Systems	1	total est.	50,000	50,000		
Under-Building Venting Systems (Future Landfill Construction)	130,680	est. sq. ft.	2.5	326,700		
Under-Building Venting Systems (100 ft. Perimeter Zone)	100,000	est. sq. ft.	2.5	250,000		
Potential Retrofit of Existing Buildings (Contingency)	1	total est.	250,000	250,000		
Engineering, Procurement, Monitoring, Reporting					$ 131,505	
Engineering for Methane Systems	1	total est.	15%	131,505		
System O&M					$ 43,835	
Equipment O&M	1	total est.	5%	43,835		
REGULATORY PROCESS (Capital)					$ 110,000	$110,000
Cleanup Action Plan, Consent Decree, Monitoring Plan	1	total est.	75,000	75,000		
Institutional Controls, Property Owner Agreements	1	total est.	35,000	35,000		
COMPLIANCE MONITORING						$452,936
Capital Costs					$ 81,500	
Well Installation, Abandonment, First Year Monitoring	1	total est.		81,500		
System O&M					$ 371,436	
Compliance Monitoring & Reporting (Years 2-30)	1	total est. NPV		371,436		

TOTAL ESTIMATED CLEANUP COSTS	Capital, Reg. & Eng.	O&M	Total
Lower Probable Costs (-25%)	$ 899,779	$ 311,453	$ 1,211,232
Probable Costs	**$ 1,199,705**	**$ 415,271**	**$ 1,614,976**
Upper Probable Costs (+30%)	$ 1,559,617	$ 539,852	$ 2,099,469

Notes:

Previous costs associated with the landfill (e.g., costs of RI/FS and Warehouse project) are not included in this table.

Alternative B: Controlled Development with Enhanced Attenuation, Institutional Controls & Monitoring

Probable Environmental Liabilities	Quantity	Units	Unit Cost	Probable Costs (Net Present Value)		
MODIFICATIONS TO SHORELINE DISCHARGE AREAS						**$457,120**
Capital Costs					*$ 364,000*	
Foot of Hilton Containment Wall (300 lin. ft., 40 ft avg. depth)	12,000	sq. ft.	22	264,000		
Closure of I&J Bulkhead Gap (50 ft.)	1	total est.	100,000	100,000		
Engineering, Procurement, Monitoring, Reporting					*$ 54,600*	
Engineering for Installation of Walls	1	total est.	15%	54,600		
System O&M 12,000 sq. ft.					*$ 38,520*	
O&M of Containment Wall	1	total est. NPV	38,520	38,520		
STORMWATER MANAGEMENT FOR LANDFILL AREA						
Stormwater drainage infrastructure necessary to support enhanced drainage in landfill areas is assumed to be provided by the City as part of area-wide redevelopment activities. These costs are not itemized in the RI/FS.						
MANAGEMENT OF LANDFILL METHANE						**$1,052,040**
Capital Costs					*$ 876,700*	
In-Building Monitoring Systems	1	total est.	50,000	50,000		
Under-Building Venting Systems (Future Landfill Construction)	130,680	est. sq. ft.	2.5	326,700		
Under-Building Venting Systems (100 ft. Perimeter Zone)	100,000	est. sq. ft.	2.5	250,000		
Potential Retrofit of Existing Buildings (Contingency)	1	total est.	250,000	250,000		
Engineering, Procurement, Monitoring, Reporting					*$ 131,505*	
Engineering for Methane Systems	1	total est.	15%	131,505		
System O&M					*$ 43,835*	
Equipment O&M	1	total est.	5%	43,835		
REGULATORY PROCESS (Capital)					*$ 110,000*	**$110,000**
Cleanup Action Plan, Consent Decree, Monitoring Plan	1	total est.	75,000	75,000		
Institutional Controls, Property Owner Agreements	1	total est.	35,000	35,000		
COMPLIANCE MONITORING						**$452,936**
Capital Costs					*$ 81,500*	
Well Installation, Abandonment, First Year Monitoring	1	total est.		81,500		
System O&M					*$ 371,436*	
Compliance Monitoring & Reporting (Years 2-30)	1	total est. NPV		371,436		

TOTAL ESTIMATED CLEANUP COSTS	Capital, Reg. & Eng.	O&M	Total
Lower Probable Costs (-25%)	$ 1,213,729	$ 340,343	$ 1,554,071
Probable Costs	**$ 1,618,305**	**$ 453,790**	**$ 2,072,095**
Upper Probable Costs (+30%)	$ 2,103,797	$ 589,927	$ 2,693,724

Notes:

Previous costs associated with the landfill (e.g., costs of RI/FS and Warehouse project) are not included in this table.

Alternative C: Complete Capping, Enhanced Attenuation, Institutional Controls and Monitoring

Probable Environmental Liabilities	Quantity	Units	Unit Cost	Probable Costs (Net Present Value)		
MODIFICATIONS TO SHORELINE DISCHARGE AREAS						$457,120
Capital Costs					$ 364,000	
Foot of Hilton Containment Wall (300 lin. ft., 40 ft avg. depth)	12,000	sq. ft.	22	264,000		
Closure of I&J Bulkhead Gap (50 ft.)	1	total est.	100,000	100,000		
Engineering, Procurement, Monitoring, Reporting					$ 54,600	
Engineering for Installation of Walls	1	total est.	15%	54,600		
System O&M 12,000 sq. ft.					$ 38,520	
O&M of Containment Wall	1	total est. NPV	38,520	38,520		
LANDFILL CAPPING						$2,697,783
Capital Costs					$ 1,343,975	
SSC & G-Street 3.5 Acres (excluding bldg, paving)						
Regrade, Compact Surface Gravels	5,647	cyd	6	33,880		
Install Storm Drains & Catch Basins	3.5	Acres	20,000	70,000		
Install Passive Venting Lines	3.5	Acres	20,000	70,000		
Place 4-Inch Aspalt Paving (2 lifts)	152,460	Sq. Feet	1.15	175,329		
Georgia Pacific 5 Acres (excluding bldg, paving)						
Regrade, Compact Surface Gravels	8,067	cyd	6	48,400		
Install Storm Drains & Catch Basins	5.0	Acres	20,000	100,000		
Install Passive Venting Lines	5.0	Acres	20,000	100,000		
Place 4-Inch Aspalt Paving (2 lifts)	217,800	Sq. Feet	1.15	250,470		
Hilton Avenue 3 Acres						
Regrade, Apply & Compact 1 foot Gravel Base	4,840	cyd	24	116,160		
Install Storm Drains & Catch Basins	3.0	Acres	20,000	60,000		
Install Passive Venting Lines	3.0	Acres	20,000	60,000		
Place 4-Inch Aspalt Paving	130,680	Sq. Feet	1.15	150,282		
PSE Substation Area 1 Acres						
Regrade, Compact Surface Gravels (Limited Access)	1,613	cyd	12	19,360		
Install Storm Drains & Catch Basins	1.0	Acres	20,000	20,000		
Install Passive Venting Lines	1.0	Acres	20,000	20,000		
Place 4-Inch Aspalt Paving (2 lifts)	43,560	Sq. Feet	1.15	50,094		
Engineering, Procurement, Monitoring, Reporting					$ 201,596	
Engineering for Installation of Cap	1	total est.	15%	201,596		
Cap O&M 12.5 Acres					$ 1,152,212	
NPV Estimate of Capping O&M (30 years)	1	total est. NPV	$1,152,212	1,152,212		
STORMWATER MANAGEMENT FOR LANDFILL AREA						
Stormwater drainage infrastructure necessary to support enhanced drainage in landfill areas is assumed to be provided by the City as part of area-wide redevelopment activities. These costs are not itemized in the RI/FS.						
MANAGEMENT OF LANDFILL METHANE						$660,000
Capital Costs					$ 550,000	
In-Building Monitoring Systems	1	total est.	50,000	50,000		
Under-Building Venting Systems (Future Landfill Construction)	Offset to landfill capping costs listed above					
Under-Building Venting Systems (100 ft. Perimeter Zone)	100,000	est. sq. ft.	2.5	250,000		
Potential Retrofit of Existing Buildings (Contingency)	1	total est.	250,000	250,000		
Engineering, Procurement, Monitoring, Reporting					$ 82,500	
Engineering for Methane Systems	1	total est.	15%	82,500		
System O&M					$ 27,500	
Equipment O&M	1	total est.	5%	27,500		
REGULATORY PROCESS (Capital)					$ 110,000	$110,000
Cleanup Action Plan, Consent Decree, Monitoring Plan	1	total est.	75,000	75,000		
Institutional Controls, Property Owner Agreements	1	total est.	35,000	35,000		
COMPLIANCE MONITORING						$452,936
Capital Costs					$ 81,500	
Well Installation, Abandonment, First Year Monitoring	1	total est.		81,500		
System O&M					$ 371,436	
Compliance Monitoring & Reporting (Years 2-30)	1	total est. NPV		371,436		

TOTAL ESTIMATED CLEANUP COSTS	Capital, Reg. & Eng.	O&M	Total
Lower Probable Costs (-25%)	$ 2,091,128	$ 1,192,250	$ 3,283,379
Probable Costs	**$ 2,788,171**	**$ 1,589,667**	**$ 4,377,839**
Upper Probable Costs (+30%)	$ 3,624,623	$ 2,066,568	$ 5,691,190

Notes:

Previous costs associated with the landfill (e.g., costs of RI/FS and Warehouse project) are not included in this table.

Alternative D: Complete Capping, Enhanced Physical Containment, Institutional Controls & Monitoring

Probable Environmental Liabilities	Quantity	Units	Unit Cost	Probable Costs (Net Present Value)		
MODIFICATIONS TO SHORELINE DISCHARGE AREAS						$115,000
Capital Costs					$ 100,000	
Wall at Foot of Hilton Included below	NA	NA	NA	NA		
Closure of I&J Bulkhead Gap (50 ft.)	1	total est.	100,000	100,000		
Engineering, Procurement, Monitoring, Reporting					$ 15,000	
Engineering for Installation of Walls	1	total est.	15%	15,000		
System O&M NA sq. ft.					$ -	
NA	NA	NA	NA	NA		
ROEDER AND LAGOON BARRIER WALLS						$1,600,225
Wall Installation					$ 1,391,500	
Grouted Wall Along Roeder (800 lin. ft., 20 ft avg. depth)	16,000	sq. ft.	25	400,000		
Management of Utility Conflicts	1	total est.	75000	75,000		
Slurry Wall Along Lagoon (1100 lin ft., 45 ft. average depth)	49,500	sq. ft.	17	841,500		
Management of Utility Conflicts	1	total est.	75000	75,000		
Engineering, Procurement, Monitoring, Reporting					$ 208,725	
Engineering for Installation of Walls	1	total est.	15%	208,725		
Wall O&M					$ -	
Assumes no active maintenance for slurry/grout walls	1	total est. NPV	-	0		
LANDFILL CAPPING						$2,697,783
Capital Costs					$ 1,343,975	
SSC & G-Street 3.5 Acres						
Regrade, Compact Surface Gravels	5,647	cyd	6	33,880		
Install Storm Drains & Catch Basins	4	Acres	20,000	70,000		
Install Passive Venting Lines	4	Acres	20,000	70,000		
Place 4-Inch Aspalt Paving (2 lifts)	152,460	Sq. Feet	1.15	175,329		
Georgia Pacific 5 Acres						
Regrade, Compact Surface Gravels	8,067	cyd	6	48,400		
Install Storm Drains & Catch Basins	5	Acres	20,000	100,000		
Install Passive Venting Lines	5	Acres	20,000	100,000		
Place 4-Inch Aspalt Paving (2 lifts)	217,800	Sq. Feet	1.15	250,470		
Hilton Avenue 3 Acres						
Regrade, Apply & Compact 1 foot Gravel Base	4,840	cyd	24	116,160		
Install Storm Drains & Catch Basins	3	Acres	20,000	60,000		
Install Passive Venting Lines	3	Acres	20,000	60,000		
Place 4-Inch Aspalt Paving	130,680	Sq. Feet	1.15	150,282		
PSE Substation Area 1 Acres						
Regrade, Compact Surface Gravels (Limited Access)	1,613	cyd	12	19,360		
Install Storm Drains & Catch Basins	1	Acres	20,000	20,000		
Install Passive Venting Lines	1	Acres	20,000	20,000		
Place 4-Inch Aspalt Paving (2 lifts)	43,560	Sq. Feet	1.15	50,094		
Engineering, Procurement, Monitoring, Reporting					$ 201,596	
Engineering for Installation of Cap	1	total est.	15%	201,596		
Cap O&M 12.5 Acres					$ 1,152,212	
NPV Estimate of Capping O&M	1	total est. NPV	$1,152,212	1,152,212		
STORMWATER MANAGEMENT FOR LANDFILL AREA						
Stormwater drainage infrastructure necessary to support enhanced drainage in landfill areas is assumed to be provided by the City as part of area-wide redevelopment activities. These costs are not itemized in the RI/FS.						
MANAGEMENT OF LANDFILL METHANE						$660,000
Capital Costs					$ 550,000	
In-Building Monitoring Systems	1	total est.	50,000	50,000		
Under-Building Venting Systems (Future Landfill Construction)	Offset to landfill capping costs listed above					
Under-Building Venting Systems (100 ft. Perimeter Zone)	100,000	est. sq. ft.	2.5	250,000		
Potential Retrofit of Existing Buildings (Contingency)	1	total est.	250,000	250,000		
Engineering, Procurement, Monitoring, Reporting					$ 82,500	
Engineering for Methane Systems	1	total est.	15%	82,500		
System O&M					$ 27,500	
Equipment O&M	1	total est.	5%	27,500		
REGULATORY PROCESS (Capital)					$ 110,000	$110,000
Cleanup Action Plan, Consent Decree, Monitoring Plan	1	total est.	75,000	75,000		
Institutional Controls, Property Owner Agreements	1	total est.	35,000	35,000		
COMPLIANCE MONITORING						$452,936
Capital Costs					$ 81,500	
Well Installation, Abandonment, First Year Monitoring	1	total est.		81,500		
System O&M					$ 371,436	
Compliance Monitoring & Reporting (Years 2-30)	1	total est. NPV		371,436		

TOTAL ESTIMATED CLEANUP COSTS	Capital, Reg. & Eng.	O&M	Total
Lower Probable Costs (-25%)	$ 3,063,597	$ 1,163,361	$ 4,226,958
Probable Costs	**$ 4,084,796**	**$ 1,551,148**	**$ 5,635,944**
Upper Probable Costs (+30%)	$ 5,310,235	$ 2,016,492	$ 7,326,727

Notes:

Previous costs associated with the landfill (e.g., costs of RI/FS and Warehouse project) are not included in this table.

Alternative E: Complete Capping with Encircling Barrier Wall and Groundwater Extraction

Probable Environmental Liabilities	Quantity	Units	Unit Cost	Probable Costs (Net Present Value)		
MODIFICATIONS TO SHORELINE DISCHARGE AREAS						$115,000
Capital Costs					$ 100,000	
Wall at Foot of Hilton (included in lagoon wall)	NA	NA	NA	NA		
Closure of I&J Bulkhead Gap (50 ft.)	1	total est.	100,000	100,000		
Engineering, Procurement, Monitoring, Reporting					$ 15,000	
Engineering for Installation of Walls	1	total est.	15%	15,000		
System O&M NA sq. ft.					$ -	
NA	NA	NA	NA	NA		
ROEDER AND LAGOON BARRIER WALLS						$1,600,225
Wall Installation					$ 1,391,500	
Grouted Wall Along Roeder (800 lin. ft., 20 ft avg. depth)	16,000	sq. ft.	25	400,000		
Management of Utility Conflicts	1	total est.	75000	75,000		
Slurry Wall Along Lagoon (1100 lin ft., 45 ft. average depth) .	49,500	sq. ft.	17	841,500		
Management of Utility Conflicts	1	total est.	75000	75,000		
Engineering, Procurement, Monitoring, Reporting					$ 208,725	
Engineering for Installation of Walls	1	total est.	15%	208,725		
Wall O&M					$ -	
Assumes no active maintenance for slurry/grout walls	1	total est. NPV	-	0		
LANDFILL CAPPING						$2,697,783
Capital Costs					$ 1,343,975	
SSC & G-Street 3.5 Acres						
Regrade, Compact Surface Gravels	5,647	cyd	6	33,880		
Install Storm Drains & Catch Basins	4	Acres	20,000	70,000		
Install Passive Venting Lines	4	Acres	20,000	70,000		
Place 4-Inch Aspalt Paving (2 lifts)	152,460	Sq. Feet	1.15	175,329		
Georgia Pacific 5 Acres						
Regrade, Compact Surface Gravels	8,067	cyd	6	48,400		
Install Storm Drains & Catch Basins	5	Acres	20,000	100,000		
Install Passive Venting Lines	5	Acres	20,000	100,000		
Place 4-Inch Aspalt Paving (2 lifts)	217,800	Sq. Feet	1.15	250,470		
Hilton Avenue 3 Acres						
Regrade, Apply & Compact 1 foot Gravel Base	4,840	cyd	24	116,160		
Install Storm Drains & Catch Basins	3	Acres	20,000	60,000		
Install Passive Venting Lines	3	Acres	20,000	60,000		
Place 4-Inch Aspalt Paving	130,680	Sq. Feet	1.15	150,282		
PSE Substation Area 1 Acres						
Regrade, Compact Surface Gravels (Limited Access)	1,613	cyd	12	19,360		
Install Storm Drains & Catch Basins	1	Acres	20,000	20,000		
Install Passive Venting Lines	1	Acres	20,000	20,000		
Place 4-Inch Aspalt Paving (2 lifts)	43,560	Sq. Feet	1.15	50,094		
Engineering, Procurement, Monitoring, Reporting					$ 201,596	
Engineering for Installation of Cap	1	total est.	15%	201,596		
Cap O&M 12.5 Acres					$ 1,152,212	
NPV Estimate of Capping O&M	1	total est. NPV	$1,152,212	1,152,212		
STORMWATER MANAGEMENT FOR LANDFILL AREA						
Stormwater drainage infrastructure necessary to support enhanced drainage in landfill areas is assumed to be provided by the City as part of area-wide redevelopment activities. These costs are not itemized in the RI/FS.						
GROUNDWATER EXTRACTION & POTW DISCHARGE						$2,296,145
Capital Costs					$ 1,610,500	
Installation of Hilton Ave Barrier Wall (1,500 ft x 25 ft avg depth)	37,500	sq. ft.	17	637,500		
Installation of C-Street Barrier Wall (1,300 ft x 30 ft avg depth)	39,000	sq. ft.	17	663,000		
Management of Utility Conflicts with Barrier Walls	1	total est.	100,000	100,000		
Installation of Extraction Wells, Pumps, Controls, Discharges	1	total est.	200,000	200,000		
Discharge Permitting	1	total est.	10,000	10,000		
Engineering, Procurement, Monitoring, Reporting					$ 42,000	
Engineering for GW Extraction System	1	total est.	20%	42,000		
System O&M 10 gpm assumed avg. discharge					$ 643,645	
Equipment O&M 10 pumping wells	1	total est. NPV	$138,612	138,612		
Wall O&M	na	na	na	na		
POTW Fees (assumes monitoring, reporting, no pre-treatment)	1	total est. NPV	$505,033	505,033		
MANAGEMENT OF LANDFILL METHANE						$660,000
Capital Costs					$ 550,000	
In-Building Monitoring Systems	1	total est.	50,000	50,000		
Under-Building Venting Systems (Future Landfill Construction)	Offset to landfill capping costs listed above					
Under-Building Venting Systems (100 ft. Perimeter Zone)	100,000	est. sq. ft.	2.5	250,000		
Potential Retrofit of Existing Buildings (Contingency)	1	total est.	250,000	250,000		
Engineering, Procurement, Monitoring, Reporting					$ 82,500	
Engineering for Methane Systems	1	total est.	15%	82,500		
System O&M					$ 27,500	
Equipment O&M	1	total est.	5%	27,500		
REGULATORY PROCESS (Capital)					$ 110,000	$110,000
Cleanup Action Plan, Consent Decree, Monitoring Plan	1	total est.	75,000	75,000		
Institutional Controls, Property Owner Agreements	1	total est.	35,000	35,000		
COMPLIANCE MONITORING						$452,936
Capital Costs					$ 81,500	
Well Installation, Abandonment, First Year Monitoring	1	total est.		81,500		
System O&M					$ 371,436	
Compliance Monitoring & Reporting (Years 2-30)	1	total est. NPV		371,436		

TOTAL ESTIMATED CLEANUP COSTS	Capital, Reg. & Eng.	O&M	Total
Lower Probable Costs (-25%)	$ 4,302,972	$ 1,646,095	$ 5,949,067
Probable Costs	**$ 5,737,296**	**$ 2,194,793**	**$ 7,932,089**
Upper Probable Costs (+30%)	$ 7,458,485	$ 2,853,231	$ 10,311,716

Notes:

Previous costs associated with the landfill (e.g., costs of RI/FS and Warehouse project) are not included in this table.

Example Costs for Long-Term Groundwater Monitoring

Year	Frequency	No. of Sampling Events	No. Wells per Event	Sample Cost per Well	Labor & Misc. per Event	Report	Total
1 1st Qtr	Initial Sampling	1	10	600	25000	0	31000
1 2-4 Qtrs	Quarterly	3	10	600	7500	10000	50500
2	Quarterly	4	10	600	7500	5000	59000
3	Quarterly	4	10	600	7500	5000	59000
4	Quarterly	4	10	600	7500	5000	59000
5	Quarterly	4	10	600	7500	5000	59000
6	Semi-Annual	2	10	600	7500	5000	32000
7	Semi-Annual	2	10	600	7500	5000	32000
8	Semi-Annual	2	10	600	7500	5000	32000
9	Semi-Annual	2	10	600	7500	5000	32000
10	Semi-Annual	2	10	600	7500	5000	32000
11	Annual	1	10	600	7500	5000	18500
12	Annual	1	10	600	7500	5000	18500
13	Annual	1	10	600	7500	5000	18500
14	Annual	1	10	600	7500	5000	18500
15	Annual	1	10	600	7500	5000	18500
16							0
17							0
18							0
19							0
20	5-Year	1	10	600	7500	5000	18500
21							0
22							0
23							0
24							0
25	5-Year	1	10	600	7500	5000	18500
26							0
27							0
28							0
29							0
30	5-Year	1	10	600	7500	5000	18500
					Total Monitoring		625,500
					First Year Costs		81,500
					NPV (6%) (Years 2-30)		$371,435.79

Basis for NPV Unit Cost of Cap Maintenance

Assumed Acreage	10 Acres	Hypothetical - Used to assess unit cost NPV
Annual Maintenance (Sealing, pothole repair)	$0.017 per sq. ft.	Crack sealing, pothole repair
Assumed Average Costs for Aggressive Repair/Replacement	1.5 $/sq. ft.	Removal & Recycling Old Asphalt, 4" New

Year	Description	Inspection Costs	Resealing, Repair Costs	Replacement Costs	Engineering, Etc. (10% of capital)	Annual Costs
1	Inspection, Repair	500	$7,405.20		740.52	8645.72
2	Inspection, Repair	500	$7,405.20		740.52	8645.72
3	Inspection, Repair	500	$7,405.20		740.52	8645.72
4	Inspection, Repair	500	$7,405.20		740.52	8645.72
5	Inspection, Repair	500	$7,405.20		740.52	8645.72
6	Inspection, Repair	500	$7,405.20		740.52	8645.72
7	Inspection, Repair	500	$7,405.20		740.52	8645.72
8	Inspection, Repair	500	$7,405.20		740.52	8645.72
9	Inspection, Repair	500	$7,405.20		740.52	8645.72
10	Resurface / Replace	500	$7,405.20	$653,400.00	66080.52	727385.72
11	Inspection, Repair	500	$7,405.20		740.52	8645.72
12	Inspection, Repair	500	$7,405.20		740.52	8645.72
13	Inspection, Repair	500	$7,405.20		740.52	8645.72
14	Inspection, Repair	500	$7,405.20		740.52	8645.72
15	Inspection, Repair	500	$7,405.20		740.52	8645.72
16	Inspection, Repair	500	$7,405.20		740.52	8645.72
17	Inspection, Repair	500	$7,405.20		740.52	8645.72
18	Inspection, Repair	500	$7,405.20		740.52	8645.72
19	Inspection, Repair	500	$7,405.20		740.52	8645.72
20	Resurface / Replace	500	$7,405.20	$653,400.00	66080.52	727385.72
21	Inspection, Repair	500	$7,405.20		740.52	8645.72
22	Inspection, Repair	500	$7,405.20		740.52	8645.72
23	Inspection, Repair	500	$7,405.20		740.52	8645.72
24	Inspection, Repair	500	$7,405.20		740.52	8645.72
25	Inspection, Repair	500	$7,405.20		740.52	8645.72
26	Inspection, Repair	500	$7,405.20		740.52	8645.72
27	Inspection, Repair	500	$7,405.20		740.52	8645.72
28	Inspection, Repair	500	$7,405.20		740.52	8645.72
29	Inspection, Repair	500	$7,405.20		740.52	8645.72
30	Resurface / Replace	500	$7,405.20	$653,400.00	66080.52	727385.72

Total O&M Costs	$ 2,415,591.60
Total NPV (6%)	$ 921,769.62
Cost Per Acre (as NPV)	$ 92,176.96
Cost Per Sq. Ft. (as NPV)	$ 2.12

Summary of Sheet-Piling Wall Maintenance Costs

Assumed Square Footage	25000 sq. ft.	
Assumed Annual Maintenance Cost	5000 $ total	Includes Electrical Power, Anode Replacement

Year	Description	Inspection Costs	Power & Repair Costs	Replacement Costs	Engineering, Etc.	Total
1	Annualized Average	500	5000			5500
2	Annualized Average	500	5000			5500
3	Annualized Average	500	5000			5500
4	Annualized Average	500	5000			5500
5	Annualized Average	500	5000			5500
6	Annualized Average	500	5000			5500
7	Annualized Average	500	5000			5500
8	Annualized Average	500	5000			5500
9	Annualized Average	500	5000			5500
10	Annualized Average	500	5000			5500
11	Annualized Average	500	5000			5500
12	Annualized Average	500	5000			5500
13	Annualized Average	500	5000			5500
14	Annualized Average	500	5000			5500
15	Annualized Average	500	5000			5500
16	Annualized Average	500	5000			5500
17	Annualized Average	500	5000			5500
18	Annualized Average	500	5000			5500
19	Annualized Average	500	5000			5500
20	Annualized Average	500	5000			5500
21	Annualized Average	500	5000			5500
22	Annualized Average	500	5000			5500
23	Annualized Average	500	5000			5500
24	Annualized Average	500	5000			5500
25	Annualized Average	500	5000			5500
26	Annualized Average	500	5000			5500
27	Annualized Average	500	5000			5500
28	Annualized Average	500	5000			5500
29	Annualized Average	500	5000			5500
30	Annualized Average	500	5000			5500

Total O&M Costs	$	165,000.00
Total NPV (6%)	$	80,248.97
Cost Per Sq. Ft. (as NPV)	$	3.21

Summary of Projected POTW Discharge Fees (Discharge, Monitoring & Reporting)

Assumed Discharge Rate	15 gpm	Valid only for complete containment alternative
Assumed Discharge Cost	0.005 $/gal	Fess assume no required pretreatment or surcharges

Year	Description	POTW Fees	Permit Analytical & Reporting	Total
1	Annualized Average	$ 39,420	12500	51920
2	Annualized Average	$ 39,420	12500	51920
3	Annualized Average	$ 39,420	12500	51920
4	Annualized Average	$ 39,420	12500	51920
5	Annualized Average	$ 39,420	12500	51920
6	Annualized Average	$ 39,420	12500	51920
7	Annualized Average	$ 39,420	12500	51920
8	Annualized Average	$ 39,420	12500	51920
9	Annualized Average	$ 39,420	12500	51920
10	Annualized Average	$ 39,420	12500	51920
11	Annualized Average	$ 39,420	12500	51920
12	Annualized Average	$ 39,420	12500	51920
13	Annualized Average	$ 39,420	12500	51920
14	Annualized Average	$ 39,420	12500	51920
15	Annualized Average	$ 39,420	12500	51920
16	Annualized Average	$ 39,420	12500	51920
17	Annualized Average	$ 39,420	12500	51920
18	Annualized Average	$ 39,420	12500	51920
19	Annualized Average	$ 39,420	12500	51920
20	Annualized Average	$ 39,420	12500	51920
21	Annualized Average	$ 39,420	12500	51920
22	Annualized Average	$ 39,420	12500	51920
23	Annualized Average	$ 39,420	12500	51920
24	Annualized Average	$ 39,420	12500	51920
25	Annualized Average	$ 39,420	12500	51920
26	Annualized Average	$ 39,420	12500	51920
27	Annualized Average	$ 39,420	12500	51920
28	Annualized Average	$ 39,420	12500	51920
29	Annualized Average	$ 39,420	12500	51920
30	Annualized Average	$ 39,420	12500	51920

Total Est. Costs	$	1,557,600
Total NPV (6%)	$	757,550
NPV Cost per gpm	$	50,503

Summary of Potential O&M Costs for Groundwater Extraction Wells

Assumed Well Number			10 wells	Hypothetical -- Basis for evaluating NPV
		Inspection, Engineering	Power, Repairs	Total
1	Annualized Average	6000	3500	9500
2	Annualized Average	6000	3500	9500
3	Annualized Average	6000	3500	9500
4	Annualized Average	6000	3500	9500
5	Annualized Average	6000	3500	9500
6	Annualized Average	6000	3500	9500
7	Annualized Average	6000	3500	9500
8	Annualized Average	6000	3500	9500
9	Annualized Average	6000	3500	9500
10	Annualized Average	6000	3500	9500
11	Annualized Average	6000	3500	9500
12	Annualized Average	6000	3500	9500
13	Annualized Average	6000	3500	9500
14	Annualized Average	6000	3500	9500
15	Annualized Average	6000	3500	9500
16	Annualized Average	6000	3500	9500
17	Annualized Average	6000	3500	9500
18	Annualized Average	6000	3500	9500
19	Annualized Average	6000	3500	9500
20	Annualized Average	6000	3500	9500
21	Annualized Average	6000	3500	9500
22	Annualized Average	6000	3500	9500
23	Annualized Average	6000	3500	9500
24	Annualized Average	6000	3500	9500
25	Annualized Average	6000	3500	9500
26	Annualized Average	6000	3500	9500
27	Annualized Average	6000	3500	9500
28	Annualized Average	6000	3500	9500
29	Annualized Average	6000	3500	9500
30	Annualized Average	6000	3500	9500

Total Monitoring	$	285,000.00
Total NPV (6%)	$	138,611.85
Cost per well	$	13,861.18

ThermoRetec

MODELED SHORELINE

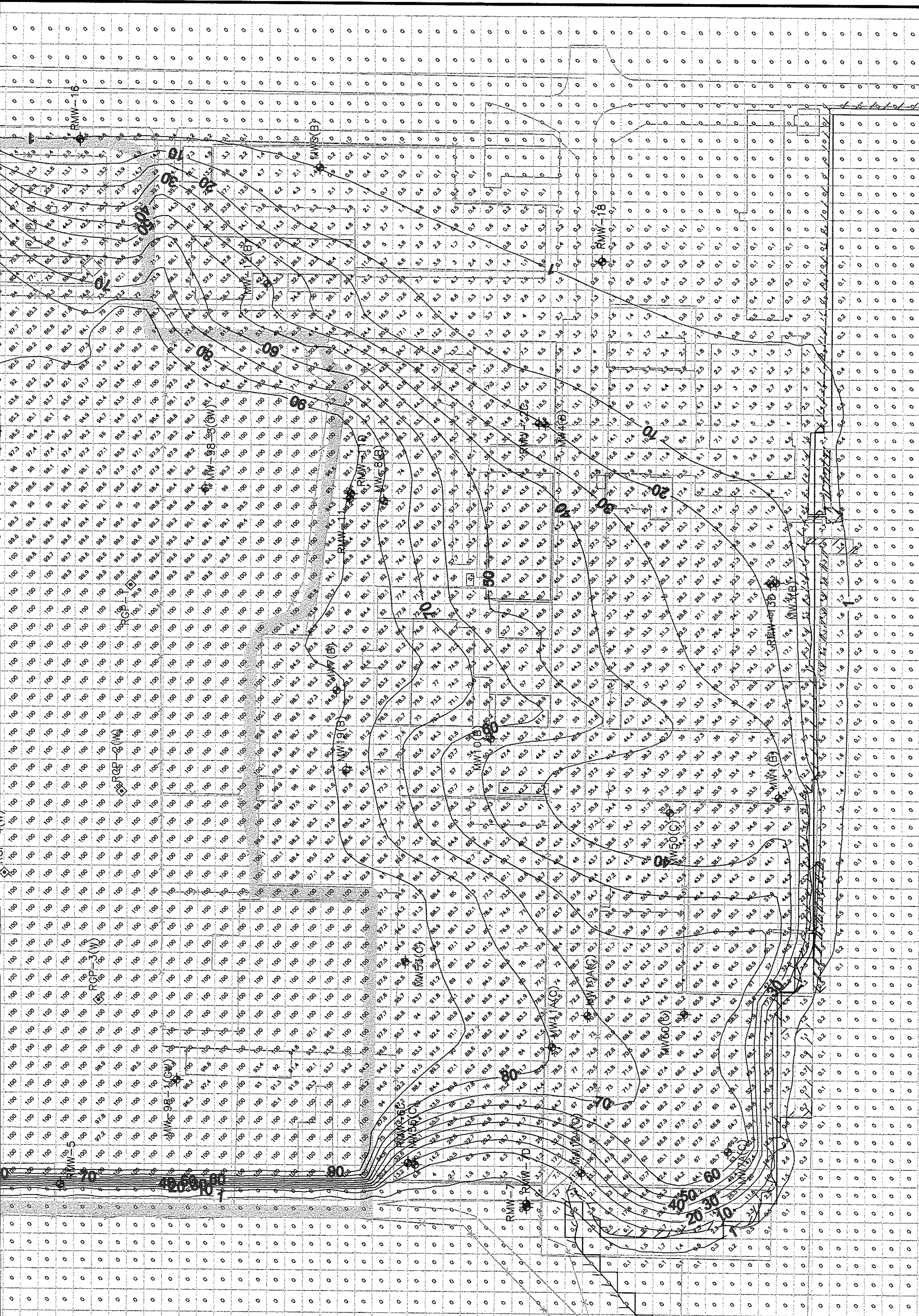
—90— MODEL-PREDICTED "LEACHATE" CONCENTRATION CONTOURS FOR LAYER 2 CELLS

0.00 LAYER 2 MODEL GRID AND PREDICTED "LEACHATE" CONCENTRATION

NOTE: SEE APPENDICES
MODEL LAYER OU

50 0

1"=100'



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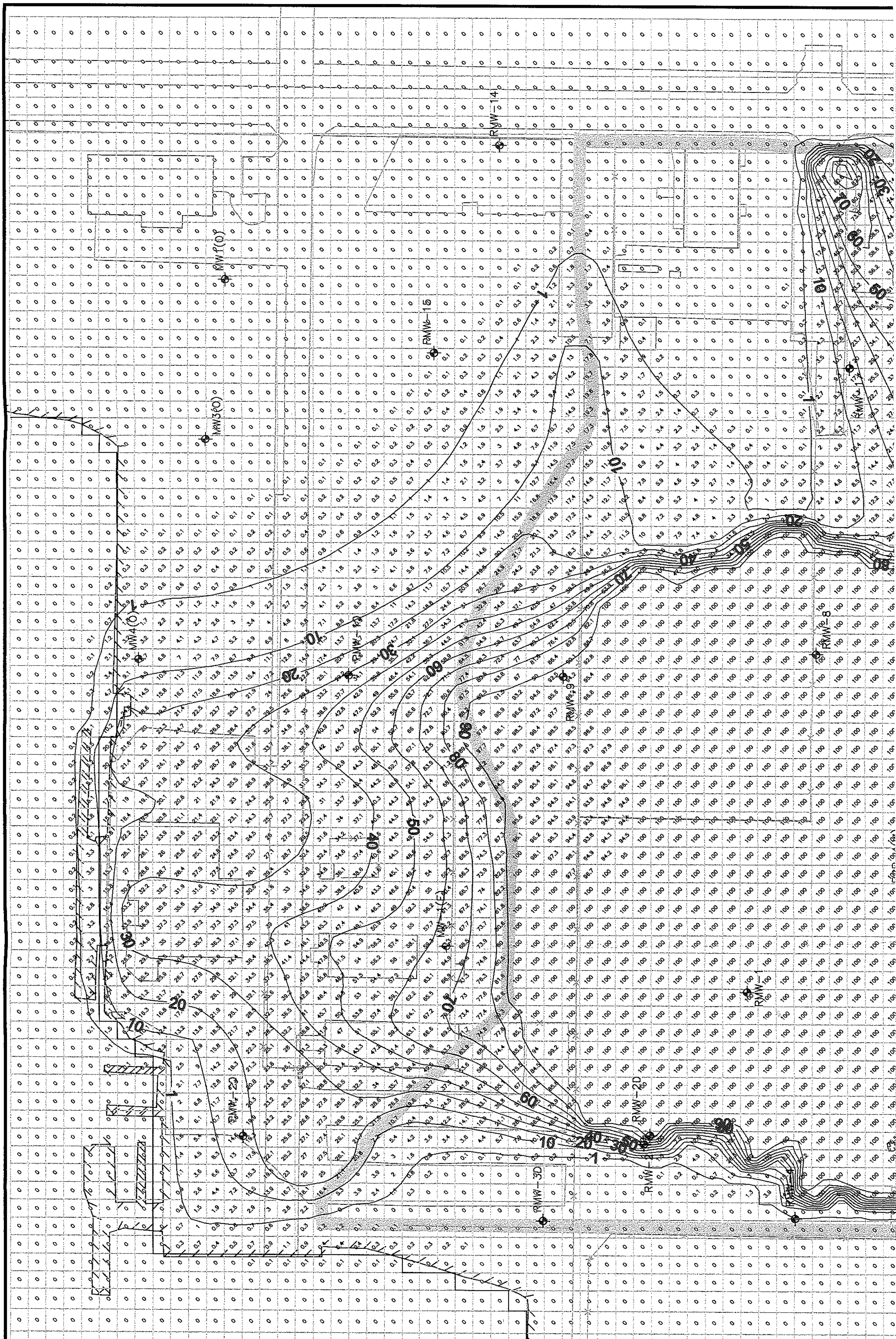
ROEDER AVENUE LANDFILL RI/FS

PORTB-03809-710

DATE: 03/12/01	DRWN: N.S.	FILE: 3809s184

ALTERNATIVE B CONCENTRATIONS
YEAR 2035, LAYER 2



ThermoRetec

MODELED SHORELINE

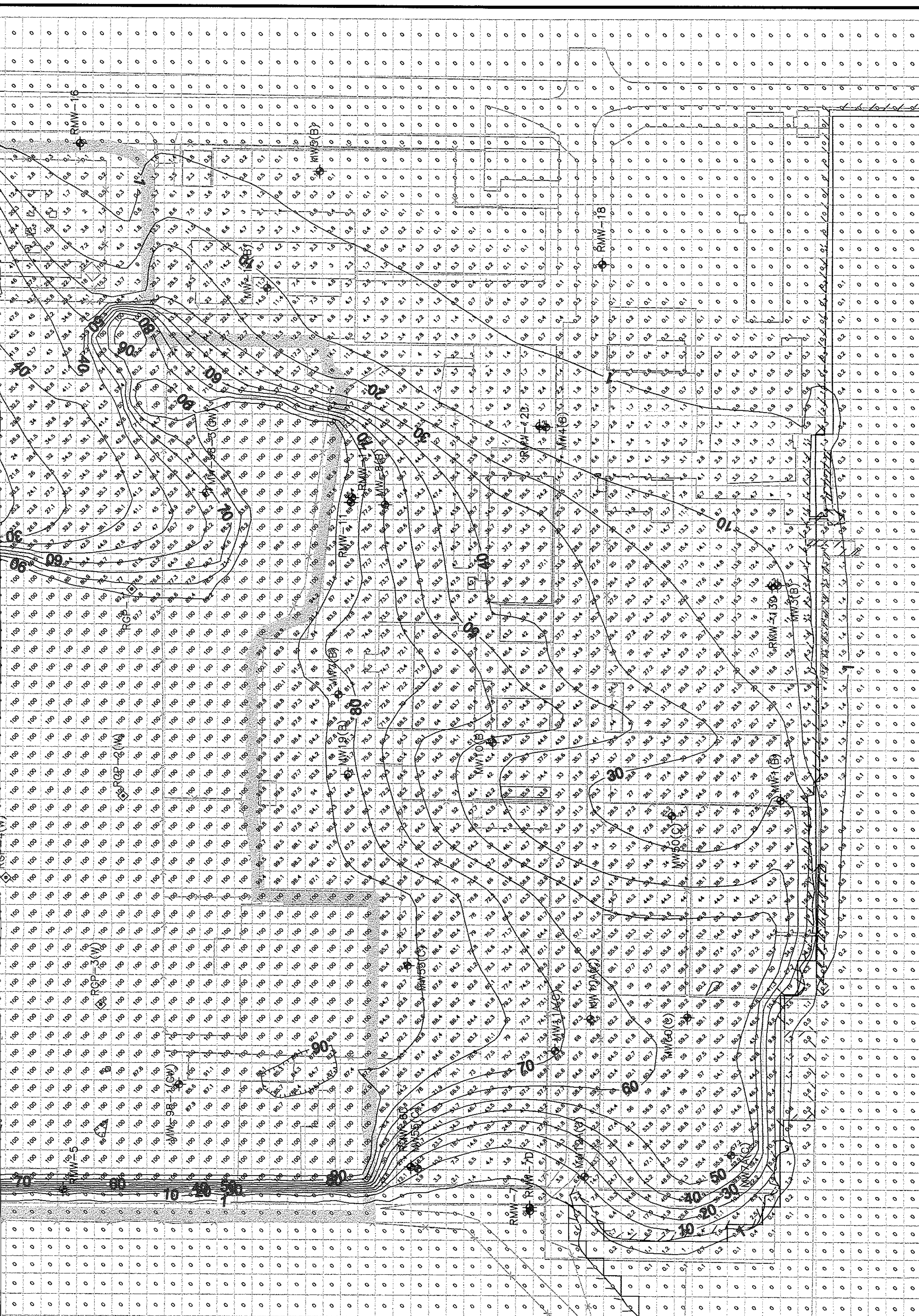
MODEL-PREDICTED "LEACHATE" CONCENTRATION CONTOURS FOR LAYER 2 CELLS

LAYER 2 MODEL GRID AND PREDICTED "LEACHATE" CONCENTRATION

NOTE: SEE APPENDICES
MODEL LAYER OU

50 0

1"=100'



G FOR ADDITIONAL
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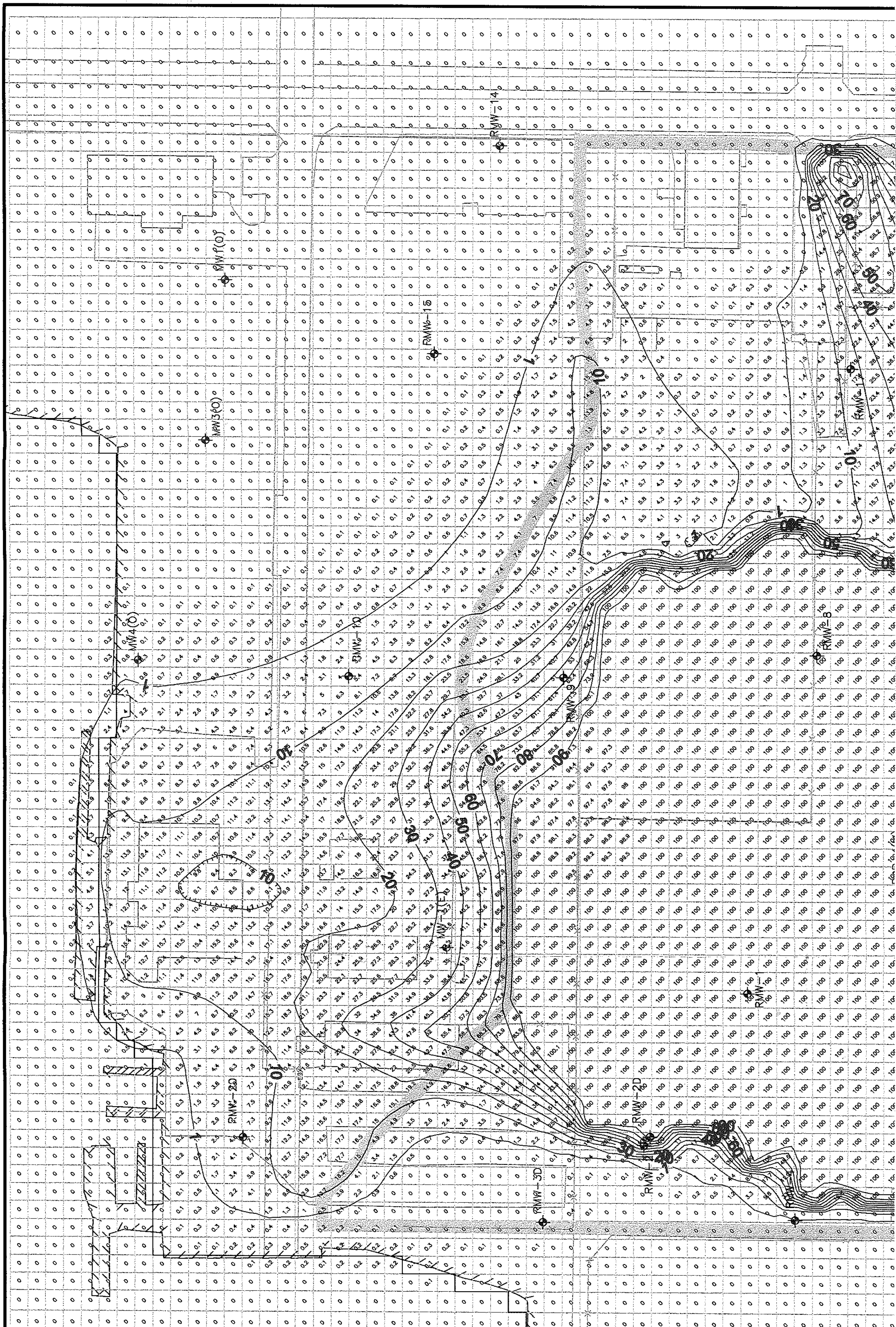
ROEDER AVENUE LANDFILL RI/FS

PORTB-03809-710

DATE: 03/06/01 | DRWN: N.S. | FILE: 3809s174

ALTERNATIVE C CONCENTRATIONS
YEAR 2035, LAYER 2



ThermoRetec

MODELED SHORELINE

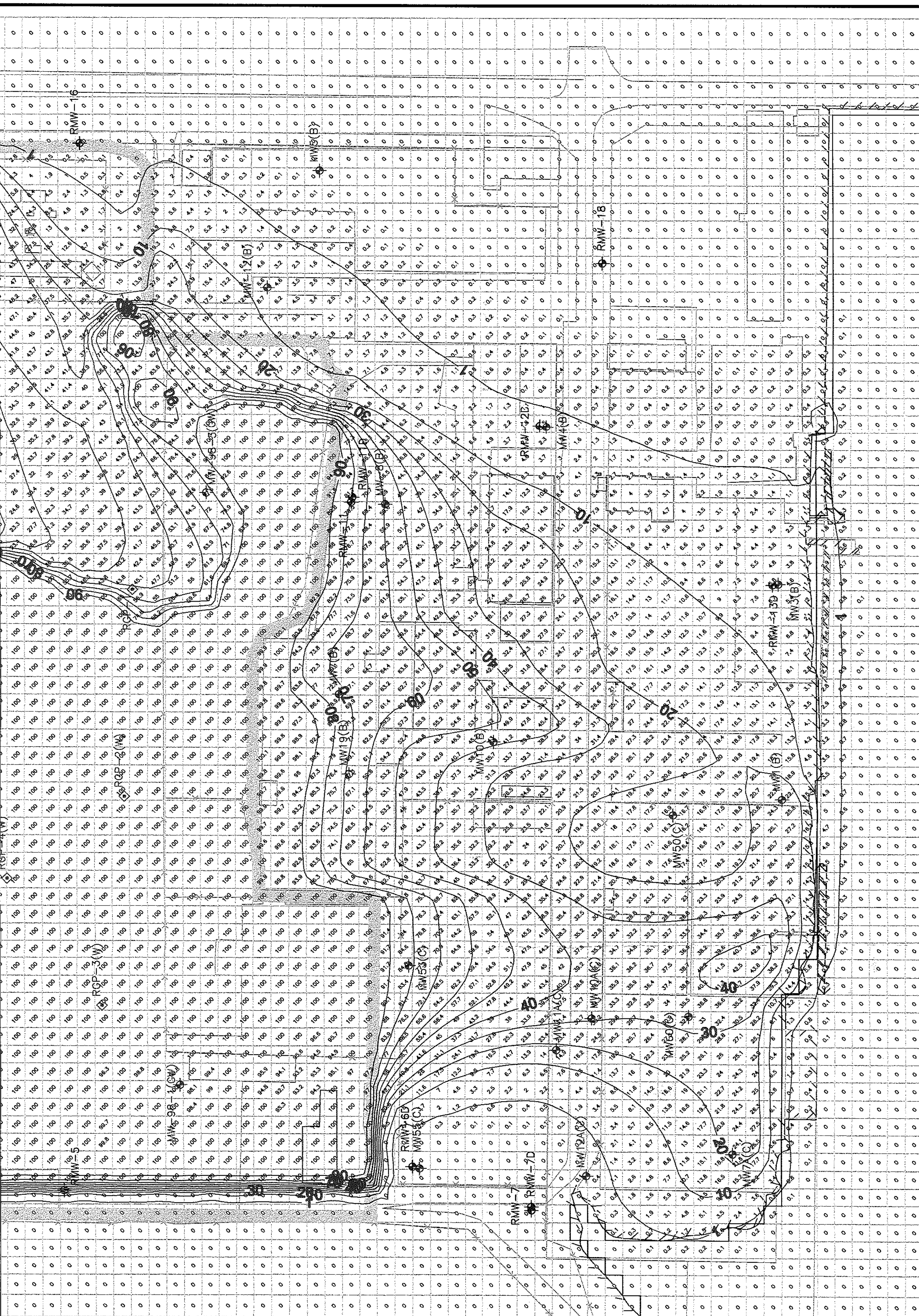
90 MODEL-PREDICTED "LEACHATE" CONCENTRATION CONTOURS FOR LAYER 2 CELLS

0.00 LAYER 2 MODEL GRID AND PREDICTED "LEACHATE" CONCENTRATION

NOTE: SEE APPENDICES
MODEL LAYER O

50 0

1"=100'



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UTPUT

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ROEDER AVENUE LANDFILL RI/FS			ALTERNATIVE D CONCENTRATIONS YEAR 2035, LAYER 2
PORTB-03809-710			
DATE: 03/12/01	DRWN: N.S.	FILE: 3809s179	