DRAFT FINAL
REMEDIAL INVESTIGATION SUMMARY REPORT
HORN RAPID LANDFILL
RICHLAND, WASHINGTON

DOCUMENT CONTROL NUMBER 835.01

October 28, 2002

Prepared for

City of Richland
Department of Public Works
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Richland, Washington 99352

Submitted by

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Approved by: ______________________________ Date: ______________
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Acronyms and Abbreviations

ASTM	American Society for Testing and Materials
COC	constituent(s) of concern
DCA	dichloroethane
DCE	dichloroethene
EPA	U.S. Environmental Protection Agency
MTCA	Model Toxics Control Act
ORP	oxidation/reduction potential
ORV	Off-road Vehicle
PCE	tetrachloroethene
PVC	polyvinyl chloride
RI	Remedial Investigation
TCE	trichloroethene
VOC	volatile organic compound
WAC	Washington Administrative Code

1.0 Introduction

This Remedial Investigation (RI) Summary Report for the Horn Rapids Landfill (Landfill) describes RI activities performed, investigation results, and provides recommendations for additional work to be performed. This RI Summary Report was prepared by Shaw Environmental & Infrastructure, Inc. under contract to the city of Richland (City).

The RI was performed to investigate the impacts from a volatile organic compound (VOC) groundwater discovered in monitoring wells located on landfill property. This RI is being performed following the City's decision to perform an independent cleanup action under the State of Washington's Model Toxics Control Act (MTCA). In 1998, the City installed two groundwater monitoring wells inside the permitted disposal area. These wells were in addition to the four existing monitoring wells located along the boundary of the Landfill. Groundwater sampled from the two new wells contained VOCs in excess of the MTCA limits (Washington Administrative Code [WAC] 173-340). Due to these exceedances, the City chose to pursue an independent cleanup of the groundwater. The independent cleanup consists of performing a RI and feasibility study as required under the MTCA.

The RI was initiated in 2000, to install four new groundwater monitoring wells to investigate the extent of impacted groundwater. The RI activities were described in the *Horn Rapids Landfill Remedial Investigation Work Plan* (Work Plan) (IT, 2000). Following well installation, groundwater samples were collected from all ten Landfill groundwater monitoring wells for five consecutive quarters. This report presents the results of the well installation and groundwater sampling and makes recommendations for additional work to be conducted at the Landfill.

1.1 Background

The City completed construction of the Landfill in 1976, and has operated it since for the disposal of municipal solid waste. The Landfill is sited within a 275-acre parcel of City property, of which 46 acres are permitted for the disposal of solid waste (Figure 1, "Horn Rapids Landfill and Vicinity Location Map"). Twin Bridges Road (formerly Grosscup) bounds the parcel on the west, on the north by Horn Rapids Road, and on the south by State Route 240.

Recently, an undocumented waste disposal area was discovered approximately 1,200 feet northwest of the northwest corner of the current permitted area boundary (Figure 2). The area is approximately one acre in size and is covered by several feet of soil. The thickness of the waste is unknown, as is the operational history of this waste site. The contents are thought to be municipal waste.

1.1.1 Groundwater Monitoring

Documented groundwater monitoring has been performed at the Landfill since 1987, and is documented in annual groundwater monitoring reports. Groundwater monitoring is currently conducted at ten monitoring wells (Figure 2, "Horn Rapids Landfill Site Map"). Well 1 is located west of the Landfill and is one of two upgradient groundwater monitoring wells. Wells 2, 3, and 4 are located along the eastern property boundary and are approximately 2,800 feet east of Well 1. Groundwater Monitoring Wells 5 and 6 were installed in 1998. These wells are located immediately east of the 46-acre active portion of the Landfill. These wells are approximately 1,300 feet east of Well 1. Four new wells were installed in January 2001 as part of this RI. Well 7 was installed upgradient of the Landfill at the northwest corner of the Landfill. Wells 8 and 9 were installed along the southern boundary of the Landfill. Well 10 was installed north of Well 5 to evaluate the extent of groundwater impacts.

Groundwater chemical monitoring data has been collected from Wells 1, 2, 3, and 4 since 1987, but the City considers the data collected before 1992 suspect[1] (Richland, 2000). Groundwater monitoring data has been collected from Wells 5 and 6 since 1998, and data from Wells 7 through 10 have been collected since April 2001.

1.1.2 Vadose Zone Monitoring

The vadose zone is monitored by four lysimeters, which were installed at the Landfill in 1993, to collect leachate from the vadose zone directly below the refuse deposit. The lysimeters are located below the active Landfill cell. Leachate from each lysimeter drains to a common sampling pit and can be collected from any of four sampling ports. Leachate samples are collected semiannually by the City. Results show that various inorganic and organic constituents have been detected in the leachate, some of which have been detected in Monitoring Wells 5 and 6 (Richland, 2002).

1.1.3 Methane Monitoring

Methane monitoring is conducted quarterly by the City from 11 permanent subsurface gas probe locations. Methane monitoring results show that a considerable amount of methane gas was detected near the location where animal carcasses were disposed. Methane has also been detected in several other monitoring locations along the adjacent to the active Landfill.

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[1] The data is suspect, because of the lack of adequate sampling equipment and procedures. This problem was corrected with the installation of new sampling pumps in early 1992.

Monitoring locations along the perimeter of the Landfill show that migration of methane gas outside of the Landfill is not occurring (Richland, 2002)

1.2 Regulatory Controls

The Landfill is regulated under WAC 173-351. After discovery of groundwater contamination by hazardous constituents in excess of their respective maximum contaminant levels, the City chose to proactively perform an independent cleanup action to remediate the groundwater. This action is taken as identified in the WAC independent remedial action process (173-340).

1.3 Organization of this Report

This report presents the results of the well installation, aquifer testing, and five quarters of groundwater monitoring for the four new monitoring wells, and makes recommendations for additional investigations at the site. Section 1.0 presented the introduction, background, and regulatory controls. Section 2.0 presents the site conditions. Section 3.0 summarizes the field activities performed. Section 4.0 discusses the results of the groundwater monitoring and extent of groundwater impact. Section 5.0 presents recommendations for additional investigations at the site. Section 6.0 presents the references used in this report.

2.0 Site Conditions

This section describes the conditions of the Landfill site and the surrounding area. Described are the physical features of the site including topography and adjacent properties and their uses; the hydrogeologic features that are important to the understanding of the occurrence and movement of groundwater and contaminants in the groundwater; and the impacts to groundwater that have been observed.

2.1 Physical Features

The Landfill is located directly east of the intersection of Twin Bridges (formerly Grosscup) Road and State Highway 240 (Figure 1). The Landfill consists of 46 acres permitted for the disposal of solid waste and support facilities including a medium-risk Hazardous Waste Receiving Facility.

West

North of the Landfill is the Off-road Vehicle (ORV) Park. A portion of the ORV Park has been developed with rest rooms and picnic facilities. A boat racing facility was constructed at the ORV Park in 1999. The racing facility consists of shallow unlined waterways and are only flooded during a race. The water is allowed to seep out of the waterways after a race.

Ground elevation of the Landfill site is between approximately 460-feet and 500-feet above mean sea level. The surface of the Landfill has been reworked through the excavation of disposal cells and the subsequent filling with solid waste. Once a cell is filled, it is covered with soil. Borrow material is being used for cover in the active portion of the Landfill.

Immediately east of the 275 acre landfill parcel are circle-irrigated agricultural fields. These fields are used to grow alfalfa hay, corn, and potatoes. Irrigation water for these circles is obtained from the Columbia River and not from a groundwater source. Irrigated fields are also located west of the Landfill across State Highway 240. These fields have been in use for more than 13 years with irrigation occurring between the months of April and October.

2.2 Hydrogeology

The Landfill is within the central Pasco Basin in the Columbia Basin physiographic subprovence of the Columbia Intermontaine Province. The area is within the rain shadow of the Cascade Mountains. Precipitation in the area averages 6.76-inches per year (HMS, 2000), with more than 40 percent of the precipitation occurring from November to January. The following sections describe the geology and hydrology of the site.

2.2.1 Geology

The following geologic units, in ascending stratigraphic order, underlie the Landfill:

- Columbia River Basalt Group with interbeds of the Ellensburg Formation
- Ringold Formation
- Plio-Pleistocene sediments
- Hanford formation

The Hanford formation is the primary geologic unit of concern at the Landfill site. The Hanford formation consists of sediments that were deposited during the numerous episodes of catastrophic rapid draining of glacial Lake Missoula in western Montana and northern Idaho. Massive volumes of water were released from the lake following breaching of the ice dams on the lake. The floodwaters scoured the land surface, and locally eroded into the Ringold Formation and basalts. These floods deposited thick sequences of sediments. The Hanford formation is separated into two lithofacies the Pasco Gravels and the Touchet Beds. The Pasco Gravels are comprised of poorly sorted gravels and coarse sands. The Touchet Beds facies consist of rhythmically bedded sequences of silt, sand, and minor gravel lenses. These sediments are located in areas where slack-water conditions existed. The Hanford formation in the vicinity of the Landfill is mantled with eolian sediments, including loess and active and stabilized sand dunes.

Depth to the top of the Columbia River Basalt group is approximately 170 feet below ground surface. Sediments below the site consist primarily of sands and silty sands of the Pasco Gravels and eolian deposits. Occasional lenses of gravel have also been noted in boring logs.

2.2.2 Hydrology

Surface water occurrence near the Landfill is limited to the occasional impoundment of water used for boat racing at the ORV Park. The Yakima River is approximately 2 miles west of the site.

Groundwater beneath the site occurs under confined to unconfined conditions. Confined to semiconfined aquifers occur within the Columbia River Basalt Group. The unconfined aquifer occurs within the Ringold and Hanford formations. This aquifer is the uppermost-unconfined aquifer beneath the site. Sources of natural recharge to this aquifer are rainfall and river water along influent reaches of the Yakima River. Artificial recharge occurs from agricultural irrigation adjacent to the east boundary and west of the Landfill across Highway 240, dust suppression at the Landfill, a small amount of irrigation at the ORV Park, and infiltration of water used to fill the boat racing facility.

Regional groundwater flow is west to east towards the Columbia River and is illustrated by the groundwater elevation map shown on Figure 3, "Regional Groundwater Elevation Map, July 1989" (Liikala, 1994). The Landfill area on the map is indicated by the series of four wells immediately west of the 375.5-feet groundwater elevation contour line. The regional horizontal groundwater gradient is approximately 0.003-feet/feet. Liikala reports an upward vertical hydraulic gradient of 0.36-feet/feet.

Groundwater elevations beneath the Landfill site have been impacted by agricultural irrigation activities. Water-level hydrographs of the ten monitoring wells are provided on Figure 4, "Horn Rapids Landfill Monitoring Well Hydrographs." These hydrographs show a steady increase in water-level elevation from 1986 through the present. The hydrographs for Wells 1 and 7 show a high peak in the summer of 2000 and 2001, likely due to the infiltration of water from the boat racing facility at the ORV Park. These peaks can also be seen on other wells, but are more subdued due their greater distance from the boat racing facility. Figures 5 through 9 are water level elevation maps for the years 1987, 1995, 1998, 2000, and 2002. These maps illustrate that water levels have been rising in all wells. This rise is interpreted to be due to artificial recharge from the irrigated fields. The impacts from the groundwater elevation rise have been the greatest in Wells MW-2, MW-3, and MW-4. The water elevation maps also show that not only have the water levels been rising, but that the flow direction and gradient have also changed. Based on the limited number of wells at the site in 1987, groundwater flow direction appears to be from west to east with a gradient of approximately 0.001-feet/feet. This is consistent for the regional groundwater flow direction reported by Liikala (1994). In 1995, the flow direction appears to be changing to southeasterly with a gradient of 0.0004-feet/feet. Two new monitoring wells (MW-5 and MW-6) were installed in 1998, and with the installation of the four new monitoring wells in 2001, the groundwater flow direction and gradient has been refined. The data show that the flow direction in the western portion of the Landfill is to the east, changing to the southeast near Wells 5 and 6 in the central portion of the Landfill. The horizontal groundwater gradient in the western portion of the Landfill is approximately 0.0008-feet/feet to the east and in the eastern portion of the Landfill, the gradient between is approximately 0.0002-feet/feet to the southeast.

The change in flow direction and gradient illustrates that groundwater has been significantly impacted by agricultural irrigation adjacent to the Landfill.

3.0 Remedial Investigation Activities

Remedial investigation activities were described in the Work Plan (IT, 2000) and consisted of the installation of four new groundwater monitoring wells, performing aquifer slug tests to determine aquifer parameters, and performing groundwater sampling and analysis for five consecutive quarters. The following describes the field activities and groundwater monitoring analytical parameters.

3.1 Monitoring Well Installation

Four groundwater monitoring wells were installed across the top of the upper water bearing zone. Well 7 was placed upgradient of the active Landfill to refine the upgradient groundwater flow direction. Wells 8 and 9 were installed along the southern boundary of the Landfill to determine whether VOC contaminants have migrated off site. Well 10 was located north of Wells 5 and 6 to evaluate the extent of groundwater impacts within the Landfill.

Wells were installed using air rotary drilling methods. Wells were logged by a geologist and boring logs prepared. The boring logs are included in Appendix A. Soil samples were collected for geotechnical testing from Wells 8, 9, and 10 to provide soil foundation data. No geotechnical samples were collected from Well 7. Samples were tested for moisture content per American Society for Testing and Materials (ASTM) Method D2216 (1998a), Atterberg Limits per ASTM Method D4318 (2002a), Sieve Analysis per ASTM Method D422 (1998b), and permeability per ASTM Method D5084 (2000b). Results of the testing are included in Appendix B.

Wells were screened across the top of the upper water-bearing zone using 2-inch inside diameter schedule 40, polyvinyl chloride (PVC) well materials. Screens were 0.010-inch machine slotted PVC. Screens were placed with approximately 10 feet of screen below the water table and 5 feet above. Table 1, "Monitoring Well Completion Details" lists the well completion details.

Following completion and development of the new monitoring wells, aquifer slug tests were conducted to determine the near-field hydraulic conductivity of the upper water bearing zone. The tests were conducted by:

- Measuring the depth to water in the well
- Installing a pressure transducer with automated data logger
- Allowing the water level to stabilize a minimum of 15 minutes prior to slug insertion

- Inserting a slug, consisting of a PVC pipe filled with sand, into the water
- Recording the water level change, recovery, and time required to reach recovery using the downhole pressure transducer and data logger.
- Performing both slug in and slug out tests.

Results are discussed in Section 4.1

3.2 Groundwater Analyses

A Grundfos Rediflo-2 submersible pump and associated tubing was installed in each well for groundwater sampling. Groundwater samples were collected from each monitoring well at the Landfill and analyzed for the following constituents

- VOC by U.S. Environmental Protection Agency (EPA) Method 6280B
- Total metals by EPA Method 6020/200.8
- Dissolved metals by EPA Method 200.8
- Sulfate and chloride by EPA Method 300.0
- Alkalinity by EPA Method 310.1
- Bicarbonate by EPA Method 2320B
- Ammonia as nitrogen by EPA Method 350.3
- Total dissolved solids by EPA Method 2540C
- Total organic carbon by EPA Method SM5310C
- Methane, ethane, and ethane by Method RSK 175

In addition, field measurements of pH, specific conductance, temperature, oxidation/reduction potential (ORP), dissolved oxygen, and ferrous iron were collected. Analytical results are provided in Appendix C.

4.0 Remedial Investigation Results

The following subsections describe the results of the RI.

4.1 Hydrogeology

The four new groundwater monitoring wells were installed across the top 10 feet of the upper unconfined aquifer at the Landfill. Slug tests were performed on the new monitoring wells to determine hydraulic conductivity of the formation. The slug tests provide an estimate of the near-field hydraulic conductivity and have a high degree of uncertainty. Both rising head and falling head tests were conducted. However, due to the limitations of the method, only the rising head test results are considered representative estimates of hydraulic conductivity. The following are the results of the slug tests:

- Well 7 – 3.1 feet per day
- Well 8 – 3.0 feet per day
- Well 9 – 7.8 feet per day
- Well 10 – 3.8 feet per day.

These slug test results are within the range previously measured of 1.7 to 15 feet per day at Wells 5 and 6 (Shannon & Wilson, 1998). Slug test calculations are provided in Appendix D.

Water level elevation data from the ten groundwater monitoring wells show that new Well 7 is upgradient of the Landfill and water level elevations are very close to those measured in the existing upgradient monitoring point, Well 1. The addition of the new upgradient monitoring wells confirm that the groundwater flow direction at the western boundary of the Landfill is to the east.

The other three new monitoring wells (Wells 8, 9, and 10) show that the groundwater flow direction changes to a predominantly southeast direction in the eastern portion of the Landfill area, and that an area of low flow gradient is present in this area (Figure 8, "Groundwater Elevation Map, February 2000"). Groundwater flow gradients change from approximately 0.0008 feet/feet to the east to approximately 0.0002 feet/feet to the southeast. As discussed in the Work Plan (IT, 2000), groundwater gradients are impacted by the agricultural irrigation occurring immediately east of the Landfill. The infiltration from irrigation causes groundwater mounding beneath the irrigated fields. This deflects the groundwater flow direction to the southeast and lowers the gradient, which also slows and deflects the movement of the VOC groundwater plume.

The average groundwater flow velocity decreases from approximately 0.01 feet/day (4 feet/year) to 0.003 feet/day (1 foot/year) across the site. The flow velocities have a high degree of uncertainty due to test methods used to estimate the hydraulic conductivity and porosity.

4.2 Groundwater Analytical Results

Groundwater samples were collected from all ten groundwater monitoring wells using the procedures described in the Work Plan (IT, 2000). Analyses performed on the samples are listed in Section 3.2. The constituents of concern (COC) for the groundwater are VOCs. Five quarters of analytical data have been collected since the initiation of the RI field activities in January 2001. Volatile organic compound detections between April 2001 and April 2002, are listed on Table 2, "Volatile Organic Compound Detections between April 2001 and April 2002." The primary COCs are 1,1-dichloroethane (DCA), cis-1,2-dichloroethene (DCE), tetrachloroethene (PCE), trichloroethene (TCE), and vinyl chloride. These compounds are found in Wells, 5, 6, 7, and 10. Historically, all of the groundwater monitoring wells have had at least one VOC detection. Figures 10 through 17 show the concentrations with time for these VOCs.

Volatile organic compound detections can be seen as early as 1992 in Wells 3 and 4 with detections of 1,1-DCA in Well 3 and PCE in Well 4 at levels slightly above regulatory limits (Figure 11, "Well 3 Volatile Organic Compound Detections with Time" and Figure 12, "Well 4 Volatile Organic Compound Detections with Time"). Detections of PCE in the upgradient well (Well 1) first were noted in the fall of 1993 (Figure 10, "Well 1 Volatile Organic Compound Detections with Time"). Detections of these VOCs plus cis-1,2-DCE and 1,2-DCA have remained at relatively low levels.

Wells 5 and 6 have the largest number of VOC detections of any of the monitoring wells (Figure 13, "Well 5 Volatile Organic Compound Detections with Time" and Figure 14, "Well 6 Volatile Organic Compound Detections with Time"). Concentrations in Well 5 have remained relatively stable with only cis-1,2-DCE increasing significantly. Volatile organic compound concentrations in Well 6 have shown an increasing trend over time. In particular for 1,1-DCA, cis-1,2-DCE, PCE, and vinyl chloride.

Well 2 historically has had only sporadic detections of VOCs. Only two detections of 1,1-DCA and one detection of 1,2-DCA, cis-1,2-DCE, methylene chloride, and PCE since 1992 have been noted. Well 8 has had only one detection of 1,1-DCA.

The distribution of the primary COCs (1,1-DCA, cis-1,2-DCE, PCE, TCE, and vinyl chloride) are shown on Figures 18 through 22. These data indicate that the source is upgradient of the

Landfill. This is demonstrated by the historical detections of PCE and 1,2-DCA at Well 1 and the detections of seven VOCs at the upgradient Well 7. The data also show the plume boundary has reached the boundary of the Landfill with consistent detections of 1,1-DCA at Wells 3 and 4. Well 8 has had only one detection of 1,1-DCA slightly above the regulatory limit (Table 2). Well 9 shows consistent detections of 1,1-DCA and PCE above the regulatory limit (Table 2 and Figure 16, "Well 9 Volatile Organic Compound Detections with Time"). Wells 5, 6, and 10 located in the central portion of the Landfill have the greatest number of VOCs detected and at the highest levels (Table 2). This does not however indicate that the source is the Landfill. The occurrence of VOCs in the two upgradient wells, which have water level elevations over a foot above the other wells, indicate that the source of the VOC plume is upgradient of the Landfill. The high number of VOC detections and concentrations in Wells 5 and 6 may indicate that the plume center of mass has moved from upgradient of the Landfill to its present position.

Chloride, nitrate, and sulfate concentrations with time are plotted on Figures 23, 24, and 25. These plots show that Well 2 experienced an increase in these three chemicals between fall 1998 and winter 2000, when concentrations returned to previous levels. This increase was likely due to irrigation impacts on adjacent fields.

Concentrations of chloride, nitrate, sulfate, and total dissolved solids (Figure 26) at Well 7 are much higher than for other wells. The reason is unclear, but it may represent a slightly different upgradient source of water. Other wells that show elevated concentrations of chloride, nitrate, sulfate, and total dissolved solids are Wells 5, 6, and 10, which are the same wells that show significant VOC impacts.

Parameters that indicate natural attenuation were measured to determine whether there is evidence that the contaminants are degrading through either biological or chemical processes. Methane, ethane, ethene, dissolved oxygen, ORP, and ferrous iron were measured. The collected data are listed on Table 3, "Natural Attenuation Indicator Parameters." Note that field measured parameters dissolved oxygen and ORP were not consistently measured. The results are inconclusive, if natural attenuation were actively occurring, elevated levels of ethane and decreased dissolved oxygen and ORP in the downgradient wells would be observed. No ethane was observed in any wells and dissolved oxygen concentrations vary only slightly. The ORP levels are lower in the wells that are positioned directly below the area of highest concentrations. Elevated methane concentrations are observed on the area of highest plume concentration; however, this is likely due to methane generated directly from the Landfill and not from natural attenuation. Methane has been observed in methane observation wells at the site, and it would be

5.0 Recommendations

The data indicate that the source of the VOC plume is upgradient of the Landfill. This is supported by consistent detections of VOCs in the two, upgradient monitoring wells. The source location is uncertain and additional investigations are necessary. A likely source for the VOCs is an undocumented disposal area located approximately 1,200 feet northwest of the northwest corner of the permitted disposal area. This area is located upgradient of the landfill and may contain source material for the groundwater contamination.

To determine if this undocumented disposal area is the contamination source, subsurface soil samples will be collected from five locations adjacent to the disposal area (Figure 27). Samples will be collected using either direct push or hollow-stem auger sampling methods at 10 feet, 20 feet, 30 feet, and 40 feet below the estimated bottom of the waste. Samples will be analyzed for VOCs by EPA Method 8260B. Results will be reported in an investigation summary letter report incorporating the results with recommendations for additional investigations.

Collection of groundwater samples from beneath this site is not recommended until it can be determined that this is the contamination source area. If VOCs are detected in the soils beneath this waste disposal area, groundwater samples will be collected during a second field mobilization. Samples will either be collected using discrete groundwater sampling methods (e.g. hydropunch sampling) or new groundwater monitoring wells will be installed and samples collected from them. If VOCs are not detected in the soils, additional groundwater sampling at other locations, upgradient of the current known contamination extent will be recommended. Recommendations will be provided in the investigation summary letter report.

6.0 References

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Shannon & Wilson, 1998, *Results of Hydrogeologic Service for the Richland Landfill, Richland, Washington*, Richland, Washington.

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Washington Administrative Code (WAC), 173-351, *Criteria for Municipal Solid Waste Landfills*, Olympia, Washington.

TABLES

Table 1
Monitoring Well Completion Details

Monitoring Well	Date Installed	Total Depth (feet)	Casing/ Screen Material	Screen Interval (feet)	Sand Pack Material	Sand Pack Interval (feet)	Bentonite Seal Interval (feet)	Grout Interval (feet)
MW-7	1/16/01	105	2-inch Diameter Schedule 40 PVC	87.5 – 102.5	10/20	84.5 - 105	68.8 – 83.5	0 – 68.8
MW-8	1/18/01	102	2-inch Diameter Schedule 40 PVC	84.5 – 99.5	10/20	81.5 – 102	72.5 - 81.5	0 – 72.5
MW-9	1/22/01	115	2-inch Diameter Schedule 40 PVC	97.5 – 112.5	10/20	93.5 – 115	83 – 92.5	0 – 83
MW-10	1/23/01	87	2-inch Diameter Schedule 40 PVC	69.5 – 84.5	10/20	66.5 – 87	57.6 – 66.5	0 – 57.6

PVC denotes polyvinyl chloride

Table 2 (continued)
Volatile Organic Compound Detections between April 2001 and April 2002

Well	Analyte	Regulatory Limit [1] (µg/L)	Concentration (µg/L)				
			4/10/01	7/25/01	10/16/01	12/18/01	3/20/02
7	Chloroethane	---	1.4	5.0	3.4	<1	<1
	1,1-DCA	1.0	3.3	11	5.3	<1	5.0
	cis-1,2-DCE	70	44	78	51	120	49
	Methylene chloride	5	17	27	10	16	7.8
	PCE	0.8	24	25	29	29	35
	TCE	3	4.6	3.7	4.1	4.5	5.6
	Trichlorofluoromethane	---	3.2	<1	3.9	<1	<1
	Vinyl chloride	0.02	<1	<1	1.8	<1	<1
	o-xylene	---	NR	0.0045	<1	<1	<1
8	1,1-DCA	1.0	<1	1.8	<1	<1	<1
9	1,1-DCA	1.0	2.9	5.7	2.9	8.1	4.7
	PCE	0.8	6.9	5.8	6.1	5.5	5.7
10	Chloroethane	---	1.9	7.0	<1	<1	<1
	Chloroform	7	11	16	6.7	<1	12
	1,1-DCA	1.0	21	36	16	8.1	32
	cis-1,2-DCE	70	2.7	6.2	2.6	<1	5.0
	Methylene chloride	5	8.8	37	9.6	<1	33
	PCE	0.8	11	10	9.3	5.5	9.6
	1,1,1-TCA	200	<1	<1	<1	<1	1.0
	TCE	3	3.0	1.7	1.4	<1	1.2
	Trichlorofluoromethane	---	3.7	4.5	<1	<1	<1
	Vinyl chloride	0.02	<1	<1	2.0	<1	2.7
	o-xylene	---	NR	0.081	<1	<1	<1

[1] Regulatory limit is based on Washington State groundwater quality criteria (Washington Administrative Code 173-200-40). If no published water quality criteria exists, limit is maximum contaminant levels from Code of Federal Regulations 40, 141.61.

µg/L denotes micrograms per liter

NR denotes not reported

DCE denotes dichloroethene

DCA denotes dichloroethane

PCE denotes tetrachloroethene

TCE denotes trichloroethene

TCA denotes trichloroethane

Table 3
Natural Attenuation Indicator Parameters

Well	Collection Date	Methane (mg/L)	Ethane (mg/L)	Ethene (mg/L)	Dissolved Oxygen (mg/L)	Oxidation/Reduction Potential (mV)	Ferrous Iron (mg/L)
1	4/10/01	<0.001	<0.002	<0.001	9.10	280	<1
	7/25/01	<0.001	<0.002	<0.001	NC	NC	0
	10/16/01	<0.001	<0.002	<0.001	NC	NC	0
	12/18/01	<0.001	<0.002	<0.001	NC	NC	<1
	3/20/02	<0.001	<0.002	<0.001	NC	NC	<1
2	4/10/01	0.0011	<0.002	<0.001	8.60	263	<1
	7/25/01	<0.001	<0.002	<0.001	NC	NC	<1
	10/16/01	<0.001	<0.002	<0.001	NC	NC	0
	12/18/01	<0.001	<0.002	<0.001	NC	NC	<1
	3/20/02	<0.001	<0.002	<0.001	NC	NC	<1
3	4/10/01	0.0011	<0.002	<0.001	8.95	254	<1
	7/25/01	<0.001	<0.002	<0.001	NC	NC	<1
	10/16/01	<0.001	<0.002	<0.001	NC	NC	0
	12/18/01	<0.001	<0.002	<0.001	NC	NC	<1
	3/20/02	<0.001	<0.002	<0.001	NC	NC	<1
4	4/10/01	0.0010	<0.002	<0.001	8.58	261	<1
	7/25/01	<0.001	<0.002	<0.001	NC	NC	<1
	10/16/01	<0.001	<0.002	<0.001	NC	NC	0
	12/18/01	<0.001	<0.002	<0.001	NC	NC	<1
	3/20/02	<0.001	<0.002	<0.001	NC	NC	<1
5	4/10/01	1.2	<0.002	<0.001	NC	NC	<1
	7/25/01	0.84	<0.002	<0.001	8.94	150	<1
	10/16/01	0.99	<0.002	<0.001	11.38	93	<1
	12/18/01	1.3	<0.002	<0.001	NC	NC	<1
	3/20/02	0.91	<0.002	<0.001	NC	NC	<1

Table 3 (continued)
Natural Attenuation Indicator Parameters

Well	Collection Date	Methane (mg/L)	Ethane (mg/L)	Ethene (mg/L)	Dissolved Oxygen (mg/L)	Oxidation/Reduction Potential (mV)	Ferrous Iron (mg/L)
6	4/10/01	5.3	<0.002	<0.001	NC	NC	<1
	7/25/01	3.5	<0.002	<0.001	8.55	108	<1
	10/16/01	4.4	<0.002	<0.001	10.88	102	<1
	12/18/01	5.0	<0.002	<0.001	NC	NC	<1
	3/20/02	4.1	<0.002	<0.001	NC	NC	<1
7	4/10/01	0.0045	<0.002	<0.001	NC	NC	<1
	7/25/01	<0.001	<0.002	<0.001	9.55	259	<1
	10/16/01	0.0012	<0.002	<0.001	NC	NC	<1
	12/18/01	0.0044	<0.002	<0.001	NC	NC	<1
	3/20/02	0.013	<0.002	<0.001	NC	NC	<1
8	4/10/01	<0.001	<0.002	<0.001	NC	NC	<1
	7/25/01	0.0010	<0.002	<0.001	9.68	186	<1
	10/16/01	<0.001	<0.002	<0.001	12.96	154	<1
	12/18/01	<0.001	<0.002	<0.001	NC	NC	<1
	3/20/02	<0.001	<0.002	<0.001	NC	NC	<1
9	4/10/01	<0.001	<0.002	<0.001	NC	NC	<1
	7/25/01	<0.001	<0.002	<0.001	9.04	156	<1
	10/16/01	<0.001	<0.002	<0.001	12.46	161	<1
	12/18/01	<0.001	<0.002	<0.001	NC	NC	<1
	3/20/02	<0.001	<0.002	<0.001	NC	NC	<1
10	4/10/01	<0.001	<0.002	<0.001	NC	NC	<1
	7/25/01	0.0023	<0.002	<0.001	8.96	144	<1
	10/16/01	0.0036	<0.002	<0.001	12.09	161	<1
	12/18/01	0.075	<0.002	<0.001	NC	NC	<1
	3/20/02	0.11	<0.002	<0.001	NC	NC	<1

mg/L denotes milligrams per liter
NC denotes not collected
mV denotes millivolts

FIGURES

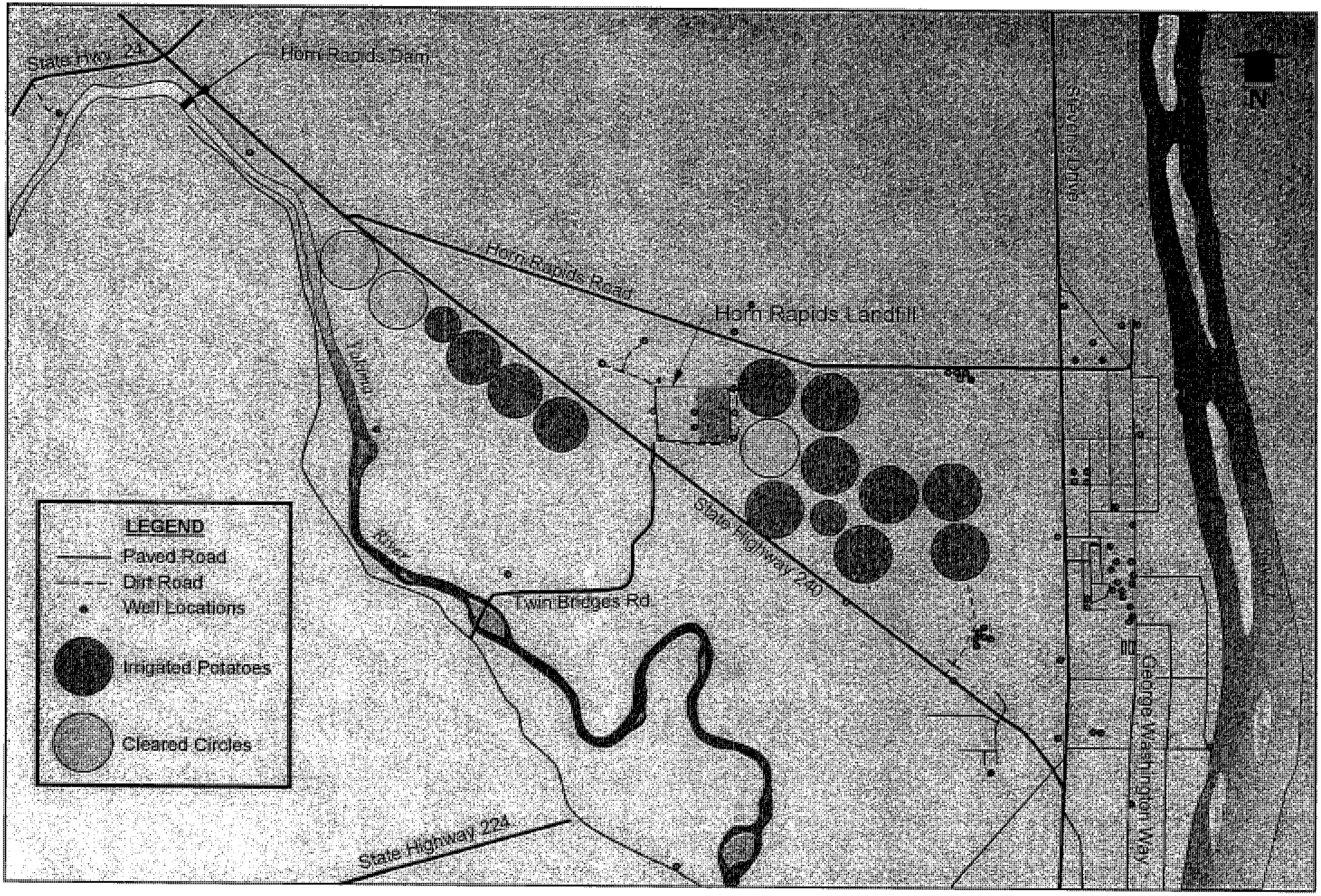
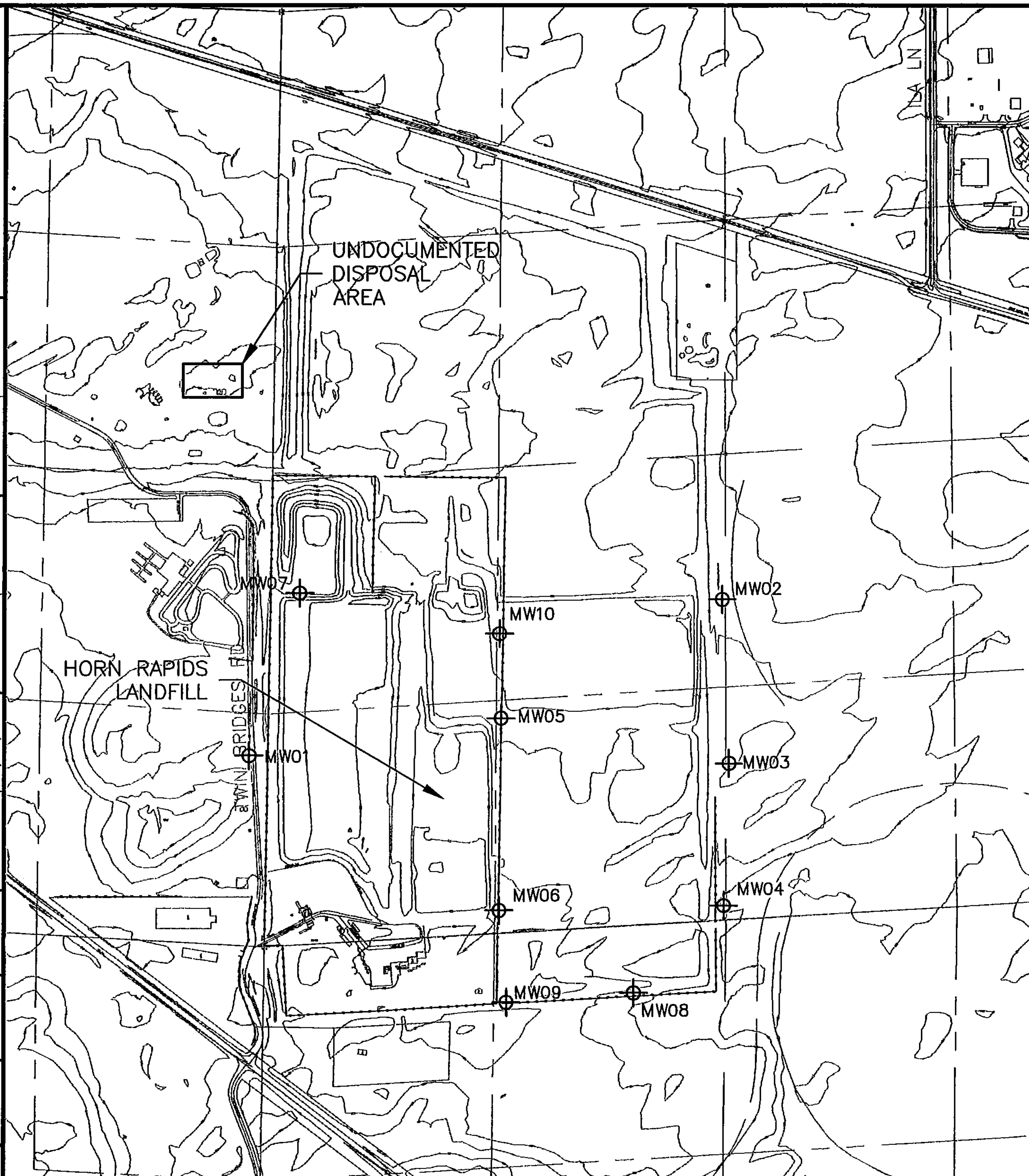


Figure 1. Horn Rapids Landfill and Vicinity Location Map



SCALE

0 500 1000 FEET

LEGEND

MONITORING WELL LOCATION

N

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HORN RAPIDS LANDFILL

FIGURE 2

HORN RAPIDS LANDFILL
SITE MAP

IMAGE	X-REF	OFFICE	DRAWN BY		CHECKED BY	APPROVED BY	DRAWING NUMBER
---	---	Concord	SCHAEFFER	8/26/02			810835-A7

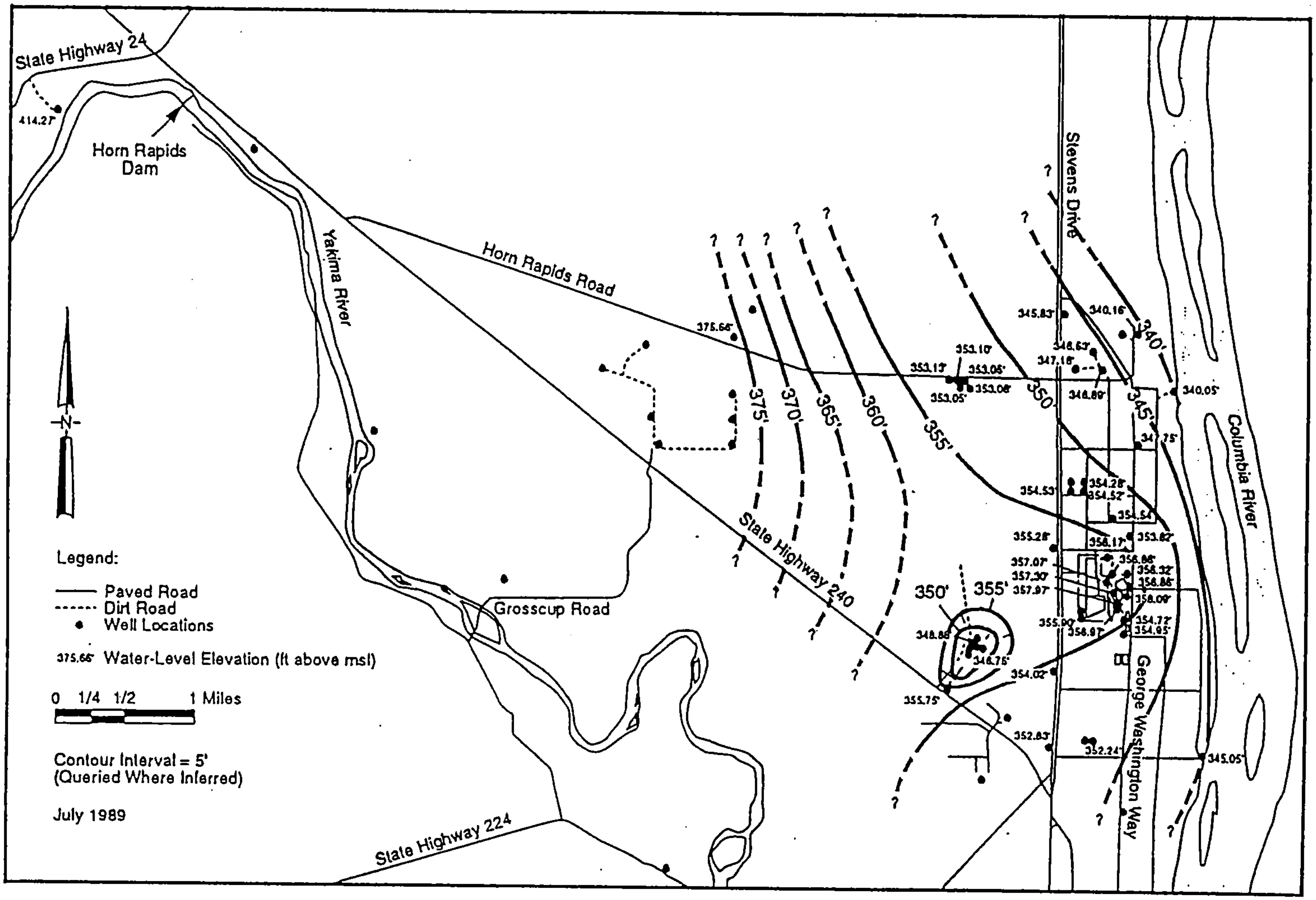


Figure 3. Study Area Water-level Elevations, July 1989

Liikala, T.L., September 1994, Hydrology Along the Southern Boundary of the Hanford Site Between the Yakima and Columbia Rivers, Washington, PNL-10094, UC-403, Pacific Northwest Laboratory, Richland, Washington.

Figure 4. Horn Rapids Landfill Well Hydrographs

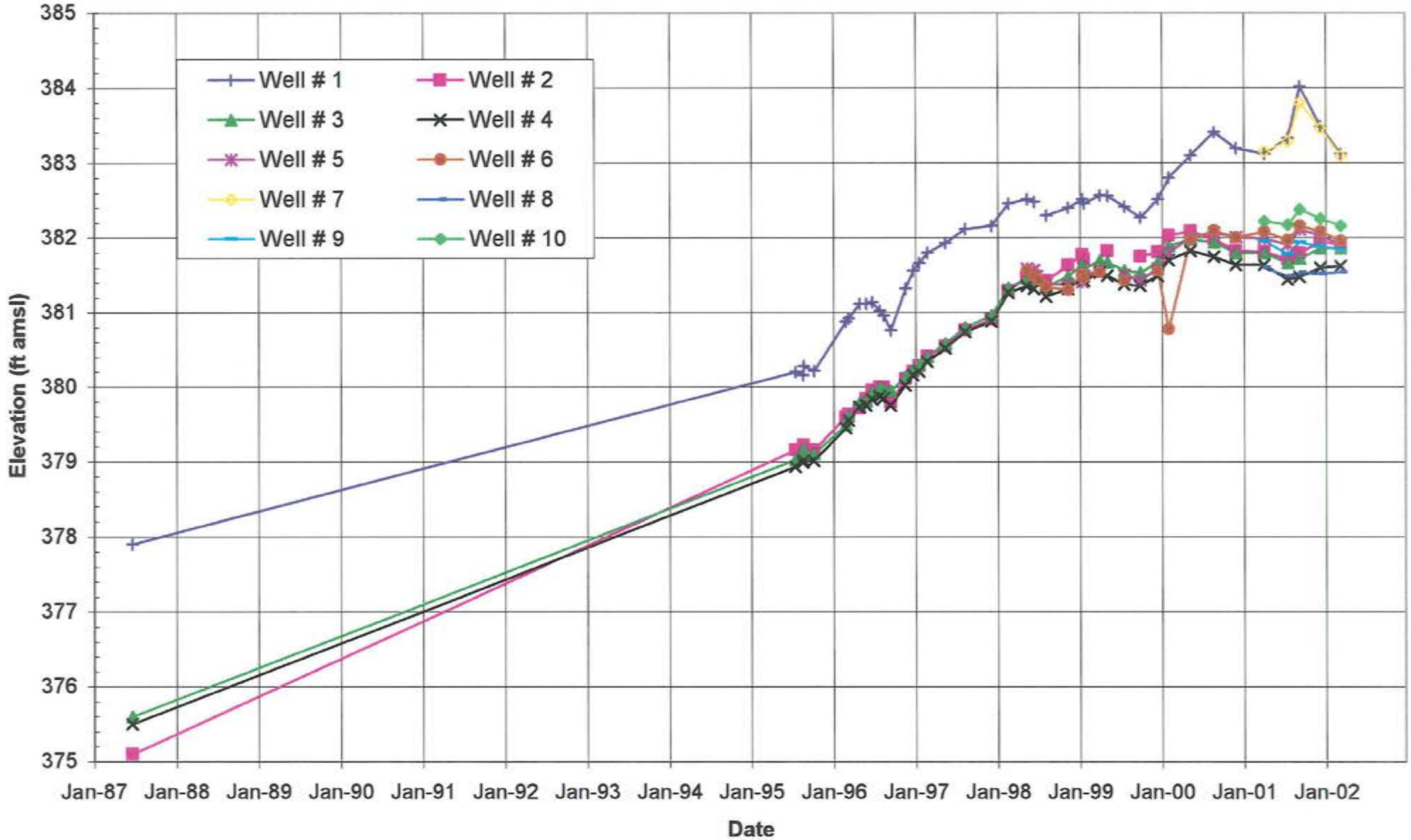
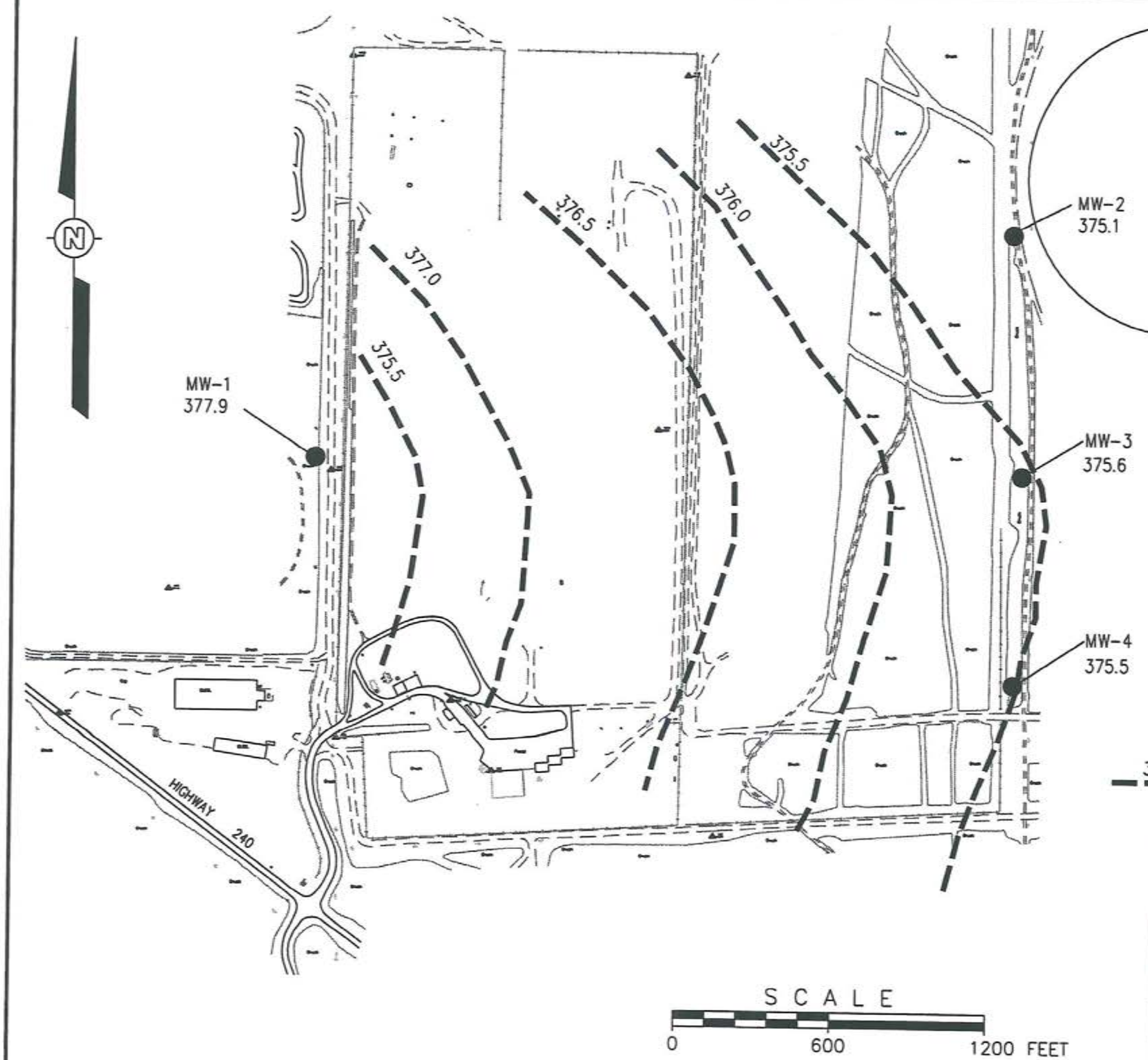


IMAGE	X-REF	OFFICE	DRAWN BY		CHECKED BY	APPROVED BY	DRAWING NUMBER
---	---	RICHLAND, WA	J. WILLIAMS	9/5/00			810835_FIG1



● EXISTING WELL

375.5 — — — GROUNDWATER ELEVATION CONTOUR IN FEET ABOVE MEAN SEA LEVEL

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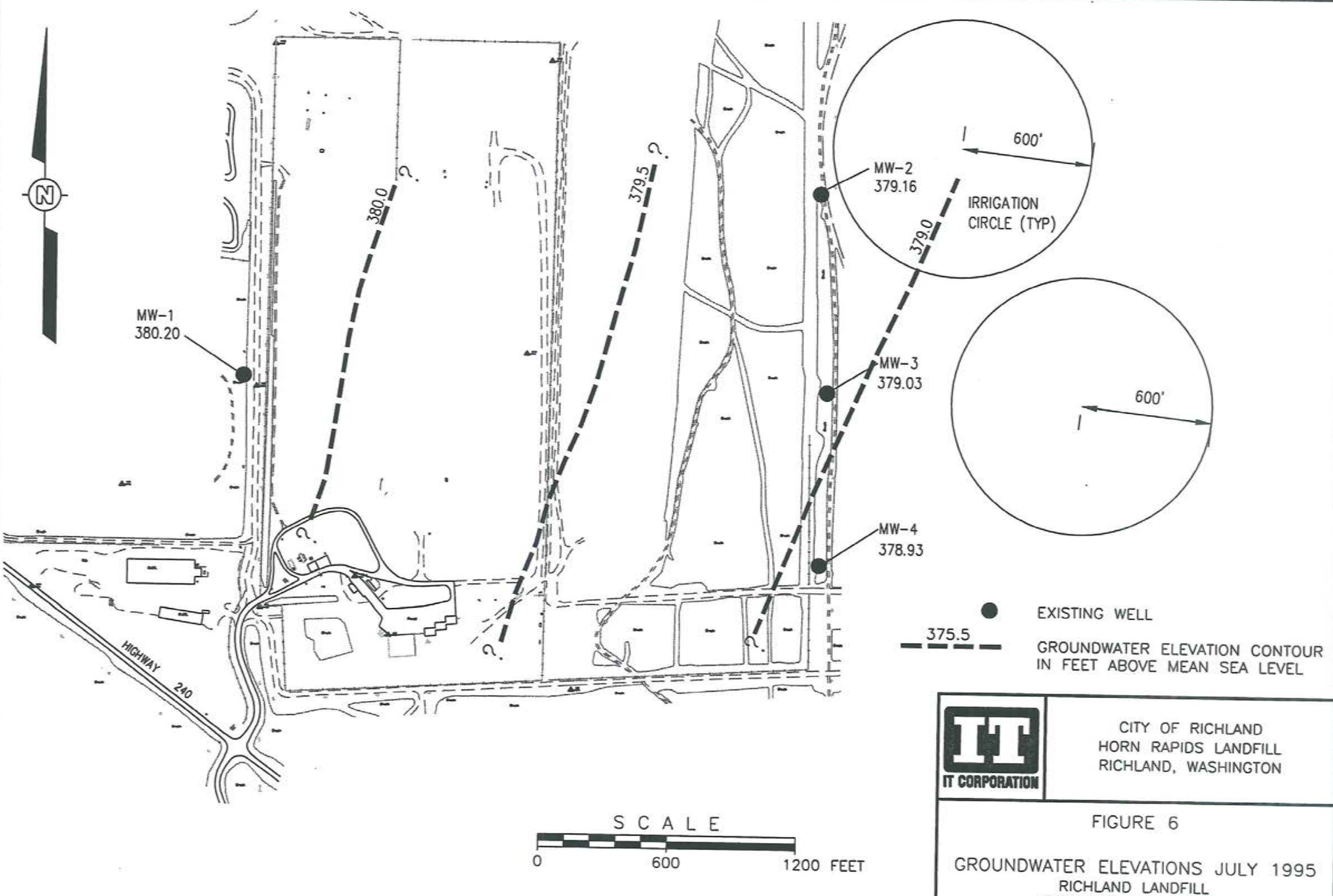
CITY OF RICHLAND
HORN RAPIDS LANDFILL
RICHLAND, WASHINGTON

FIGURE 5

GROUNDWATER ELEVATIONS 1987
RICHLAND LANDFILL
RICHLAND, WASHINGTON

IMAGE	X-REF	OFFICE	DRAWN BY		CHECKED BY		APPROVED BY		DRAWING NUMBER 810835_FIG2
---	---	RICHLAND, WA	J. WILLIAMS	9/5/00					



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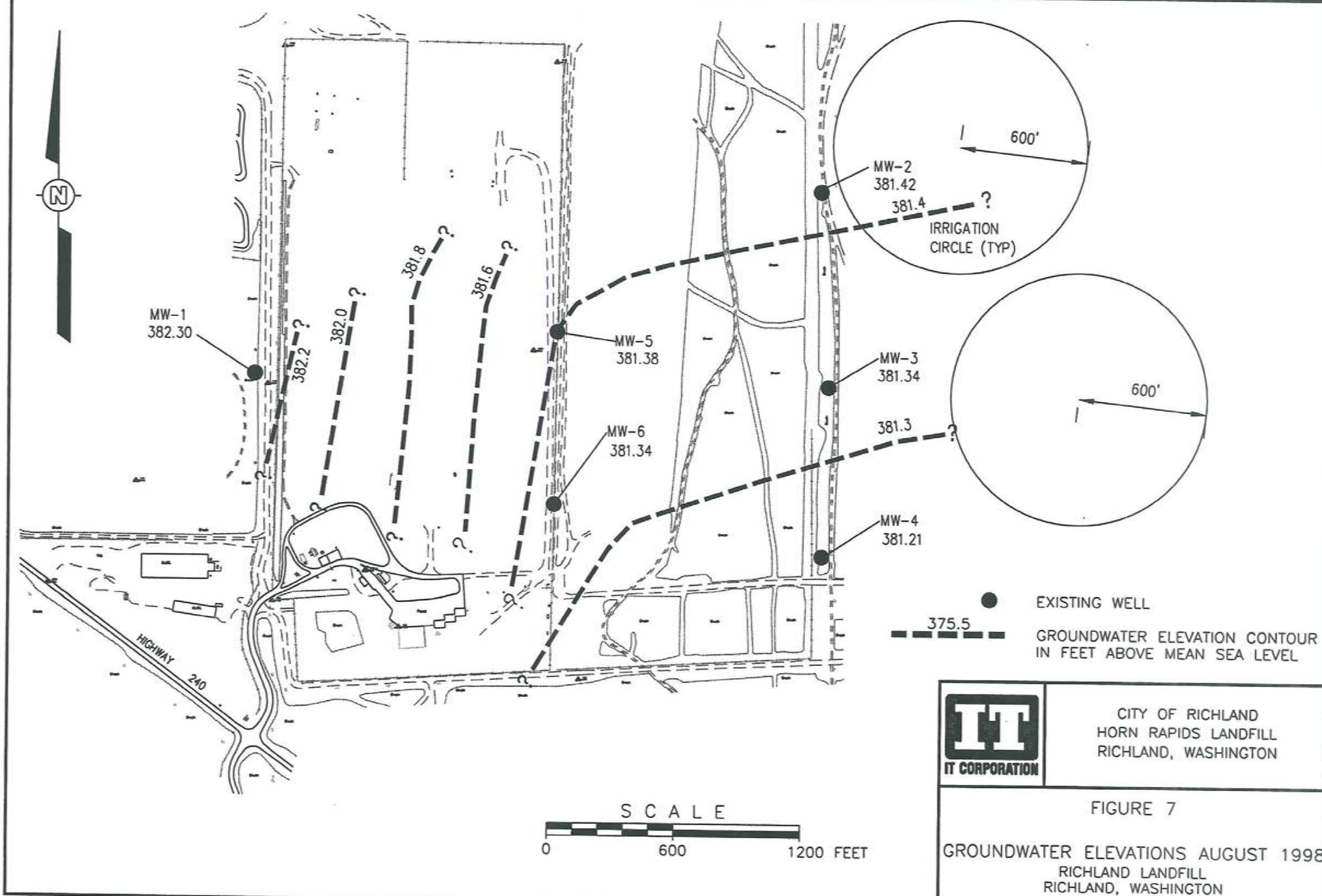
CITY OF RICHLAND
HORN RAPIDS LANDFILL
RICHLAND, WASHINGTON

FIGURE 6

GROUNDWATER ELEVATIONS JULY 1995
RICHLAND LANDFILL
RICHLAND, WASHINGTON

IMAGE	X-REF	OFFICE	DRAWN BY		CHECKED BY		APPROVED BY		DRAWING NUMBER
---	---	RICHLAND, WA	J. WILLIAMS	9/5/00					810835_FIG3



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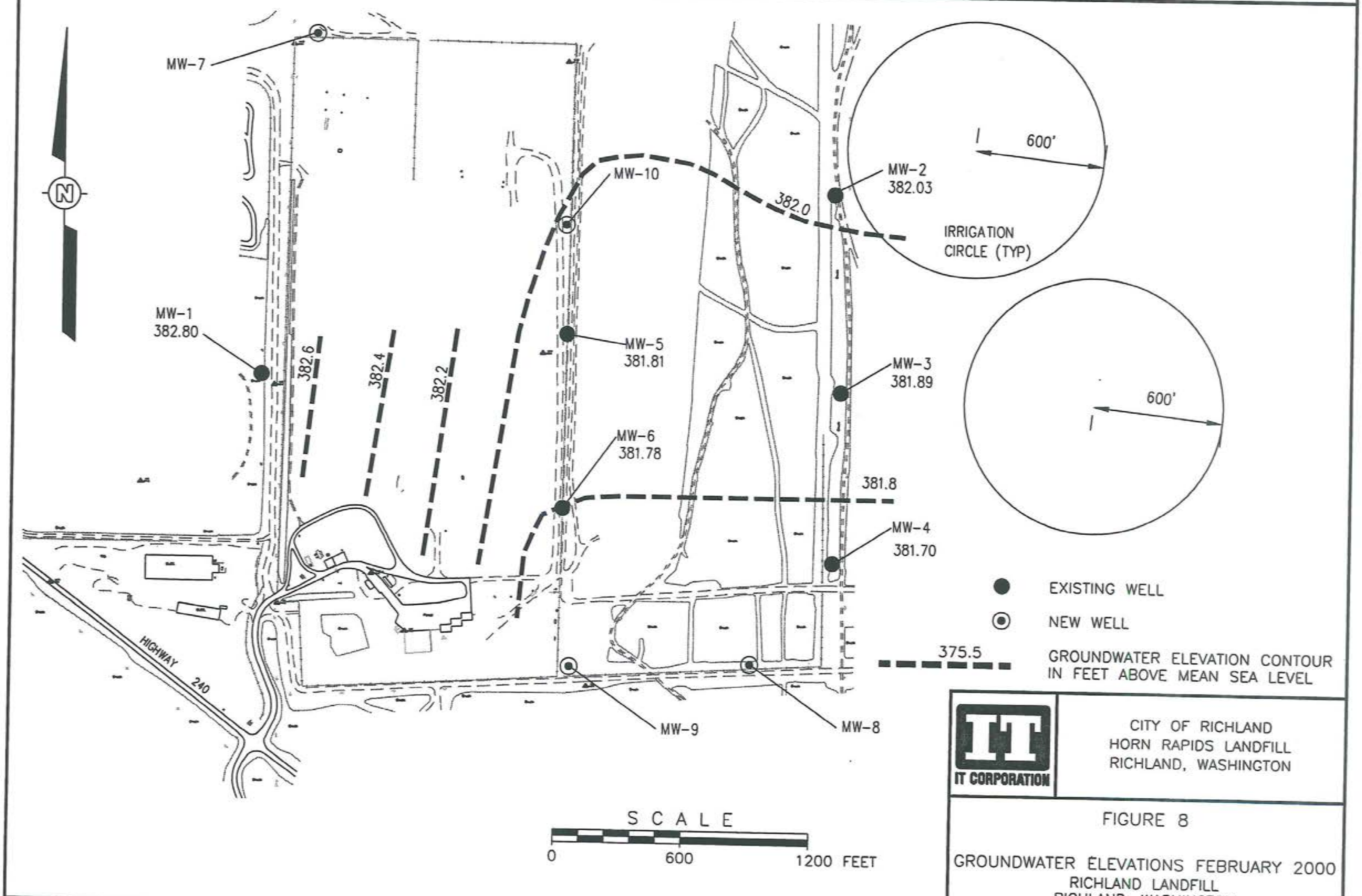
CITY OF RICHLAND
HORN RAPIDS LANDFILL
RICHLAND, WASHINGTON

FIGURE 7

GROUNDWATER ELEVATIONS AUGUST 1998
RICHLAND LANDFILL
RICHLAND, WASHINGTON

IMAGE	X-REF	OFFICE	DRAWN BY		CHECKED BY		APPROVED BY		DRAWING NUMBER
---	---	RICHLAND, WA	J. WILLIAMS	9/5/00					810835_FIG4

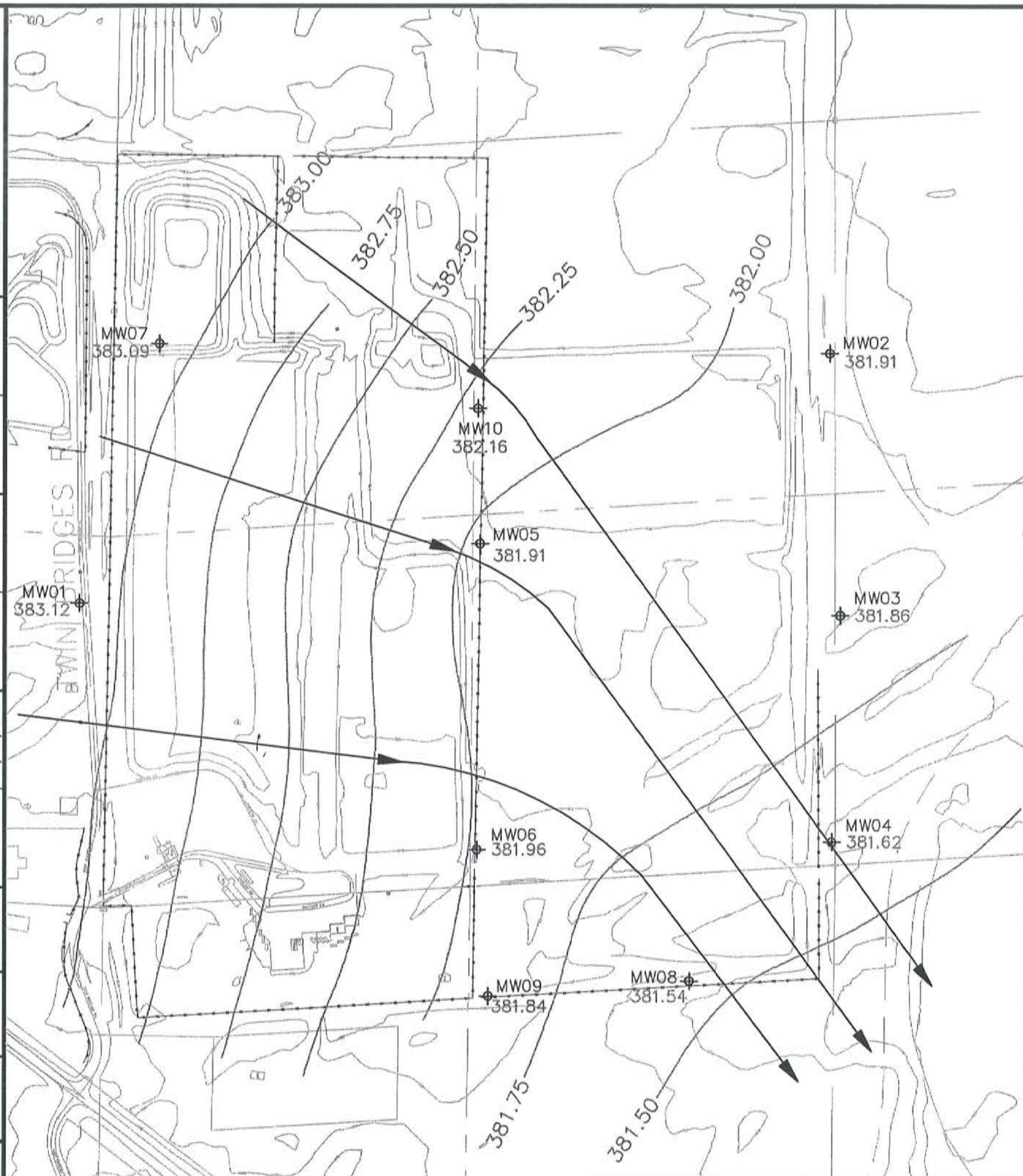


IT CORPORATION

CITY OF RICHLAND
HORN RAPIDS LANDFILL
RICHLAND, WASHINGTON

FIGURE 8

GROUNDWATER ELEVATIONS FEBRUARY 2000
RICHLAND LANDFILL
RICHLAND, WASHINGTON



DRAWING NUMBER 810835-A1

IMAGE	X-REF	OFFICE	DRAWN BY	CHECKED BY	APPROVED BY
---	---	Concord	SCHAEFFER 7/17/02		

SCALE

0 500 1000 FEET

LEGEND

⌖ MONITORING WELL LOCATION

381.84 GROUNDWATER ELEVATION (FEET)

GROUNDWATER ELEVATION CONTOUR (FEET)

GROUNDWATER FLOW LINE

N

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HORN RAPIDS LANDFILL

FIGURE 9

GROUNDWATER ELEVATION MAP
MARCH 2002

Figure 10. Well 1 Volatile Organic Compound Detections with Time

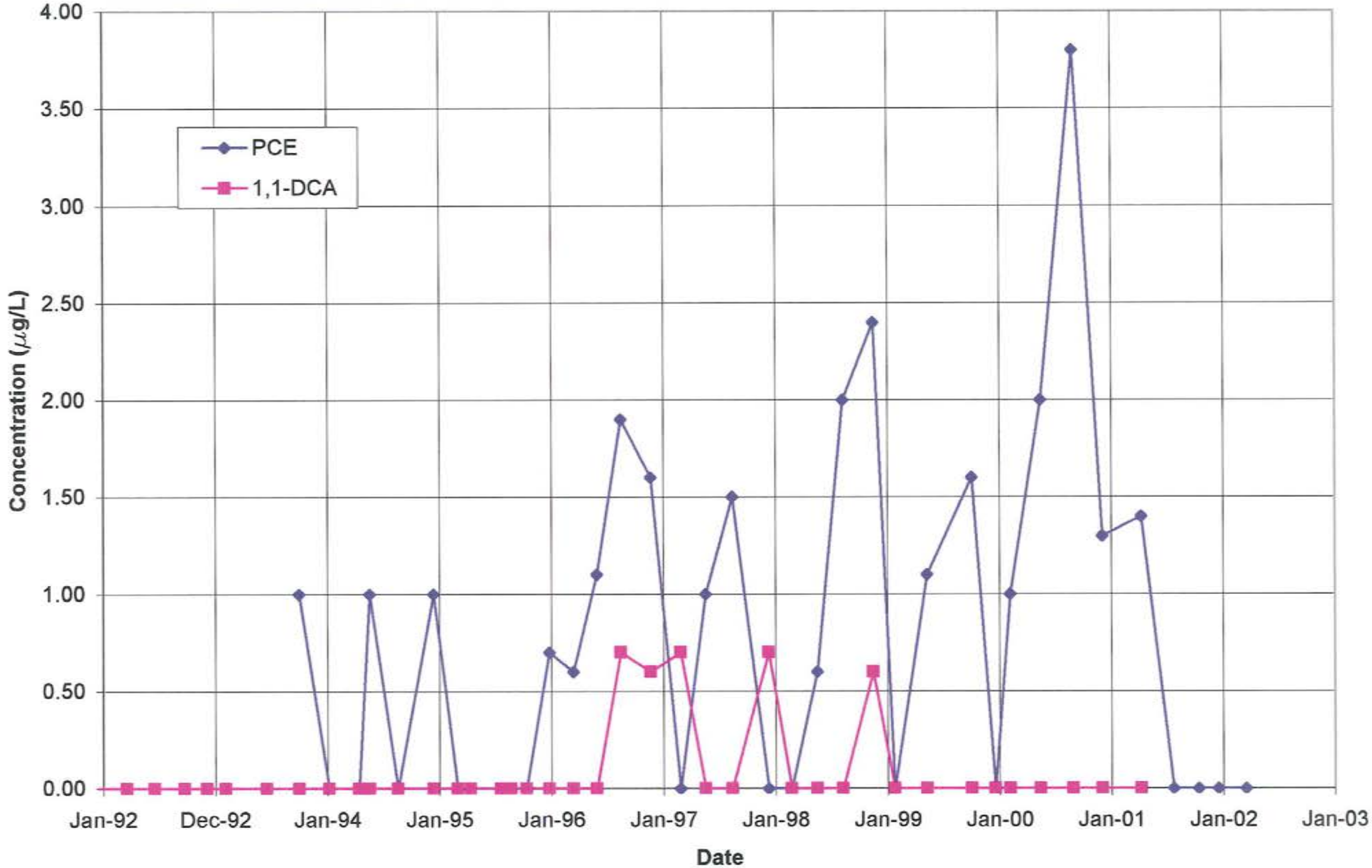


Figure 11. Well 3 Volatile Organic Compound Detections with Time

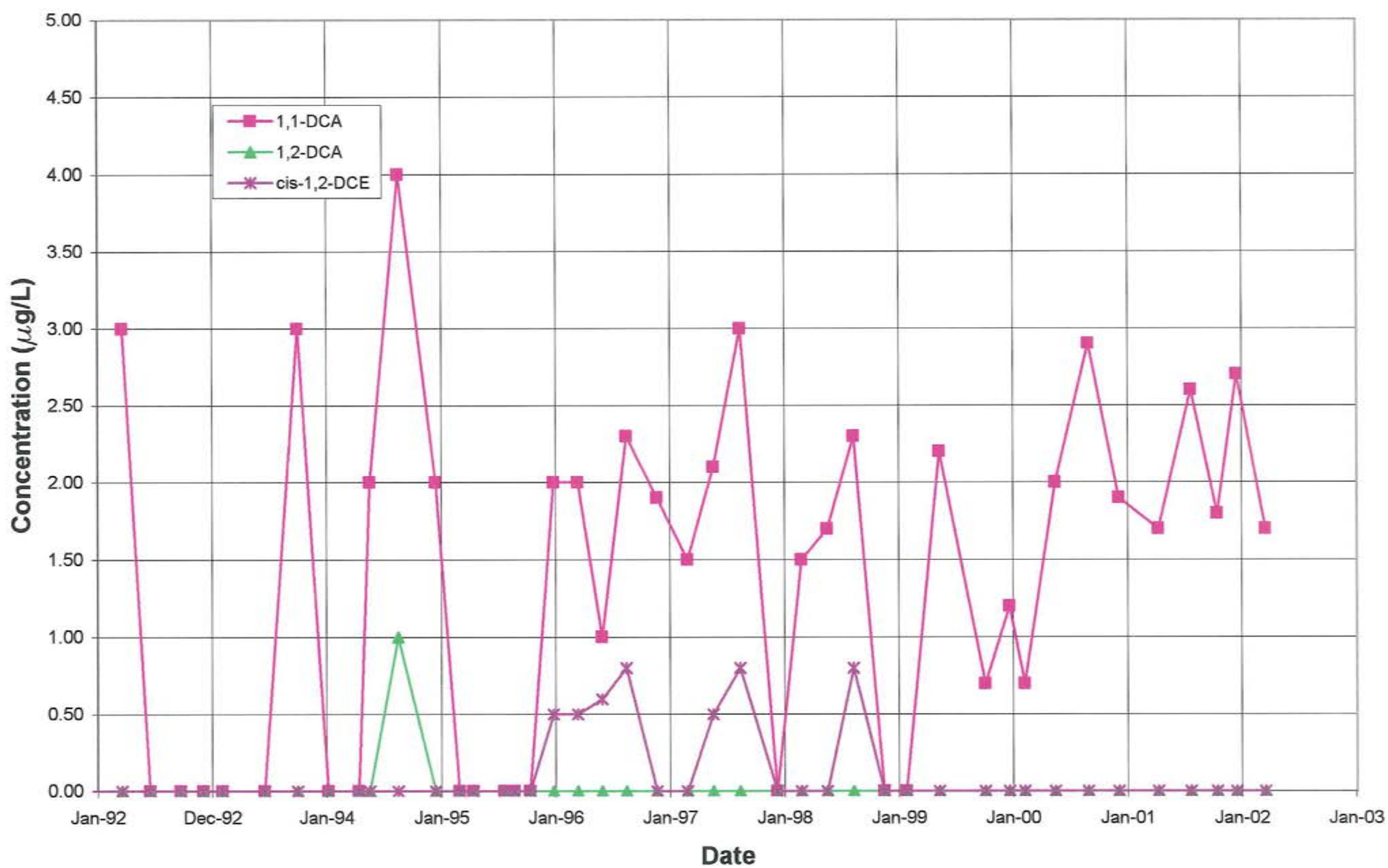


Figure 12. Well 4 Volatile Organic Compound Detections with Time

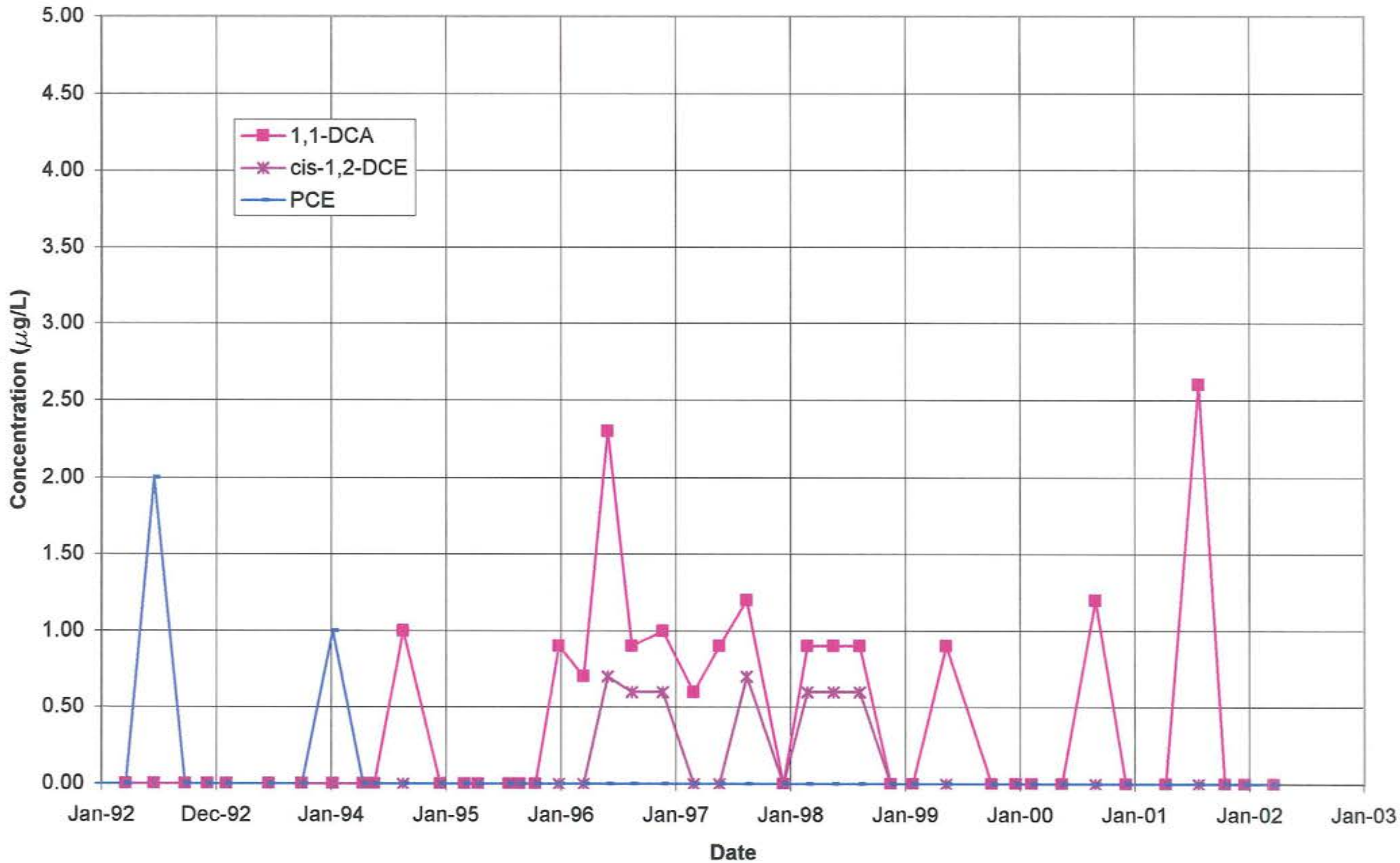


Figure 13. Well 5 Volatile Organic Compound Detections with Time

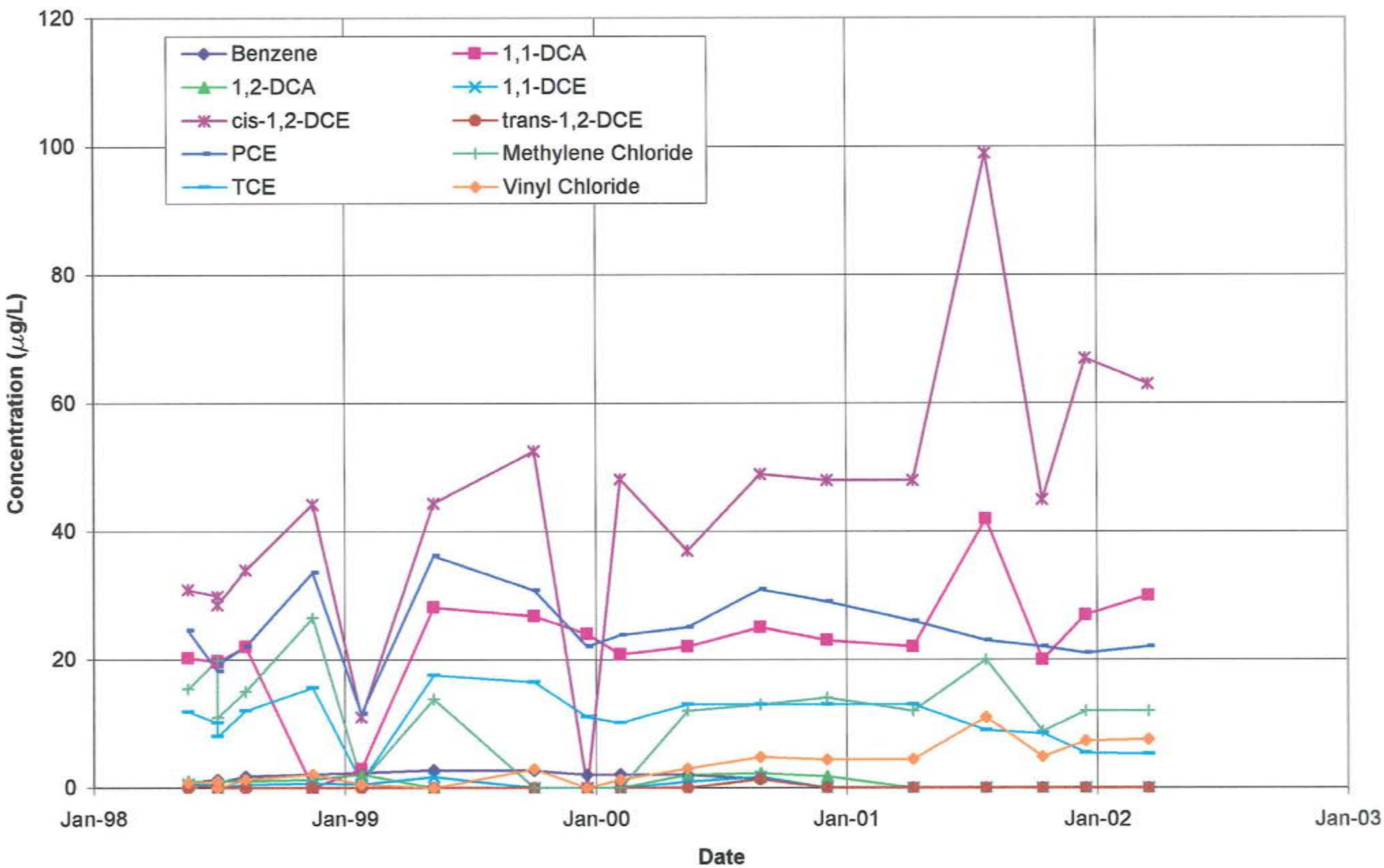


Figure 14. Well 6 Volatile Organic Compound Detections with Time

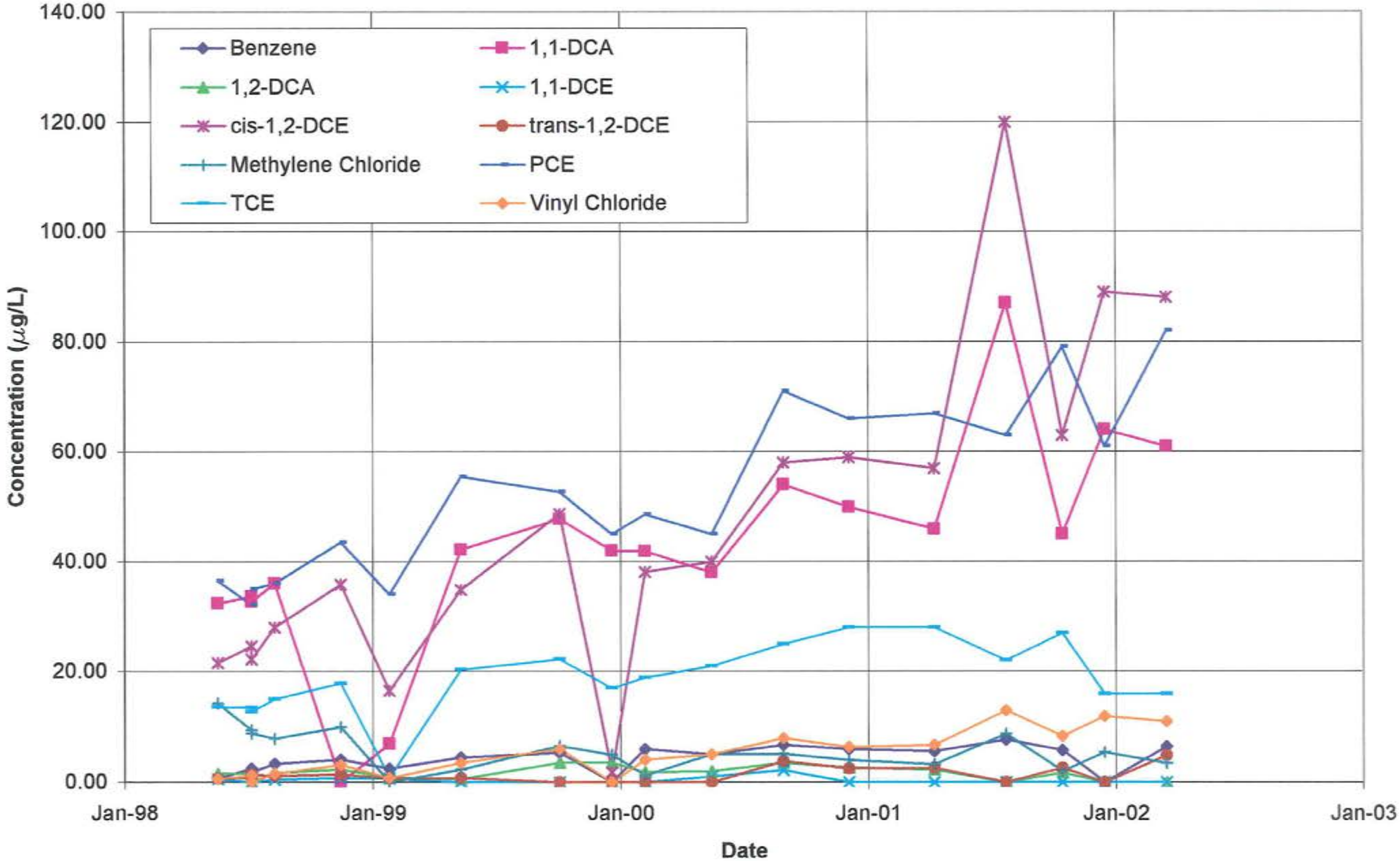


Figure 15. Well 7 Volatile Organic Compound Detections with Time

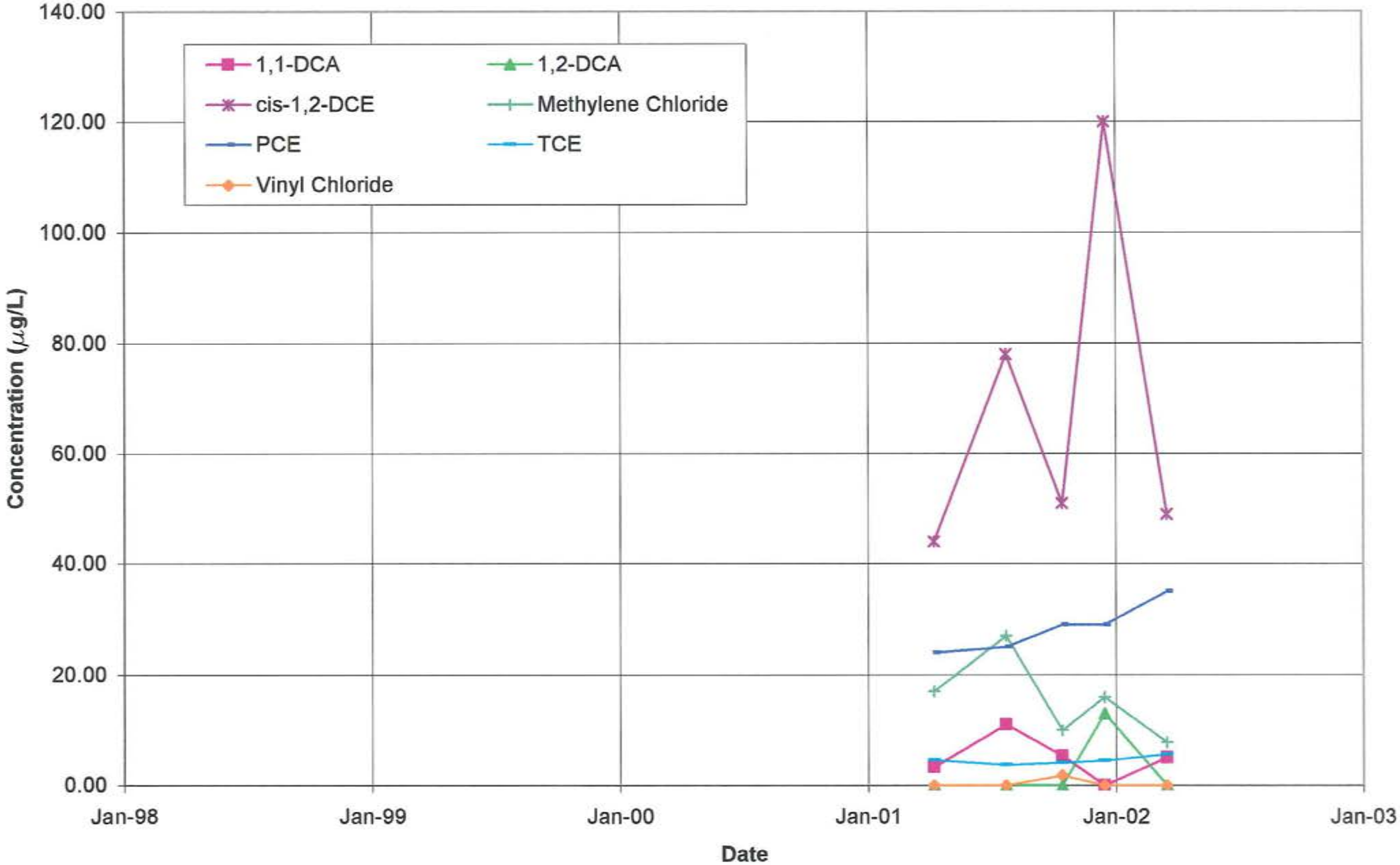


Figure 16. Well 9 Volatile Organic Compound Detections with Time

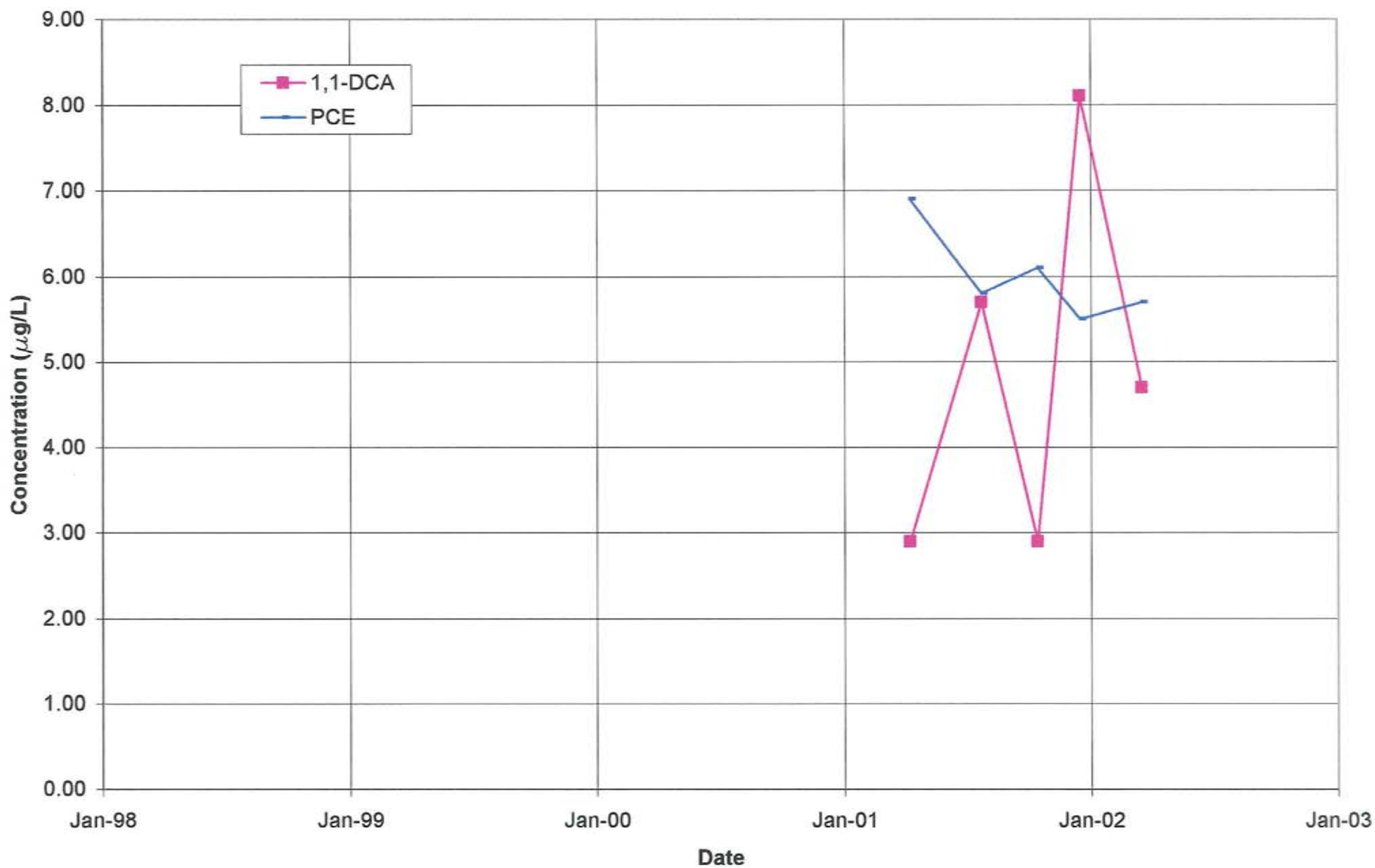


Figure 17. Well 10 Volatile Organic Compound Detections with Time

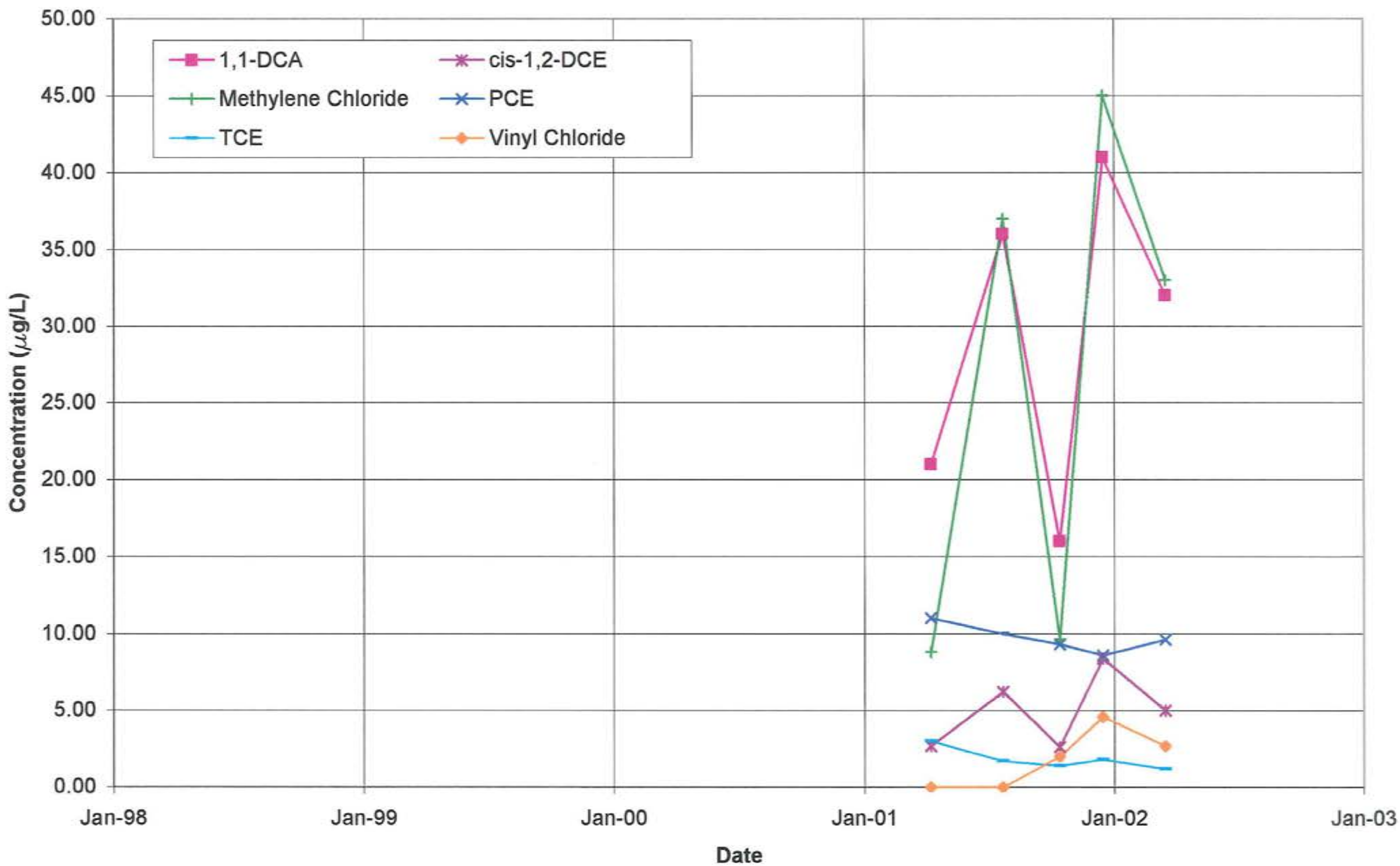
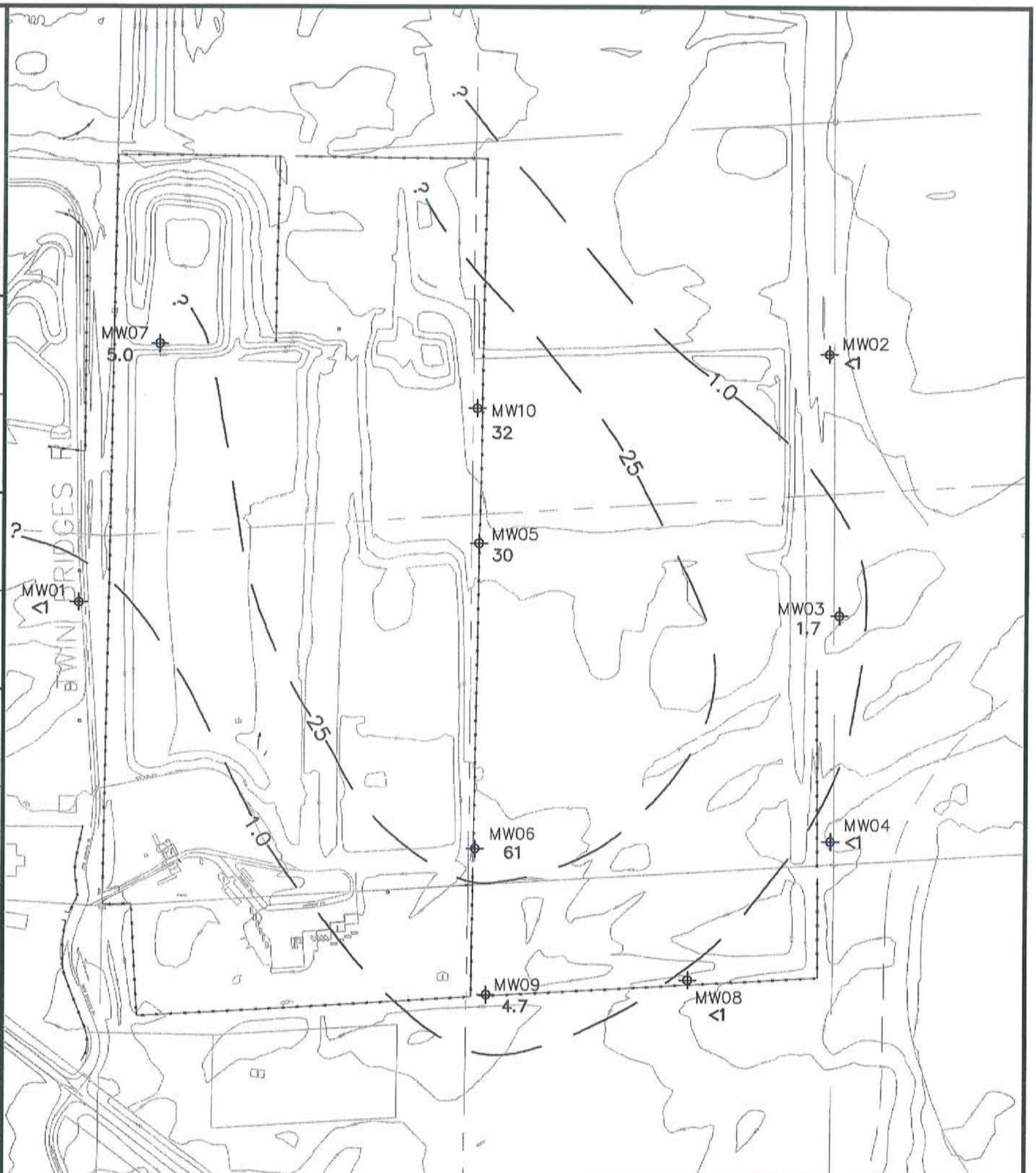


IMAGE	X-REF	OFFICE	DRAWN BY		CHECKED BY	APPROVED BY	DRAWING NUMBER
---	---	Concord	SCHAEFFER	7/17/02			810835-A2



SCALE

0 500 1000 FEET

LEGEND

MONITORING WELL LOCATION

30 1,1–DCA CONCENTRATION IN $\mu g/L$

1,1–DCA ISOCONCENTRATION CONTOUR

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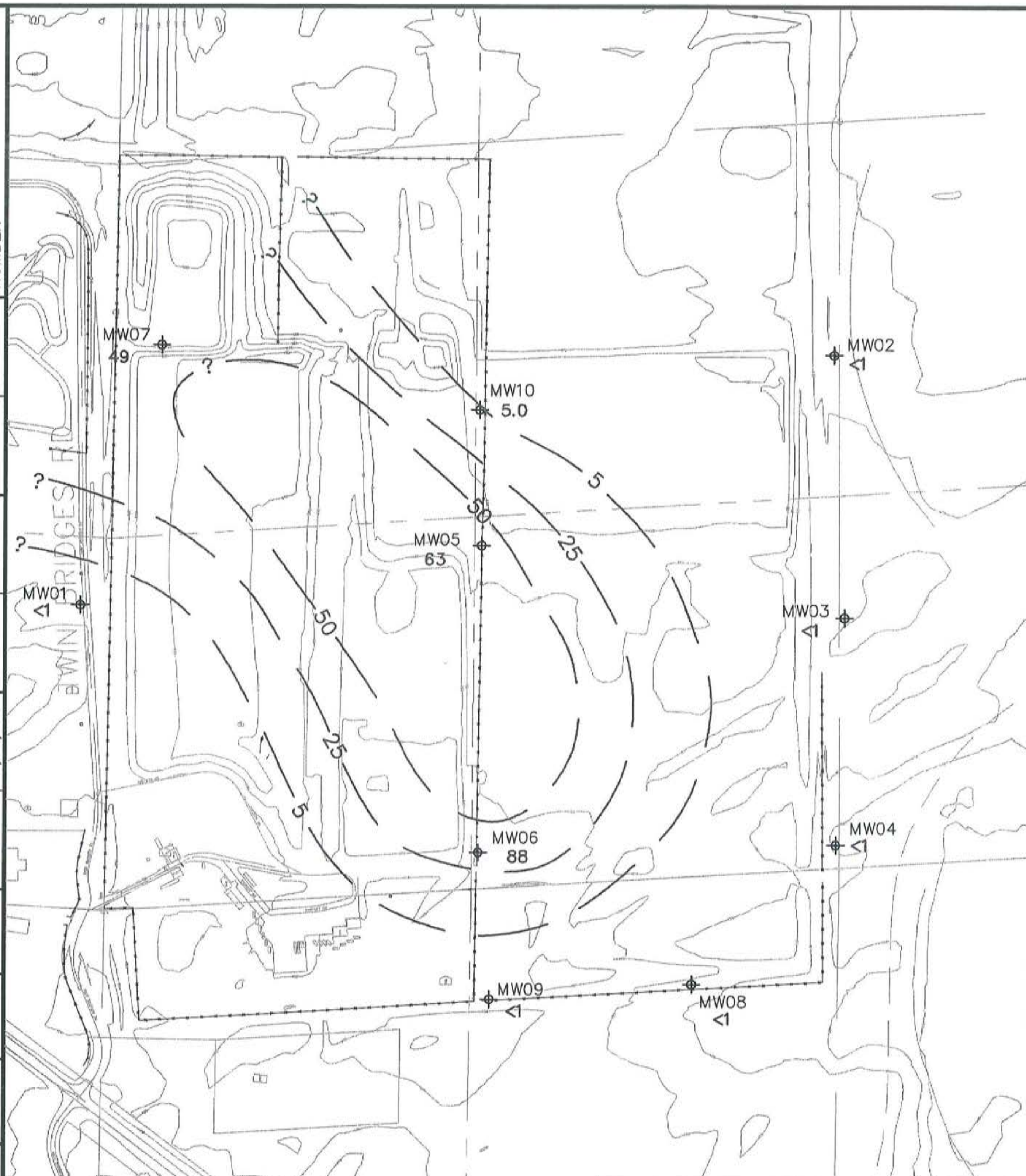
FIGURE 18

1,1–DCA ISOCONCENTRATION MAP
MARCH 2002

IMAGE	X-REF	OFFICE	DRAWN BY	CHECKED BY	APPROVED BY	DRAWING NUMBER
---	---	Concord	SCHAEFFER 7/17/02			810835-A3



SCALE

0 500 1000 FEET

LEGEND

⌖ MONITORING WELL LOCATION

63 CIS-1,2-DCE CONCENTRATION IN µg/L

⁀ CIS-1,2-DCE ISOCONCENTRATION CONTOUR

(N)

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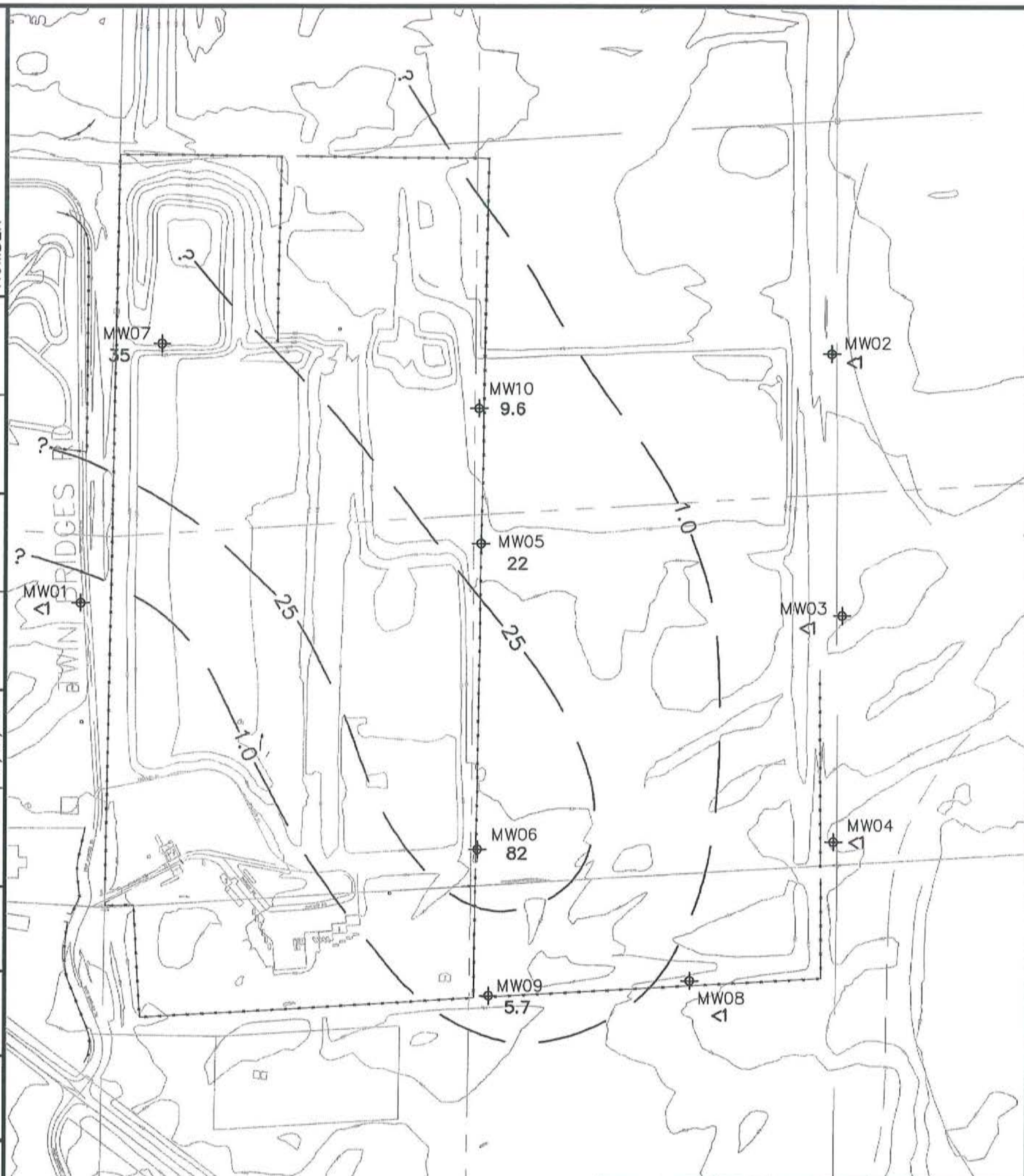
HORN RAPIDS LANDFILL

FIGURE 19

CIS-1,2-DCE ISOCONCENTRATION MAP
MARCH 2002

DRAWING NUMBER 810835-A4

IMAGE	X-REF	OFFICE	DRAWN BY		CHECKED BY	APPROVED BY
---	---	Concord	SCHAEFFER	7/17/02		



SCALE

0 500 1000 FEET

LEGEND

⌖ MONITORING WELL LOCATION

22 PCE CONCENTRATION IN $\mu g/L$

PCE ISOCONCENTRATION CONTOUR

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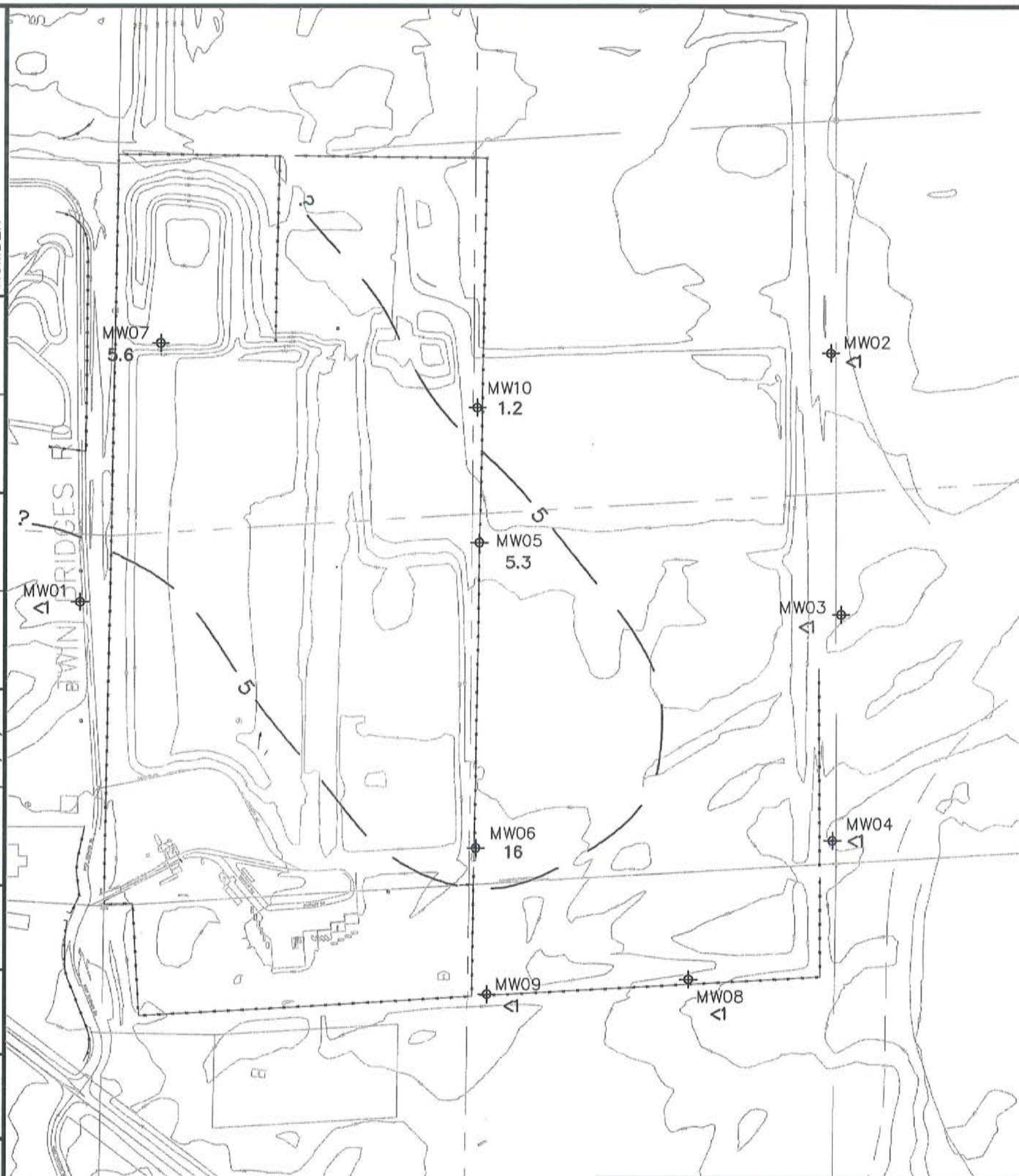
FIGURE 20

PCE ISOCONCENTRATION MAP
MARCH 2002

IMAGE	X-REF	OFFICE	DRAWN BY		CHECKED BY	APPROVED BY	DRAWING NUMBER
---	---	Concord	SCHAEFFER	7/17/02			810835-A5



SCALE

0 500 1000 FEET

N

LEGEND

MONITORING WELL LOCATION

5.3 TCE CONCENTRATION IN $\mu g/L$

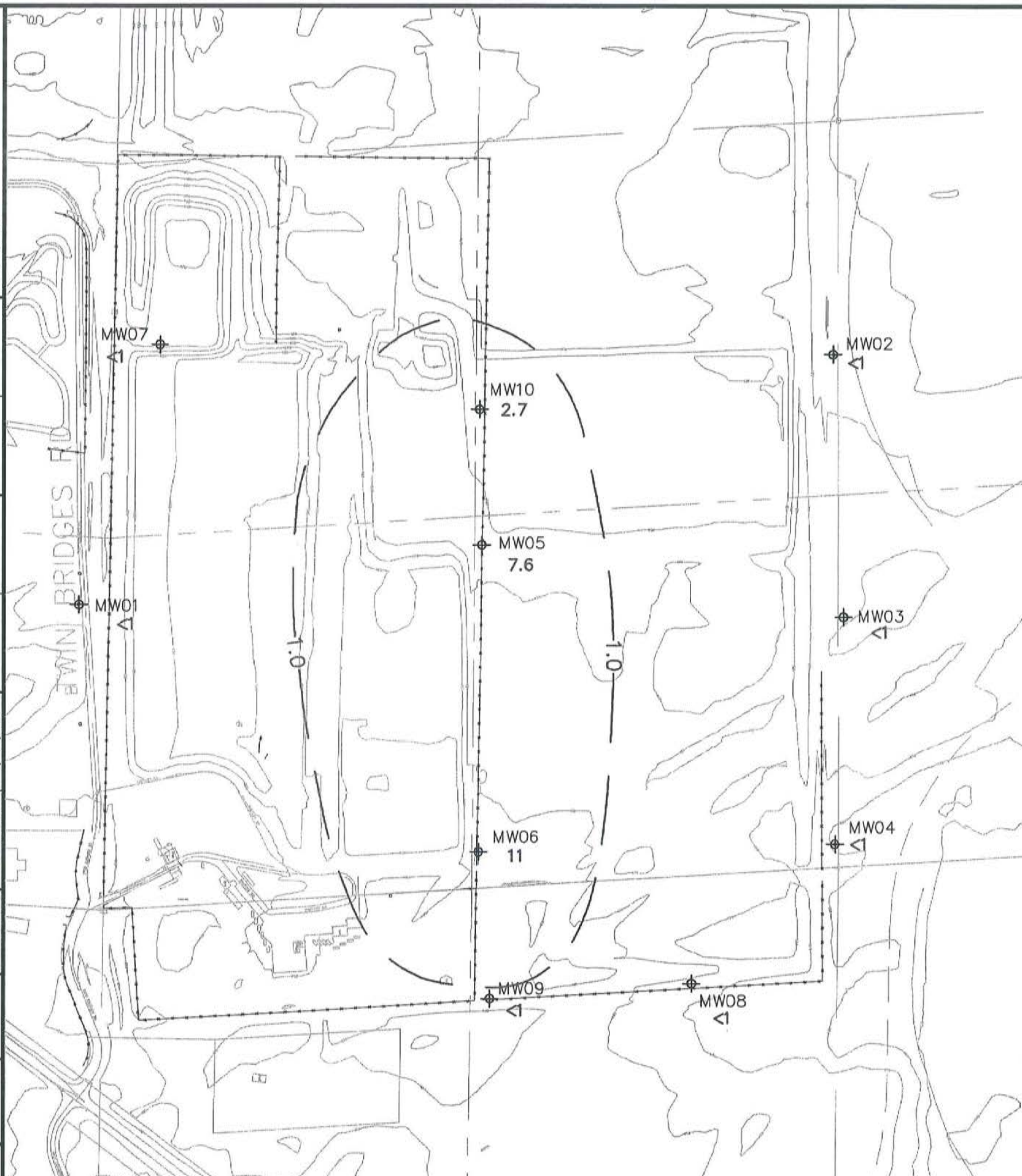
TCE ISOCONCENTRATION CONTOUR

Shaw E & I, Inc.

HORN RAPIDS LANDFILL

FIGURE 21

TCE ISOCONCENTRATION MAP
MARCH 2002



SCALE

0 500 1000 FEET

LEGEND

⌖ MONITORING WELL LOCATION

2.7 VINYL CHLORIDE CONCENTRATION IN $\mu g/L$

VINYL CHLORIDE ISOCONCENTRATION CONTOUR

N

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Shaw E & I, Inc.

HORN RAPIDS LANDFILL

FIGURE 22

VINYL CHLORIDE ISOCONCENTRATION MAP
MARCH 2002

IMAGE	X-REF	OFFICE	DRAWN BY		CHECKED BY	APPROVED BY	DRAWING NUMBER
---	---	Concord	SCHAEFFER	7/17/02			810835-A6

Figure 23. Chloride Concentration with Time

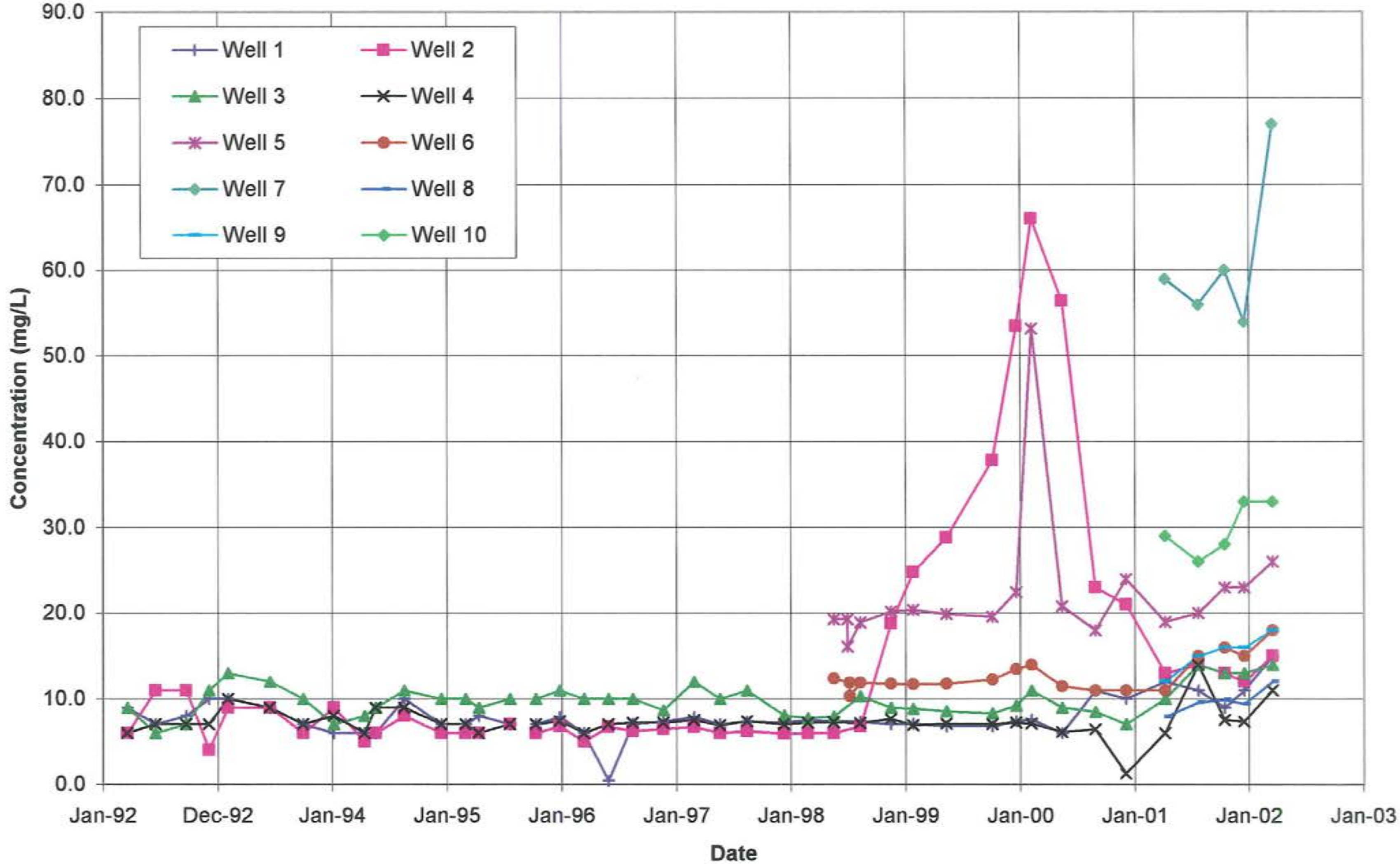


Figure 24. Nitrate Concentration with Time

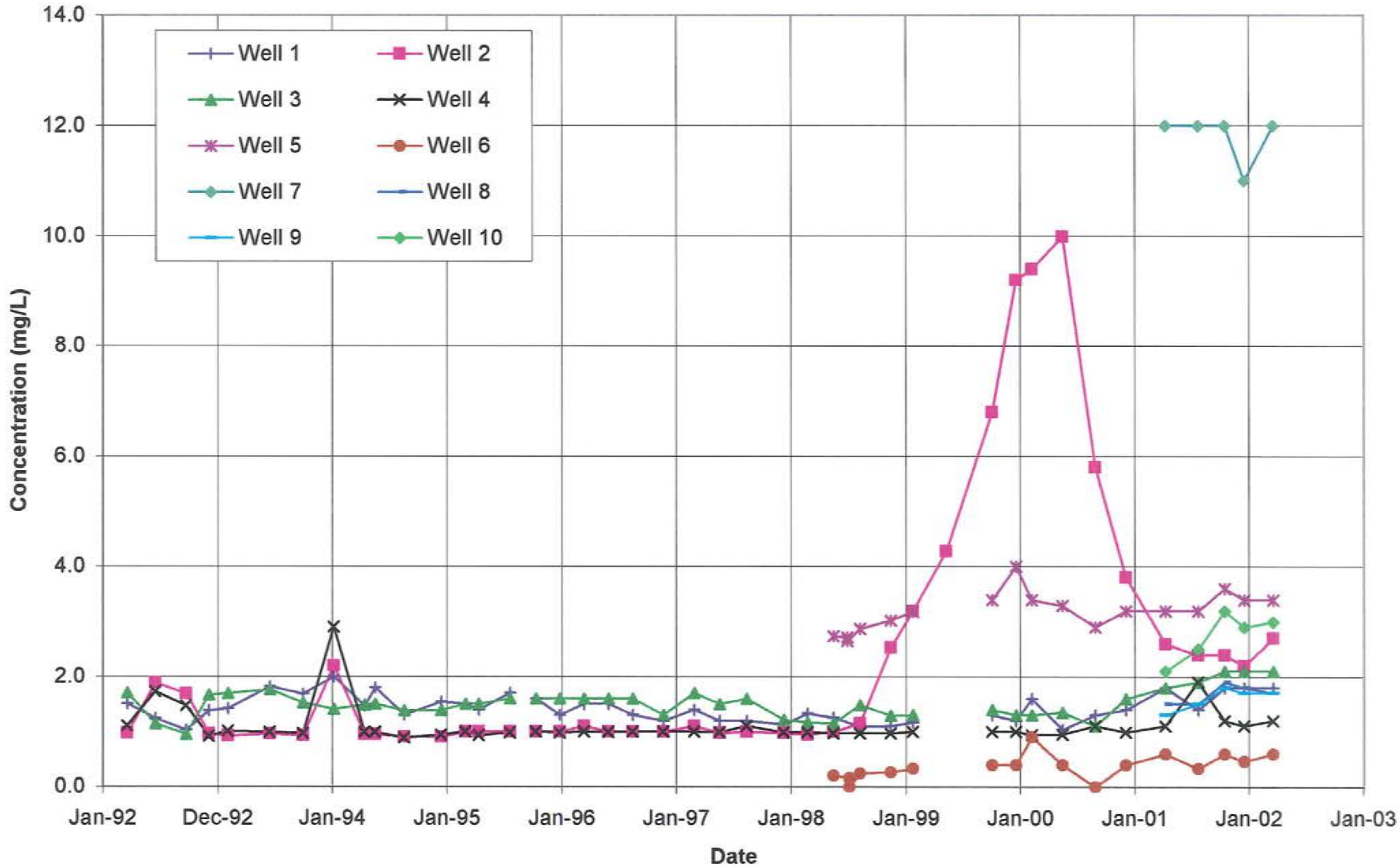


Figure 25. Sulfate Concentration with Time

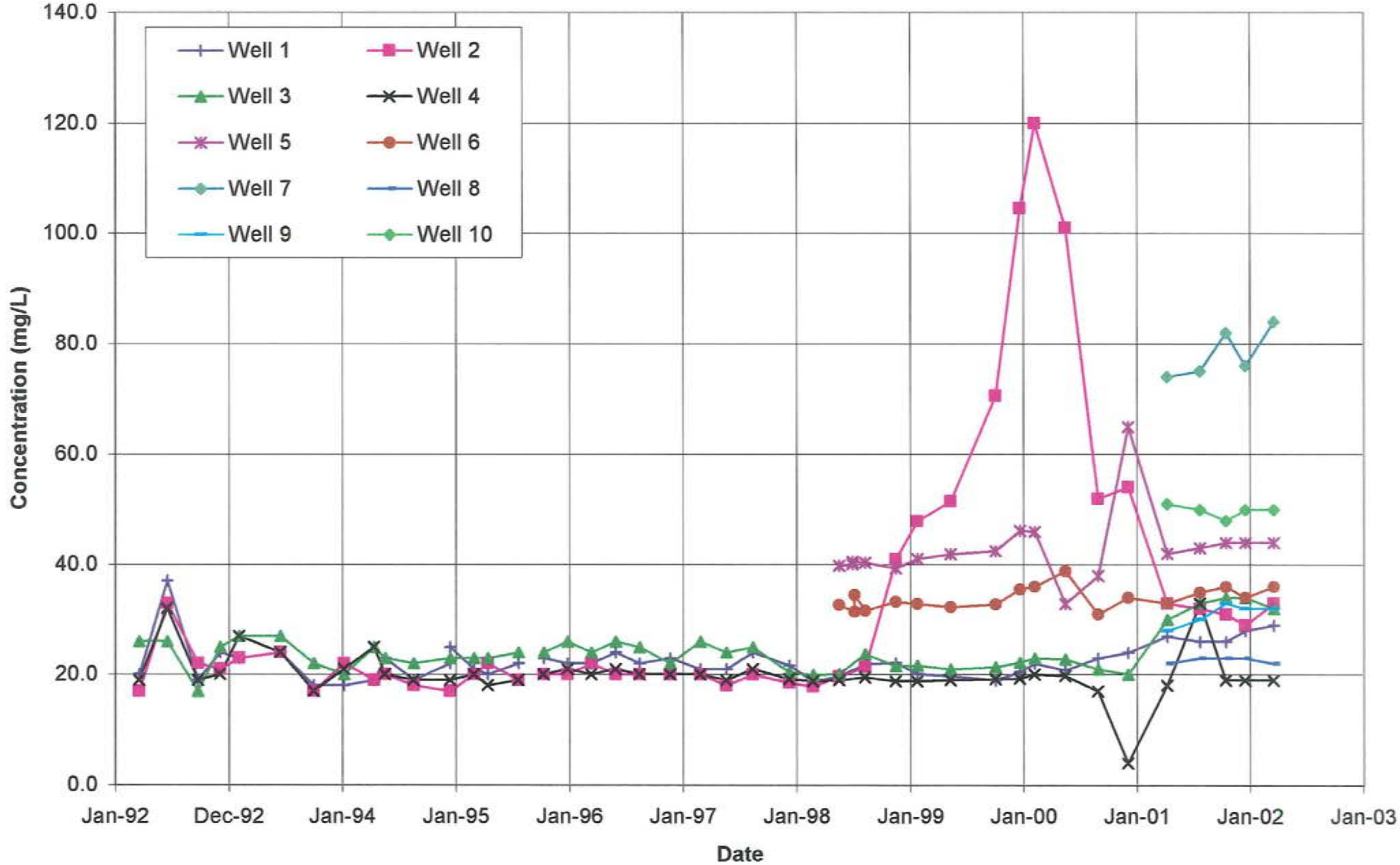
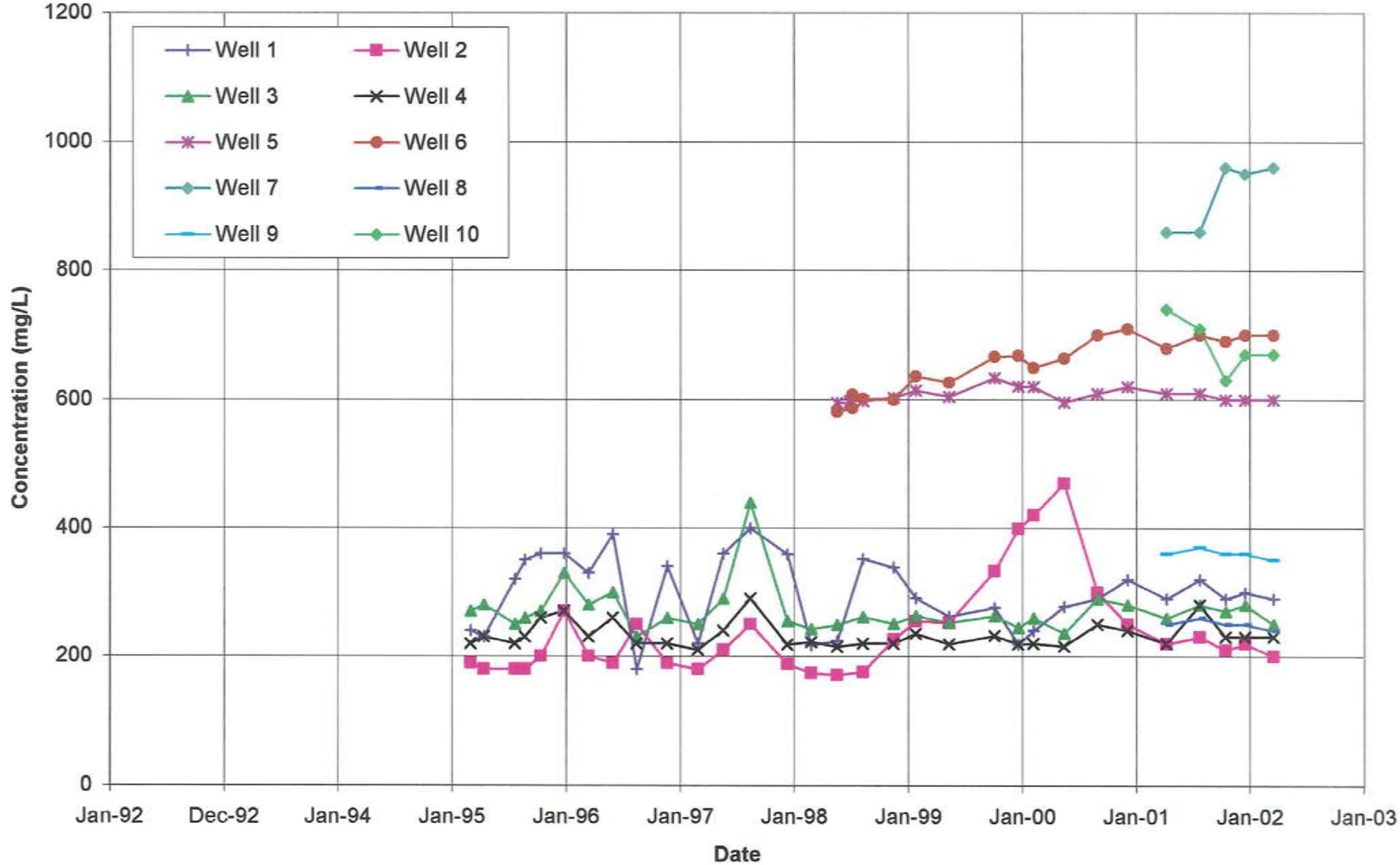


Figure 26. Total Dissloved Solids Concentration with Time



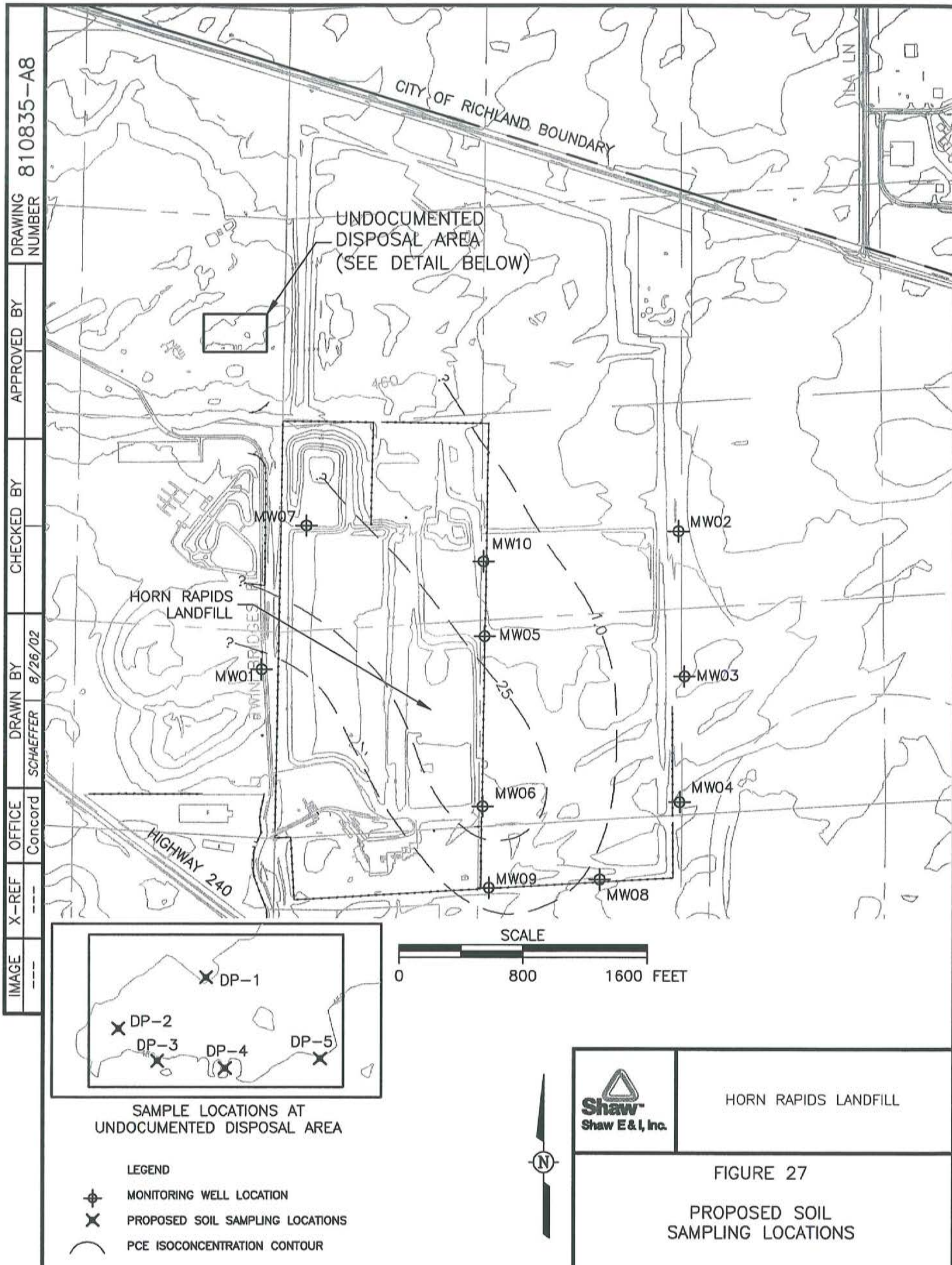


FIGURE 27

PROPOSED SOIL SAMPLING LOCATIONS

APPENDIX A
MONITORING WELL BORING LOGS

INTERNATIONAL TECHNOLOGY CORPORATION

VISUAL CLASSIFICATION OF SOILS

PROJECT NUMBER: 810835	PROJECT NAME: RICHLAND HORN RAPIDS LANDFILL	
BORING NUMBER: MW07	COORDINATES:	DATE: 1/24/01
ELEVATION:	GWL: Depth 91 Date/Time 1/24/01	DATE STARTED: 1/24/01
ENGINEER/GEOLOGIST: G. HAMILTON	Depth Date/Time	DATE COMPLETED: 1/25/01
DRILLING METHODS: Air-Rotary - Tubex		PAGE 1 OF 4

DEPTH ( )	SAMPLE TYPE & NO.	BLOWS ON SAMPLER PER ( )	RECOVERY ( )	DESCRIPTION	USCS SYMBOL	MEASURED CONSISTENCY (TSF)	WELL CONSTRUCTION	REMARKS
0	NA	NA	NA	0-10 POORLY GRADED FINE-GRAINED SAND, BROWN TO TAN COLOR	SP			8-IN DIAMETER STEEL PROTECTIVE CASING; CONCRETE 0-2ft
5				POORLY GRADED FINE-GRAINED SAND				
10				10-18 POORLY GRADED SILTY FINE TO MEDIUM-GRAINED SAND, 80% FINE TO MEDIUM SAND, 20% SILT/CLAY	SM			6-IN DIAMETER BOREHOLE
15				POORLY GRADED VERY FINE TO FINE-GRAINED SAND WITH SILT. 95% SAND 5% SILT				CEMENT/BENTONITE GROUT 2-68.8ft
				18-21 POORLY GRADED MEDIUM-GRAINED SAND LIGHT TAN COLOR	SP			
20				21-28	SW/SP			
25				MODERATELY GRADED, VERY FINE TO MEDIUM-GRAINED SAND				WELL CASING, 2-IN ID SCH40 PVC +2-87.5ft
30				28-35 POORLY GRADED FINE TO MEDIUM-GRAINED SAND	SP			

NOTES:

Drilling Contractor Environmental West

Drilling Equipment Schramm Tubex

Driller: Ron Sink

Kelly Hill, Gary Baker

INTERNATIONAL TECHNOLOGY CORPORATION

VISUAL CLASSIFICATION OF SOILS

PROJECT NUMBER: 810835	PROJECT NAME: RICHLAND HORN RAPIDS LANDFILL	
BORING NUMBER: MW07	COORDINATES:	DATE: 1/24/01
ELEVATION:	GWL: Depth Date/Time	DATE STARTED: 1/24/01
ENGINEER/GEOLOGIST: G. HAMILTON	Depth Date/Time	DATE COMPLETED: 1/25/01
DRILLING METHODS: Air Rotary - Tubex		PAGE 2 OF 4

DEPTH ( )	SAMPLE TYPE & NO.	BLOWS ON SAMPLER PER ( )	RECOVERY ( )	DESCRIPTION	USCS SYMBOL	MEASURED CONSISTENCY (TSF)	WELL CONSTRUCTION	REMARKS
30	NA	NA	NA	POORLY GRADED FINE TO MEDIUM-GRAINED SAND	SP			
35				35-37 VERY FINE GRAINED SAND WITH PIECES of Clay	SC/ML			
				37-45 MODERATELY GRADED, MEDIUM to COARSE-GRAINED, SAND GRAINS TO 3MM, WITH PIECES OF BROWN CLAY	SW			CEMENT BENTONITE GROUT 2-68.8 ft
40								
45				45-48 POORLY GRADED, MEDIUM GRAINED SAND	SP			WELL CASING, 2-IN ID SCH40, PVC+2 - 87.5 ft
				48-49 WELL GRADED, ~~FINE SAND & GRAVEL~~ FINE TO MEDIUM GRAINED SAND, WELL ROUNDED 5-10MM GRAVEL	GM			
50				49-68 WELL GRADED GRAVELLY SAND, ROUNDED GRAVEL TO 7MM, VERY FINE TO MEDIUM-GRAINED SAND	SW			
55								6-IN DIAMETER BORE HOLE
60				MODERATELY SORTED FINE TO MEDIUM-GRAINE SAND	SP/SW			

NOTES:

Drilling Contractor ____________________

Drilling Equipment ____________________

Driller: ____________________

INTERNATIONAL TECHNOLOGY CORPORATION

VISUAL CLASSIFICATION OF SOILS

PROJECT NUMBER: 810835	PROJECT NAME: RICHLAND HORN RAPIDS LANDFILL	
BORING NUMBER: MW07	COORDINATES:	DATE: 1/24/01
ELEVATION:	GWL: Depth Date/Time	DATE STARTED: 1/24/01
ENGINEER/GEOLOGIST: S. Hamilton	Depth Date/Time	DATE COMPLETED: 1/25/01
DRILLING METHODS: Air Rotary Tuber		PAGE 3 OF 4

DEPTH ( )	SAMPLE TYPE & NO.	BLOWS ON SAMPLER PER ( )	RECOVERY ( )	DESCRIPTION	USCS SYMBOL	MEASURED CONSISTENCY (TSF)	WELL CONSTRUCTION	REMARKS
60	NA	NA	NA	MODERATELY SORTED FINE TO MEDIUM GRAINED SAND	SP/SW			CEMENT/BENTONITE GROUT Z - 68.8 ft
65				WELL GRADED GRAVELY SAND, GRAVEL to 10 MM, COARSE TO MEDIUM-GRAINED SAND	SW			6-IN DIAMETER BOREHOLE
70				68-73 POORLY GRADED FINE-GRAINED SAND VERY POORLY GRADED, VERY FINE TO FINE-GRAINED SAND, MICA FLAKES TO 0.5 mm, QUARTZ AND BASALT GRAINS.	SM			WELL CASING, 2-IN ID, SHD 40 PVC +2-87.5 ft
75				73-78 POORLY GRADED FINE-GRAINED SAND, WITH OCCASIONAL GRAVEL TO 1.2 CM.	SP			BENTONITE CHIP SEAL 68.8 - 83.5 ft
80				78-83 VERY FINE-GRAINED SILTY SAND POORLY GRADED FINE SAND WITH SILT	SM			
85				83-91 POORLY GRADED COARSE GRAVEL, WELL ROUNDED WITH FINES WELL ROUNDED FINE TO COARSE-GRAINED GRAVEL WITH FINES	GM			10-20 MESH SILICA SAND 83.5-105 ft CENTRALIZER WELL SCREEN 2-IN ID, SCH 40 PVC 0.010-IN MACHINE SLOTTED 87.5-102.5 ft
90								

NOTES:

Drilling Contractor

Drilling Equipment

Driller:

INTERNATIONAL TECHNOLOGY CORPORATION

VISUAL CLASSIFICATION OF SOILS

PROJECT NUMBER: 810835	PROJECT NAME: Horn Rapids Landfill		
BORING NUMBER: MW07	COORDINATES:		DATE: 1/24/01
ELEVATION:	GWL: Depth	Date/Time	DATE STARTED: 1/24/01
ENGINEER/GEOLOGIST: G. HAMILTON	Depth	Date/Time	DATE COMPLETED: 1/25/01
DRILLING METHODS: Air Rotary - Tubex			PAGE 4 OF 4

DEPTH ( )	SAMPLE TYPE & NO.	BLOWS ON SAMPLER PER ( )	RECOVERY ( )	DESCRIPTION	USCS SYMBOL	MEASURED CONSISTENCY (TSF)	WELL CONSTRUCTION	REMARKS
90				FINE to COARSE-GRAINED GRAVEL WITH SAND WELL ROUNDED, WET	GM			▽ 91 ft SATURATED
				91-104 VERY WELL GRADED SANDY GRAVEL, GRAVEL IS WELL ROUNDED to 1CM	GW			10-20 MESH SILICA SAND 83.5 - 105 ft
95								WELL SCREEN 2-IN ID SCH 40 PVC, 0.010-IN MACHINE SLOTTED SCREEN 87.5 - 102.5
100				WELL GRADED SAND AND GRAVEL, FINE TO COARSE-GRAINED SAND, GRAVEL WELL ROUNDED TO 8MM				6-ID DIAMETER BOREHOLE
								Bottom Sump, 2-IN ID, SHD 40 WELL CASING WITH END CAP 102.5 to 105 FT
				104-105 WELL GRADED SAND AND GRAVEL WITH SILT	GM			CENTRALIZER
105				TD = 105				

NOTES:

Drilling Contractor

Drilling Equipment

Driller:

INTERNATIONAL TECHNOLOGY CORPORATION

VISUAL CLASSIFICATION OF SOILS

PROJECT NUMBER: 810835	PROJECT NAME: Richland, Horn Rapids Landfill	
BORING NUMBER: MW08	COORDINATES:	DATE: 1/18/01
ELEVATION:	GWL: Depth 89.5 Date/Time 1/18/01	DATE STARTED: 1/18/01
ENGINEER/GEOLOGIST: G. Hamilton	Depth Date/Time	DATE COMPLETED: 1/18/01
DRILLING METHODS: Air Rotary - TUBEX		PAGE 1 OF 4

DEPTH ( )	SAMPLE TYPE & NO.	BLOWS ON SAMPLER PER (6 in.)	RECOVERY (in)	DESCRIPTION	USCS SYMBOL	MEASURED CONSISTENCY (TSF)	WELL CONSTRUCTION	REMARKS
								locking WELL CAP
					CONCRETE			8-in STEEL PROTECTIVE CASING
				Poorly graded very fine to fine-grained SAND				CEMENT/BENTONITE GROUT 2-71.2 ft
5		10/13/13	18	poorly graded very fine-grained SAND with silt, medium dense	SM			2-IN DIA SCH 40, PVC WELL CASING 0-84.5 FT
10		7/10/14	18	Poorly sorted very fine-grained SAND with silt, medium dense				
15		15/33/50	17	Poorly sorted very fine to fine grained SAND w , very dense				
20	NS			Poorly graded very FINE to FINE-GRAINED SAND with SILT				NO SAMPLE, BIT CAM LOCKED OPEN
25	HRL S003	30/50	11	23-40 Poorly GRADED VERY FINE TO FINE GRAINED SAND, VERY DENSE	SP/SM			
30								

NOTES:

Drilling Contractor ENVIRONMENTAL WEST EXPLORATION

Drilling Equipment SCHRAMM ROTARY AIR - TUBEX

Driller: RON SINK
Kelly HILL, CASEY BAKER

INTERNATIONAL TECHNOLOGY CORPORATION

VISUAL CLASSIFICATION OF SOILS

PROJECT NUMBER: 810835	PROJECT NAME: RICHLAND HORN RAPIPS LANDFILL	
BORING NUMBER: MW08	COORDINATES:	DATE: 1/18/01
ELEVATION:	GWL: Depth Date/Time	DATE STARTED: 1/18/01
ENGINEER/GEOLOGIST: G. HAMILTON	Depth Date/Time	DATE COMPLETED: 1/18/01
DRILLING METHODS: Air Rotary Tubex		PAGE 2 OF 4

DEPTH ( )	SAMPLE TYPE & NO.	BLOWS ON SAMPLER PER ( )	RECOVERY ( )	DESCRIPTION	USCS SYMBOL	MEASURED CONSISTENCY (TSF)	WELL CONSTRUCTION	REMARKS
30				Poorly GRADED FINE-GRAINED SAND with <5% MEDIUM SAND	SP			NO SAMPLE, BIT CAM JAMMED with SAND
								2-IN DIA SCH 40 PVC WELL CASING 0-84.5 FT
35		34/50	11	POORLY GRADED FINE to MEDIUM-GRAINED SAND, VERY DENSE				
								CEMENT/BENTONITE GROUT 2-71.5 ft
40		4/22/50	17	40-42 FINE to MEDIUM-GRAINED SAND WITH SOME FINE to COARSE-GRAINED GRAVEL, VERY DENSE SOIL	GC			
				42-45 POORLY GRADED FINE to MEDIUM-GRAINED SAND	SW			6-IN DIA BOREHOLE
45		25/50	10	45-46 WELL GRADED FINE to COARSE-GRAINE SAND, PREDOMINATELY FINE to MEDIUM GRAINED. <5% FINE GRAVEL and Clay	GC			
				46-55				
50		10/50	11	POORLY GRADED FINE TO MEDIUM-GRAINED SAND, VERY DENSE SOIL	SP			
55				55-71.5 WELL GRADED VERY FINE to COARSE-GRAINED SAND, with some MICA GRAINS	SW			NOT SAMPLED DUE TO SAND-LOCKED BIT CAM
60								

NOTES:

Drilling Contractor

Drilling Equipment

Driller:

INTERNATIONAL TECHNOLOGY CORPORATION

VISUAL CLASSIFICATION OF SOILS

PROJECT NUMBER: 810835	PROJECT NAME: RICHLAND HORN RAPIDS LANDFILL
BORING NUMBER: MW08	COORDINATES:
	DATE: 1/18/01
ELEVATION:	GWL: Depth Date/Time
	DATE STARTED: 1/18/01
ENGINEER/GEOLOGIST: G HAMILTON	Depth Date/Time
	DATE COMPLETED: 1/18/01
DRILLING METHODS: Air Rotary Tubex	PAGE 3 OF 4

DEPTH ( )	SAMPLE TYPE & NO.	BLOWS ON SAMPLER PER ( )	RECOVERY ( )	DESCRIPTION	USCS SYMBOL	MEASURED CONSISTENCY (TSF)	WELL CONSTRUCTION	REMARKS
60		6/25/45	18	WELL GRADED FINE TO COARSE-GRAINED SAND, VERY DENSE SOIL	SW			2-IN SCH 40 PVC WELL CASING, 0-84.5 FT
65				WELL GRADED MEDIUM TO COARSE-GRAINED SAND, < 5% FINE GRAINED WELL ROUNDED GRAVEL				NOT SAMPLED DUE TO SAND LOCKED BIT CAM
								CEMENT/BENTONITE GROUT 2-72.5 ft
70		5/11/25		WELL GRADED FINE TO COARSE-GRAINED SAND WITH WELL ROUNDED GRAVEL				6-in dia Borehole
75				POORLY GRADED VERY FINE to FINE SAND WITH FLAKES of MICA	SM			BENTONITE SEAL (HYDRATED CHIPS) 72.5-81.5 ft
80		2/3/30		POORLY GRADED VERY FINE TO FINE-GRAINED SAND WITH TRACE FLAKES OF MICA, MEDIUM TO DENSE SOIL				
								10-20 MESH SILICA SAND 81.5-102 ft
85				POORLY GRADED, GRAVELLY VERY FINE TO FINE-GRAINED SAND, 80% SAND, 20% GRAVEL, DAMP	SP			2-IN DIA. SCH. 40 PVC SCREEN 0.010-IN MACHINE SLOT 84.5-99.5 ft
90				COBBLE AND PEPPLE GRAVEL WITH fine SAND AND SILT, COBBLES to 3 CM, SATURATED, WELL ROUNDED	GM			▽ WATER LEVEL STABILIZED AT 89.3 FT

NOTES:

Drilling Contractor ______________________

Drilling Equipment ______________________

Driller: ______________________

INTERNATIONAL TECHNOLOGY CORPORATION

VISUAL CLASSIFICATION OF SOILS

PROJECT NUMBER: 810835	PROJECT NAME: RICHLAND HORN RAPIDS LANDFILL		
BORING NUMBER: MW08	COORDINATES:		DATE: 1/18/01
ELEVATION:	GWL: Depth 89.5	Date/Time 1/18/01	DATE STARTED: 1/18/01
ENGINEER/GEOLOGIST: G HAMILTON	Depth	Date/Time	DATE COMPLETED: 1/18/01
DRILLING METHODS: Air Rotary Tubex			PAGE 4 OF 4

DEPTH ( )	SAMPLE TYPE & NO.	BLOWS ON SAMPLER PER ( )	RECOVERY ( )	DESCRIPTION	USCS SYMBOL	MEASURED CONSISTENCY (TSF)	WELL CONSTRUCTION	REMARKS
90	XXXX HRL S004	15/50	10		SP/GM			6-IN DIA BOREHOLE
95				COBBLE AND PEBBLE GRAVEL with Fine GRAIND SAND AND SILT	GM			2-IN DIA PVC WELL SCREEN, SCH 40, 0.010-IN MACHINE SLOT, 84.5 – 99.5 ft 10-20 MESH SILICA SAND 84.5 to 99.5 FT
100		20/50	10	COBBLE AND PEBBLE GRAVEL WITH FINE GRAIND SAND AND SILT, WELL ROUNDED, to 1.5 CM DIAMETER				2.5 ft Bottom sump w/ END CAP, SCH 40, 2-IN DIA. PVC
				TD = 102 FT				
105								

NOTES:

Drilling Contractor ____________________

Drilling Equipment ____________________

Driller: ____________________

INTERNATIONAL TECHNOLOGY CORPORATION

VISUAL CLASSIFICATION OF SOILS

PROJECT NUMBER: 810835	PROJECT NAME: RICHLAND HORN RAPIDS LANDFILL	
BORING NUMBER: MW09	COORDINATES:	DATE: 1/16/01
ELEVATION:	GWL: Depth Date/Time	DATE STARTED: 1/16/01
ENGINEER/GEOLOGIST: G. HAMILTON	Depth Date/Time	DATE COMPLETED: 1/22/01
DRILLING METHODS: AIR ROTARY - TUBEX		PAGE 1 OF 4

DEPTH ( )	SAMPLE TYPE & NO.	BLOWS ON SAMPLER PER (6-IN)	RECOVERY ( ) IN	DESCRIPTION	USCS SYMBOL	MEASURED CONSISTENCY (TSF)	WELL CONSTRUCTION	REMARKS
								8-IN ID PROTECTIVE STEEL CASING W/ LOCKING LID
				0-3 POORLY GRADED FINE GRAINED SAND	SP			CONCRETE FILL 0-2 FT
				3-33 POORLY GRADED FINE TO MEDIUM-GRAINED SAND with SILT, VERY DENSE				
5		22/18/43	18		SM			CEMENT/BENTONITE GROUT 2-83 FT
10		50	1	POORLY GRADED VERY FINE SILTY SAND W/ OCCATIONAL COBBLES				Blocked sample tube
								2-IN ID, SCH 40, PVC WELL CASING 0-97.5 ft
15		50	4	POORLY GRADED VERY FINE-GRAINED SILTY, SAND, VERY DENSE SOIL, with OCCATIONAL Cobbles				
								6-IN DIAMETER BOREHOLE
20		18/50	11.5	POORLY GRADED VERY FINE-GRAINED SILTY SAND, VERY DENSE				
					SM			
25	HRL S001	30/50	11	POORLY GRADED VERY FINE-GRAINED SILTY SAND, Very DENSE SOIL	SP/SM			
30								

NOTES:

Drilling Contractor ENVIRONMENTAL WEST EXPLORATION

Drilling Equipment SCHRAMM AIR ROTARY - TUBEX

Driller: RON SINK

KELLY HILL, CASEY BAKER

243B-3-86

INTERNATIONAL TECHNOLOGY CORPORATION

VISUAL CLASSIFICATION OF SOILS

PROJECT NUMBER: 810835	PROJECT NAME: Horn Rapids Landfill	
BORING NUMBER: MW 09	COORDINATES:	DATE: 1/16/01
ELEVATION:	GWL: Depth Date/Time	DATE STARTED: 1/16/01
ENGINEER/GEOLOGIST: G Hamilton	Depth Date/Time	DATE COMPLETED: 1/22/01
DRILLING METHODS: Air Rotary - Tubex		PAGE 3 OF 4

DEPTH ( )	SAMPLE TYPE & NO.	BLOWS ON SAMPLER PER ( )	RECOVERY ( )	DESCRIPTION	USCS SYMBOL	MEASURED CONSISTENCY (TSF)	WELL CONSTRUCTION	REMARKS
60					SW			NO SAMPLE SAND-LOCCED REAMER BIT
				62-64 WELL GRADED GRAVELY FINE to COARSE GRAINED SAND, FINE-GRAINED GRAVEL	GM			CEMENT/BENTONITE GROUT 2-83 ft
				64-65 POORLY GRADED SILTY VERY FINE-GRAINED SAND	SM			
65	HRL S002	20/50	10	65-68 POORLY GRADED VERY FINE TO MEDIUM-GRAINED SAND	SP			6-IN BOREHOLE
70		4/25/50	0	68-71 WELL GRADED COARSE TO VERY COARSE GRAINED SAND with GRAVEL	SW			70 ft SAMPLER BREAKS off In Hole 70-78 Drill through SAMPLER & PUSH SAMPLER AHEAD OF Bit
				71-72 WELL GRADED GRAVEL WITH FINE to COARSE-GRAINED SAND	GW			
75				72-87 WELL GRADED MEDIUM TO COARSE GRAINED SAND	SW			
80		2/2/16	18	WELL GRADED MEDIUM TO COARSE-GRAINED SAND				
85								BENTONITE CHIPS SEAL 83-92.5 ft
				87-100 POORLY SORTED VERY FINE-GRAINED SAND and SILT	SM			2-IN ID, SCH 40 PVC WELL CASING 0-97.5 ft
90								

NOTES:

Drilling Contractor ________

Drilling Equipment ________

Driller: ________

INTERNATIONAL TECHNOLOGY CORPORATION

VISUAL CLASSIFICATION OF SOILS

PROJECT NUMBER: 810835	PROJECT NAME: Horn Rapids Landfill		
BORING NUMBER: MW09	COORDINATES:	DATE: 1/17/01	
ELEVATION:	GWL: Depth Date/Time	DATE STARTED: 1/16/01	
ENGINEER/GEOLOGIST: G. HAMILTON	Depth Date/Time	DATE COMPLETED: 1/22/01	
DRILLING METHODS: Air Rotary Tubex		PAGE 4	OF 4

DEPTH ( )	SAMPLE TYPE & NO.	BLOWS ON SAMPLER PER ( )	RECOVERY ( )	DESCRIPTION	USCS SYMBOL	MEASURED CONSISTENCY (TSF)	WELL CONSTRUCTION	REMARKS
90	1	18/50	9	POORLY GRADED VERY FINE-GRAINED SAND	SM			BENTONITE CHIPS SEAL 83-92.5 ft
95				POORLY SORTED VERY FINE-GRAINED SAND AND SILT, WITH TRACE Clay SIZE PARTICLES	SM/SC			2-IN ID, SCH 40 PVC WELL CASING 0-97.5 ft
100				100-101 POORLY SORTED clayey VERY FINE-GRAINED SAND AND SILT,	SC			10-20 MESH SILICA SAND 93.5-115
				101-115 POORLY SORTED SILTY GRAVEL, 85-90% GRAVEL, 10-15% SILT, WET	GM			▽ WATER LEVEL 103 ft
105								WELL SCREEN, 2-IN ID, SCH 40 PVC, 0.010-IN MACHINE SLOT SCREEN 97.5-112.5
110								6-IN BOREHOLE
								Bottom sump, 2-IN ID SCH 40 PVC WELL CASING WITH END CAP
115				TD = ~~105 ft~~ 115 ft				

NOTES:

Drilling Contractor

Drilling Equipment

Driller:

INTERNATIONAL TECHNOLOGY CORPORATION

VISUAL CLASSIFICATION OF SOILS

PROJECT NUMBER: 810835	PROJECT NAME: RICHLAND HORNRAPIDS LANDFILL	
BORING NUMBER: MW10	COORDINATES:	DATE: 1/22/01
ELEVATION:	GWL: Depth 74.0 Date/Time 1/22/01	DATE STARTED: 1/22/01
ENGINEER/GEOLOGIST: B HAMILTON	Depth 72.3 Date/Time 1/24/01 0800	DATE COMPLETED: 1/22/01
DRILLING METHODS: AIR ROTARY - TUBEX		PAGE 1 OF 3

DEPTH ( )	SAMPLE TYPE & NO.	BLOWS ON SAMPLER PER (6-IN)	RECOVERY (IN)	DESCRIPTION	USCS SYMBOL	MEASURED CONSISTENCY (TSF)	WELL CONSTRUCTION	REMARKS
0				0-15 POORLY GRADED FINE-GRAINED SAND				8-IN I.D STEEL PROTECTIVE CASING WITH LOCKING LID. CONCRETE
5	HRL S005	8/30/49	18	POORLY GRADED VERY FINE-GRAINED SAND BROWN/TAN	SP			CEMENT/BENTONITE GROUT 2-57.6 ft
10		15/30/50	16	POORLY GRADED VERY FINE TO FINE-GRAINED SAND, 10% Biotite MICA				2-IN I.D, SCH40, PVC WELL CASING
15		10/38/49		15-20 POORLY GRADED FINE-TO MEDIUM-GRAINED SAND decrease in MICA CONTENT	SP			6-IN BOREHOLE
20		15/47/50	17	20-24 WELL GRADED, VERY FINE TO MEDIUM GRAINED SAND	SW			
				@23 ft 8-10 mm GRAVEL STRINGER, WELL Rounded Pebbles				
25		15/50	11	24-26 POORLY GRADED FINE-GRAINED SAND	SM			
				26-33 WELL GRADED MEDIUM TO COARSE-GRAINED SAND	SW			
30								

NOTES:

Drilling Contractor ENVIRONMENTAL WEST EXPLORATION

Drilling Equipment RON SINK

Driller: Kelly Hill, CASEY BAKER

INTERNATIONAL TECHNOLOGY CORPORATION

VISUAL CLASSIFICATION OF SOILS

PROJECT NUMBER: 831835	PROJECT NAME: RICHLAND HORN RAPIDS LANDFILL	
BORING NUMBER: MW10	COORDINATES:	DATE: 1/22/01
ELEVATION:	GWL: Depth Date/Time	DATE STARTED: 1/22/01
ENGINEER/GEOLOGIST: G. HAMILTON	Depth Date/Time	DATE COMPLETED: 1-22-01
DRILLING METHODS:		PAGE 2 OF 3

DEPTH ( )	SAMPLE TYPE & NO.	BLOWS ON SAMPLER PER ( )	RECOVERY ( )	DESCRIPTION	USCS SYMBOL	MEASURED CONSISTENCY (TSF)	WELL CONSTRUCTION	REMARKS
30		5/43/50	15	WELL GRADED FINE- TO COARSE-GRAINED SAND	SW			
				33-43	SM			CEMENT/BENTONITE GROUT 2-57.6 ft
35		10/27/40	18	GRADED VERY FINE to MEDIUM-GRAINED SAND WITH TRACE SILT				
40				FINE-GRAINED SAND WITH SILT				NO SAMPLE, SAND LOCKED REAMER ON BIT
				43-50 WELL GRADED FINE TO MEDIUM-GRAINED SAND with <5% COARSE SAND and FINE ROUNDED GRAVEL	SW			2-IN COBBLE BLOCKED SAMPLER
45		30/50	11					2-IN I.D. SCH 40, PVC WELL CASING
50		6/25/45	18	50-60 POORLY GRADED MEDIUM-GRAINED SAND	SP			
55				POORLY GRADED FINE TO MEDIUM-GRAINED SAND WITH OCCATIONAL WELL ROUNDED PEBBLES				BENTONITE CHIPS 57.6-66.5 ft
60								

NOTES:

Drilling Contractor ______

Drilling Equipment ______

Driller: ______

INTERNATIONAL TECHNOLOGY CORPORATION

VISUAL CLASSIFICATION OF SOILS

PROJECT NUMBER: 810835	PROJECT NAME: RICHLAND HORN RAPIDS LANDFILL	
BORING NUMBER: MW10	COORDINATES:	DATE: 1/22/01
ELEVATION:	GWL: Depth 740 Date/Time 1/22/01	DATE STARTED: 1/22/01
ENGINEER/GEOLOGIST:	Depth 723 Date/Time 1/24/01 0800	DATE COMPLETED: 1/22/01
DRILLING METHODS:		PAGE 3 OF 3

DEPTH ( )	SAMPLE TYPE & NO.	BLOWS ON SAMPLER PER ( )	RECOVERY ( )	DESCRIPTION	USCS SYMBOL	MEASURED CONSISTENCY (TSF)	WELL CONSTRUCTION	REMARKS
60		11/40/50	15	60-72 POORLY GRADED VERY FINE TO FINE-GRAINED SAND WITH SILT	SM			BENTONITE CHIPS 57.6-66.5 ft
65				SILTY SAND				
								2-IN ID, SCH 40, PVC WELL CASING 0-69.5 ft
70		15/40/50	17	POORLY GRADED SILTY VERY FINE-GRAINED SAND, WITH OCCASIONAL 4CM COBBLE				10-20 MESH SILICA SAND 66.5-87.0 ft
				72-87 GRAVEL TO 10 MM				▽ WATER LEVEL 72.3 ft 1/24/01
75				GRAVEL, WELL ROUNDED GRAVEL TO 10MM				▽ WATER LEVEL 74.0 ft 1/22/01
								WELL SCREEN, 2-IN ID, SCH 40, PVC, 0.010-IN MACHINE SLOT 69.5-84.5 ft
80	HRL-S006	13/50	10	GRAVEL, WELL ROUNDED GRAVEL TO 10MM	GP			6-IN DIAMETER BORE HOLE
85								BOTTOM SUMP, 2-IN ID WELL CASING WITH END CAP 84.5-87.0 ft
				TD = 87 ft				
90								

NOTES:

Drilling Contractor

Drilling Equipment

Driller:

APPENDIX C
GROUNDWATER ANALYTICAL RESULTS

Table C-1 Remedial Investigation Analytical Results

Well	Well 1					Well 2				
Sampling Date	4/10/2001	7/25/2001	10/16/2001	12/18/2001	3/20/2002	4/10/2001	7/25/2001	10/16/2001	12/18/2001	3/20/2002
Field Parameters										
pH	6.87	6.75	7.09	6.83	7.06	7.25	7.17	7.28	7.16	7.06
Temperature (degrees Celsius)	19.3	22.3	17.4	13.6	16.4	18	24.4	18.5	12.5	15.5
Conductivity (umohs/cm)	483	464	430	410	405	346	313	352	284	293
Dissolved oxygen (mg/L)	9.1	NM	NM	NM	NM	8.6	NM	NM	NM	NM
Oxidation-reduction potential (mV)	280	NM	NM	NM	NM	263	NM	NM	NM	NM
Ferrous Iron (mg/L)	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Anions/Cations (mg/L)										
Antimony	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Arsenic	0.006	0.007	0.006	0.0058	0.0079	0.004	0.005	0.005	0.0047	0.0056
Barium	0.028	0.029	0.027	0.026	0.028	0.021	0.020	0.020	0.020	0.020
Beryllium	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Cadmium	<0.001	<0.001	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Chromium	0.008	0.011	0.005	0.0041	0.0087	0.005	0.007	0.004	0.0032	0.0043
Cobalt	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Copper	0.002	0.002	0.003	<0.001	<0.001	0.001	0.001	0.002	<0.001	<0.001
Lead	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Nickel	<0.001	<0.001	<0.001	0.0016	0.0019	0.002	<0.001	<0.001	0.0021	0.0017
Selenium	<0.001	0.002	<0.001	<0.001	<0.001	<0.001	0.002	<0.001	<0.001	<0.001
Silver	<0.001	<0.001	<0.005	<0.001	0.0021	<0.001	<0.001	<0.005	<0.001	<0.001
Thallium	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Vanadium	0.013	0.013	0.012	0.013	0.013	0.013	0.014	0.012	0.015	0.012
Zinc	0.004	0.003	0.008	<0.001	0.0037	0.003	0.003	0.005	<0.001	<0.001
Nitrate Nitrogen	1.8	1.4	1.8	1.8	1.8	2.6	2.4	2.4	2.2	2.7
Calcium	66	76	66	69	85	44	45	46	43	50
Sodium	16	15	14	14	14	12	10	11	10	10
Bicarbonate	200	230	210	210	210	110	110	110	120	110
Chloride	12	11	9	11	15	13	14	13	12	15
Magnesium	14	14	13	14	12	9.5	9.1	10	9.4	7.9
Potassium	6.7	6.1	4.7	5.9	5.9	5.6	4.7	3.7	4.7	4.5
Sulfate	27	26	26	28	29	33	32	31	29	33
Alkalinity	200	230	210	210	210	110	110	110	120	110
Iron	0.0098	<0.008	<0.008	0.022	0.13	0.028	<0.008	<0.008	0.015	0.086
Manganese	0.006	<0.003	<0.003	<0.003	<0.001	<0.003	<0.003	<0.003	<0.003	<0.001
Ammonia Nitrogen	0.038	<0.01	0.050	<0.03	<0.03	0.038	<0.01	0.036	<0.03	<0.03
TOC	<1.5	<1.5	0.9	0.9	0.8	<1.5	<1.5	0.7	0.6	0.6
TDS	290	320	290	300	290	220	230	210	220	200
Volatile Organic Compounds (μg/L)										
Acetone	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
Acrylonitrile	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Benzene	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1

Table C-1 Remedial Investigation Analytical Results

Well	Well 1					Well 2				
Sampling Date	4/10/2001	7/25/2001	10/16/2001	12/18/2001	3/20/2002	4/10/2001	7/25/2001	10/16/2001	12/18/2001	3/20/2002
Bromochloromethane	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Bromodichloromethane	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Bromoform	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Carbon Disulfide	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Carbon Tetrachloride	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Chlorobenzene	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Chloroethane	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Chloroform	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Dibromochloromethane	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
1,2-Dibromo-3-chloropropane	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
1,2-Dibromoethane	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
1,2-Dichlorobenzene	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
1,4-Dichlorobenzene	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
trans-1,4-Dichloro-2-butene	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
1,1-Dichloroethane	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
1,2-Dichloroethane	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
1,1-Dichloroethene	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
cis-1,2-Dichloroethene	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
trans-1,2-Dichloroethene	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
1,2-Dichloropropane	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
cis-1,3-Dichloropropene	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
trans-1,3-Dichloropropene	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Ethylbenzene	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
2-Hexanone	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
Bromomethane	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Chloromethane	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Dibromomethane	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Methylene Chloride	<1	<4	<1	<1	<1	<1	<4	<1	2.1	<1
2-Butanone	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
Iodomethane	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
4-Methyl-2-pentanone	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
Styrene	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
1,1,1,2-Tetrachloroethane	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
1,1,2,2-Tetrachloroethane	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Tetrachloroethene	1.4	<1	<1	<1	<1	<1	<1	<1	<1	<1
Toluene	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
1,1,1-Trichloroethane	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
1,1,2-Trichloroethane	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Trichloroethene	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Trichlorofluoromethane	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
1,2,3-Trichloropropane	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Vinyl Acetate	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2

Table C-1 Remedial Investigation Analytical Results

Well	Well 1					Well 2				
Sampling Date	4/10/2001	7/25/2001	10/16/2001	12/18/2001	3/20/2002	4/10/2001	7/25/2001	10/16/2001	12/18/2001	3/20/2002
Vinyl Chloride	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Xylene - total	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Methane	<1	<1	<1	<1	<1	1.1	<1	<1	<1	<1
Ethane	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Ethene	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1

Table C-1 Remedial Investigation Analytical Results

Well	Well 3					Well 4				
Sampling Date	4/10/2001	7/25/2001	10/16/2001	12/18/2001	3/20/2002	4/10/2001	7/25/2001	10/16/2001	12/18/2001	3/20/2002
Field Parameters										
pH	7.13	7.15	7.46	7.31	7.34	7.25	7.03	7.49	7.14	7.36
Temperature (degrees Celsius)	19.1	24.4	18.3	13.3	16.4	19.7	22.8	17.8	15.1	15.9
Conductivity (umohs/cm)	412	386	451	388	374	344	331	186	295	314
Dissolved oxygen (mg/L)	8.95	NM	NM	NM	NM	8.58	NM	NM	NM	NM
Oxidation-reduction potential (mV)	254	NM	NM	NM	NM	261	NM	NM	NM	NM
Ferrous Iron (mg/L)	<1	<1	NM	<1	<1	<1	<1	<1	<1	<1
Anions/Cations (mg/L)										
Antimony	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.003	<0.001	<0.001
Arsenic	0.008	0.009	0.008	0.0085	0.0097	0.004	0.009	0.005	0.0047	0.0058
Barium	0.024	0.024	0.024	0.026	0.024	0.026	0.024	0.027	0.028	0.026
Beryllium	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Cadmium	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Chromium	0.009	0.009	0.005	0.0041	0.0055	0.007	0.009	0.004	0.0028	0.0047
Cobalt	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Copper	0.002	0.002	0.002	<0.001	<0.001	0.001	0.002	0.002	<0.001	<0.001
Lead	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Nickel	0.004	0.003	0.002	0.0023	0.0017	<0.001	0.003	<0.001	0.0012	0.0012
Selenium	<0.001	0.001	<0.001	<0.001	<0.001	<0.001	0.001	<0.001	<0.001	<0.001
Silver	<0.001	<0.001	<0.005	<0.001	<0.001	<0.001	<0.001	<0.005	<0.001	<0.001
Thallium	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Vanadium	0.017	0.016	0.015	0.018	0.014	0.014	0.016	0.013	0.016	0.012
Zinc	0.005	0.004	0.007	<0.001	0.0014	0.005	0.004	0.005	<0.001	<0.001
Nitrate Nitrogen	1.8	1.9	2.1	2.1	2.1	1.1	1.9	1.2	1.1	1.2
Calcium	59	65	62	62	78	47	65	50	49	56
Sodium	15	13	13	13	13	13	13	12	11	11
Bicarbonate	170	170	180	180	170	160	170	170	160	150
Chloride	10	14	13	13	14	6	14	7.5	7.3	11
Magnesium	11	11	12	11	10	10	11	11	11	8.9
Potassium	7.2	6.2	5.2	6.2	6.2	6.1	6.2	3.8	5.2	4.9
Sulfate	30	33	34	34	32	18	33	19	19	19
Alkalinity	170	170	180	180	170	160	170	170	160	150
Iron	0.040	0.014	0.0086	0.021	0.12	0.0085	0.014	<0.008	0.013	0.089
Manganese	<0.003	<0.003	<0.003	<0.003	<0.001	<0.003	<0.003	<0.003	<0.003	<0.001
Ammonia Nitrogen	0.062	<0.01	0.034	<0.03	<0.03	0.032	<0.01	<0.03	<0.03	<0.03
TOC	<1.5	<1.5	0.6	0.6	0.5	<1.5	<1.5	0.5	0.6	<0.5
TDS	260	280	270	280	250	220	280	230	230	230
Volatile Organic Compounds (μg/L)										
Acetone	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
Acrylonitrile	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Benzene	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1

Table C-1 Remedial Investigation Analytical Results

Well	Well 3					Well 4				
Sampling Date	4/10/2001	7/25/2001	10/16/2001	12/18/2001	3/20/2002	4/10/2001	7/25/2001	10/16/2001	12/18/2001	3/20/2002
Bromochloromethane	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Bromodichloromethane	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Bromoform	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Carbon Disulfide	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Carbon Tetrachloride	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Chlorobenzene	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Chloroethane	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Chloroform	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Dibromochloromethane	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
1,2-Dibromo-3-chloropropane	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
1,2-Dibromoethane	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
1,2-Dichlorobenzene	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
1,4-Dichlorobenzene	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
trans-1,4-Dichloro-2-butene	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
1,1-Dichloroethane	1.7	2.6	1.8	2.7	1.7	<1	2.6	<1	<1	<1
1,2-Dichloroethane	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
1,1-Dichloroethene	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
cis-1,2-Dichloroethene	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
trans-1,2-Dichloroethene	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
1,2-Dichloropropane	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
cis-1,3-Dichloropropene	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
trans-1,3-Dichloropropene	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Ethylbenzene	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
2-Hexanone	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
Bromomethane	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Chloromethane	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Dibromomethane	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Methylene Chloride	<1	<4	<1	<1	<1	<1	<4	<1	<1	<1
2-Butanone	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
Iodomethane	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
4-Methyl-2-pentanone	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
Styrene	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
1,1,1,2-Tetrachloroethane	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
1,1,2,2-Tetrachloroethane	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Tetrachloroethene	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Toluene	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
1,1,1-Trichloroethane	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
1,1,2-Trichloroethane	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Trichloroethene	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Trichlorofluoromethane	3.3	3.7	3.7	<1	<1	<1	3.7	<1	<1	<1
1,2,3-Trichloropropane	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Vinyl Acetate	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2

Table C-1 Remedial Investigation Analytical Results

Well	Well 3					Well 4				
Sampling Date	**4/10/2001**	**7/25/2001**	**10/16/2001**	**12/18/2001**	**3/20/2002**	**4/10/2001**	**7/25/2001**	**10/16/2001**	**12/18/2001**	**3/20/2002**
Vinyl Chloride	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Xylene - total	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Methane	1.1	<1	<1	<1	<1	1.0	<1	<1	<1	<1
Ethane	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Ethene	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1

Table C-1 Remedial Investigation Analytical Results

Well	Well 5					Well 6				
Sampling Date	4/10/2001	7/25/2001	10/16/2001	12/18/2001	3/20/2002	4/10/2001	7/25/2001	10/16/2001	12/18/2001	3/20/2002
Field Parameters										
pH	6.58	6.17	6.77	6.27	6.44	6.44	6.22	7.14	6.31	6.5
Temperature (degrees Celsius)	20.2	22.3	20.88	17.4	17.1	23.1	24.1	21.89	18.5	18.1
Conductivity (umohs/cm)	813	709	889	756	761	926	733	1029	843	881
Dissolved oxygen (mg/L)	8.94	NM	11.38	NM	NM	8.55	NM	10.88	NM	NM
Oxidation-reduction potential (mV)	150	NM	93	NM	NM	108	NM	102	NM	NM
Ferrous Iron (mg/L)	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Anions/Cations (mg/L)										
Antimony	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Arsenic	0.002	0.002	0.002	0.0022	0.0032	0.001	0.002	0.002	0.0016	0.0021
Barium	0.090	0.093	0.093	0.10	0.085	0.096	0.092	0.099	0.11	0.088
Beryllium	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Cadmium	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Chromium	0.017	0.025	0.009	0.0031	0.018	0.021	0.023	0.012	0.0027	0.011
Cobalt	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Copper	0.003	0.004	0.003	0.0015	0.0011	0.004	0.005	0.004	0.0020	0.0015
Lead	<0.001	<0.001	<0.001	<0.001	0.0012	<0.001	<0.001	<0.001	<0.001	<0.001
Nickel	0.002	0.002	0.002	0.0046	0.0080	0.002	0.002	0.002	0.0051	0.0061
Selenium	<0.001	0.001	<0.001	<0.001	<0.001	<0.001	0.002	<0.001	<0.001	<0.001
Silver	<0.001	<0.001	<0.005	<0.001	<0.001	<0.001	<0.001	<0.005	<0.001	<0.001
Thallium	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Vanadium	0.012	0.014	0.009	0.0095	0.010	0.013	0.013	0.010	0.0093	0.0094
Zinc	0.013	0.011	0.011	0.011	0.010	0.013	0.009	0.008	0.0077	0.0073
Nitrate Nitrogen	3.2	3.2	3.6	3.4	3.4	0.6	0.33	0.6	0.47	0.6
Calcium	160	170	170	160	170	190	200	190	180	220
Sodium	21	18	18	17	17	27	24	23	24	27
Bicarbonate	470	480	500	510	490	610	610	620	630	610
Chloride	19	20	23	23	26	11	15	16	15	18
Magnesium	35	34	35	32	33	41	41	42	39	44
Potassium	11	9.8	6.8	9.3	9.0	13	11	7.5	11	11
Sulfate	42	43	44	44	44	33	35	36	34	36
Alkalinity	470	480	500	510	490	610	610	620	630	610
Iron	0.033	<0.008	<0.008	0.046	0.37	<0.008	<0.008	0.020	0.048	0.45
Manganese	0.011	0.011	0.0082	0.0088	0.018	0.027	0.023	0.020	0.021	0.020
Ammonia Nitrogen	0.048	<0.01	0.030	0.14	0.73	0.043	0.023	<0.03	<0.03	<0.03
TOC	<1.5	<1.5	1.3	2.1	4.4	1.6	<1.5	1.5	2.0	1.5
TDS	610	610	600	600	600	680	700	690	700	700
Volatile Organic Compounds (μg/L)										
Acetone	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
Acrylonitrile	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Benzene	<1	<1	<1	<1	<1	5.6	7.7	5.8	<1	6.5

Table C-1 Remedial Investigation Analytical Results

Well	Well 5					Well 6				
Sampling Date	4/10/2001	7/25/2001	10/16/2001	12/18/2001	3/20/2002	4/10/2001	7/25/2001	10/16/2001	12/18/2001	3/20/2002
Bromochloromethane	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Bromodichloromethane	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Bromoform	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Carbon Disulfide	<2	<2	<2	<2	<2	4.9	<2	<2	<2	<2
Carbon Tetrachloride	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Chlorobenzene	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Chloroethane	1.6	<1	<1	<1	<1	<1	<1	<1	<1	<1
Chloroform	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Dibromochloromethane	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
1,2-Dibromo-3-chloropropane	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
1,2-Dibromoethane	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
1,2-Dichlorobenzene	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
1,4-Dichlorobenzene	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
trans-1,4-Dichloro-2-butene	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
1,1-Dichloroethane	22	42	20	27	30	46	87	45	64	61
1,2-Dichloroethane	1.2	<1	<1	<1	<1	2.3	<1	1.7	<1	<1
1,1-Dichloroethene	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
cis-1,2-Dichloroethene	48	99	45	67	63	57	120	63	89	88
trans-1,2-Dichloroethene	<1	<1	<1	<1	<1	2.6	<1	2.6	<1	4.8
1,2-Dichloropropane	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
cis-1,3-Dichloropropene	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
trans-1,3-Dichloropropene	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Ethylbenzene	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
2-Hexanone	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
Bromomethane	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Chloromethane	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Dibromomethane	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Methylene Chloride	12	20	8.8	12	12	3.2	8.7	2	5.4	3.4
2-Butanone	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
Iodomethane	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
4-Methyl-2-pentanone	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
Styrene	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
1,1,1,2-Tetrachloroethane	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
1,1,2,2-Tetrachloroethane	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Tetrachloroethene	26	23	22	21	22	67	63	79	61	82
Toluene	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
1,1,1-Trichloroethane	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
1,1,2-Trichloroethane	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Trichloroethene	13	9	8.5	5.5	5.3	28	22	27	16	16
Trichlorofluoromethane	3.7	3.7	4.0	<1	<1	<1	<1	<1	<1	<1
1,2,3-Trichloropropane	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Vinyl Acetate	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2

Table C-1 Remedial Investigation Analytical Results

Well	Well 7					Well 8				
Sampling Date	4/10/2001	7/25/2001	10/16/2001	12/18/2001	3/20/2002	4/10/2001	7/25/2001	10/16/2001	12/18/2001	3/20/2002
Field Parameters										
pH	6.5	6.33	6.43	6.09	6.34	7.27	6.87	6.53	7.13	7.16
Temperature (degrees Celsius)	20.2	26.6	18.6	16.7	17.2	19.8	22.1	19.2	15	16
Conductivity (umohs/cm)	982	755	974	928	936	391	120	188	345	344
Dissolved oxygen (mg/L)	9.55	NM	NM	NM	NM	9.68	NM	12.96	NM	NM
Oxidation-reduction potential (mV)	259	NM	NM	NM	NM	186	NM	154	NM	NM
Ferrous Iron (mg/L)	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Anions/Cations (mg/L)										
Antimony	<0.001	0.002	<0.001	<0.001	<0.001	<0.001	0.001	<0.001	<0.001	<0.001
Arsenic	<0.001	0.002	0.002	0.0018	0.0027	0.005	0.007	0.007	0.0063	0.0073
Barium	0.11	0.104	0.118	0.14	0.13	0.028	0.024	0.026	0.025	0.022
Beryllium	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Cadmium	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Chromium	0.014	0.031	0.020	0.0062	0.026	0.007	0.010	0.005	0.0039	0.0068
Cobalt	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Copper	0.005	0.004	0.004	0.0017	0.0017	0.002	0.002	0.003	0.0025	0.0012
Lead	<0.001	<0.001	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Nickel	0.005	0.004	0.005	0.0088	0.0087	0.003	0.004	0.003	0.0033	0.0038
Selenium	<0.001	0.003	0.001	<0.001	0.001	<0.001	0.002	<0.001	<0.001	<0.001
Silver	<0.001	<0.001	<0.005	<0.001	<0.001	<0.001	<0.001	<0.005	<0.001	<0.001
Thallium	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Vanadium	0.008	0.012	0.010	0.0086	0.012	0.012	0.015	0.014	0.016	0.012
Zinc	0.009	0.006	0.011	0.0038	0.0084	0.006	0.002	0.011	<0.001	0.0018
Nitrate Nitrogen	12	12	12	11	12	1.5	1.5	1.9	1.8	1.7
Calcium	230	240	280	260	290	52	55	53	54	63
Sodium	27	25	28	27	31	16	14	13	13	13
Bicarbonate	560	580	750	740	740	160	170	180	180	160
Chloride	59	56	60	54	77	7.9	9.6	9.9	9.4	12
Magnesium	43	44	55	48	58	11	10	11	11	9.6
Potassium	11	11	9.5	11	11	6.8	5.6	3.6	5.6	5.5
Sulfate	74	75	82	76	84	22	23	23	23	22
Alkalinity	560	580	750	740	740	160	170	180	180	160
Iron	0.16	0.10	0.12	0.12	0.74	0.50	0.046	0.067	0.072	0.15
Manganese	0.13	0.033	0.034	0.013	0.010	0.050	0.0047	0.0035	<0.003	0.0034
Ammonia Nitrogen	0.046	<0.01	0.047	0.049	0.040	0.040	0.038	<0.03	<0.03	<0.03
TOC	3.9	<1.5	3.3	2.5	2.3	<1.5	<1.5	0.9	1.0	1.0
TDS	860	860	960	950	960	250	260	250	250	240
Volatile Organic Compounds (μg/L)										
Acetone	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
Acrylonitrile	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Benzene	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1

Table C-1 Remedial Investigation Analytical Results

Well	Well 7					Well 8				
Sampling Date	4/10/2001	7/25/2001	10/16/2001	12/18/2001	3/20/2002	4/10/2001	7/25/2001	10/16/2001	12/18/2001	3/20/2002
Bromochloromethane	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Bromodichloromethane	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Bromoform	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Carbon Disulfide	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Carbon Tetrachloride	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Chlorobenzene	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Chloroethane	1.4	5.0	3.4	<1	<1	<1	<1	<1	<1	<1
Chloroform	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Dibromochloromethane	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
1,2-Dibromo-3-chloropropane	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
1,2-Dibromoethane	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
1,2-Dichlorobenzene	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
1,4-Dichlorobenzene	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
trans-1,4-Dichloro-2-butene	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
1,1-Dichloroethane	3.3	11	5.3	<1	5	<1	1.8	<1	<1	<1
1,2-Dichloroethane	<1	<1	<1	13	<1	<1	<1	<1	<1	<1
1,1-Dichloroethene	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
cis-1,2-Dichloroethene	44	78	51	120	49	<1	<1	<1	<1	<1
trans-1,2-Dichloroethene	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
1,2-Dichloropropane	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
cis-1,3-Dichloropropene	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
trans-1,3-Dichloropropene	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Ethylbenzene	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
2-Hexanone	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
Bromomethane	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Chloromethane	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Dibromomethane	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Methylene Chloride	17	27	10	16	7.8	<1	<4	<1	<1	<1
2-Butanone	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
Iodomethane	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
4-Methyl-2-pentanone	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
Styrene	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
1,1,1,2-Tetrachloroethane	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
1,1,2,2-Tetrachloroethane	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Tetrachloroethene	24	25	29	29	35	<1	<1	<1	<1	<1
Toluene	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
1,1,1-Trichloroethane	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
1,1,2-Trichloroethane	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Trichloroethene	4.6	3.7	4.1	4.5	5.6	<1	<1	<1	<1	<1
Trichlorofluoromethane	3.2	<1	3.9	<1	<1	<1	<1	<1	<1	<1
1,2,3-Trichloropropane	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Vinyl Acetate	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2

Table C-1 Remedial Investigation Analytical Results

Well	Well 7					Well 8				
Sampling Date	4/10/2001	7/25/2001	10/16/2001	12/18/2001	3/20/2002	4/10/2001	7/25/2001	10/16/2001	12/18/2001	3/20/2002
Vinyl Chloride	<1	<1	1.8	<1	<1	<1	<1	<1	<1	<1
Xylene - total	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Methane	<1	4.5	1.2	4.4	13	1.0	<1	<1	<1	<1
Ethane	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Ethene	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1

Table C-1 Remedial Investigation Analytical Results

Well	Well 9					Well 10				
Sampling Date	4/10/2001	7/25/2001	10/16/2001	12/18/2001	3/20/2002	4/10/2001	7/25/2001	10/16/2001	12/18/2001	3/20/2002
Field Parameters										
pH	6.86	6.59	6.5	6.82	6.88	6.36	6.07	5.81	6.22	6.46
Temperature (degrees Celsius)	20.7	25.5	19.95	16.4	16.8	18.5	22.5	20.3	16.1	17.3
Conductivity (umohs/cm)	539	471	564	483	488	911	734	855	829	784
Dissolved oxygen (mg/L)	9.04	NM	12.46	NM	NM	8.96	NM	12.09	NM	NM
Oxidation-reduction potential (mV)	156	NM	161	NM	NM	144	NM	161	NM	NM
Ferrous Iron (mg/L)	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Anions/Cations (mg/L)										
Antimony	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Arsenic	0.002	0.002	0.002	0.0020	0.0029	0.001	0.002	0.001	0.0013	0.0016
Barium	0.041	0.039	0.041	0.043	0.038	0.096	0.085	0.084	0.10	0.081
Beryllium	<0.001	<0.001	<0.001	<0.001	<0.001	0.001	<0.001	<0.001	<0.001	<0.001
Cadmium	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Chromium	0.009	0.013	0.006	0.0021	0.0085	0.028	0.028	0.011	0.0018	0.0025
Cobalt	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Copper	0.003	0.002	0.003	<0.001	0.0017	0.003	0.003	0.003	0.0013	<0.001
Lead	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Nickel	0.002	0.002	0.002	0.0035	0.0035	0.005	0.002	0.002	0.0056	0.0055
Selenium	<0.001	0.002	<0.001	<0.001	<0.001	<0.001	0.003	<0.001	<0.001	<0.001
Silver	<0.001	<0.001	<0.005	<0.001	<0.001	<0.001	<0.001	<0.005	<0.001	<0.001
Thallium	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Vanadium	0.010	0.010	0.009	0.0097	0.0087	0.013	0.013	0.008	0.0072	0.0056
Zinc	0.008	0.003	0.006	0.0014	0.0037	0.008	0.006	0.006	0.0024	0.0048
Nitrate Nitrogen	1.3	1.5	1.8	1.7	1.7	2.1	2.5	3.2	2.9	3
Calcium	85	89	86	87	100	210	190	180	190	210
Sodium	19	17	16	17	17	21	19	18	20	19
Bicarbonate	260	260	260	270	260	580	550	490	560	520
Chloride	12	15	16	16	18	29	26	28	33	33
Magnesium	18	18	19	19	17	38	37	35	36	40
Potassium	7.7	6.7	3.9	6.7	7.0	11	10	6.4	10	9.8
Sulfate	28	30	33	32	32	51	50	48	50	50
Alkalinity	260	260	260	270	260	580	550	490	560	520
Iron	0.16	0.025	0.11	0.061	0.19	0.29	0.0088	<0.008	0.080	0.45
Manganese	0.0085	0.0034	0.0032	<0.003	0.0013	0.054	0.022	0.013	0.014	0.013
Ammonia Nitrogen	0.043	0.060	<0.03	<0.03	<0.03	0.040	<0.01	<0.03	<0.03	<0.03
TOC	<1.5	<1.5	1.2	1.4	1.2	<1.5	<1.5	1.3	1.4	1.1
TDS	360	370	360	360	350	740	710	630	670	670
Volatile Organic Compounds (μg/L)										
Acetone	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
Acrylonitrile	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Benzene	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1

Table C-1 Remedial Investigation Analytical Results

Well	Well 9					Well 10				
Sampling Date	4/10/2001	7/25/2001	10/16/2001	12/18/2001	3/20/2002	4/10/2001	7/25/2001	10/16/2001	12/18/2001	3/20/2002
Bromochloromethane	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Bromodichloromethane	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Bromoform	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Carbon Disulfide	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Carbon Tetrachloride	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Chlorobenzene	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Chloroethane	<1	<1	<1	<1	<1	1.9	7.0	<1	<1	<1
Chloroform	<1	<1	<1	<1	<1	11	16	6.7	18	12
Dibromochloromethane	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
1,2-Dibromo-3-chloropropane	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
1,2-Dibromoethane	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
1,2-Dichlorobenzene	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
1,4-Dichlorobenzene	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
trans-1,4-Dichloro-2-butene	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
1,1-Dichloroethane	2.9	5.7	2.9	8.1	4.7	21	36	16	41	32
1,2-Dichloroethane	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
1,1-Dichloroethene	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
cis-1,2-Dichloroethene	<1	<1	<1	<1	<1	2.7	6.2	2.6	8.4	5
trans-1,2-Dichloroethene	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
1,2-Dichloropropane	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
cis-1,3-Dichloropropene	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
trans-1,3-Dichloropropene	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Ethylbenzene	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
2-Hexanone	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
Bromomethane	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Chloromethane	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Dibromomethane	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Methylene Chloride	<1	<4	<1	<1	<1	8.8	37	9.6	45	33
2-Butanone	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
Iodomethane	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
4-Methyl-2-pentanone	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
Styrene	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
1,1,1,2-Tetrachloroethane	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
1,1,2,2-Tetrachloroethane	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Tetrachloroethene	6.9	5.8	6.1	5.5	5.7	11	10	9.3	8.6	9.6
Toluene	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
1,1,1-Trichloroethane	<1	<1	<1	<1	<1	<1	<1	<1	<1	1.0
1,1,2-Trichloroethane	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Trichloroethene	<1	<1	<1	<1	<1	3	1.7	1.4	1.8	1.2
Trichlorofluoromethane	<1	<1	<1	<1	<1	3.7	4.5	<1	<1	<1
1,2,3-Trichloropropane	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Vinyl Acetate	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2

Table C-1 Remedial Investigation Analytical Results

Well	Well 9					Well 10				
Sampling Date	4/10/2001	7/25/2001	10/16/2001	12/18/2001	3/20/2002	4/10/2001	7/25/2001	10/16/2001	12/18/2001	3/20/2002
Vinyl Chloride	<1	<1	<1	<1	<1	<1	<1	2	4.6	2.7
Xylene - total	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Methane	<1	<1	<1	<1	<1	2.3	81	3.6	75	11
Ethane	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Ethene	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1

NM - not measured
<1 - denotes concentration was less than the listed value
umhos/cm - micromhos per centimeter
mV - millivolts
mg/L - milligram per centimeter
μg/L - micrograms per centimeter

APPENDIX D
SLUG TEST CALCULATIONS

Horn Rapids Landfill Slug Test Calculation

By: RDL	Date: 02/12/01	Subject: Calculation Brief for Est. Hydraulic Cond.	Sheet No.	1 of 4
Chkd By: Jwo	Date: 2/16/01	from Slug tests @ Horn Rapids Landfill	Proj. No.	910835

Method: Bower and Rice Slug Test Analysis (1976, 1989)

The Bower and Rice Method (1976) for slug test analysis can be applied to fully or partially penetrating wells. The method is designed to estimate the hydraulic conductivity of the aquifer surrounding the screened portion of the well. The well is a single well test and provides only a very near field estimate of hydraulic conductivity.

The slug test method for estimating hydraulic conductivity involves the introduction or withdrawal of a volume of water to the aquifer. This can be completed by adding or withdrawing water from the aquifer or displacing the water in the aquifer by inserting or removing a mass. In this case a PVC pipe filled with clean sand was inserted and withdrawn from the well to induce a volume change in the aquifer. The water level change and recovery was monitored and recorded using a downhole pressure transducer and data logger.

Bower and Rice Slug Test analysis

$K = ((r_c^2 * \ln(R_e/r_w))/2L_{scr}) * (1/t) * \ln(H_0/H_t)$

where: K = Aquifer hydraulic conductivity in ft/day

r_c = radius of the well screen

t = time since slug injection or removal at H_t

H_t = Head in the well at the time t

H_0 = water level change from static at time = 0

R_e = radius of influence of the test

r_w = effective radius of the well (radius of well and gravel pack)

L_{scr} = length of well screen

$\ln(R_e/r_w) = [(1.1/\ln(Z/r_w)) + (A+B*\ln((D-Z)/r_w)))/(L_{scr}/r_w)]^{-1}$

where: Z = the distance from the water table to the bottom of the well screen. Equals L on graph used to calculate A & B

D = the aquifer thickness from well log for Horn Rapids ORV Park.

A & B = values determined from graph in Bower and Rice (1979)

MW07 Slug In

r_c =	0.08	ft
t =	11	seconds
H_t =	0.1	ft
H_0 =	0.19	ft
r_w =	0.25	ft
L_{scr} =	15	ft
$\ln(R_e/r_w)$ =	2.64	
Z =	12.08	ft
D =	66	ft
A =	3	
B =	0.5	
K =	**3.08**	**ft/day**

Horn Rapids Landfill Slug Test Calculation

MW07 Slug Out

r_c =	0.08	ft
t =	37	seconds
$H_{t=}$	0.1	ft
H_0 =	0.4	ft
r_w =	0.25	ft
L_{scr} =	15	ft
$\ln(R_e/r_w)$ =	2.64	
Z =	12.08	ft
D =	66	ft
A =	3	
B =	0.5	
K =	**1.98**	**ft/day**

MW08 Slug In

r_c =	0.08	ft
t =	12	seconds
$H_{t=}$	0.1	ft
H_0 =	0.16	ft
r_w =	0.25	ft
L_{scr} =	15	ft
$\ln(R_e/r_w)$ =	2.58	
Z =	10.14	ft
D =	66	ft
A =	2.8	
B =	0.48	
K =	**2.02**	**ft/day**

MW08 Slug Out

r_c =	0.08	ft
t =	16	seconds
$H_{t=}$	0.1	ft
H_0 =	0.25	ft
r_w =	0.25	ft
L_{scr} =	15	ft
$\ln(R_e/r_w)$ =	2.58	
Z =	10.14	ft
D =	66	ft
A =	2.8	
B =	0.48	
K =	**2.96**	**ft/day**

Horn Rapids Landfill Slug Test Calculation

MW09 Slug In

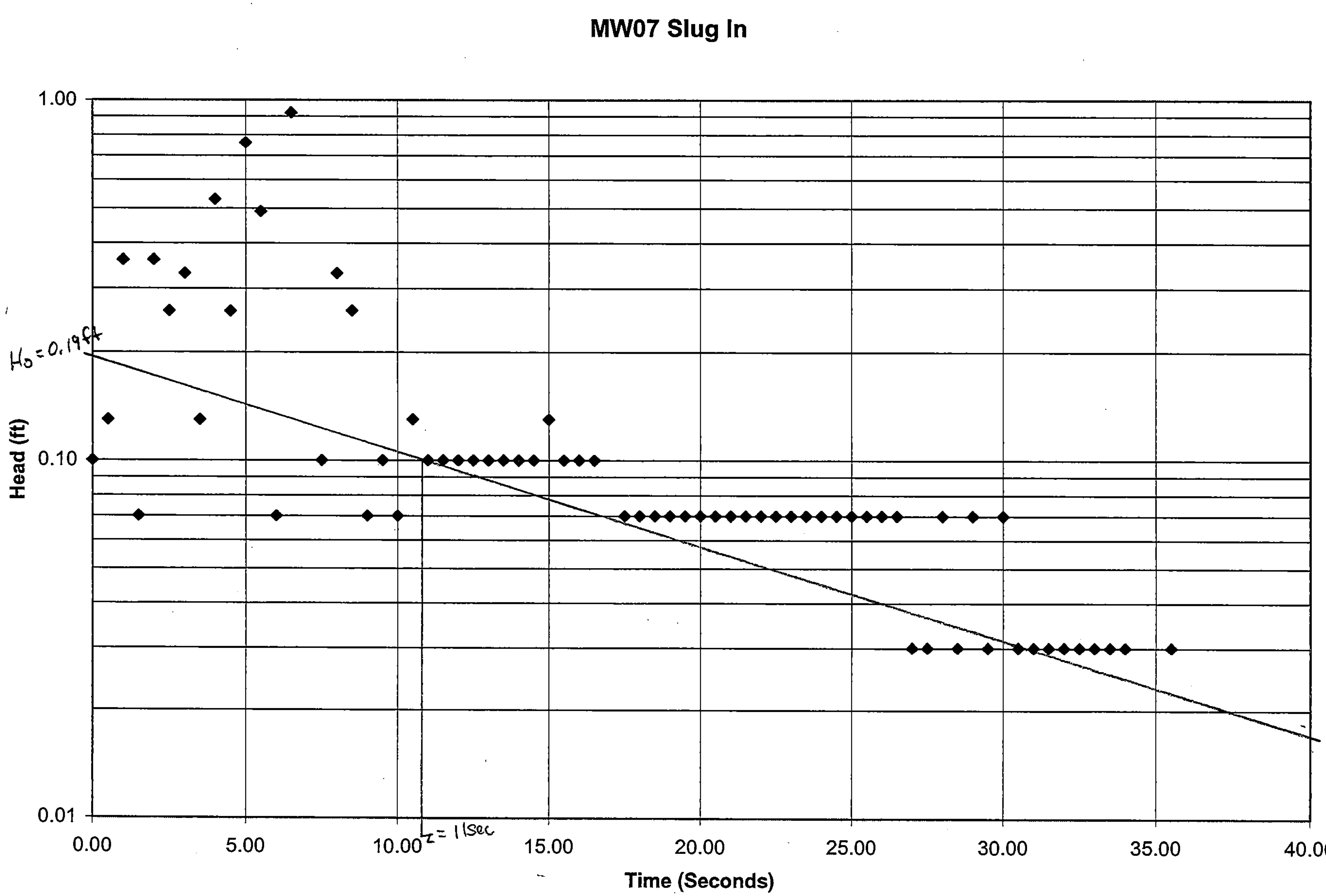
r_c =	0.08	ft
t =	4.5	seconds
$H_{t=}$	0.1	ft
H_0 =	0.55	ft
r_w =	0.25	ft
L_{scr} =	15	ft
$\ln(R_e/r_w)$ =	2.56	
Z =	9.09	ft
D =	66	ft
A =	2.6	
B =	0.45	
K =	**19.42**	**ft/day**

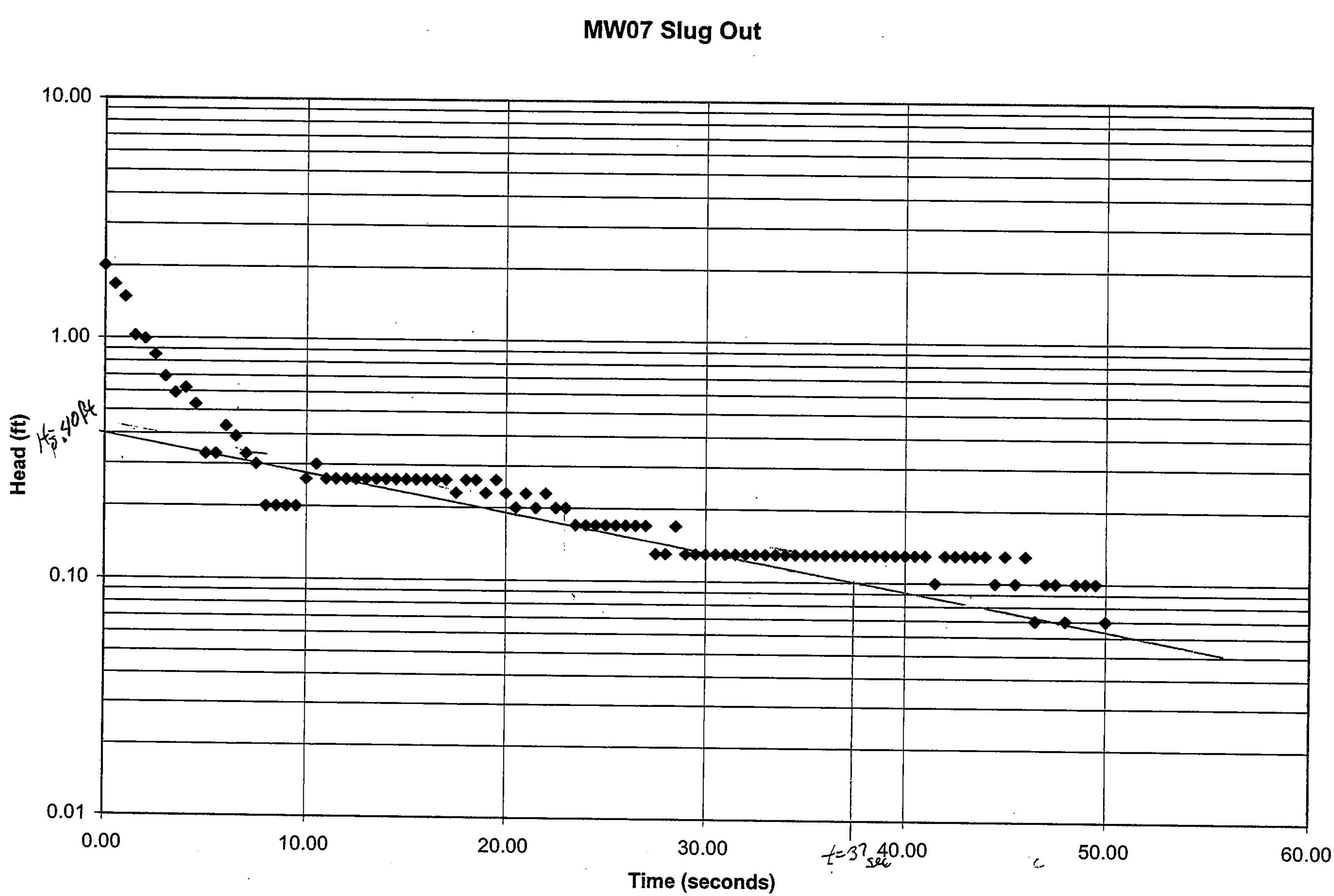
MW09 Slug Out

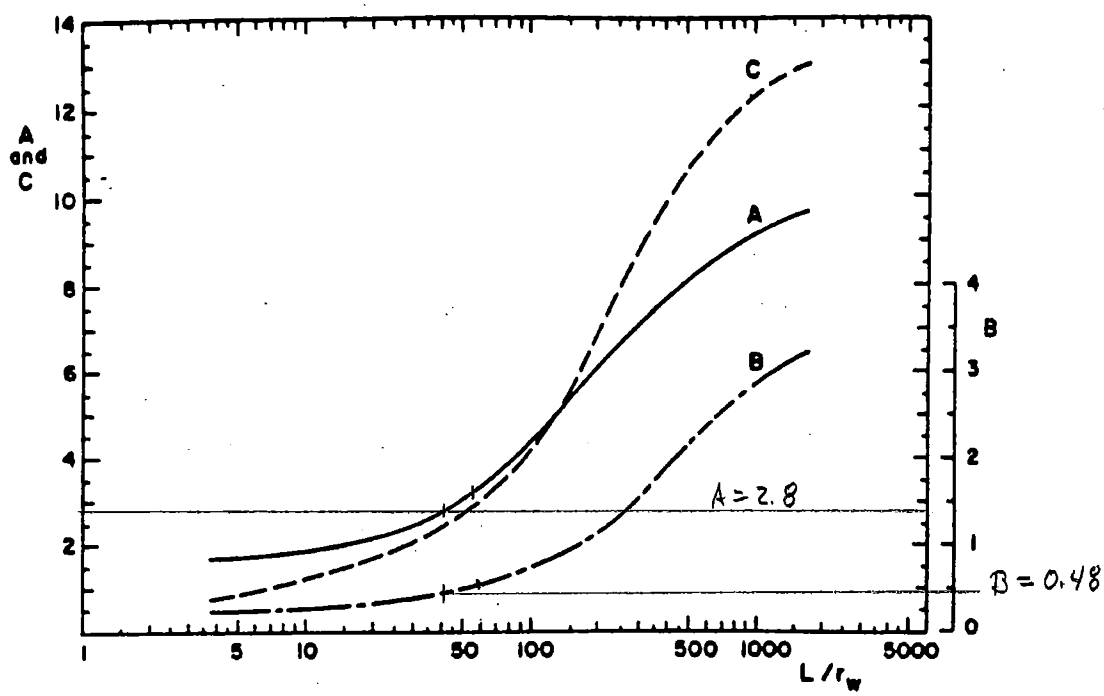
r_c =	0.08	ft
t =	6	seconds
$H_{t=}$	0.1	ft
H_0 =	0.25	ft
r_w =	0.25	ft
L_{scr} =	15	ft
$\ln(R_e/r_w)$ =	2.56	
Z =	9.09	ft
D =	66	ft
A =	2.6	
B =	0.45	
K =	**7.83**	**ft/day**

MW10 Slug In

r_c =	0.08	ft
t =	60	seconds
$H_{t=}$	0.01	ft
H_0 =	0.095	ft
r_w =	0.25	ft
L_{scr} =	15	ft
$\ln(R_e/r_w)$ =	2.62	
Z =	11.27	ft
D =	66	ft
A =	2.95	
B =	0.49	
K =	**1.96**	**ft/day**


MW07 Slug In
Head (ft)
1.00
0.10
0.01
Time (Seconds)
0.00
5.00
10.00
15.00
20.00
25.00
30.00
35.00
40.00
Ho = 0.19ft
t = 11sec

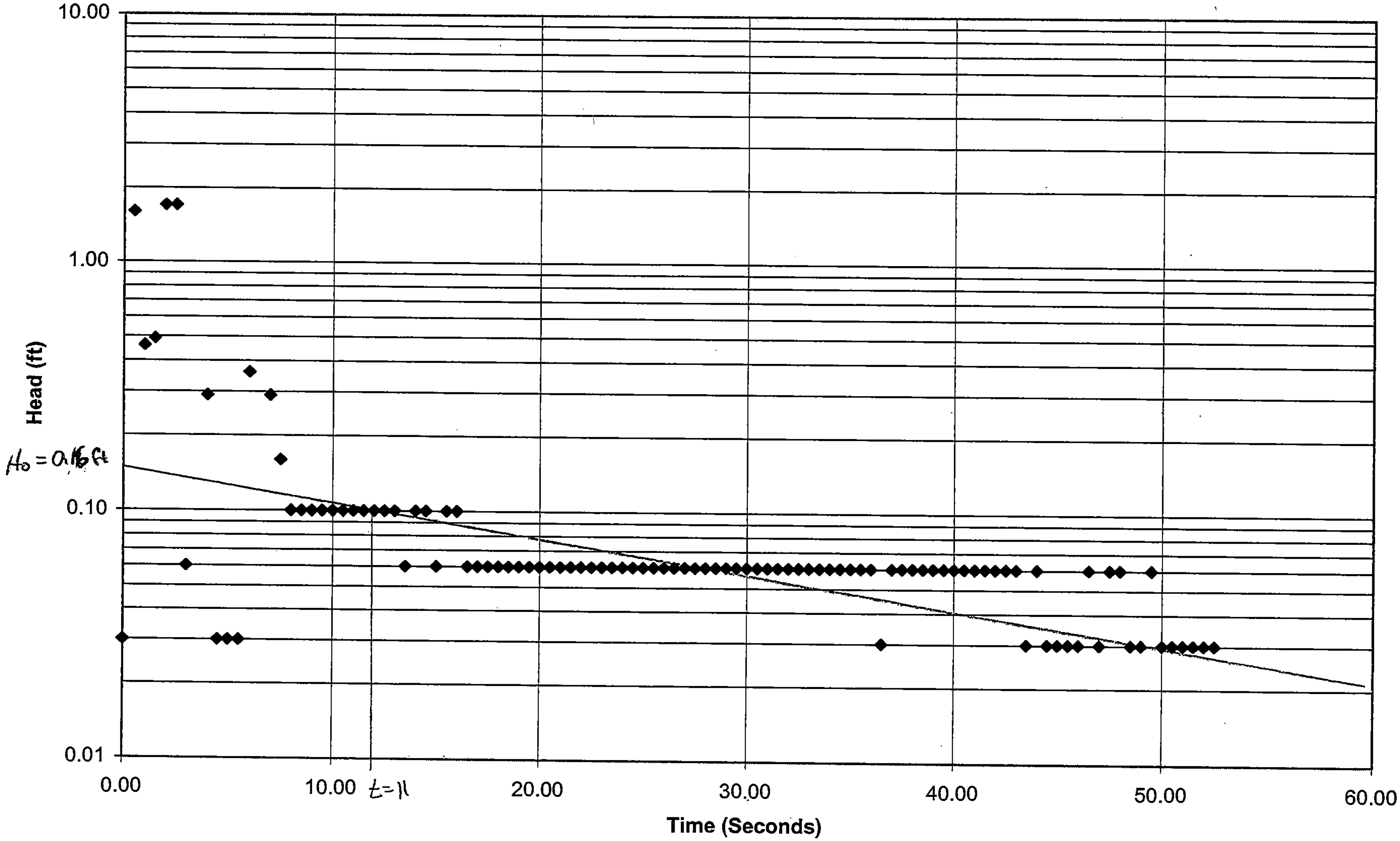

MW07 Slug Out
10.00
1.00
0.10
0.01
Head (ft)
0.00
10.00
20.00
30.00
40.00
50.00
60.00
Time (seconds)
H₀ .40ft
t=37 sec



Curves relating coefficients *A*, *B*, and *C* to L/r_w.

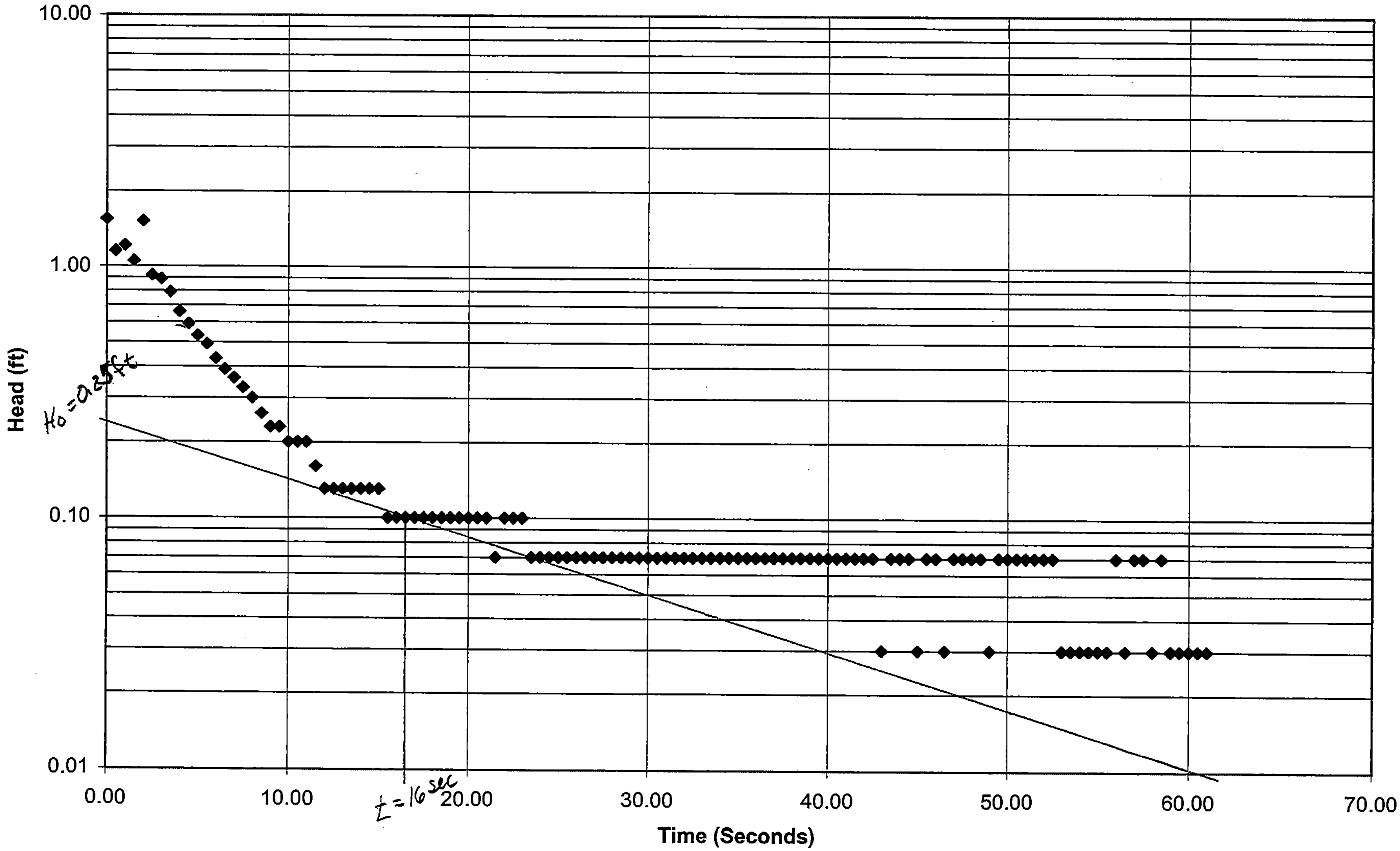
MW08 $L/R_W = 40.6$

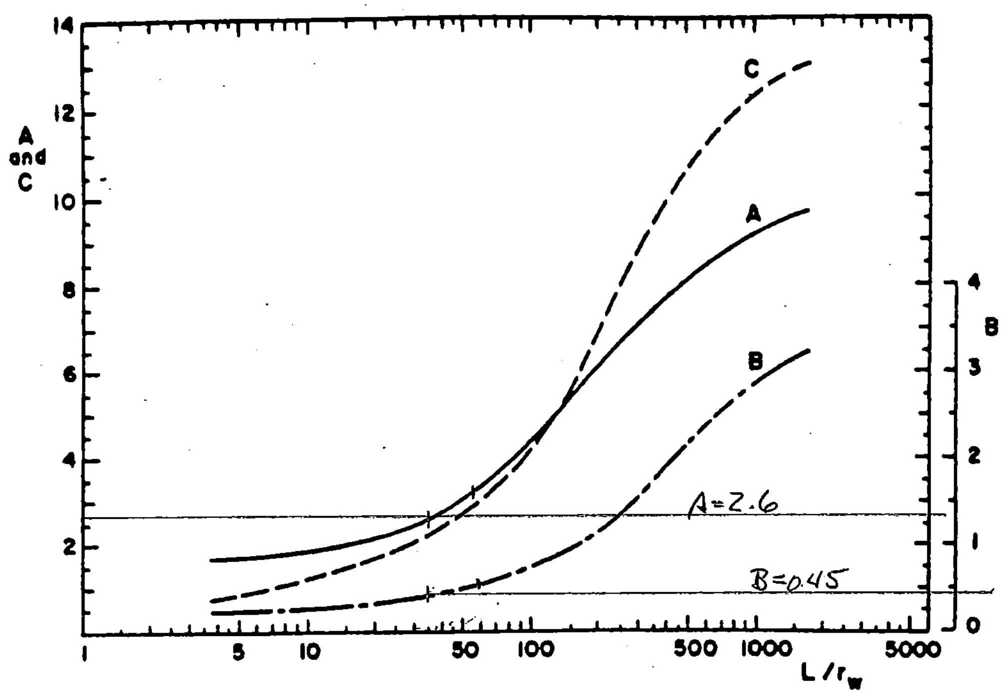
MW08 Slug In



10.00
1.00
0.10
0.01
Head (ft)
0.00
10.00
20.00
30.00
40.00
50.00
60.00
Time (Seconds)

MW08 Slug Out

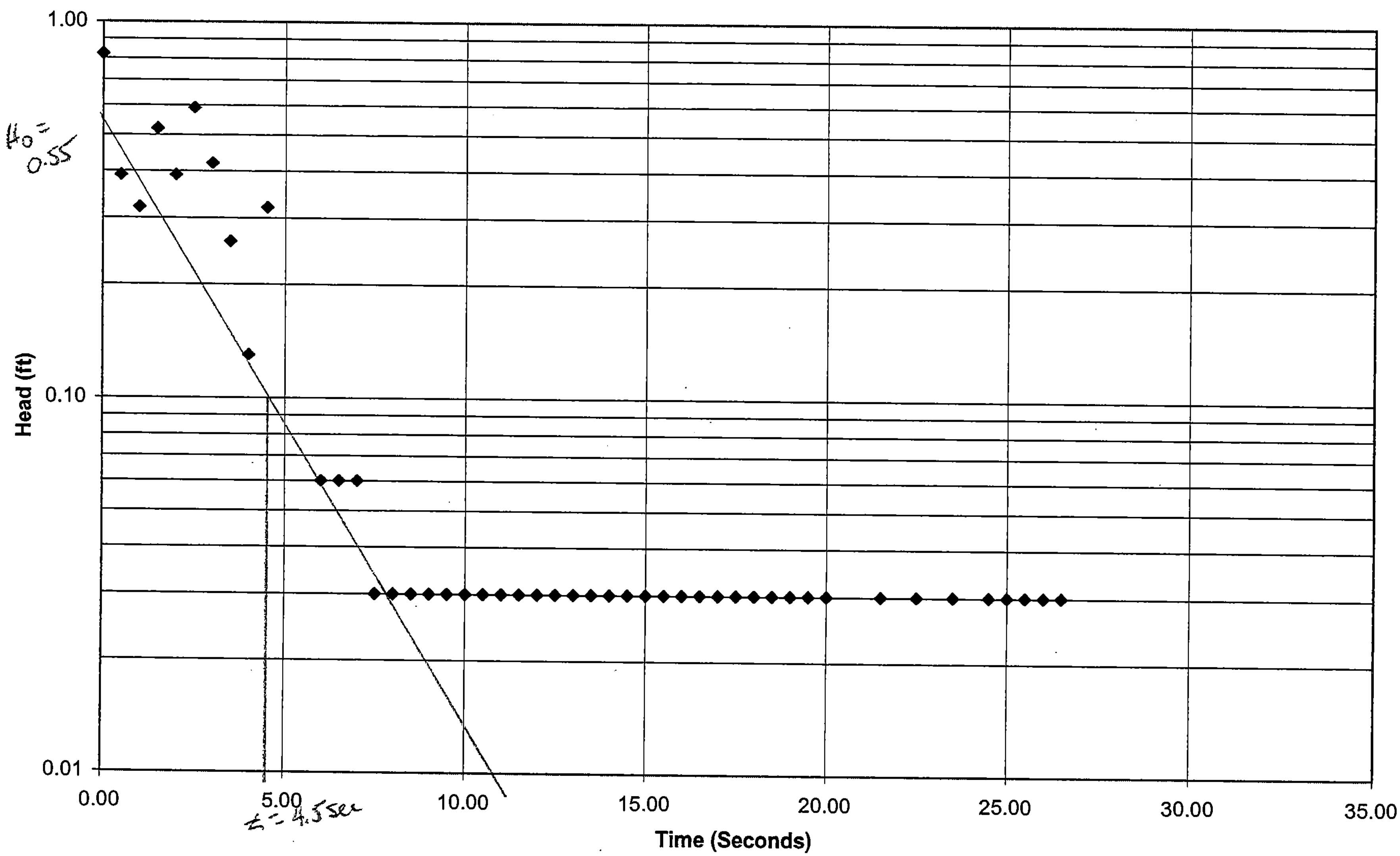




Curves relating coefficients *A*, *B*, and *C* to L/r_w.

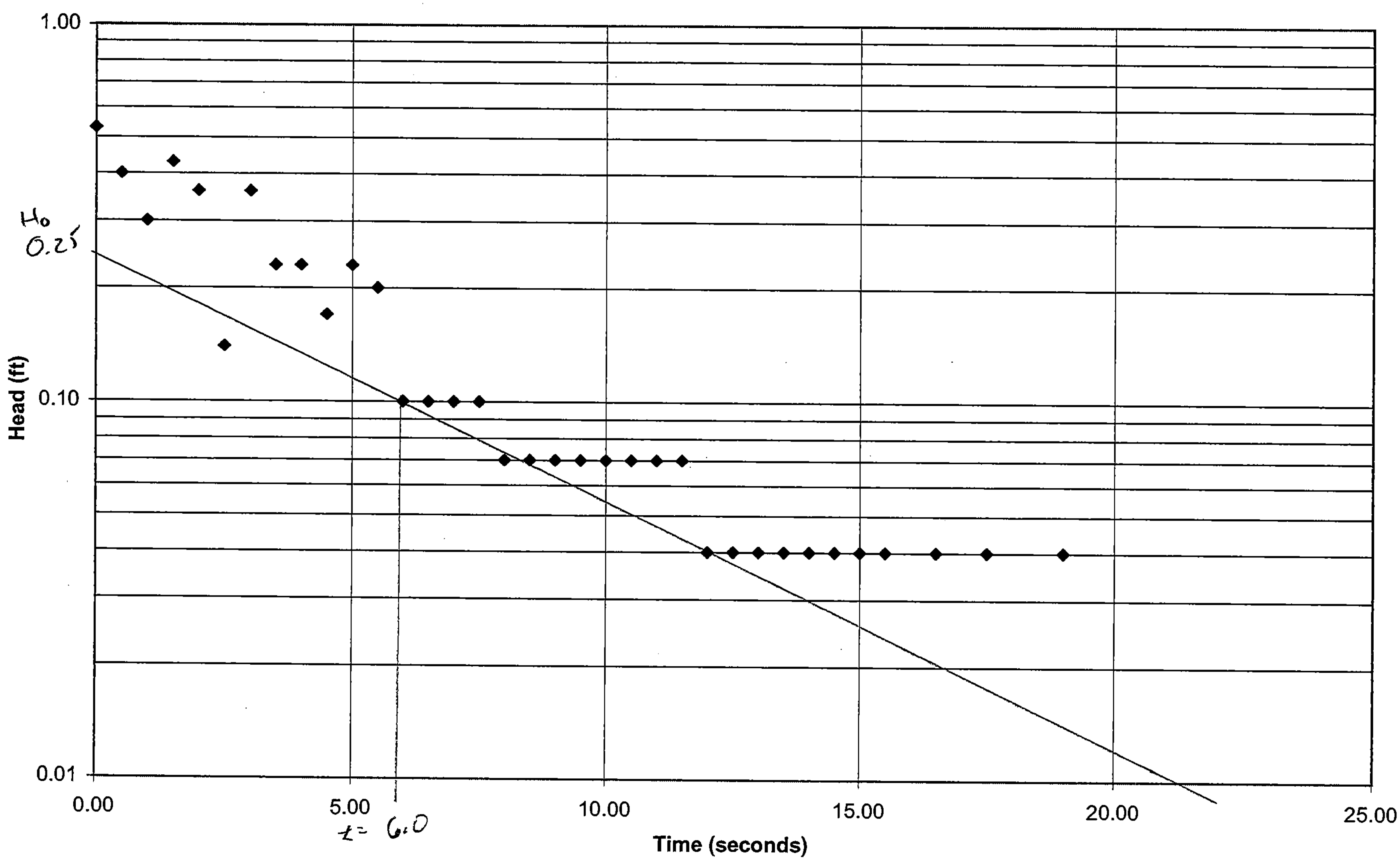
MW09 $L/R_w = 36.4$

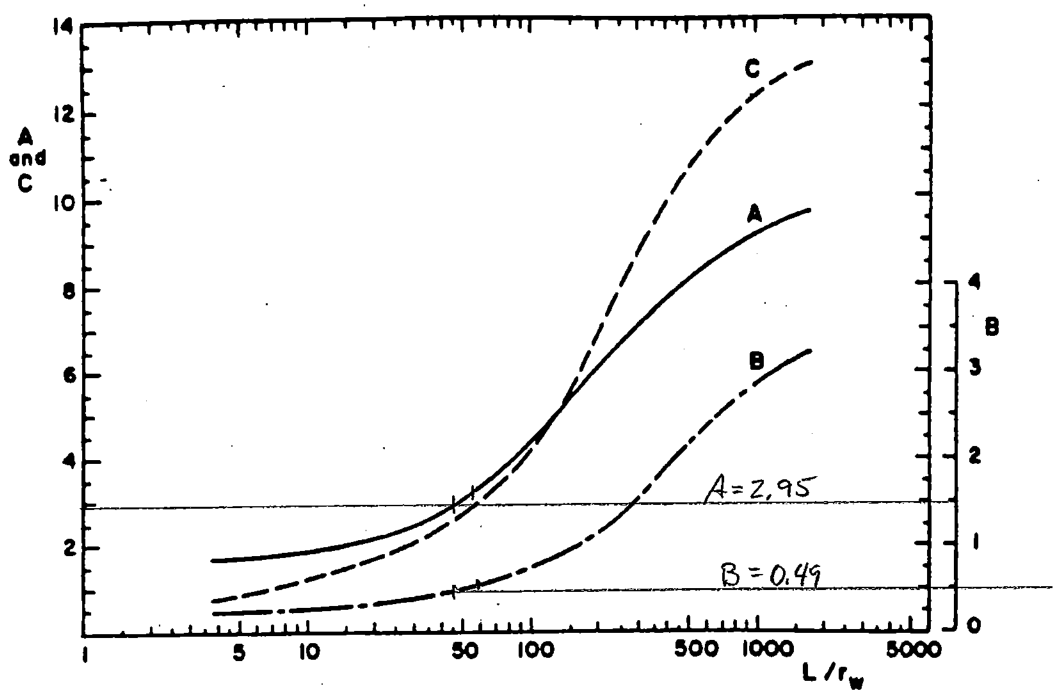
MW09 Slug In



1.00
0.10
0.01
Head (ft)
$H_0 = 0.55$
0.00
5.00
10.00
15.00
20.00
25.00
30.00
35.00
$t = 4.5$ sec
Time (Seconds)

MW09 Slug Out

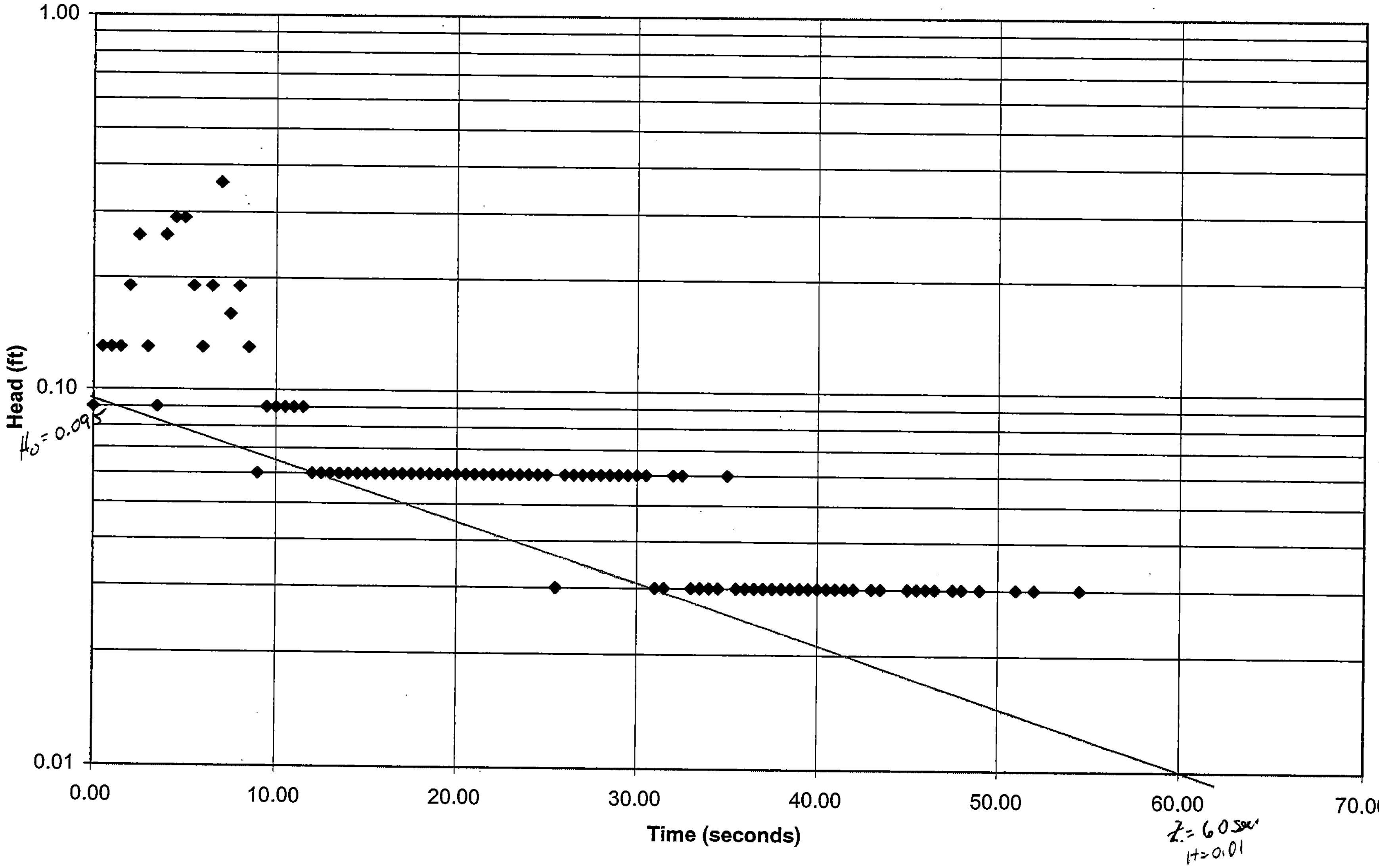




Curves relating coefficients *A*, *B*, and *C* to L/r_w.

MW10. $L/r_w = 45.8$.

MW10 Slug In



1.00
0.10
0.01
Head (ft)
H_0 = 0.095
0.00
10.00
20.00
30.00
40.00
50.00
60.00
70.00
Time (seconds)
t_0 = 60 sec
H = 0.01

MW10 Slug Out