East Garrington Gas Plant Looking Northeast Towards the

***Trench and Gate* Research Site**

THE UNIVERSITY OF CALGARY

The *Trench and Gate* Groundwater Remediation System

by

Marc W. Bowles

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies for acceptance, a thesis entitled “The *Trench and Gate* Groundwater Remediation System” submitted by Marc W. Bowles in partial fulfilment of the requirements for the degree of Master of Science.

Supervisor, Dr. Laurence R. Bentley
Department of Geology and Geophysics

Dr. Cathy Ryan
Department of Geology and Geophysics

Dr. Angus Chu
Department of Civil Engineering

Date

ABSTRACT

Funnel and Gate technologies are inappropriate for remediating groundwater contamination in low permeability sediments like glacial tills, because the design produces mounding effects which force flow underneath and around funnel walls.

The *Trench and Gate* is a modified Funnel and Gate system suitable for installation in tills. Modifications include the addition of high hydraulic conductivity trenches along the up-gradient side of the funnel walls and a reinfiltration gallery down-gradient of the treatment gate. Preferential groundwater flow through the added high permeability infrastructure prevents mounding and induces a capture zone both horizontally, and vertically larger than the cross-sectional funnel area. Coupled with bioremediation catalyzed by biosparging, or other remediation technologies, the system constitutes an economical, in-situ, long-term contaminant plume capture and treatment method, suitable for low to moderate permeability sediments. A prototype *Trench and Gate* was successfully installed at the East Garrington Gas Plant, Alberta, Canada.

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DEDICATION

This thesis is dedicated to my loving wife Wendy and our supportive children Jill, Timothy, and Ross who spent too many weekends and evenings without “Dad” so that the theory could become a reality.

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“Let a man profess to have discovered some new Patent Powder Pimperlimplimp, a single pinch of which being thrown into each corner of a field will kill every bug throughout its whole extent, and people will listen to him with attention and respect. But tell them of any simple common sense plan, based on correct scientific principles, to check and keep within reasonable bounds the insect foes of the farmer, and they will laugh you to scorn.”

Benjamin Walsh
The Practical Entomologist
1866

“Anybody else want to negotiate?”

Bruce Willis
The Fifth Element
1997

1. INTRODUCTION

1.1 BACKGROUND

Contamination of shallow groundwater by petroleum hydrocarbons and other contaminants has become one of the most serious problems facing the oil and gas and other industries. At numerous facilities throughout the world, contaminated groundwater is hosted by fine-grained deposits such as silt and clay glacial tills. To date, effective and economical treatment of contamination in these low hydraulic conductivity media has been hampered by slow average linear groundwater flow velocities. Capture and remediation of groundwater in these types of sediments is problematic, and in some instances, treatment of till-borne contaminated groundwater is considered cost prohibitive. Thus, there is an obvious need for an economical and practical method for remediating groundwater in low permeability sediments and preventing off-site migration of contaminants.

1.2 RATIONALE

Recently, many advances have been made in the field of hydrocarbon contaminated groundwater and soil remediation. Vapour extraction, bioventing, and pump and treat systems are all examples of effective treatment techniques. However, many of these methods are either too expensive in terms of equipment and operating costs, or not readily adaptable to treating groundwater contamination in tills. Thousands of hydrocarbon processing facilities in the Canadian prairies, elsewhere in Canada, and the world, are constructed on clayey or silty sediments, especially till. Remediation of these sites has generally been undertaken using conventional methods such as excavation followed by land farming, thermal desorption, or disposal to a landfill, with the expectation that removing the hydrocarbon source from the soil will result in groundwater clean up. Direct treatment of groundwater contamination in tills has been hampered by slow groundwater flow rates. To overcome this problem, expensive remediation techniques such as close-spaced extraction wells and hydro-fracturing have been employed. In other instances, treatment of the contaminated groundwater is considered not practical as it is difficult to justify large scale, clean-up operations. Yet the need for some form of groundwater remediation is recognized.

An attractive alternative to the traditional and newer remediation techniques listed above is the use of Funnel and Gate technology (Starr and Cherry, 1994). This system uses impermeable barriers such as sheet piling to “funnel” groundwater flow through a treatment zone or “gate.” The in-situ method requires minimal upkeep once installed and should prevent off site migration of contaminants. However, research on this method has focused primarily on groundwater contamination in media with much higher hydraulic conductivities (*i.e.,* sand and gravel), for which several remediation techniques (*e.g.,* pump and treat) already exist.

A modified Funnel and Gate interception system, re-engineered for use in lower hydraulic conductivity sediments, represents an alternative groundwater remediation technique that is potentially a cost effective method of plume treatment and containment; both primary concerns of regional and national regulatory agencies. The modified Funnel and Gate system, dubbed *Trench and Gate*, consists of an impermeable funnel with the addition of high hydraulic conductivity “drainage trenches” along the inside edges of the funnel, and a high permeability down-gradient reinfiltration gallery. A comparison of the Funnel and Gate and *Trench and Gate* designs is provided in Figure 1-1.

The *Trench and Gate* design has many advantages. The combination of a cut-off wall and adjacent drainage trench, as compared with traditional stand alone barriers:

1. improves drainage of the contaminated zone;
2. increases the size of the capture zone; and,
3. prevents damming effects such as mounding which force contaminants around or under funnel walls.

Contaminated groundwater captured in this manner can be treated by biodegradation or other techniques as it flows through the system. In-situ treatment and the use of natural hydraulic gradients to move the contaminants to the treatment infrastructure, ensures that on-going costs will be minimized as compared to maintenance-intensive ex-situ remediation designs. The use of groundwater bioremediation techniques is advantageous in that it allows for a simple treatment system that effectively transforms both heavy and light end hydrocarbons into innocuous products.

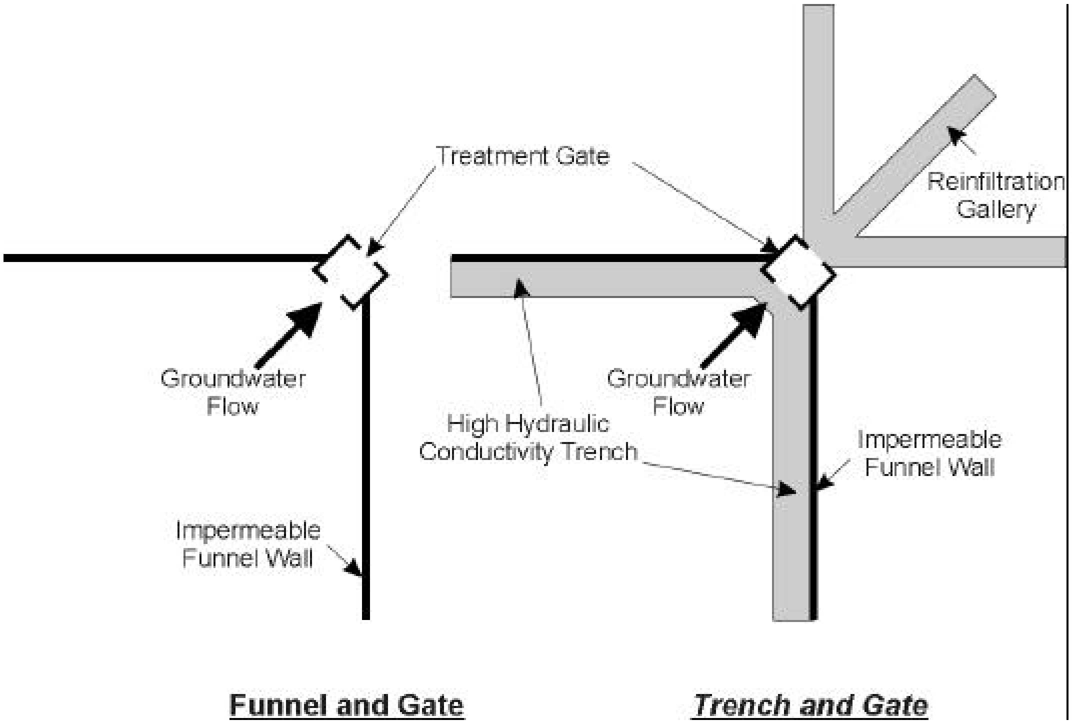


Figure 1-1 Plan View Schematic Comparison of Funnel and Gate and *Trench and Gate* Groundwater Remediation Systems.

It is envisaged that by using innovative combinations of existing technologies (*i.e.,* Funnel and Gate and bioremediation) coupled with unique design modifications, a practical alternative to expensive ex-situ treatment systems for low permeability units can be designed. Such a system could potentially be used at hundreds of contaminated sites with similar hydrogeological settings. Minor modifications to the *Trench and Gate* treatment system will also allow for the remediation of non-hydrocarbon contaminants (*e.g.,* metals).

1.3 SITE SELECTION AND HISTORY

The Amoco-operated East Garrington Gas Plant is located at LSD 11-17-34-3 W5M in Red Deer County, Alberta. The plant was constructed in 1975 and processes raw gas. Preliminary environmental site investigations took place at the plant in 1990 and consisted of initial and follow-up soil vapour surveys (Hazmacon, 1990a and 1990b). Survey results outlined broad areas of concern with elevated hydrocarbon vapours. Later the same year, a series of 14 piezometers was installed as part of a hydrogeological exploration program (O'Connor, 1991). Piezometer monitoring (O'Connor, 1992 and Komex, 1993) confirmed the presence of dissolved BTEX (benzene, ethylbenzene, toluene, and xylenes) over much of the site and local areas of LNAPL (light non-aqueous phase liquids) or free product.

The East Garrington site was selected for the *Trench and Gate* research program for the following reasons:

1. the facility was expected to be in operation for many years, thus allowing for consideration of a long term remediation method;
2. the facility was constructed over what was reported to be low permeability glacial sediments;
3. reported dissolved hydrocarbon concentrations in groundwater were in excess of Canadian drinking water guidelines (Health Canada, 1996); and,
4. potential off-site migration of dissolved hydrocarbon contaminants needed to be prevented.

1.4 PROJECT OBJECTIVE

The objective of this research project was to modify the design of the Funnel and Gate system for use in low permeability sediments such as glacial tills, thus remediating contaminated groundwater and preventing off-site migration of contaminants. To assess this hypothesis, a pilot-scale, modified Funnel and Gate treatment system, termed the *"Trench and Gate"* remediation system was designed and installed at the Amoco-operated East Garrington Gas Plant, Alberta (Figure 1-2 and Figure 1-3).

Figure 1-2 East Garrington Gas Plant Location Map (LSD 11-17-34-3 W5M).

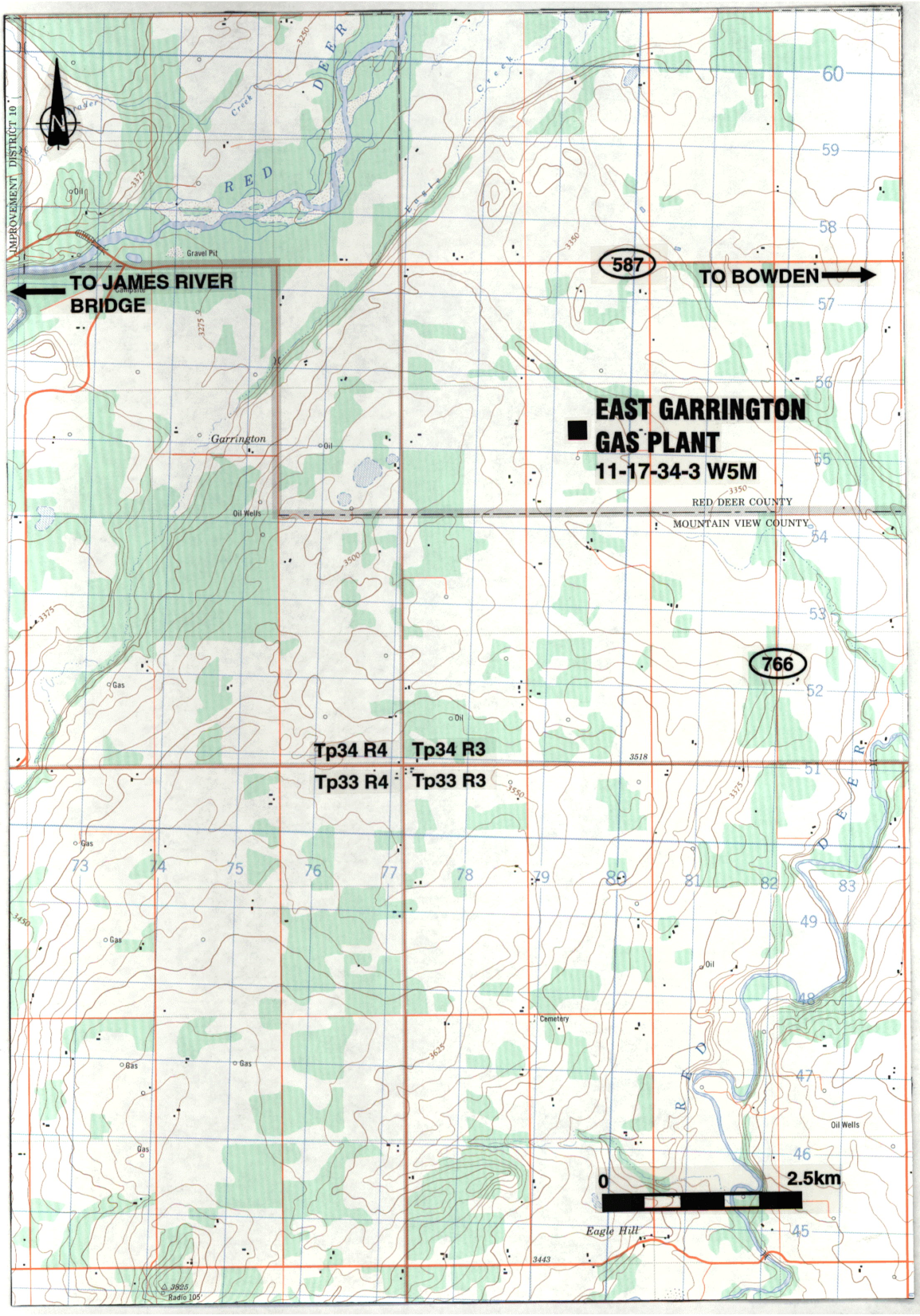


Figure 1-3 Location, Topography, and Drainage Map.

Due to the ambitious nature of the project and the interrelation of a number of different lines of research it was necessary to integrate, in the discussion that follows, project summaries of some of the research performed by others. In particular, research synopses are included of :

- computer groundwater flow modelling work performed by Bill Hoyne (Hoyne in prep.) which is used to confirm that flow around the *Trench and Gate* system behaves as predicted by theory;
- biodegradation experiments undertaken by David Granger (Granger, 1997) which are used to illustrate that the system is capable of degrading high concentrations of dissolved contaminants and to determine if biodegradation is nutrient limited; and,
- meteorological and groundwater level monitoring data collected by David Thomas (in prep.) which illustrates the relationship between groundwater recharge, horizontal hydraulic gradient, and flux through the treatment system.

These research projects, which constitute excellent stand-alone studies, are discussed in order to present a comprehensive overview of the *Trench and Gate* Project and the integrated project components. This is done because the primary objective of the thesis is to outline the original design concept behind the *Trench and Gate* system, discuss the implementation and monitoring of the pilot scale system, and assess system performance. Accordingly, trying to discuss the system without reference to this relevant background information would result in a less than comprehensive overview and an incomplete assessment of the original idea that underlies the design concept.

1.5 PREVIOUS RESEARCH

1.5.1 Groundwater Flow in Till

Contaminant transport in tills is controlled by advection and dispersion through the pores and fractures of geological media. Advection and dispersion rates are also a function of hydraulic gradients which may be influenced by minor changes in topographic elevation and grain size. Due to the fine grain size and the "tight" nature of tills, groundwater flow through the matrix by these processes is very slow and as a result, in some cases, may not follow Darcy's Law. However, tills often contain high permeability sand lenses that can act as conduits for focusing and accelerating groundwater flow. Sand lenses are generally discontinuous, although relatively extensive intratill sands have been found. Contribution to flow from these sand units must be ascertained on a site by site basis.

Fractures are also one of the major controlling factors of permeability and are common in most silty and clayey tills. Fractures may range in aperture from less than 1 µm to 50 µm or more and even relatively small fractures can contribute significantly to flow. They are found throughout the weathered zone and occasionally extend down into the unweathered zone. Fractures can be recognized in the field by the presence of Fe and Mn oxides imparting yellow to orange staining, clay alteration minerals, secondary carbonates, and alteration haloes (D'Astous *et al.,* 1989). Authigenic gypsum is also quite common. However, Keller *et al.* (1988) found that gypsum is not present in fractures below shallow depression focused recharge areas, but is present away from these areas. This is presumably due to dissolution of gypsum by fresh recharging meteoric waters. Fractures within the unweathered zone may not be marked by a change in colour or an associated alteration halo. Fractures may be due to desiccation or stress relief following unloading caused by glacial retreat and melt out.

Where numerous fractures are present, as in the weathered zone, several authors (*e.g.,* Rowe and Booker, 1990; Ruland *et al.,* 1991; and others) have found that fracture flow is the dominant mode of groundwater movement, providing that the fractures exceed a minimum breakthrough aperture tentatively estimated to be smaller than 10 µm (Harrison *et al.,* 1992). Where fracture spacing is very close, on the order of centimetres or less, flow has been successfully modelled using an equivalent porous medium approach (McKay *et al.,* 1993b). This was confirmed by drilling, sampling, and analysis of pore and fracture waters, both of which were found to have a chemical make up similar to that of an artificially introduced experimental solute. Fracture flow has also been successfully modelled by McKay *et al.* (1993a) using the fracture flow method of Snow (1968 and 1969). Based on the assumption that flow through a fracture can be approximated as laminar flow between two smooth parallel plates, then the hydraulic conductivity of a fracture K_f is given by:

$$K_f = (2b)^2 \frac{\rho g}{12\mu}$$

Equation 1-1

and the velocity for steady state isothermal flow is given by:

$$v = K_f i$$

Equation 1-2

where:

$2b$ = the fracture aperture
μ = the flow viscosity
ρ = the fluid density
i = the gradient
g = the acceleration of gravity

Rewriting this equation in terms of specific discharge or flux (q in L/T):

$$q = (2b)^3 \frac{\rho g}{12\mu} I$$

Equation 1-3

it can be seen that discharge is proportional to the cube of the aperture. The cubic law illustrates that larger fractures provide a much more significant contribution to mass transport than smaller fractures, since doubling the fracture aperture more than doubles the flow through the fracture. McKay *et al.* (1993a) also found that fracture porosities decrease exponentially with depth. Thus even relatively small fractures can contribute significantly to flow.

Considering the research outlined above, it was expected that fractures would play an important role in controlling groundwater flow in the sediments at the East Garrington Plant. Since fractures vary considerably in their areal distribution and heterogeneity, it was expected that hydraulic conductivity determinations would also vary depending on the size of the area tested and the method used. Accordingly, a number of different methods were used to measure hydraulic conductivity. Hydraulic conductivity tests are discussed in Section 3.

1.5.2 Hydrocarbon Biodegradation

Bacterial break down of organic compounds into simpler compounds is referred to as biodegradation. When this process is used to break down hydrocarbons or other contaminants, using either natural or artificially enhanced conditions, it is referred to as bioremediation. Bacterial decomposition rates are controlled by the bond strength of the compound being broken down, the availability of a suitable terminal electron acceptor, and the presence of an adequate supply of nutrients necessary for the degrading microorganisms.

Biodegradation reactions can take place in both aerobic and anaerobic systems. In aerobic systems O_2 is used as the electron acceptor, while NO_3, SO_4, Fe, and Mn are the common electron acceptors for anaerobic systems. In aerobic systems the generalized formula for biodegradation can be written as:

$$\text{Organic compound} + O_2 \xrightarrow[\textit{bacteria}]{} CO_2 + H_2O + \text{Energy} + \text{Biomass}$$

Since aerobic biodegradation reactions for BTEX are typically much more rapid than anaerobic ones, this reaction was chosen as the mechanism for remediation of the contaminated water in the *Trench and Gate* system. Biosparging studies (Lord *et al.*, 1995 and Hinchee, 1994) have shown that simple oxygenation of contaminated groundwater by bubbling air enables aerobic degradation of dissolved hydrocarbons (*e.g.,* BTEX) by naturally occurring bacteria. Thus, biosparging of groundwater was chosen as the optimum technology for the East Garrington site. This system was preferred because no special source of oxygen other than atmospheric air need be added to maintain an adequate supply of available oxygen for the biodegradation process. It was also considered an attractive option because a source of compressed air was readily available from the instrument air compressor located on site.

Accordingly, the monitoring of in-situ dissolved oxygen concentrations was considered to be of utmost importance for determining the success of the *Trench and Gate* system, as rapid biodegradation required an aerobic environment in excess of 2.0 mg/L. Similarly, it was thought that routine monitoring of redox potential (Eh) in groundwater would allow for assessment of how the system was performing, as continuous addition of oxygen to oxygen-depleted groundwater should result in an increase in Eh.

1.5.3 Funnel and Gate

The Funnel and Gate remediation system is based on the installation of low hydraulic conductivity cut-off walls below ground to “funnel” contaminated groundwater through a high hydraulic conductivity remediation zone or zones referred to as “Gates” or “Reactors” (Starr and Cherry, 1994 and Weber and Barker, 1994). The use of sparging to promote biodegradation within these gates was suggested by Starr and Cherry (1994) and volatilization by sparging has been mathematically modelled by Pankow *et al.* (1993). The Funnel and Gate design works on the assumption that a proportion of the streamlines entering the Funnel and Gate area will be captured by the system, while others will be forced around the ends, or possibly below the bottom of the cut-off walls (Starr and Cherry, 1994 and Shikaze *et al.*, 1995).

The Funnel and Gate system has three inherent disadvantages:

1. since some of the streamlines will veer around the end of the walls (Fitts, 1997), the funnel width has to considerably exceed the plume width in order to accomplish 100% capture;
2. unless the walls are set into a low hydraulic conductivity unit, some streamlines will also short circuit the remediation system by going underneath the walls (Shikaze and Austrins, 1995); and,
3. due to the damming effect of the walls, and depending on the hydraulic conductivity of the sediments, groundwater may tend to mound behind the funnel walls, possibly resulting in upward vertical smearing of LNAPLs if present.

The first two effects may be even more pronounced in low hydraulic conductivity sediments.

2. SITE CHARACTERIZATION

2.1 CLIMATE AND PHYSIOGRAPHY

The East Garrington project site is located within the Alberta Plains physiographic region, fairly close to the Rocky Mountain Foothills belt (Bostock, 1967). Relief is moderate with undulating topography (Figure 1-3). The plant is located on the side of a gentle hill which locally slopes northeast toward the confluence of the Red Deer and Little Red Deer Rivers. The ground elevation declines from about 1,030 masl (metres above sea level) at the plant site, to about 975 masl on the banks of the Little Red Deer River. Locally elevations do not exceed 1,070 masl. Regionally, the surface drainage is toward the northeast reflecting regional topographic gradients. However, in the area of the plant, local surface water can drain to the southeast along paleodrainage channels, one of which can be seen northeast of the plant in the Frontispiece.

Dominant drainage features in the project area include the Red Deer River and Little Red Deer River. Near the town of Sundre (Figure 1-2), the Red Deer River has a drainage area of 2,490 km^2 (Gauging Station 05CA001, Environment Canada, 1991). It has a mean annual flow of 20 m^3/sec. Flows are at a maximum in June, with a mean monthly discharge of 80.5 m^3/sec. Flow is at a minimum in winter, with the lowest mean monthly discharge of 4.36 m^3/sec occurring in January. The Little Red Deer River, located approximately 6 km east-southeast of the site has a drainage area of 2,560 km^2 near the river mouth, upstream of gauging station 05CB001 (Environment Canada, 1991). Its mean annual flow is 4.13 m^3/sec. Maximum flows occur in April, with a mean monthly discharge of 10.80 m^3/sec. Flow is at a minimum in January, with the lowest mean monthly discharge of 0.408 m^3/sec.

A long-term meteorological station is located nearby in the town of Olds. January, with a mean temperature of -11.2 °C, is the coldest month, while July is the warmest month, with a mean temperature of 16.1 °C. The mean annual temperature is 2.9 °C (Ozoray and Barnes, 1977).

The mean annual precipitation at the gas plant is approximately 462 mm (Ozoray and Barnes, 1977). Potential evapotranspiration exceeds precipitation from May to October. Data collected from an on-site weather station suggests that there may be slightly more precipitation and that it may be slightly windier at the East Garrington site than it is in Olds (Thomas, in prep.).

2.2 BEDROCK GEOLOGY

The subcropping stratigraphic unit throughout the region is the Paleocene Paskapoo Formation (Figure 2-1). The structure is uncomplicated, being almost flat-lying with a dip of less than 1° to the west. The Paskapoo Formation forms a broad band of near-horizontal strata between the structurally complex Rocky Mountain belt to the west and its termination by erosion to the east.

The Paskapoo Formation is composed predominantly of interbedded hard to soft mudstone, siltstone, and fine-grained sandstone (Glass, 1990). Minor limestone, coal, pebble conglomerate, and bentonite beds are also present. Occasional massive to cross-bedded, medium to coarse-grained sandstones occur throughout the formation. At the East Garrington site, near-surface Paskapoo sedimentary rock consists primarily of a silty shale with occasional interbedded sandstone units. At the erosional contact between the Paskapoo Formation and overlying Quaternary deposits, the Paskapoo is marked by a thin zone of bedrock regolith less than 1 m thick. The Paskapoo Formation has a thickness of approximately 600 m locally (Ozoray and Barnes, 1977). In the area of the plant, the bedrock topography is undulating but appears to dip gently to the north.

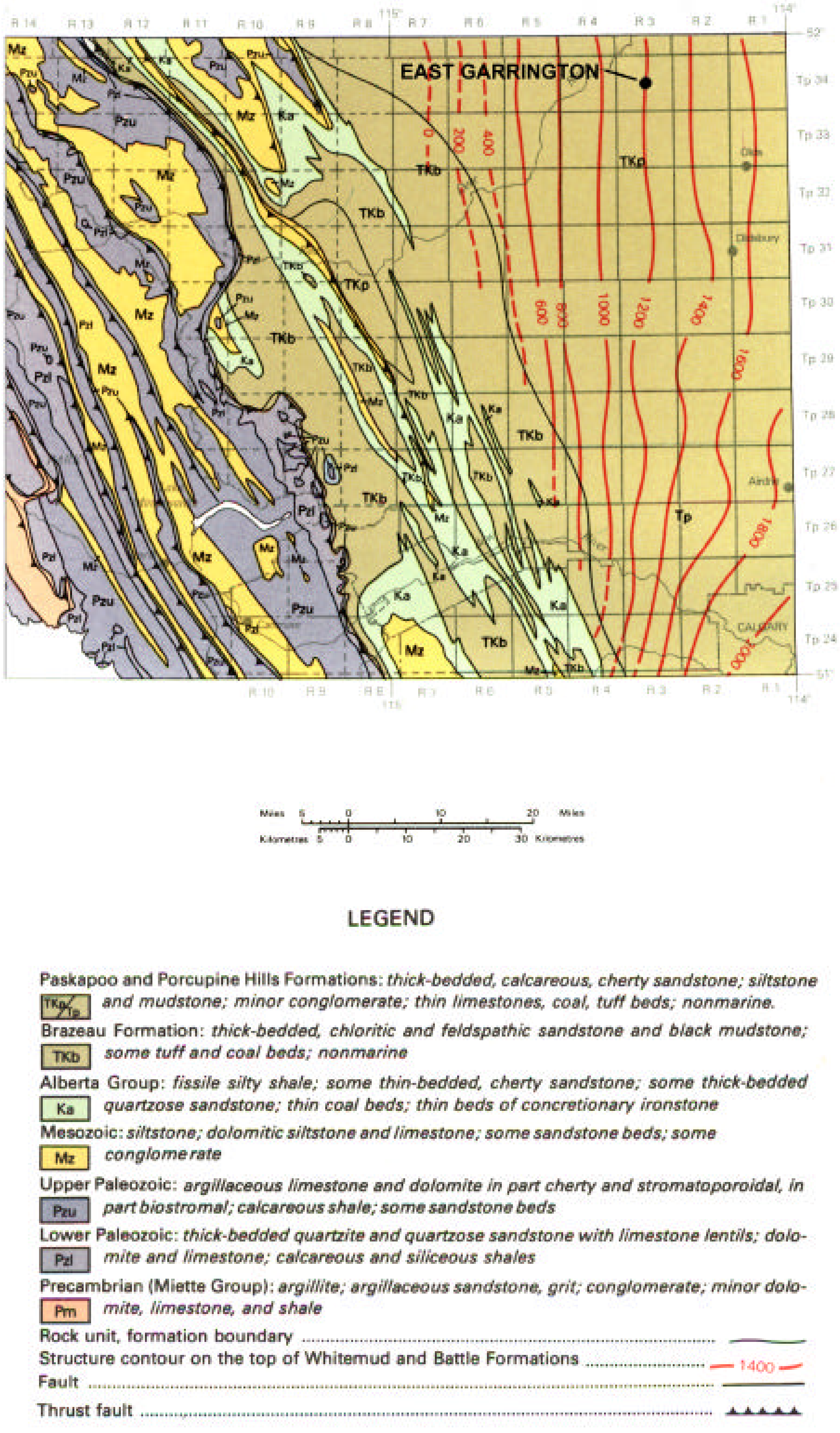


Figure 2-1 Bedrock Geology (Ozoray and Barnes, 1977).

2.3 SURFICIAL DEPOSITS

Site characterization of the Quaternary deposits was undertaken using a combination of existing data, airphoto interpretation, surficial geological mapping, recording of observations made during excavation programs, and detailed logging of drillholes during piezometer installation programs. Drill logs for all piezometers completed on site and additional boreholes drilled to re-log the geology at existing piezometers installed by O'Connor (1991), are included in Appendix I.

Quaternary deposits in the study area are largely of glacial origin. A generalized overview of the regional Quaternary geology as compiled by Shetson (1987) is provided in Figure 2-2. Locally, the geology is more complex. An interpretation of the Quaternary geology in the plant area, as determined from airphoto interpretation and ground truthing is provided on an annotated aerial photograph (Figure 2-3) and a schematic (southwest/northeast trending) cross-section of the area (Figure 2-4). Generalized descriptions of the Quaternary units as used in the two figures are provided in Table 2-1.

The depositional history is quite complex, perhaps reflecting the combined influence of the Cordilleran and Laurentide ice sheets and the possible reworking of one ice sheet's sediments by the other. Glacial deposits near the plant site, especially to the south and west, consist primarily of draped moraine and stagnation moraine till (Mm and Mp). Locally the till is composed of a mottled yellow brown silty clay. It may contain from 5 to 35% or more fine gravel to cobble sized rounded to subrounded rocks. These are composed primarily of siltstone, sandstone, quartzites, and other sedimentary rocks. Less than 5% of these rocks are composed of igneous or metamorphic rocks, but the mix of sedimentary and igneous cobble rock types may also reflect the provenance of the two different ice sheets.

Till deposits are generally heterogeneous and contain irregular lenses of sand or silt. Indirect evidence of fractures in the till, as inferred from the presence of gypsum and rusty staining, is occasionally evident. In places, the tills are weakly calcareous and contain trace to minor fine grained disseminated carbonate blebs. Accessory amounts of fine coal fragments are also quite common. Irregular areas of yellow to red iron staining are common throughout. With depth, this unit grades to an unweathered grey colour below approximately three metres.

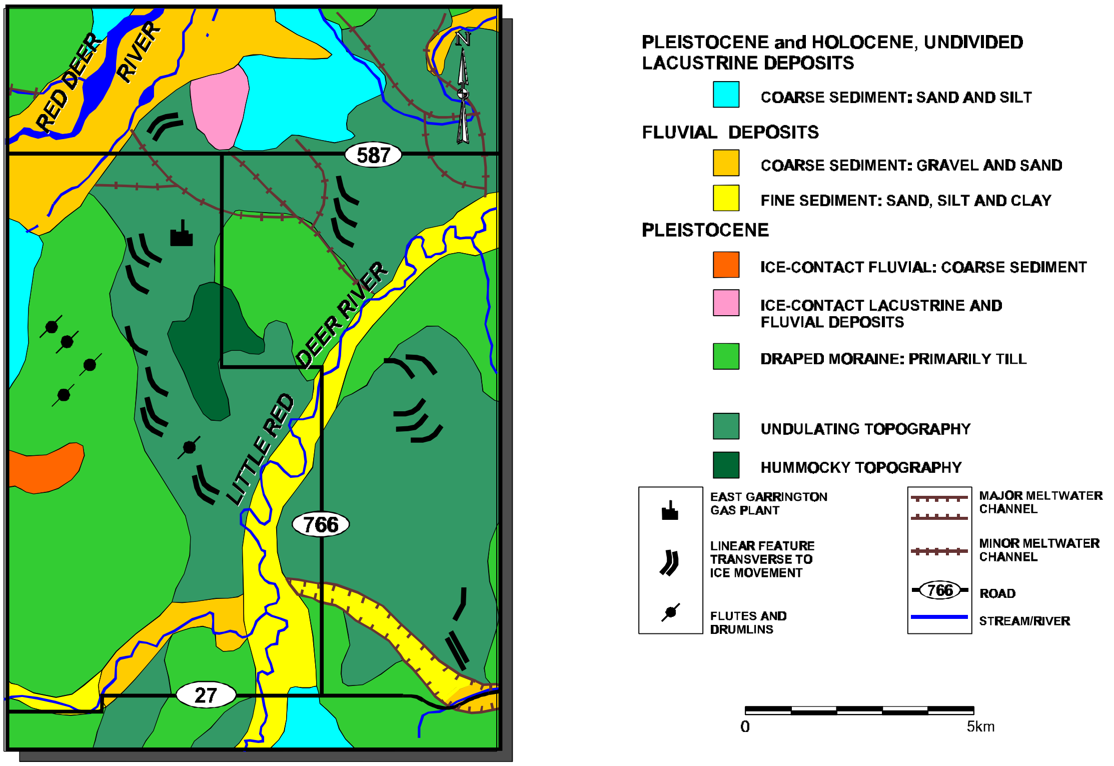


Figure 2-2 Regional Surficial Geology (Shetson, 1987).

Map Symbol	Terrain Unit
Gb	Glaciofluvial blanket
Gc	Glaciofluvial channel
Mp	Moraine plain

Figure 2-3 Annotated Air Photo of the East Garrington Area.

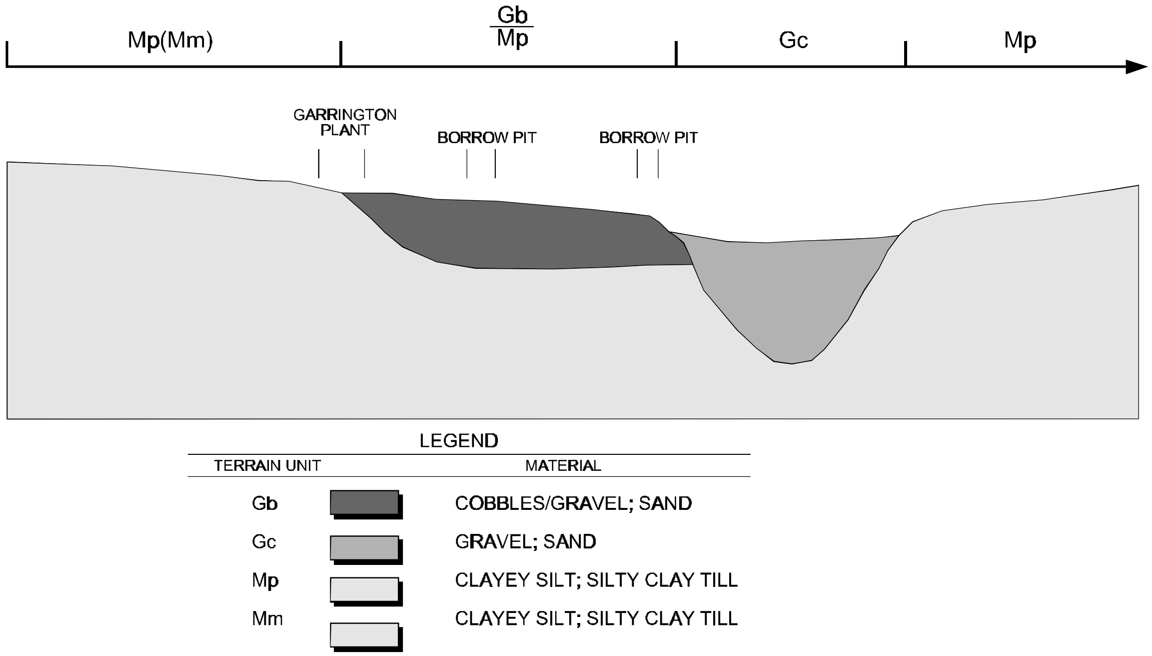


Figure 2-4 Interpreted Schematic Cross-Section of the Quaternary Geology in the Vicinity of the East Garrington Plant Site (Looking Northwest).

Table 2-1 Terrain Units in the East Garrington Area

Map Symbol	Terrain Unit	Principal Texture	Thickness of Material	Soil Drainage
Gb	Glaciofluvial blanket	Cobble/Gravel: Some sand and fines	1 to 3 metres	Well drained
Gc	Glaciofluvial channel	Gravel: Some sand and fines	1 to 5 metres+	Well drained
Mm	Rolling Moraine	Silty clay and clayey silt till	> 3.5 metres	Moderately well to poorly drained in depressions
Mp	Moraine plain	Silty clay and clayey silt till	>5 metres	Moderately well drained

To the northeast of the plant there are at least two, and possibly more, gravel rich deposits. These glaciofluvial gravel deposits are associated with an old southeast trending glacial meltwater channel. Based on field mapping and airphoto interpretation, the meltwater channel would appear to have been active during at least two periods. The first of these was a high energy event that laid down the majority of the sediments associated with the drainage area. This was followed by a second lower energy event that may have partially reworked the existing deposits.

Deposits associated with the second event have been variously interpreted as reworked glaciofluvial or periglacial deposits and have been deposited topographically above the earlier deposits. This second event produced an uncommon deposit characterized by a high cobble content, that is clast supported in some places, shows no evidence of imbrication, and contains appreciable fines. Samples of the till from within this area were submitted for X-ray diffraction analyses (XRD). Results from the analysis are presented in Table 2-2 and sample locations are shown on the plot plan of the facility (Figure 2-5).

Table 2-2 X-Ray Diffraction Analyses

Piezometer	**Sample Depth (m)**	**Mineral Content by Percentage**						
		Quartz	Feldspar	Kaolinite	Illite	Smectite	Calcite	Dolomite
94-15C	2.44 - 2.59	53%	3%	1%	1%	1%	0%	41%
94-16A	0.91 - 1.22	49%	12%	1%	2%	1%	3%	32%
94-16A	2.03 - 2.44	68%	7%	1%	2%	1%	8%	13%
94-17A	1.37 - 1.68	81%	12%	3%	3%	1%	0%	0%
94-17A	1.83 - 2.13	85%	10%	1%	2%	1%	0%	1%
94-17A	3.05 - 3.20	57%	25%	2%	2%	1%	6%	7%
94-17A	3.96 - 4.27	67%	14%	2%	2%	0%	6%	8%
94-18A	2.74 - 2.90	66%	11%	3%	4%	1%	6%	8%
94-19A	1.83 - 2.13	58%	26%	3%	2%	1%	5%	5%
94-20A	2.44 - 2.60	69%	23%	3%	3%	1%	6%	10%

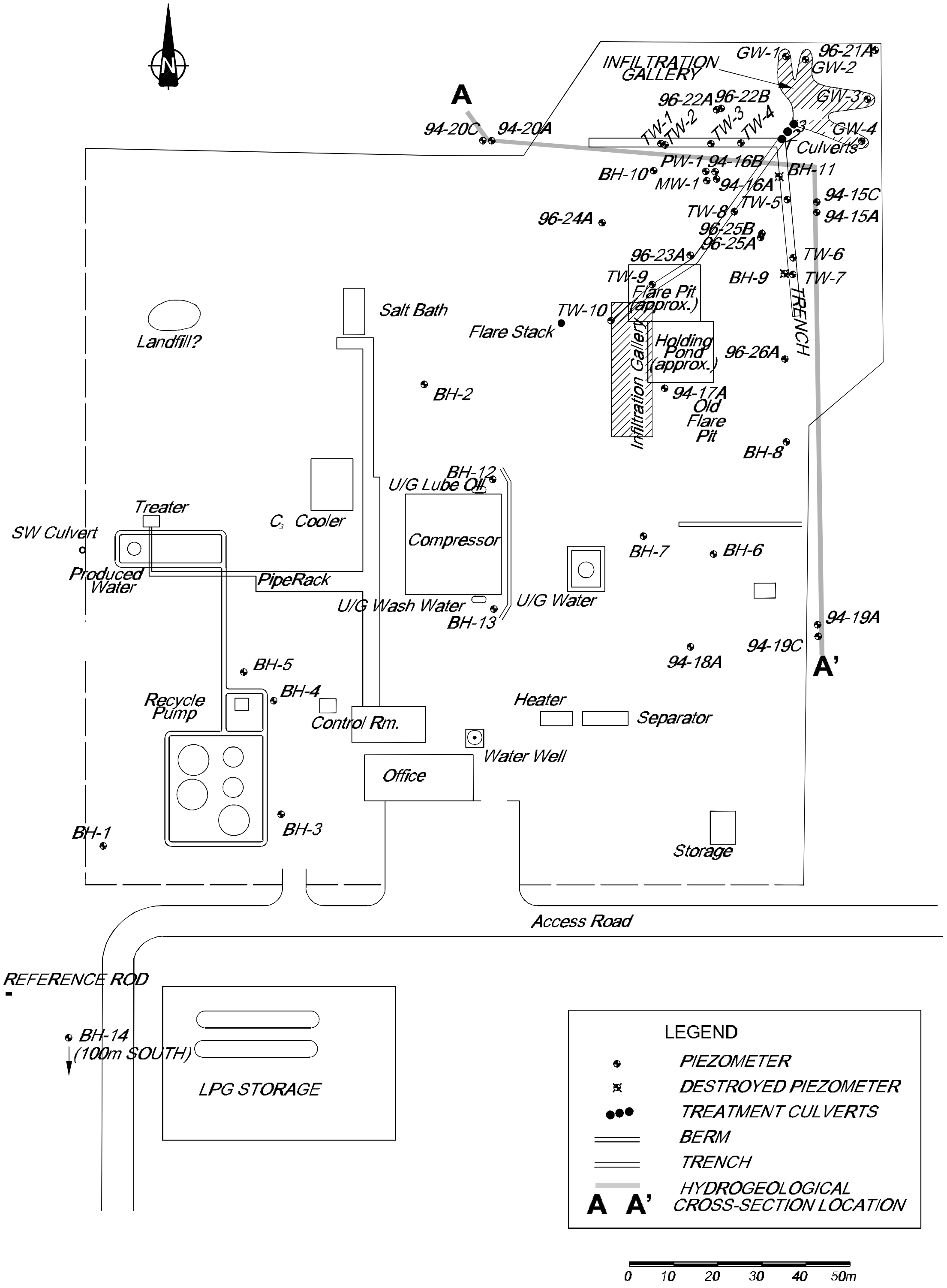


Figure 2-5 Site Plan of the East Garrington Gas Plant.

XRD results illustrate that the matrix of the cobble-rich unit is composed primarily of a clay sized fraction dominated by quartz and containing very few clay minerals. The contact between this unit and the more classical silty clay till strikes roughly northwest and cuts across the northeastern corner of the plant site. There is no distinct contact between the units, and evidence from drilling indicates the units grade into each other. An approximate contact has been established between the two units based on field observations, aerial photograph interpretation, and an electromagnetic (EM38) geophysical survey (Figure 2-6). This provisional contact trends roughly northwest across the site, is located just northeast of the flare stack, and is roughly defined by the 16 mS/m conductivity contour. Paleochannels within this unit have a profound influence on groundwater and surface water flow at the site, as observed during spring run-off.

Both the silty clay till and the cobble rich deposits, sometimes referred to as a cobble till in the logs, are underlain by a grey clay-rich sandy to silty basal till that contains abundant bedrock chips. This till, which may be up to 2.2 m thick, grades directly into the regolithic bedrock zone.

Much of the site was brought up to present grade during construction using a combination of local material such as re-worked till, material from nearby borrow pits, and pit run. Fill material was laid down atop old soil horizons and an organic rich wetland deposit. The thickness of these organic horizons, which are readily identified by their dark black to brown colour, can be as much as 0.4 m. In the area of the plant, the total thickness of all surficial deposits averages approximately 6 m. A hydrogeological cross-section of the plant, constructed approximately through the area where the *Trench and Gate* system was installed, is presented as Figure 2-7. The location of the *Trench and Gate* installation and the cross-section transect is shown in plan view on Figure 2-5.

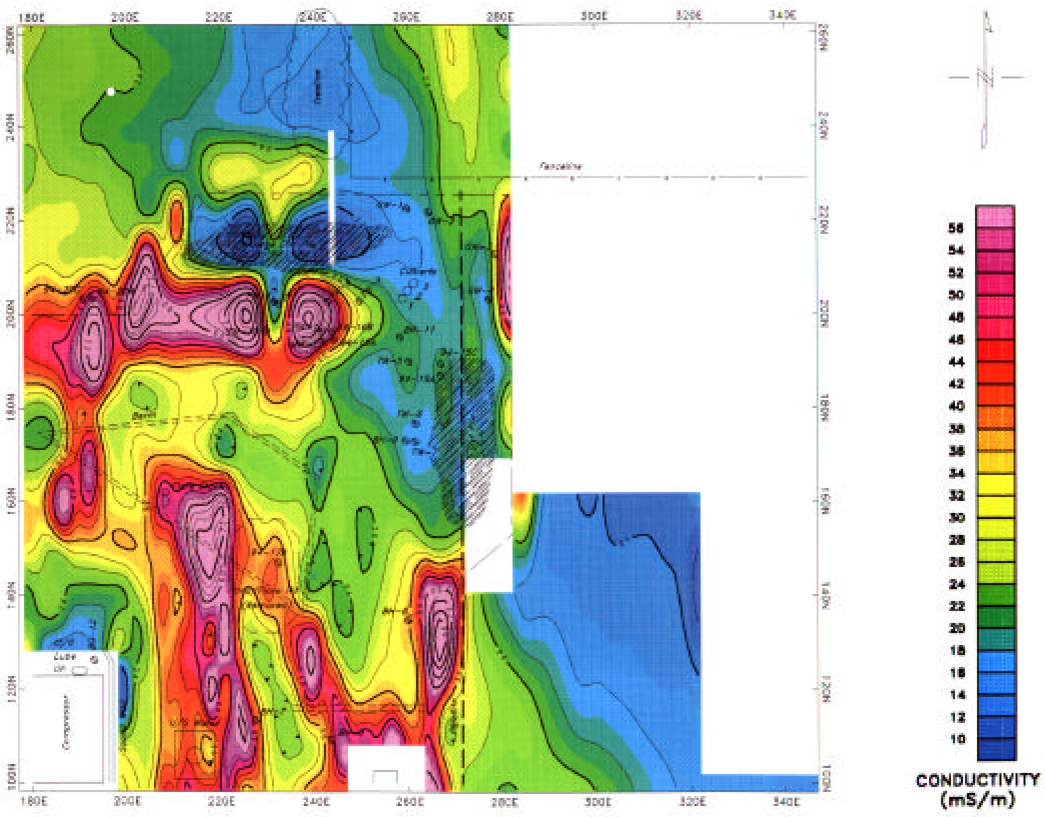


Figure 2-6 Electromagnetic (EM-38) Map of the Northeast Corner of the East Garrington Site.

2.4 GROUNDWATER MONITORING NETWORK

A total of 32 piezometers have been installed at the East Garrington site, including three wells completed in bedrock. All piezometers completed by O'Connor Associates (1992) are designated with a BH- prefix and installed in till. Piezometers completed by Komex International Ltd. are identified with A or B suffixes if installed in the first or second groundwater-bearing zones in till, or with a C if installed in bedrock. Other wells or sampling points are designated by the prefixes: CW (Culvert Well) for sampling points within the treatment gate; GW (Gallery Well) for wells installed in the reinfiltration gallery; TW (Trench Well) for wells installed within the trenches; PW (Pumping Well); and, MW (Monitoring Well) for the monitoring well associated with the pumping well.

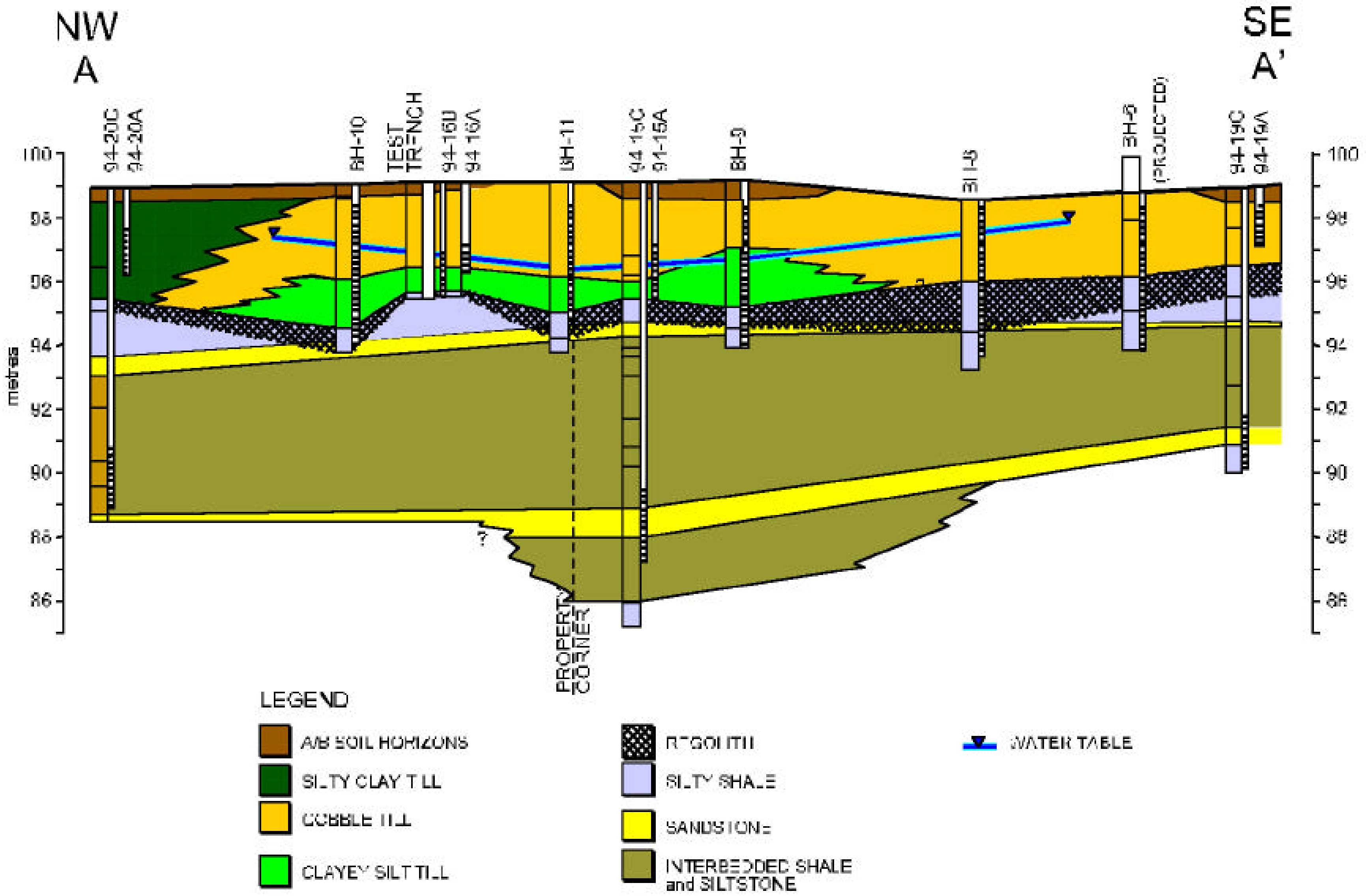


Figure 2-7 Hydrogeological Cross-Section A-A'.

A site map showing the location of piezometers is presented as Figure 2-5. Piezometers were first installed at the site in 1990 by O’Connor (1991). Subsequent installation programs were completed by Komex in 1994 and 1996. The purpose of these two programs was to further delineate groundwater impact discovered by O’Connor and to refine the understanding of groundwater flow patterns. Piezometers were constructed according to accepted hydrogeologic practices using bentonite seals to prevent annular leakage. Borehole logs and piezometer construction details are provided in Appendix I.

3. HYDRAULIC CONDUCTIVITY TESTING

Estimation of the bulk hydraulic conductivity (*K*) of the sediments was an essential first step in characterizing the site and subsequently in determining the expected flux for the treatment system. Hydraulic conductivity testing was carried out using several different methods as described in the following sections. Results from these tests were used to calculate a bulk hydraulic conductivity.

3.1 LABORATORY TESTS

Hydraulic conductivities were measured in the laboratory using falling head permeameters, and estimated from effective grain sizes after the method of Hazen (1911). Results from the permeameter laboratory tests are summarized in Table 3-1.

Table 3-1 Permeameter Hydraulic Conductivity Test Results

Geological Unit	**Silty Clay Tills**	**Cobble Unit**
Minimum *K* (m/s)	2.1×10^{-11}	2.4×10^{-9}
Maximum *K* (m/s)	2.4×10^{-9}	2.4×10^{-9}
Median *K* (m/s)	6.1×10^{-11}	2.4×10^{-9}
Mean *K* (m/s)	2.2×10^{-10}	2.4×10^{-9}
Standard Deviation	3.1×10^{-10}	-
Population (n)	3	1

Permeameter results were considered unacceptable as they were not in keeping with accepted values for these types of geological media. Lack of agreement was attributed to the small sample size tested, which failed to provide a representative field scale value.

Estimation of hydraulic conductivity from grain size was undertaken using Hazen's formula:

$$K = Cd_{10}^2 \qquad \textbf{Equation 3-1}$$

where:

- d_{10} is the effective grain size diameter in centimetres and is defined as the value where 10% of the particles are finer and 90% coarser by weight;
- C varies from 100 to 150 cm/s depending on the material; and,
- K is the hydraulic conductivity in cm/s.

Representative samples collected from the site yielded laboratory measured effective grain sizes of 0.02 and 0.008 cm for the cobble till and silty clay tills respectively. Substituting these values into the formula and using a value of 100 for C, yields hydraulic conductivities of 4×10^{-4} m/s for the cobble unit and 6×10^{-7} m/s for the till. These calculated values were more in keeping with expectations and were thus considered a reasonable first approximation of hydraulic conductivity.

3.2 PIEZOMETER TESTS

Hydraulic conductivity tests were conducted to determine *in-situ* hydraulic conductivity values on single piezometers (Freeze and Cherry, 1979). These tests were performed by measuring the static water level, removing water from the piezometer, and recording the rise in water level with time during recovery.

Water was removed from the piezometers, using either a bailer or Waterra tubing with an inertial foot valve, until the piezometer was dry or a significant drawdown was obtained. At that point, bailing was stopped and recovering groundwater levels were measured at selected time intervals using a standard hand-held electric water level sounder in the well.

Groundwater recovery level measurements and interpretation graphs are provided in Appendix II. In some cases the rate of groundwater recovery was very slow and, due to time constraints, groundwater recovery data were collected only for as long as was practical. In other cases, where a drawdown could not be achieved, piezometers were arbitrarily assigned a hydraulic conductivity of $>10^{-5}$ m/s (Table 1, Appendix III).

For “BH” series wells where borehole completion information was unknown, hydraulic conductivity calculations were made assuming the borehole diameter was 15 cm and screen lengths were from the base of the borehole to 1.0 m below ground level.

Water level recovery data were analyzed using the Bouwer-Rice (1976) method for unconfined aquifers and the Cooper *et al*. (1967) method for confined aquifers as described in the AQTESOLV for Windows User’s Guide (Geraghty & Miller, Inc., 1996).

Hydraulic conductivity estimates obtained using these methods are approximate due to the relatively small volume of water removed from the wellbore. Consequently, they are only representative of the zone within the immediate vicinity of the screened interval. Small variations in grain size and texture, or fracture density and aperture size, can greatly affect hydraulic conductivity values within zones of similar lithology. Therefore, these methods provides only an indication of the order of magnitude of the hydraulic conductivity.

In general, the part of the displacement curve that showed the greatest rate response was chosen as the basis of the *K* estimate, resulting in conservative (greater) values. However, the difference between conservative and non-conservative results rarely exceeded half an order of magnitude. During the initial phases of a *K* test, sand pack drainage may contribute water to the piezometer, resulting in an initial rapid rate of response. The data were qualitatively analyzed to ensure that the part of the curve chosen for the *K* estimate was not significantly influenced by sand pack drainage.

For confined aquifer test analyses (94-15C, 94-19C, and 94-20C), the results are presented as K derived from transmissivity (T). The T result was divided by the thickness (b) of the groundwater-bearing zone, as inferred from the borehole log, to obtain a value for K. Based on observations made during drilling, shale units are expected to have very low permeabilities and were accordingly assigned a hydraulic conductivity of $< 1.0 \times 10^{-9}$ m/s.

Hydraulic conductivity tests results varied considerably across the site. A summary of values and statistics for the various units is provided in Table 3-2.

Table 3-2 Summary of Drawdown-Derived Hydraulic Conductivities

Hydrogeological Unit	**Maximum *K*** (m/s)	**Minimum *K*** (m/s)	**Mean *K*** (m/s)	**Median *K*** (m/s)	**Standard Deviation**	**Population** (n)
Clayey Silt Till	1.7×10^{-5}	9.9×10^{-9}	2.9×10^{-6}	9.0×10^{-8}	6.0×10^{-6}	8
Silty Clay Till	5.3×10^{-7}	5.6×10^{-10}	1.4×10^{-7}	1.3×10^{-7}	1.6×10^{-7}	11
Cobble Till	3.3×10^{-6}	2.5×10^{-9}	5.6×10^{-7}	8.9×10^{-8}	9.9×10^{-7}	11
Bedrock	5.2×10^{-5}	4.7×10^{-8}	2.1×10^{-5}	1.1×10^{-5}	2.7×10^{-5}	3

Inspection of the table reveals that there are a wide range of hydraulic conductivity values for each unit. This likely reflects site heterogeneity and the variable contribution of fractures and sand lenses to permeability.

3.3 EXPERIMENTAL TRENCH HYDRAULIC CONDUCTIVITY TESTING

3.3.1 Test Design

Given the wide range of values from the above tests, and since the results for the tests represent very local conditions only, a trench pumping test was designed to test a larger volume over a longer time. The test trench was completed in the area where the remediation system was to be installed adjacent to piezometer nest 16 (Figure 2-5). Unfortunately, the trench pumping test had to be conducted during the winter of 1995 in preparation for designing the *Trench and Gate* system which was to be installed during the approaching field season. During the winter months the water table dropped below the cobble-rich till into the underlying clayey silt till. As a result, the hydraulic conductivity of the more permeable unit could not be determined.

Design parameters for the trench pumping test were initially determined using a drawdown test. Groundwater was pumped out of the trench rapidly using a submersible pump installed in Pumping Well 1 (PW-1) and the trench was left to recover. Water levels in the trench (MW-1) and nearby monitoring wells (16B) were recorded using pressure transducers and data loggers. The layout of the trench and piezometers is shown in Figure 3-1 and a schematic of the drawdown within the trench and adjacent piezometers is presented as Figure 3-2. The initial results, which showed a 70% recovery in the trench over a four day period, were evaluated and used to determine the optimum pumping parameters for a second constant head drawdown test.

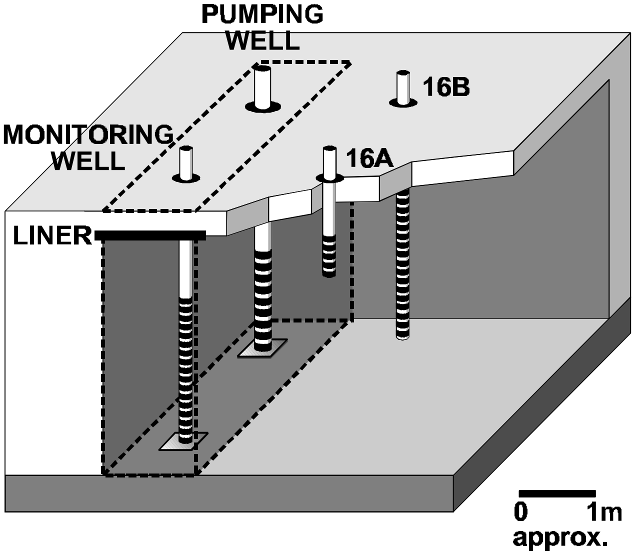


Figure 3-1 Schematic of Trench Pumping Test Layout.

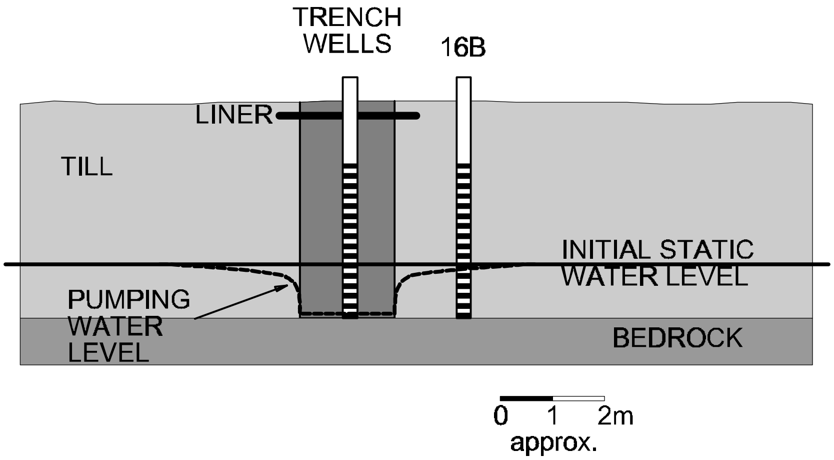


Figure 3-2 Drawdown Within the Trench and Piezometers During the Trench Pumping Test.

During the second test, the water level in the trench was depressed approximately 0.7 m below the static level, and an attempt was made to maintain this drawdown for five days using a displacement pump. The pump was then shut off and the water level in the trench allowed to recover. Piezometric levels in the trench and nearby monitoring wells were again recorded using pressure transducers and data loggers. Interpretation of the recovery data was hampered by:

- not having a second monitoring well closer to the trench as the drawdown in 16B was limited;
- not pumping out the trench fast enough;
- temporary failure of the pump on the third day;
- imprecise pump flux monitoring; and,
- uncertainty regarding seepage face development or skin effects within the trench.

3.3.2 Test Results

Results of the second pumping test for the monitoring well (MW-1) installed in the trench, and adjacent piezometer 16B, located 1.8 m away from the edge of the trench, are presented as Figure 3-3 and Figure 3-4, respectively. Inspection of the graphs reveals that despite having pumped the trench essentially continuously for five days, only twelve centimetres of drawdown was induced in the adjacent monitoring well. This is indicative of the relatively low permeability of clayey silt till overlying the bedrock.

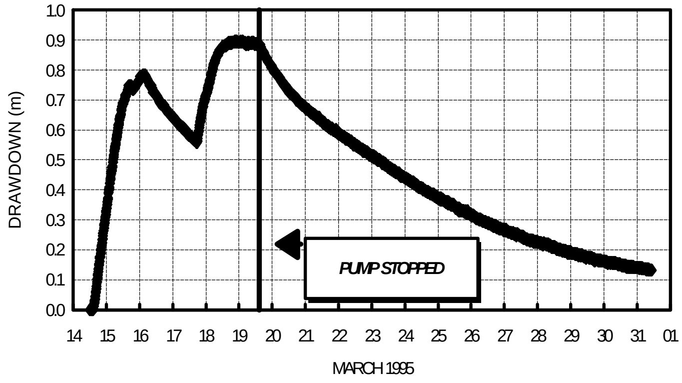


Figure 3-3 Drawdown vs. Time For Monitoring Well MW-1.

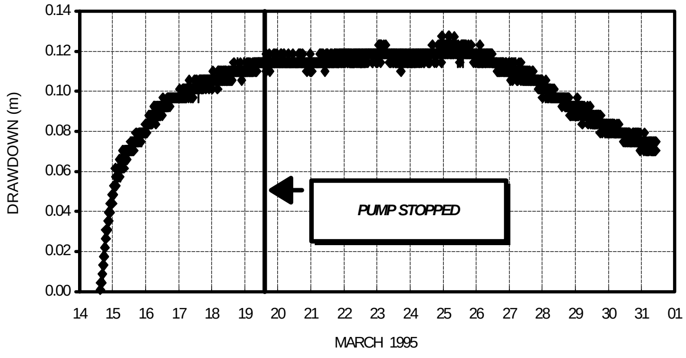


Figure 3-4 Drawdown vs. Time for Piezometer 16B.

Drawdown data for the trench pumping test were interpreted using a number of graphical and calculation-based approaches (Bowles and Bentley, 1995). Two of these approaches use derivations based on Darcy's (1856) equation to estimate the hydraulic conductivity of the sediments around the trench and are presented below. The two approaches are based on a number of simplifying assumptions including:

1. the aquifer being tested is unconfined, as well as being essentially infinite, homogeneous and isotropic over the area influenced by the test;
2. prior to the commencement of pumping, the water table is horizontal over the area influenced by the test;
3. the monitoring well (16B) and the trench, both fully penetrate the entire thickness of the aquifer;
4. the underlying bedrock contact is impermeable and horizontal; and,
5. well losses are negligible.

Details of the two approaches are described below.

Approach 1

In the first approach, early time recovery data is used to approximate a flow rate into the trench. Water levels in the trench and piezometer are then used to calculate hydraulic conductivity. During recovery, flow into the trench (Q) is equal to the rate of change in the volume of water in the trench. Q may therefore be calculated from trench length, trench width, the change in the height of the water with respect to time and drainable pore space in the trench, as follows:

$$Q = n_d \frac{\partial h}{\partial t} lw$$ **Equation 3-2**

where:

Q = inflow rate (m^3/s);

n_d = drainable porosity (specific yield, unitless);

l = trench length (m);

w = trench width (m); and,

$\frac{\partial h}{\partial t}$ = the change in head with respect to time in the trench.

The derivative term can be approximated from the slope of the drawdown vs. time curve in Figure 3-5 as 1.7 x 10^{-6} m/s. This slope is taken from the early part of the recovery data, and hence the corresponding Q is the flow into the trench immediately after the pump is turned off.

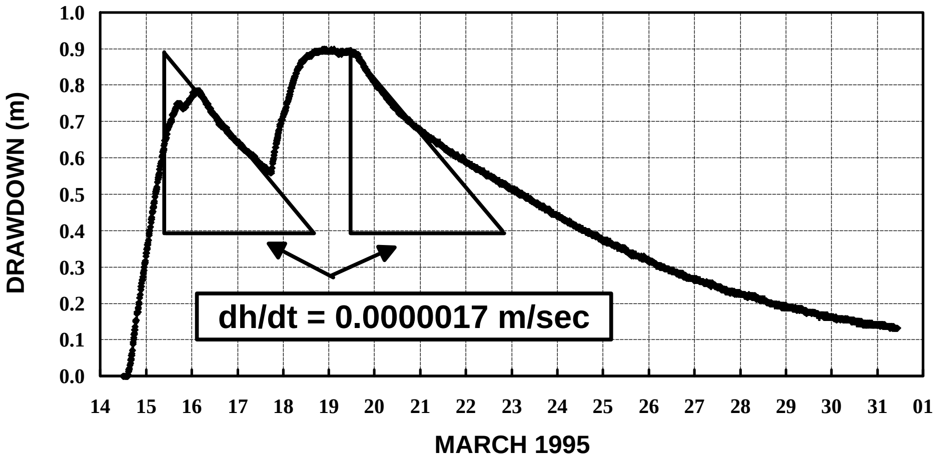


Figure 3-5 Drawdown vs. Time for Monitoring Well MW-1.

If Q^* is defined as the volumetric flow into the trench, per unit length of trench perimeter, it can be written as:

$$Q^* = \frac{Q}{2(l + w)}$$ **Equation 3-3**

The Darcy (1856) equation may be applied to flow towards a unit length of trench as:

$$Q^* = Kih = Kh\frac{\P h}{\P l} \qquad \textbf{Equation 3-4}$$

where l is the distance outwards from the trench face and h is the saturated thickness of the aquifer at distance l. Integrating between l = 0 (trench face), and $l = L$ (piezometer 16B):

$$\int_{0}^{L} Q^* \P l = K\int_{h_T}^{h_P} h \P h \qquad \textbf{Equation 3-5}$$

gives:

$$Q^* L = \frac{K}{2}\left(h_P^2 - h_T^2\right) \qquad \textbf{Equation 3-6}$$

which may be rewritten as:

$$Q^* = \frac{K}{2L}\left(h_P^2 - h_T^2\right) \qquad \textbf{Equation 3-7}$$

where:

K = hydraulic conductivity (m/s);

L = distance between piezometer and trench face (m);

h_P = height (above bedrock) of water inside monitoring piezometer 16B at the time the pump was shut off (m); and,

h_T = height (above bedrock) of water inside the trench at the time the pump was shut off (m).

This approach assumes that infiltration through each trench face may be treated as if it were perpendicular flow into an infinitely long trench. As a result, it assumes no significant flow input from trench corners.

Combining equations 3-2, 3-3, and 3-7 and rearranging to solve for K gives:

$$K = n_d\, L\frac{lw}{(l+w)}\frac{1}{\left(h_P^2 - h_T^2\right)}\frac{\P h}{\P t} \qquad \textbf{Equation 3-8}$$

Substituting measured and assumed values of:

n_d = 0.24 (Domenico and Schwartz, 1990);

l = 3.6 m;

w = 0.9 m;

$\frac{\partial h}{\partial t}$ = 1.7×10^{-6} m/s;

L = 1.2 m;

h_P = 0.805 m; and,

h_T = 0.135 m;

into Equation 3-8 yields a K of 5.6×10^{-7} m/s, a reasonable value as compared to known values for similar types of sediments.

Approach 2

The second approach used to estimate K, approximates flux into the trench as steady state radial flow towards a large diameter well. This approach is based on the assumption that the system had reached a quasi steady state (*i.e.*, constant drawdown) towards the end of the pumping portion of the test. The assumption is supported by the observation that drawdown in piezometer 16B was changing little at the time the pump was shut off (see Figure 3-4). Since the pumping rate for the test could only be measured manually and infrequently, a pumping rate has to be inferred. During the late stages of the pumping part of the test, the drawdown in the trench is constant, and hence the inflow into the trench, Q, is equal to the pumping rate. If it is assumed that there is only a gradual change in Q after pumping is stopped, the volume of Q calculated from early time recovery data in Equation 3-2 may be used as an approximation for the steady state pumping rate.

Taking the Darcy (1856) equation, transposed into cylindrical coordinates, for radial flow towards a well, at a radius r, where the saturated aquifer thickness is h:

$$\frac{\partial \quad h}{\partial \quad t} \qquad \textbf{Equation 3-9}$$

and integrating between r_T (effective radius of well), and r_P (radial distance to piezometer):

$$Q\int_{r_T}^{r_P}\frac{\P r}{r} = 2pK\int_{h_T}^{h_P} h\P h$$ **Equation 3-10**

gives:

$$Qln(r_P\ /\ r_T) = pK(h_P^2 - h_T^2)$$ **Equation 3-11**

which may be re-written as:

$$K = \frac{Qln\left(r_P/r_T\right)}{p\left(h_P^2 - h_T^2\right)}$$ **Equation 3-12**

where:

Q = total volumetric discharge (m^3/s);

K = hydraulic conductivity (m/s);

h_P = height (above bedrock) of water inside monitoring piezometer 16B at the time the pump was shut off (m);

h_T = height (above bedrock) of water inside the trench at the time the pump was shut off (m);

r_P = the distance (m) between the centre of the trench (pumping well) and piezometer 16B (see below); and,

r_T = the effective radius (m) of the pumping well (trench).

Since the pumping trench was not circular, r_T was approximated by calculating an equivalent well radius based on a well with a circumference equal to the perimeter around the trench or

$$r_T = \frac{l + w}{p}$$ **Equation 3-13**

where l and w are the length and width of the trench, respectively, as previously defined. L is the distance from the trench face to the monitoring well, as previously defined, and therefore the radial distance to the piezometer r_P is given by

$$r_P = r_T + L$$ **Equation 3-14**

Using the previously defined values in Equation 3-12, calculating r_T and r_P from equations 3-13 and 3-14, and Q from Equation 3-2, yields a K of 4.1 x 10^{-7} m/s. This value compares favourably with the one calculated from Approach 1 and is also considered to be in keeping with the expected bulk hydraulic conductivity of the till tested during the trench pumping.

Other data analyses (Bowles and Bentley, 1995) yielded somewhat larger bulk hydraulic conductivity estimates ranging from 9 x 10^{-6} to 6 x 10^{-5} m/s. These values were somewhat greater than expected as compared with other methods of estimation.

Additional attempts might be made to analyze the data using other analytical methods and numerical flow modelling. No further attempt was made, however, the data obtained from the test and other methods were considered sufficiently accurate for estimating the expected flux and designing the *Trench and Gate* system. At the time of the test, it was not understood how much greater the hydraulic conductivity of the cobble till was than the underlying clayey silt till. This resulted in a significant under estimation of the expected influx of water into the trench during construction (see Section 5.1.3).

3.4 PREDICTING TREATMENT FLUXES FROM BULK HYDRAULIC CONDUCTIVITIES

Estimates of hydraulic conductivity varied depending on the method used but in general, and as would be expected, estimates increased when large volumes were tested. Using the largest (worst case) K value as estimated from the trench pumping test, an approximation of the expected flux (Q) through the *Trench and Gate* system was made using the following formula:

$$Q = KiA \qquad \textbf{Equation 3-15}$$

where:

A = the area (l x h) = 248 m^2 is calculated from the length 62 m (linear distance between two ends of the funnel) multiplied by the saturated thickness - h (approximately 4 m);

i = the average horizontal hydraulic gradient (see Section 5.2) = 0.035; and,

K = 6.0×10^{-5} m/s.

This calculation yields a maximum expected flux of 5.2×10^{-4} m^3/s or approximately 31 litres per minute.

4. HYDROGEOLOGY

4.1 REGIONAL HYDROGEOLOGY

The regional hydrogeological setting of the plant is shown in Figure 4-1 and the legend for this map and subsequent cross-sections is included as Figure 4-2. Cross-sections through the East Garrington area are presented as Figure 4-3 and Figure 4-4 and the cross section locations are shown on Figure 4-1. The subcropping Paskapoo Formation bedrock in this area has been assigned an expected yield in the range of 2 to 8 L/s. This is presumably due to fracture porosity as most of the bedrock is composed of shale with limited matrix porosity. It is also in general agreement with the yield from the on-site water well used for domestic supply.

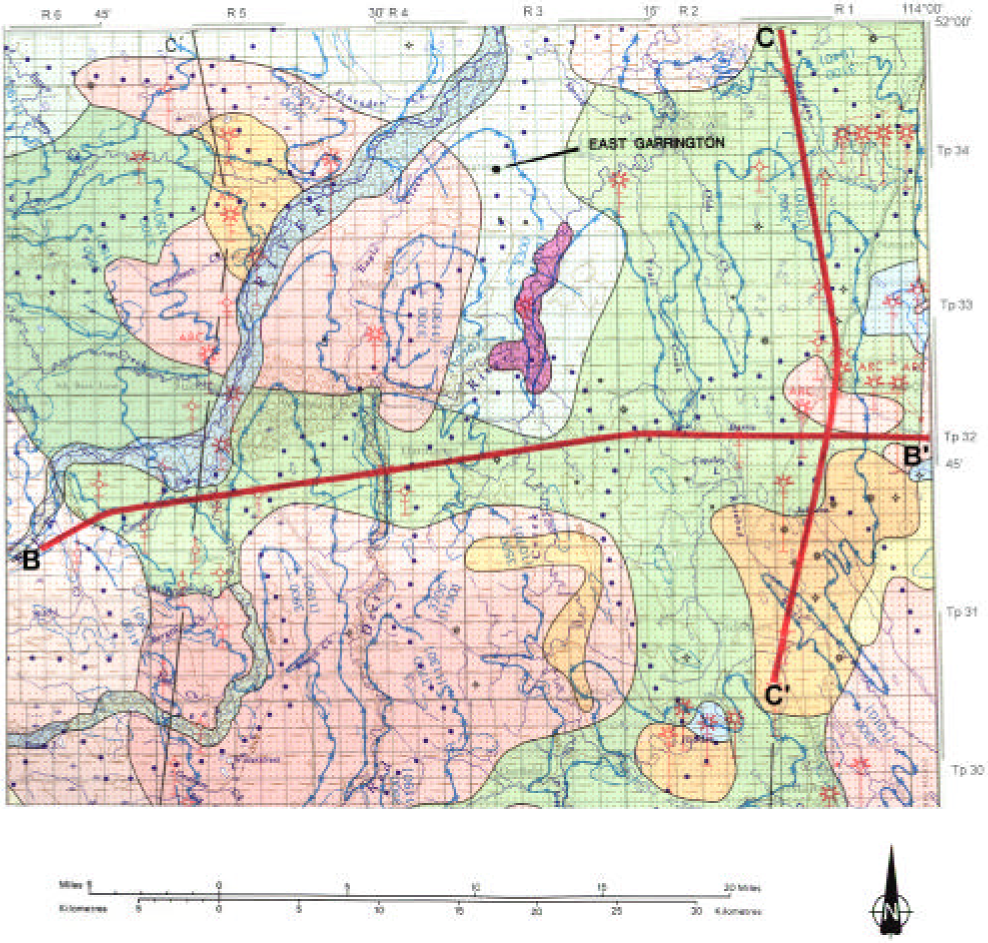


Figure 4-1 Regional Hydrogeological Map Showing Locations of Hydrogeological Cross-Sections (Ozoray and Barnes, 1977).

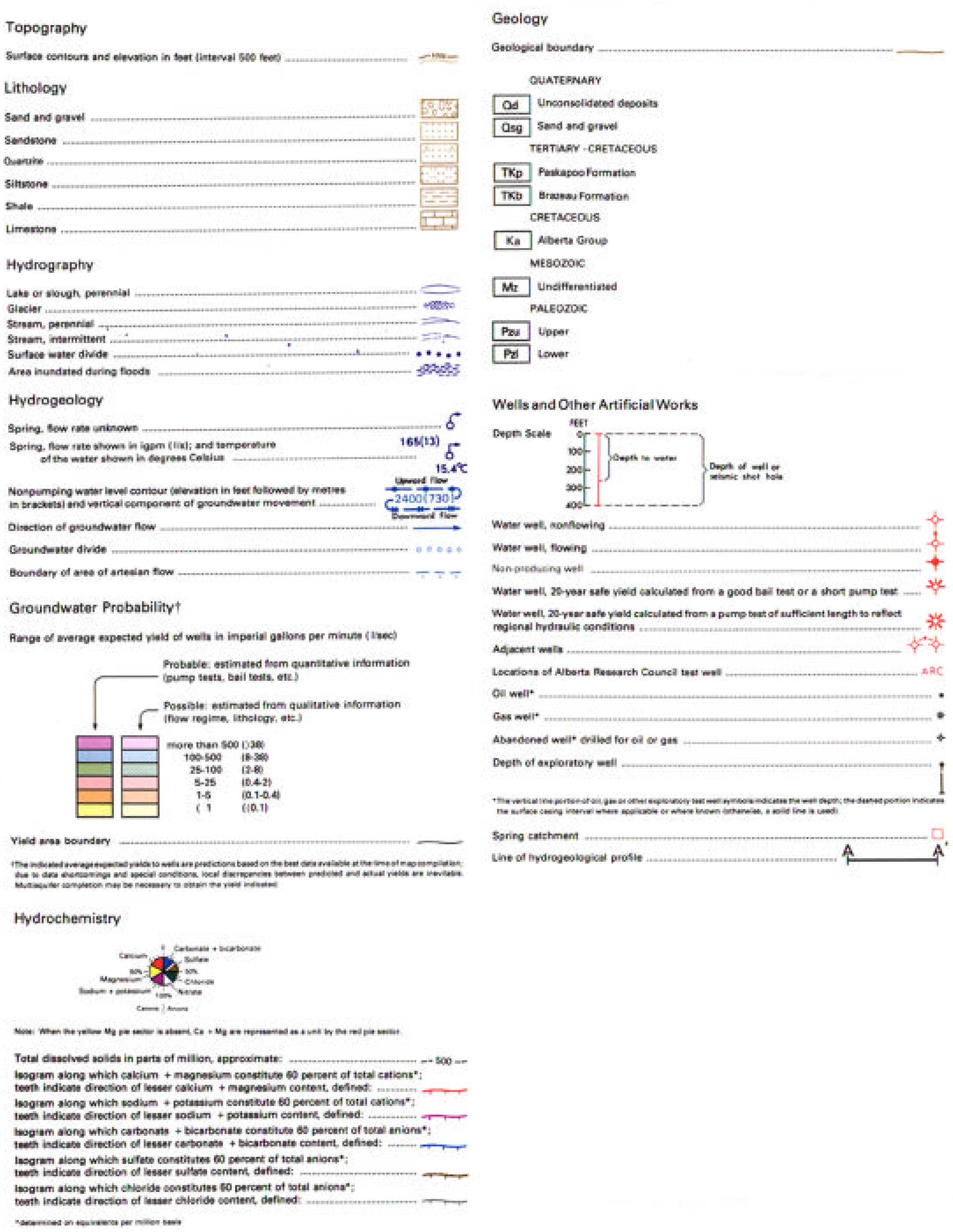
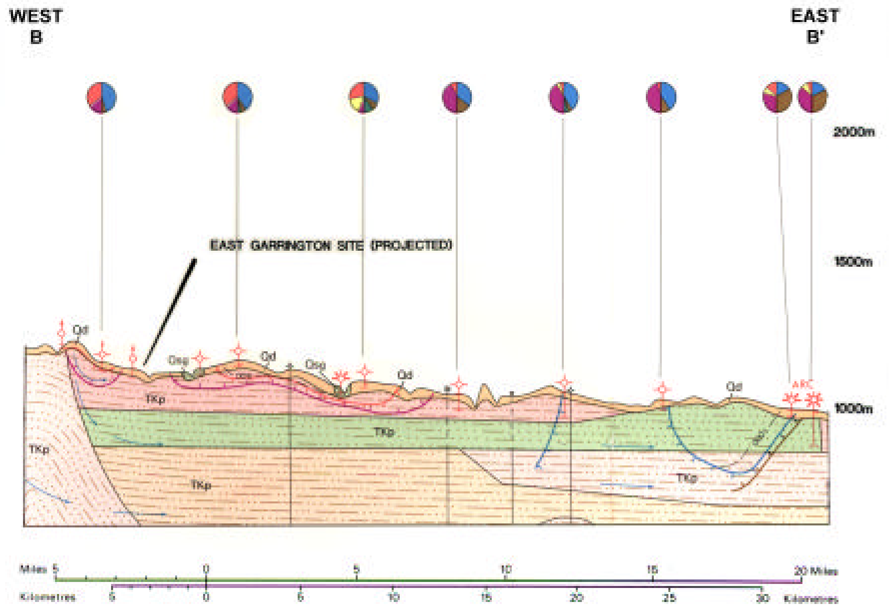
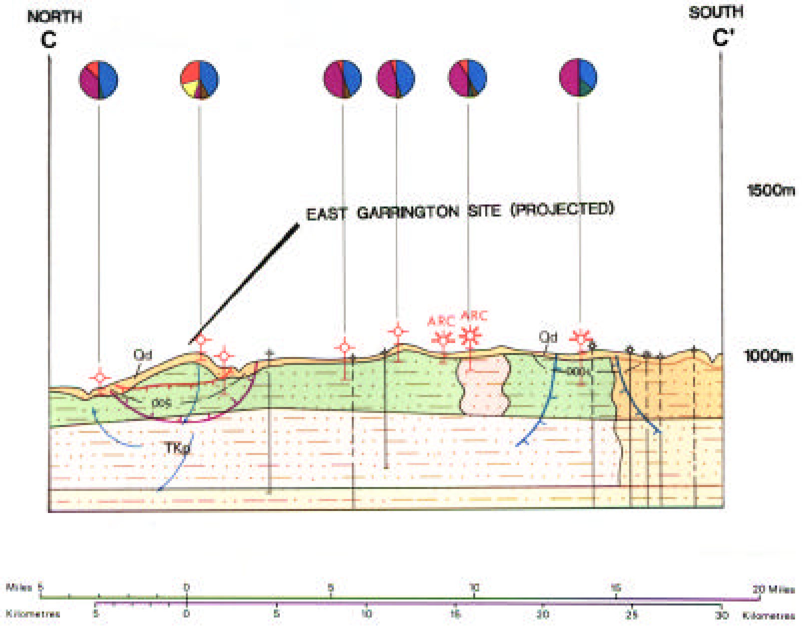


Figure 4-2 **Hydrogeological Legend to Accompany Regional Hydrogeological Maps and Cross-Sections (Ozoray and Barnes, 1977).**



Vertical exaggeration of the hydrogeological profiles is approximately 21X.

Figure 4-3 Regional Hydrogeological Cross-Section B-B'(Ozoray and Barnes, 1977).



Vertical exaggeration of the hydrogeological profiles is approximately 21X.

Figure 4-4 Regional Hydrogeological Cross-Section C-C' (Ozoray and Barnes, 1977).

Regional groundwater flow directions are towards the north or northeast and vertical groundwater gradients can be either upwards or downwards, which is presumably dependent on temporal fluctuations in recharge. Regionally, surficial deposits, especially those along river valleys, may constitute usable supplies of groundwater, but locally they do not. In the East Garrington area, Ozoray and Barnes (1977) list the predominant hydrochemical groundwater type as being one where bicarbonate and carbonate make up more than 60% of the total anions and cations are dominated by calcium and magnesium.

Hydrogeological characteristics of deeper bedrock units were not considered relevant to this study as they were unlikely to influence local recharge/discharge conditions, be used as a source of drinking water, or be otherwise relevant to the contamination scenario at the East Garrington Plant.

4.2 SITE HYDROGEOLOGY

4.2.1 Groundwater Flow

Groundwater flow directions across the site have consistently been toward the northeast since monitoring was initiated (see Section 6.1.3). Flow within the site is controlled by the generally gently north-eastward dipping topography. Recharge to the uppermost groundwater-bearing zone occurs as a result of precipitation on-site and more importantly via recharge from the wetland southwest of the facility (Figure 2-3). Water levels in the wetland (referred to as the Reference Rod) were routinely collected with potentiometric elevations from the piezometers (Appendix, Table 1) to determine gradients across the site.

Piezometers could not be installed down-gradient of the plant, but topographic elevations and observations made during periods of high water table elevations suggest that at least a portion of groundwater flow discharges into the southeast trending surface paleodrainage channel(s) located just northeast of the site. From there, surface water flow carries it away towards the southeast. Some, or all, of the groundwater flow may also continue on towards the northeast. Uncertainty regarding flow directions is compounded by the local interrelation between surface water, groundwater, and the presence of a surface water divide that appears to run through, or close to, the site (Figure 4-1).

Horizontal gradients are seasonally dependent, steepen during the summer, and vary from approximately 0.02 to 0.04 for the central part of the facility. They are substantially flatter in the northeast corner of the facility where the higher *K* sediments are located. Based on an average *K* value for the site of approximately 5.0 x 10^{-7} m/s, an average summer gradient (*i*) of 0.035 and an expected effective porosity (n_e) of 0.2 (DeMarsily, 1986) the average linear groundwater flow velocity (v) for the site as calculated from the formula:

$$v = \frac{Ki}{n_e}$$ **Equation 4-1**

is 8.7 x 10^{-8} m/s or approximately 5 m per year.

4.2.2 Groundwater Type

The major ion water chemistry and mineralization of groundwater samples collected on site is presented in Table 3 of Appendix III and has been characterized on an expanded Durov diagram (Figure 4-5).

The seven different groundwater types present on site can be grouped together into three major classes as detailed below:

1. Ca:HCO_3+CO_3, Ca-Mg:HCO_3+CO_3, Ca-Na:HCO_3+CO_3, and Ca-Mg-Na:HCO_3+CO_3. These four hydrochemical types represent background (*i.e.*, recently recharged) conditions with most groundwaters belonging to the Ca-Mg:HCO_3+CO_3 hydrochemical type. This group also includes the hydrochemical water type of the surface water from the wetland (Reference Rod) southwest of the facility. This is indirect evidence to support the assumption that the wetland controls recharge to the uppermost groundwater-bearing zone in the facility.

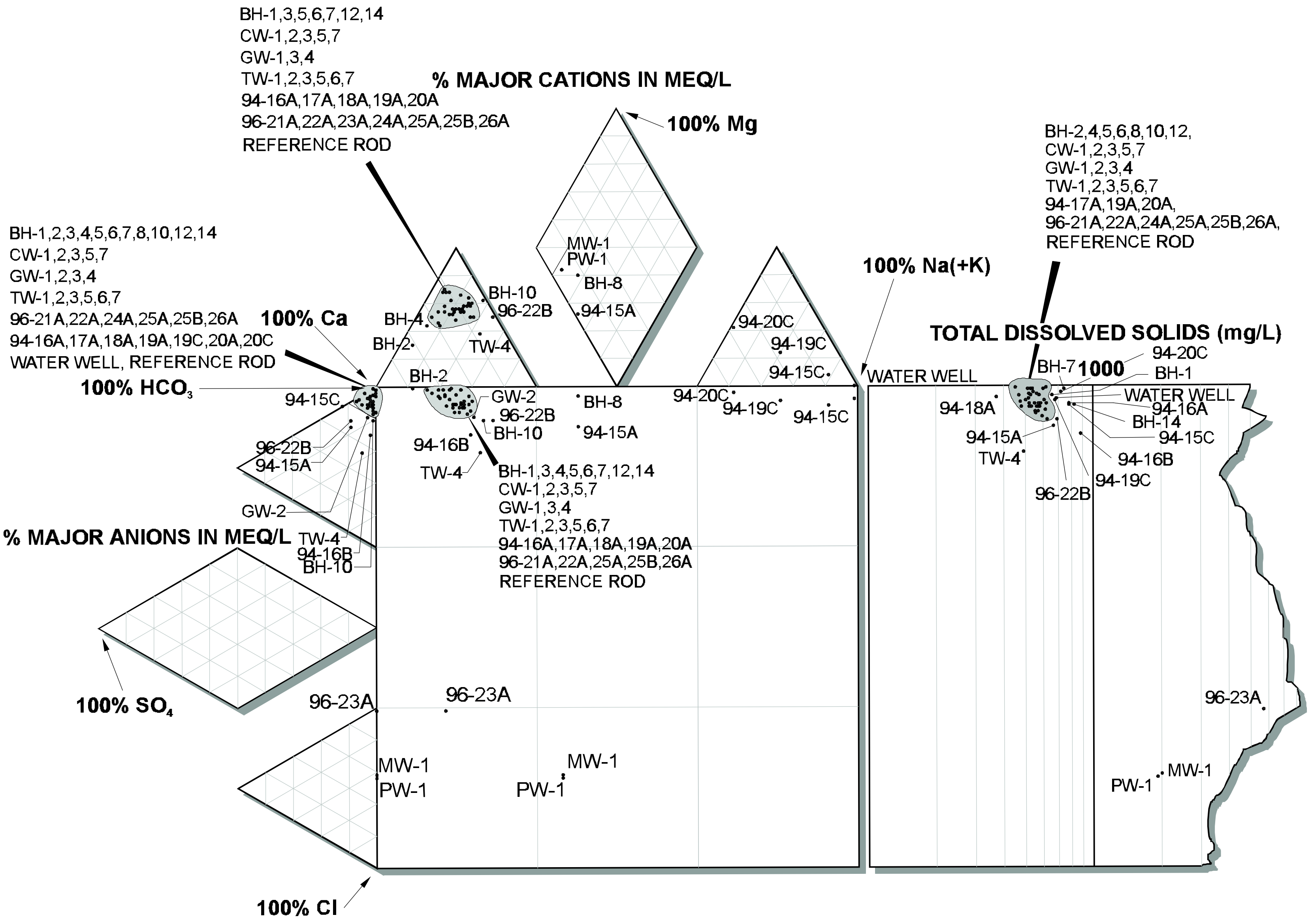


Figure 4-5 Expanded Durov Diagram.

2. Na:HCO_3+CO_3 and Na-Ca-Mg: HCO_3+CO_3. These groundwater types represent bedrock conditions in the shallow bedrock piezometers and the facility water well. The predominance of the Na cation is due to natural softening of the groundwater.
3. Ca-Mg-Cl:HCO_3+CO_3. Unlike the other water types present on the property, this hydrochemical type contains appreciable chloride ion concentrations indicative of contamination by produced water. Only three piezometers (96-23A, MW-1, and PW-1) yield groundwater belonging to this hydrochemical type.

It is noteworthy that piezometers MW-1 and PW-1 show elevated chloride concentrations as compared to 94-16A and 94-16B which are located just a few metres distant. This observation suggests that excavation and replacement by higher permeability material and/or pumping of the test trench produced a preferential pathway for the transport of chloride enriched water. These two wells are also located closer to the bull's eye of an electromagnetic high delineated during the geophysical survey (Figure 2-6).

4.3 CONTAMINANT HYDROGEOLOGY

4.3.1 Contaminant Sources, Types, and Distribution

Four major sources of groundwater contamination have been identified at the plant (Figure 2-5). These include:

1. product spills in the tank farm;
2. condensate and produced water overflows from the underground water storage tank area;
3. overflows from an underground storage tank containing used lubricating oil; and,

4. dissolved phase hydrocarbons leaching from an abandoned flare pit and pond.

Measurable LNAPL accumulations, which generally do not exceed one centimetre in thickness, are only present in monitoring wells immediately adjacent to the tank farm (BH-3, -4, and -5) and the underground lubricating oil storage tank (BH-12).

The highest concentrations of dissolved phase hydrocarbons (Appendix III, Table 4) have been measured in piezometer BH-7 (10 mg/L total BTEX) and piezometer BH-4 which yielded volatile (C_6 to C_{11}) and semi-volatile (C_{12} to C_{22}) total purgeable hydrocarbon concentrations of 11 and 187 mg/L, respectively. However, the result from piezometer BH-4 represents a single condensate spill and is not representative of the usual conditions.

Based on data collected, it appears that at least two distinct plumes are present in the northeast corner of the site. The first plume originates from the underground water storage tank and eastward flowing surface spills. The plume manifests itself as high dissolved hydrocarbon concentrations in piezometers BH-6, BH-7, and possibly 96-26A. Interestingly, there is only one historical BTEX detection in piezometer BH-8 where the plume would be expected. The infrequent detections may be attributed to the location of BH-8 in a local depression focused recharge centre where surface water frequently accumulates. This centre possibly recharges the well with fresh unimpacted water.

The second plume appears to be migrating from the abandoned flare pit and areas of associated soil contamination. This is most obvious in the dissolved hydrocarbon results from piezometer 96-23A. Other sources such as the tank farm may also be contributing to this latter plume, but there is insufficient data to quantify the potential input. Cyclical temporal variations in dissolved hydrocarbon content, thought to be associated with seasonal changes in water table variations, are not evident in the long term data. The apparently random variation in BTEX content is therefore attributed to contaminant transport by pulses, possibly caused by precipitation events.

4.3.2 Contaminant Behaviour in Groundwater

Contaminants of concern at the East Garrington site are primarily hydrocarbons. The mobility of these contaminants is dependent on the hydrogeologic environment and the physiochemical characteristics of the hydrocarbons. Monocyclic aromatic compounds such as benzene, toluene, ethylbenzene, and o-, m-, p-xylenes (BTEX) are among the most water soluble compounds found in petroleum products such as condensate. In areas of free product accumulation, some of the hydrocarbons will be dissolved into the aqueous phase according to their respective partitioning coefficients. Aqueous solubilities of specific compounds will vary with temperature, ionic strength, the presence of other hydrocarbons and the amount of organic carbon in bedrock. BTEX solubilities as well as other physical and chemical properties are provided in Table 4-1.

Table 4-1 Physical and Chemical Properties of BTEX Compounds

Compound	**Formula**	**Formula Weight** (g/mol)	**Specific Density** (20/4°C)	**Vapour Pressure** (mm Hg @ 20-25°C)	**Water Solubility** (mg/L at 20-25°C)	**log K_{ow}**	**log K_{oc}**	**Henry's Law Constant (unitless)**
Benzene	C_6H_6	78.11	0.877	76	1,780	2.1	1.9	0.224
Toluene	C_7H_8	92.14	0.867	22	515	2.6	2.1	0.274
Ethyl-benzene	C_8H_{10}	106.17	0.867	7	152	3.1	2.2	0.270
Xylenes	C_8H_{10}	106.17	≈0.880	≈8	≈180	≈3	≈2	0.245

From Montgomery and Welkom (1989).

As a result of the processes of advection, dispersion, diffusion, and retardation, contaminants will move at different rates. Physical and chemical data illustrate that, benzene will be less retarded than other BTEX compounds in equivalent hydrogeologic environments. Because it will be transported the greatest distance, and is a known human carcinogen, benzene is considered the most appropriate indicator of hydrocarbon contamination for this study. Condensate from the East Garrington plant contains a large proportion of benzene, thus confirming its suitability. Finally, it appears particularly appropriate as sampling down-gradient of contaminant sources yields significant benzene concentrations.

Attenuation of dissolved hydrocarbons can occur by destructive or non-destructive processes (Buscheck *et al.*, 1996). Non destructive attenuation mechanisms include dispersion, diffusion, dilution by recharge, and sorption. Destructive attenuation mechanisms include chemical and biological mass loss processes. The latter is considered an effective remediation tool. At the East Garrington site, attenuation via biodegradation was deemed particularly attractive because of its simplicity and the limited need for artificial intervention.

Under aerobic conditions, unacclimated aqueous biodegradation half lives for benzene have been estimated to range between 5 and 16 days. However, under unacclimated anaerobic conditions, estimated half-lives range from 16 weeks to 24 months (Howard *et al.*, 1991). The rapid biodegradation rate for benzene and other hydrocarbons under aerobic conditions was why biosparging was chosen as the optimum remediation technology for use in the gates.

Aerobic biodegradation at the East Garrington site is assumed to occur under the generalized formula for the degradation of benzene as presented below.

AEROBIC
BIODEGRADATION

$$C_6H_6 + 7.5\ 0_2 \longrightarrow 6CO_2 + 3H_2O$$

$$\textit{Benzene} + \textit{Dissolved Oxygen} \xrightarrow[\textit{bacteria}]{} \textit{Carbon Dioxide} + \textit{Water}$$

5. *TRENCH AND GATE*

5.1 HYDRAULICS AND DESIGN

5.1.1 Theory and Conceptual Design

Modification of the Funnel and Gate system to create the *Trench and Gate* system, is based on the concept of focusing groundwater flow through media of comparatively higher hydraulic conductivity (Bowles *et al.*, 1995 and Bowles *et al.*, 1997). Just as groundwater flow through a highly permeable lens of sand can be significantly more than in a surrounding clayey till (Figure 5-1), so, too, can the trench and infiltration gallery focus flow in the *Trench and Gate* system. Thus, the Funnel and Gate system was redesigned to take advantage of this fundamental principle.

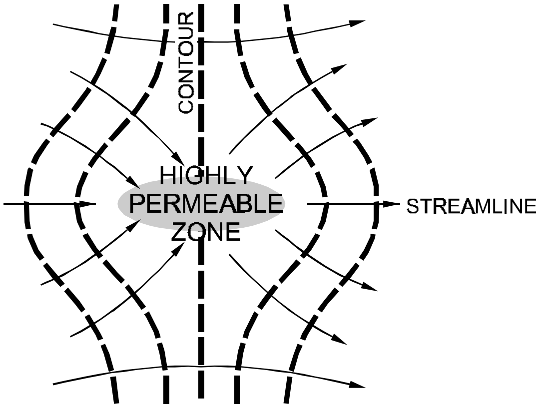


Figure 5-1 Effect of High Permeability Zone on Groundwater Flow (after Bear, 1979).

A schematic of the original concept for the *Trench and Gate* system is provided as Figure 5-2. The *Trench and Gate* system was designed as an in-situ method for treating hydrocarbon contaminated groundwater in low hydraulic conductivity glacial sediments. The system is composed of a cut-off trench excavated in till. The original design called for anchoring the trench into shallow, relatively impermeable bedrock or other suitably impermeable material, such as deeper unweathered and unfractured tills. The down-gradient side, the top, and the base of the trench are sealed with a synthetic liner, and the trench is backfilled with a layered, highly permeable aggregate (gravel or drain rock). The aggregate is required to encourage drainage and prevent groundwater mounding along the walls of the trench. Slotted PVC is added to the trench to act as a preferential flow path to reduce fluid potential losses due to friction and tortuosity. Two such trenches are constructed at an angle to each other and hydraulically down-gradient of the contamination.

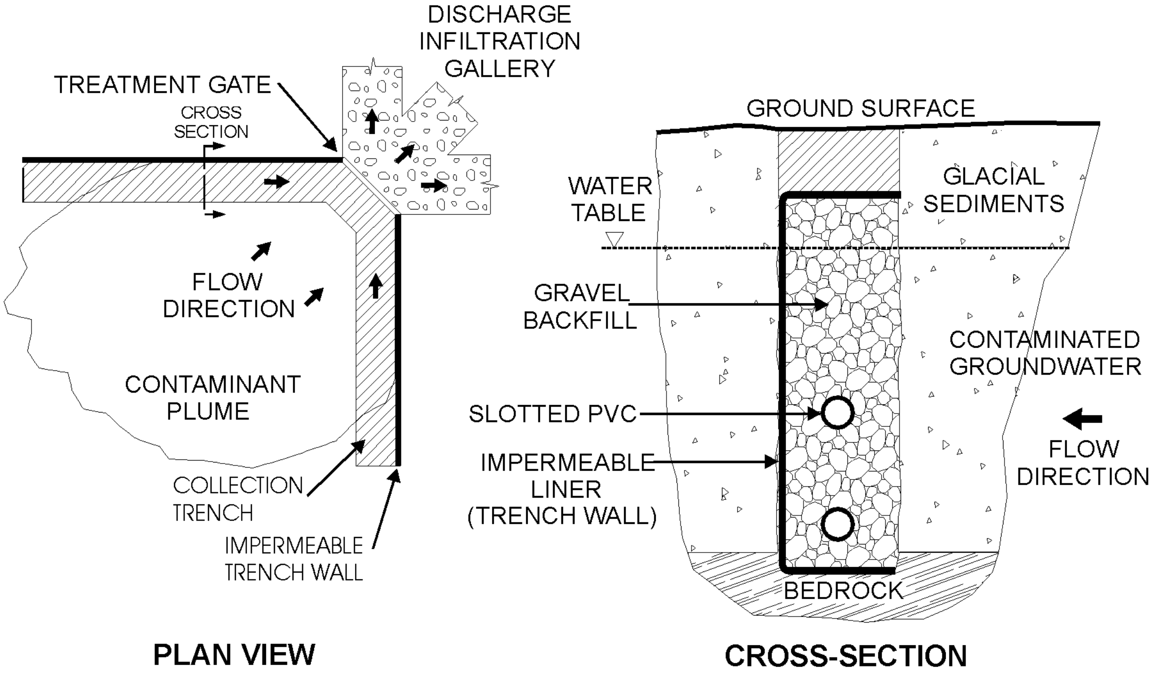


Figure 5-2 Schematic of *Trench and Gate* Design.

At the intersection of the trenches, natural gradients channel contaminated groundwater through a permeable wall or treatment gate. In the gate, air is sparged into the contaminated groundwater. This promotes natural hydrocarbon biodegradation. Infrastructure to deliver nutrients, other remediating fluids (*e.g.*, acids or bases), or solutions to prevent biofouling are also installed during construction. The gate is of a modular design to facilitate repairs or changes, and can be modified to treat different kinds of contaminants. Following treatment, the groundwater flows back into the till through an infiltration gallery. The infiltration gallery design is purposely generous in terms of contact area with the till. This is for two reasons:

1. to facilitate re-infiltration of the groundwater, thus preventing mounding on the down-gradient side; and,
2. in case the treated water is no longer compatible with the untreated water causing precipitation of minerals and a concomitant reduction in effective porosity.

Monitoring wells are installed up-gradient, down-gradient, and along the trench to measure hydraulic head changes due to the interception system, and to enable hydrochemical monitoring of degradation of dissolved phase hydrocarbons.

Monitoring of groundwater levels and construction of groundwater flow maps, as well as computer modelling, has shown that, unlike the Funnel and Gate systems, the capture zone for *Trench and Gate* systems is as wide as, or wider than, the width of the funnel between the up-gradient ends of the trench walls. Additionally, the high hydraulic conductivity trench appears to focus groundwater flow upwards. This prevents contaminant plumes from descending below the trench walls, and allows the system to be used in a hanging curtain configuration. Thus the *Trench and Gate* system effectively ‘pulls’ flow inwards rather than simply trying to force flow inwards as in the Funnel and Gate system.

Prior research into the flow fields surrounding Funnel and Gate systems revealed that significant portions of flow moved around the outside of the funnel walls (Fitts, 1997). A schematic comparison of flow fields for the *Trench and Gate* and Funnel and Gate systems in both areal and cross-sectional orientations is presented as Figure 5-3 and Figure 5-4, respectively.

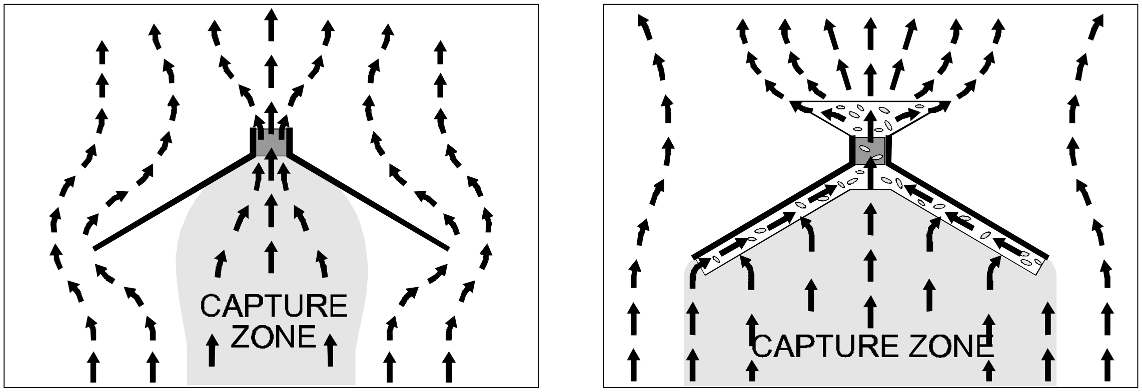


Figure 5-3 Plan View Schematic Comparison of Flow Lines and Capture Zones for the Funnel and Gate and *Trench and Gate* Systems.

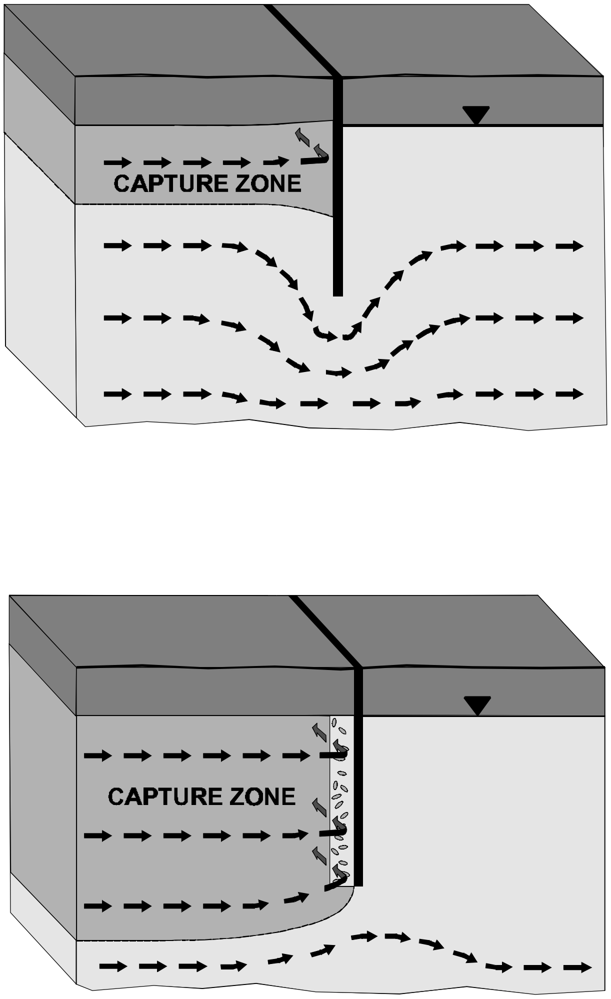


Figure 5-4 Cross-Section Schematic Comparison of Flow Lines and Capture Zones for the Funnel and Gate and *Trench and Gate* Systems.

5.1.2 Engineering Design

The East Garrington *Trench and Gate* system was designed based on site characterization and engineering/cost limitations. Collection trenches generally follow the conceptual design. They are 5 m deep, excavated to bedrock and lined with a reinforced arctic grade geosynthetic on the down-gradient side. However, because of the unstable slope conditions slit trenches could not be used and the top portion of the trench had to be sloped back A schematic cross-section of the way the trench was actually completed is shown in Figure 5-5. The trench is backfilled with screened gravel and instrumented with PVC monitoring wells.

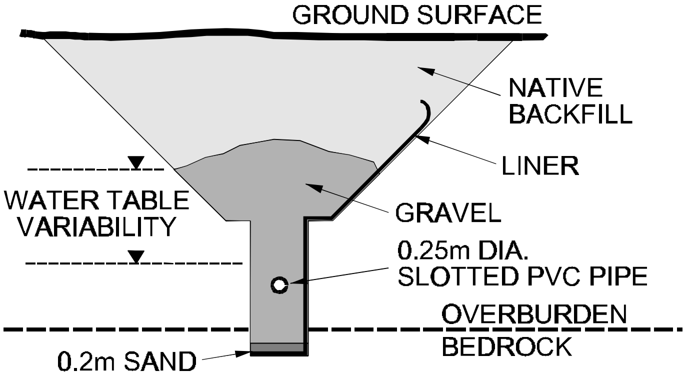


Figure 5-5 Schematic Cross-Section of Trench Construction Details.

Monitoring wells are constructed in an “L” shape with a long foot extending down the trench (Figure 5-6). The horizontal section of the “L," as well as the vertical portion below and slightly above the water table, is constructed of slotted PVC and connected to a solid riser pipe running to surface. These monitoring wells (labelled TW for Trench Wells) are installed approximately every 15 m along the trench (see Figure 2-5), and are capped at the down-gradient end of the foot. The wells were designed to serve a dual purpose. Their primary purpose is to serve as monitoring wells. Their secondary purpose, and the reason for their “L” shape and position near the water table, is to act as conduits to inject remediating or other fluids. Prior to construction, it was unknown whether there might be problems with biofouling or mineral precipitation within the trenches. So the “L” shaped wells were added as a provision for injecting and distributing along the length of the trench a biocide, acid, or other type of fluid. To date, no such action has proved necessary.

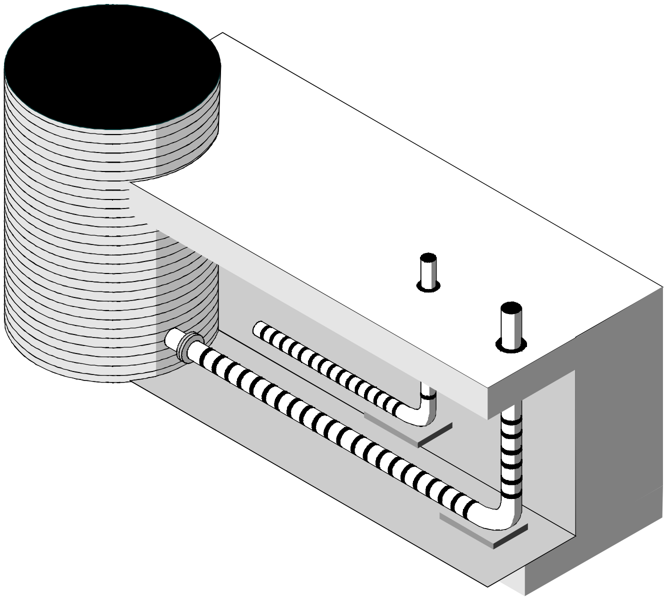


Figure 5-6 Schematic of "L" Shaped Monitoring Well Arrangement.

Underlying these monitoring wells is a continuous length of larger diameter, slotted PVC pipe flanged to the opening in the first gate. These pipes were designed with a large diameter to facilitate clean-outs if they become necessary, and also have risers located near the end of the trench so they too can serve as monitoring wells (Figure 5-6). However, their primary function is to act as a submerged tile drainage system. Groundwater entering the trench preferentially flows along the PVC pipe to the treatment gate, thus reducing fluid potential losses due to friction and tortuosity. Such losses are of particular concern at this site because the low gradient within the small pilot system produces a minimal (*i.e.,* <2 cm) head drop along the trench arms. Excessive fluid potential losses could result in stagnation of the water within the *Trench and Gate* system when a back pressure develops as a result of aeration in the gate.

Original plans called for construction of a permeable wall treatment system. This design was discarded in favour of a gate design due to easier field construction and suitability for long term maintenance. The gate residence time was calculated based on the expected flux and volume of the gates to ensure that there was sufficient time for groundwater within the gates to be fully oxygenated and to allow for at least partial biodegradation of dissolved petroleum hydrocarbons.

Using a calculated volume for three culverts that make up the trench gates of 31.52 m^3 (from $\pi r^2 h$ where r = 0.91 and h is assumed to be 4 m) and an expected flux of 5.2×10^{-4} m^3/s (see Section 3.4), yields a minimum residence time for water passing through the system of 16.8 hours, assuming no short-circuiting of flow paths. This figure was deemed adequate for treatment as a worst case scenario. The use of three in-series culverts was deemed preferable to using one large culvert, or a permeable wall, as it is ideal for the completion of field experiments (see Section 5.2.2) and allows for measurement of concentrations before and after treatment. Incorporation of a divider within the second culvert provides a method for monitoring of experimental (treated) and control (untreated) streams. Having three in-series gates also proves more economical in terms of made-to-order culvert costs and allows for isolation of the gates, or sections of the gates, using keystone valves. Additionally, culverts can be filled with a substrate or growth medium for hydrocarbon-degrading bacteria.

The gate is constructed of three 1.8 m diameter by 6 m high cylindrical culverts set vertically into a cement base (Figure 5-7). Drawings of the piping and civil engineering details (Drawings 1 and 2 respectively) are included in the pocket. The culverts are connected to the large diameter PVC pipe in the trench arms, each other, and the infiltration gallery via a series of welded steel pipes and flanges. Pipes connecting the culverts are equipped with valves so that flow can be shut off and the culverts pumped out should repairs or the installation of additional infrastructure become necessary. Two flow meters are installed in the first culvert to measure the flux from each trench arm. The first culvert also contains the biosparging component, a spiralled micro-pore hose attached to a galvanized base that keeps it anchored to the floor of the first culvert. Air injected into the hose produces fine bubbles. Bubbling serves both as an aeration and mixing mechanism. Air for biosparging is obtained from the instrument air compressor at the gas plant. The system is designed such that if simple aeration resulting in oxygenation of the groundwater and biodegradation of hydrocarbons is insufficient for remediation purposes, the pressure can be increased and volatiles can be removed by sparging. Off-gasses would then be run into the nearby flare stack if necessary.

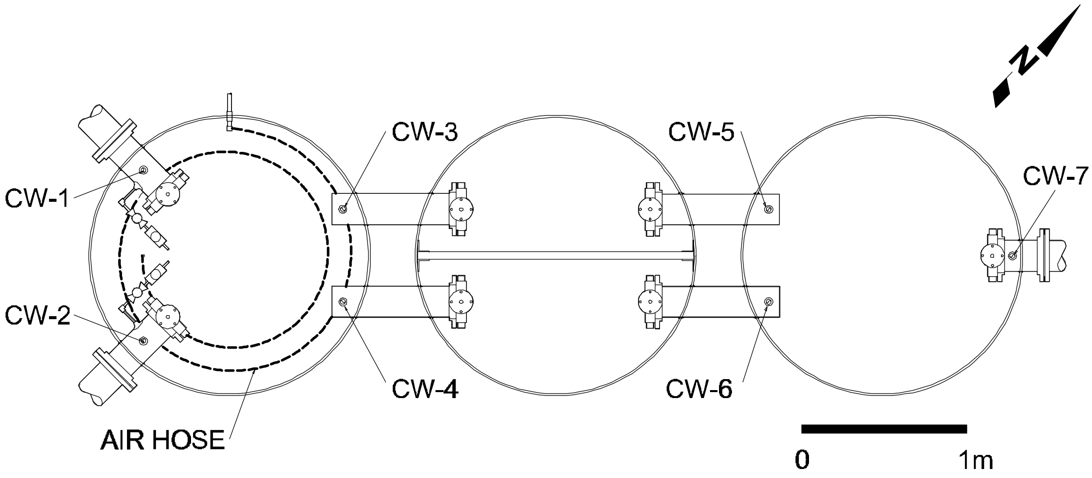


Figure 5-7 Plan View of Culvert Arrangement.

From the first culvert, oxygenated water flows through two pipes into the second culvert, which is divided down the middle. The dual compartment culvert is designed for experiments involving either two different treatment streams or comparisons between treated and untreated streams. Water from the second culvert flows through additional piping into a third culvert where it is again allowed to mix and, if necessary, treated prior to release. Sample ports (labelled with the prefix CW) connected to surface via PVC tubing and instrumented with Waterra sampling systems are built into each of the inlet or outlet pipes in every culvert, allowing for sequential sampling during treatment (Figure 5-7). The culverts are sealed with fibreglass lids with built-in manholes to allow easy access to sampling ports.

Treated water flows out of the last culvert into an infiltration gallery. The gallery is composed of a finger arrangement of slit trenches excavated into the glacial sediments and backfilled with washed gravel. At the end of each finger, monitoring wells are constructed in the backfill material to allow for on-going hydrochemical and hydraulic monitoring of the system. Arrangement of the gallery fingers (Figure 5-8) had to be altered from an idealized fan arrangement (Figure 5-2) due to the presence of an underground pipeline.

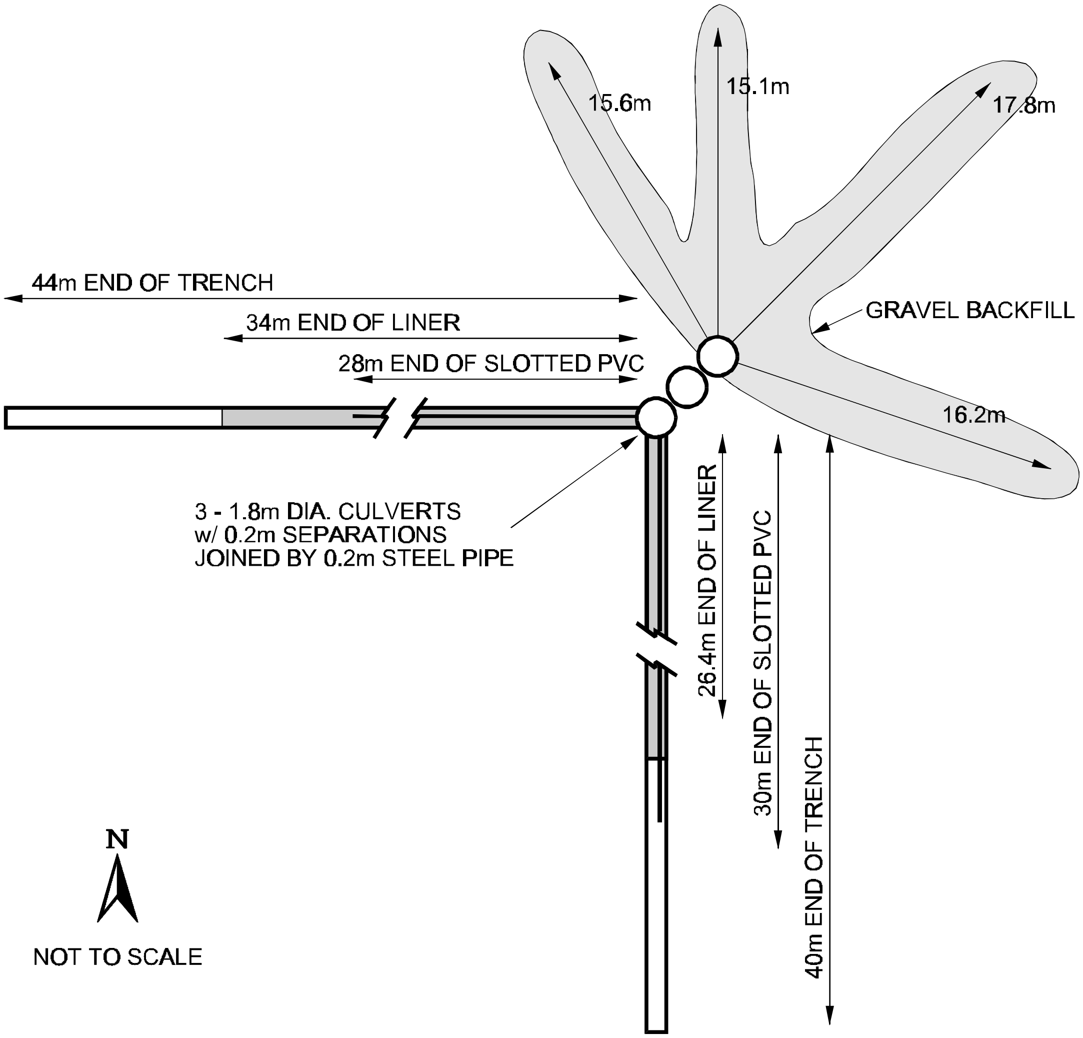


Figure 5-8 Infiltration Gallery and Trench Layout.

5.1.3 Installation

While digging the trench used for the hydraulic conductivity test, it was observed that the cobble till unit was very unstable, and that the trench was subject to significant sloughing. These conditions precluded construction of the pilot system using slit trenches as originally envisioned, so different construction techniques were evaluated.

The first alternative considered was stabilization of the overburden sediments by freezing, using cryogenic technology developed for the oil and gas industry. The plan was to excavate a shallow trench into the sediments which would then be frozen by recirculating liquid nitrogen through the trench. Following freezing and propagation away from the trench of a frost field, the sediments would likely stand up to trenching using vertical walls. This alternative was discarded, being both prohibitively expensive, and not guaranteed to work. Instead, a standardized construction technique involving the excavation of a sloped trench was undertaken.

When excavation was attempted in August 1995, it was discovered that high levels of precipitation received during the summer had caused a rise of the water table into the overlying cobble unit. The higher permeability of the cobble unit allowed a much higher flux of groundwater into the excavation than had been predicted. The large quantity of groundwater influx prevented completion of the *Trench and Gate* system at that time as it necessitated wider trench excavations and an impractical trench de-watering and pumping effort. As a result, the program was postponed while alternative solutions were sought.

One of the alternative solutions contemplated was replacing the synthetic liners by a continuous wall of interlocking sheet piling. Down-gradient of this wall, a temporary sheet piling enclosure was to have been used for gate construction. Completion of the gates would have been followed by perforation of the sheet piling wall to allow groundwater entry into the culverts. The temporary enclosure was then to be removed. This would have been followed by excavating along the front (up-gradient side) of the sheet piling and backfilling with drain rock. In this scenario, the up-gradient trench would not have been excavated down to bedrock. Instead, excavating down to a point below the lowest water table elevation would have been sufficient to provide a conduit for groundwater flow towards the gate, thus preventing groundwater mounding. This method also proved to be cost prohibitive, even when preliminary stripping of the overburden down to the water table was considered as an option to reduce the cost of installing the sheet piling.

Failing to find a suitable alternative, completion of the *Trench and Gate* system using standard construction techniques was chosen. Details of the construction methodologies and a construction schedule are presented in Appendix IV.

Appraisal of the system following the first year of operation has revealed that future *Trench and Gate* installations may have to be modified to prevent groundwater recharge from occurring directly through the trench arms during precipitation events and the spring melt-out of the frost wedge. Significant recharge in this manner may cause groundwater mounding in the trench if the infiltration gallery is incapable of discharging this large and sudden flux of surface water into the till. This in turn, could lead to the system backing up and concomitant groundwater flow around the ends of the trench. Infiltration directly through the trench can be prevented by sealing the top of the trench with a synthetic liner or a bentonite slurry and mounding fill back over the trenches to compensate for later consolidation.

Difficulties were also encountered with the impeller flow meters originally installed in the first culvert. These were either incapable of resolving flux volumes during periods of low flow or possibly restricted flow through the system. As a result, they were replaced by Controlotron flow meters capable of being data logged and measuring the low flows. Installation of the gate separator in the second culvert following system emplacement also proved to be a challenge and future installations requiring a divider should have this separator installed prior to the system being lowered into the excavation.

5.2 TREATMENT OF CONTAMINATED GROUNDWATER

5.2.1 Isolation and Identification of Hydrocarbon Degrading Bacterial Species

After operating the system for several months, a biological slime was found to be growing on the walls of the culverts that were used to construct the gate. A slimy froth also began to accumulate on the surface of the water in the first culvert. Samples of both the water and the froth in this culvert were collected in sterilized containers and brought to the laboratory for isolation and identification of possible hydrocarbon degrading bacterial species. Details of the experimental design, procedures, and materials used for isolating the bacteria are provided below (Bowles *et al.*, 1997).

Isolation Media

To ensure the isolation of hydrocarbon degrading bacteria, media lacking an intrinsic carbon source is required. Atlas (1981) stated that the use of agar media has probably resulted in the "counting of non-hydrocarbon" degraders due to the inclusion of organic contaminants in agar media. He therefore recommended the use of silica gel as a solidifying agent when enumerating hydrocarbon degraders.

Dalynn Laboratory Products used the method of Funk and Krulwich (1964) to prepare a silica based media for this study. Following this method, a standard inorganic nutrient mixture (Bacto Bushnell-Hass Broth) was incorporated. This mixture was chosen because of its limited carbon content and because it is recommended for the microbiological examination of fuels by the Society of Industrial Microbiologists Committee on Microbial Deterioration of Fuels (Difco, 1994).

Experimental and Control Plates

Negative control plates were run to ensure the media was free of metabolizable carbon. These plates were inoculated using 1 mL of the specimen. The inoculated plates were placed into a sealed chamber with an open vial containing water.

Positive control plates were used to determine the presence or absence of micro-organisms in the inoculant water. These plates were prepared identically to the negative and experimental control plates except they included 1% dextrose. Positive control plates were inoculated with 1 mL of specimen water and placed into a sealed chamber with an open vial of water.

The experimental plates used to isolate the hydrocarbon degrading bacteria were also inoculated with 1 mL of the specimen water and placed into a closed vessel, but with the addition of a source of carbon vapours (*viz.,* BTEX) and a vial of water. The hydrocarbon source used was condensate from the East Garrington plant. This condensate is sweet (*i.e.,* it does not come from an H_2S rich source), composed primarily of light end hydrocarbons and has a relatively high vapour pressure.

Experimental Design

All tests were run in triplicate and were incubated aerobically at room temperature for two weeks prior to examining growth. Plates were incubated in an inverted position to reduce condensation on the media surface. To prevent hydrocarbon deterioration of plastic petri-dishes (and the subsequent diffusion of the plastic materials into the media), the experimental plates were prepared using glass petri-dishes.

After incubation, the sealed vessels were opened and examined. Growth patterns were interpreted using Table 5-1. Isolates were delivered to the Alberta Provincial Laboratory of Health for speciation.

Isolation of Hydrocarbon Degraders

Initially, all three plates showed growth (+/+/+). Accordingly, the colonies were re-plated and re-incubated for two weeks. Examination of the secondary plates yielded the anticipated (+/+/-) pattern.

Table 5-1 Growth Results Matrix for Bacteria

Experi-mental	Positive Control	Negative Control	Interpretation	Action
+	+	+	Media contaminated with metabolizable carbon.	Re-plate existing growth on secondary plates and re-incubate at room temperature for two weeks.
-	-	-	Sample essentially sterile.	Re-sample, re-plate, or amplify.
-	+	-	Non-hydrocarbon degraders present.	Confirm interpretation on replicates.
+	+	-	Hydrocarbon degraders present.	Conduct speciation on the experimental plate.

Notes: (+) Denotes growth occurred on the plate; and,
(-) Denotes that no growth occurred on the plate.

Rationale for Re-plating and Incubation of the +/+/+ Result

The growth of organisms on the negative control plate indicates that a carbon source was present during the primary isolation.

Examination of the components used to construct the media indicated that no carbon source was present in its make-up. The powdered silica gel used (Grade 923, Lot # 96066, Fisher Scientific), which was dissolved using a 7% KOH solution, contains volatile acid concentrations (as CH_3COOH) of < 0.001%. Likewise, the Bacto Bushnell-Hass media was composed solely of inorganic salts (Difco, 1994).

However, examination of the inoculating water indicated high levels of dissolved hydrocarbons. It was hypothesized that the transfer of the inoculating water to the primary plates resulted in the transfer of a metabolizable carbon source. The re-plating of the primary isolates to secondary plates without the corresponding transfer of carbon contaminated water was needed to prove this hypothesis.

The secondary plates showed the anticipated +/+/- growth pattern indicating that the carbon contaminant had been removed. Thus, it can be deduced that the isolates on the secondary experimental plate were using the hydrocarbon vapour as their sole carbon source.

Identification and Significance of Isolates

The four isolates identified were:

> *Pseudomonas putida:* The ability of *P. putida* to degrade a variety of hydrocarbons such as BTEX and phenolics has been well documented previously (Heald and Jenkins, 1996).
>
> *Pseudomonas fluorescens:* Cultures of *P. fluorescens* capable of using aromatic hydrocarbons as a sole carbon source have been previously isolated (Marconi *et al.,* 1996).
>
> *Stenotrophomonas maltophilia*: *S. maltophilia* has been demonstrated to degrade hexahydro-1, 3, 5-trinitro-1, 3, 5 triazine (Binks *et al.,* 1995). It has also previously been isolated as a toluene and xylenes degrader (Su and Kafkewitz, 1996).
>
> *Rhodococcus sp:* *R. sp*. have been characterized with an ability to degrade a wide variety of PCB isomers (Wang *et al.,* 1995) including bi-, tri-, tetra- and pentachlorophenols (Masai *et al.,* 1995).

5.2.2 Biodegradation and Nutrient Amendment Experiments

Microcosm experiments performed at the University of Waterloo suggested that given an adequate supply of dissolved oxygen, biodegradation of BTEX compounds at the East Garrington site was limited by phosphorous and not nitrogen concentrations (Granger, 1997). To test this hypothesis, and to demonstrate that the remediation system could degrade high concentrations of dissolved hydrocarbons, a one month field trial was undertaken. The experimental set-up for the field trial is presented in Figure 5-9.

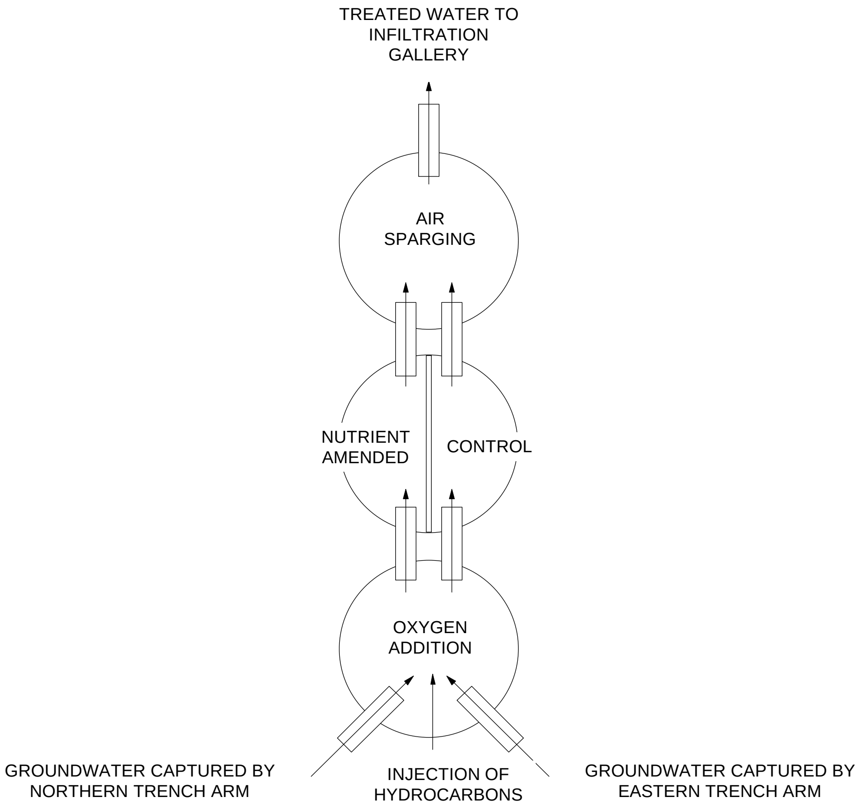


Figure 5-9 Schematic Diagram of Experimental Gate Treatment System (Granger, 1997).

During the trial, groundwater spiked with condensate was added to existing contaminated groundwater in the first of the three in-series treatment gates. This increased the total dissolved BTEX loading from approximately 0.04 to 2.5 mg/L. Groundwater was aerated in the first gate by sparging with pure oxygen, instead of atmospheric air (21% O_2), to ensure that dissolved oxygen concentration was not a limiting factor for biodegradation. Following sparging, the water was divided into two separate streams and allowed to flow through into the second gate. The control stream was left untreated while the second stream was amended by the addition of nitrogen and phosphorous. Nitrogen was added to the system by diffusion through low density polyethylene emitter tubes filled with pure gaseous anhydrous ammonia. Phosphorus was added as a solid in the form of crushed apatite and powdered commercial fertilizer. These two solids, chosen to provide both slow and rapid release phosphorous sources, were mixed together and poured into a slotted PVC well screen which was installed inside the second gate. A schematic representation of the nutrient amendment infrastructure as installed in the gate is shown in Figure 5-10.

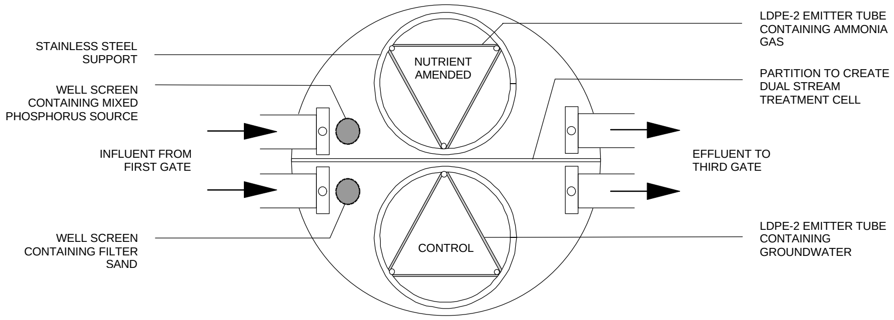


Figure 5-10 Plan View of Nutrient Amendment System in the Second Gate (Granger, 1997).

Analysis of effluent from the second gate showed that biodegradation of BTEX compounds occurred much more rapidly in the amended stream than in the control stream (Granger, 1997). Total BTEX concentrations in the amended stream decreased by at least an order of magnitude during an estimated residence time of 24 hours, while concentrations on the central side remained essentially unchanged. When the experiment was repeated and ammonia was added to the control side as well, the results changed little - confirming that phosphorus is the limiting nutrient. Any dissolved hydrocarbons remaining in the third gate were removed by aggressive sparging with air. Effluent nitrogen concentrations measured as NO_2+NO_3 as N were well below Canadian drinking water guidelines (Health Canada, 1996). The experiment clearly demonstrated that the system is capable of rapid, in-situ degradation of dissolved BTEX concentrations typical of highly contaminated plumes.

6. DISCUSSION

6.1 HYDRAULIC EVALUATION

6.1.1 Computer Groundwater Modelling

To confirm that the system would perform as predicted, the flow field around the *Trench and Gate* infrastructure was modelled using the University of Waterloo's FRAC3DVS program (Therrien and Sudicky, 1994). FRAC3DVS is a three dimensional groundwater flow and solute transport model that can represent discretely fractured and low permeability media. The Funnel and Gate system was also modelled to illustrate the differences in flow fields for the two systems.

Details of the modelling parameters used are provided in Hoyne (in prep.) and Hoyne and Bentley (1997). They used a simplified two layer hydrostratigraphic model with constant head boundary (Dirichlet) conditions for the four sides and no flow boundary conditions for the top and bottom of the model. The top layer, designed to represent an unconfined groundwater-bearing glacial till, was assigned a hydraulic conductivity of 1.7 x 10^{6} m/s. Underlying the till is bedrock composed primarily of shale with interbedded sandstones units. This unit was assumed to have a hydraulic conductivity of 1.0 x 10^{-8} m/s. The gravel in the trenches and the infiltration gallery was assigned a hydraulic conductivity of 1.7 x 10^{-3} m/s. The impermeable barrier was modelled using the cut-off wall parameter in FRAC3DVS. Treatment zones were modelled as enclosed cut-off walls and the infiltration gallery is configured as a parallelepiped rather than the actual finger arrangement.

Figure 6-1 is a plan view of the flow lines in and around the *Trench and Gate* system and infiltration gallery as modelled using the above parameters. Groundwater flow direction is from the southwest (lower left hand corner) towards the northeast (upper right hand corner). For this simulation, the average linear flow velocity in the till outside of the trench is 3.3 x 10^{-8} m/sec or approximately 1 m/year. Inspection of the figure reveals that groundwater flow is focused towards the high permeability trenches and then along the trenches and into the treatment zone. Following treatment and discharge into the infiltration gallery, the flow lines fan out again as the water is reinfiltrated into the till. Results of the simulation suggest that the flow field around the *Trench and Gate* will behave as predicted.

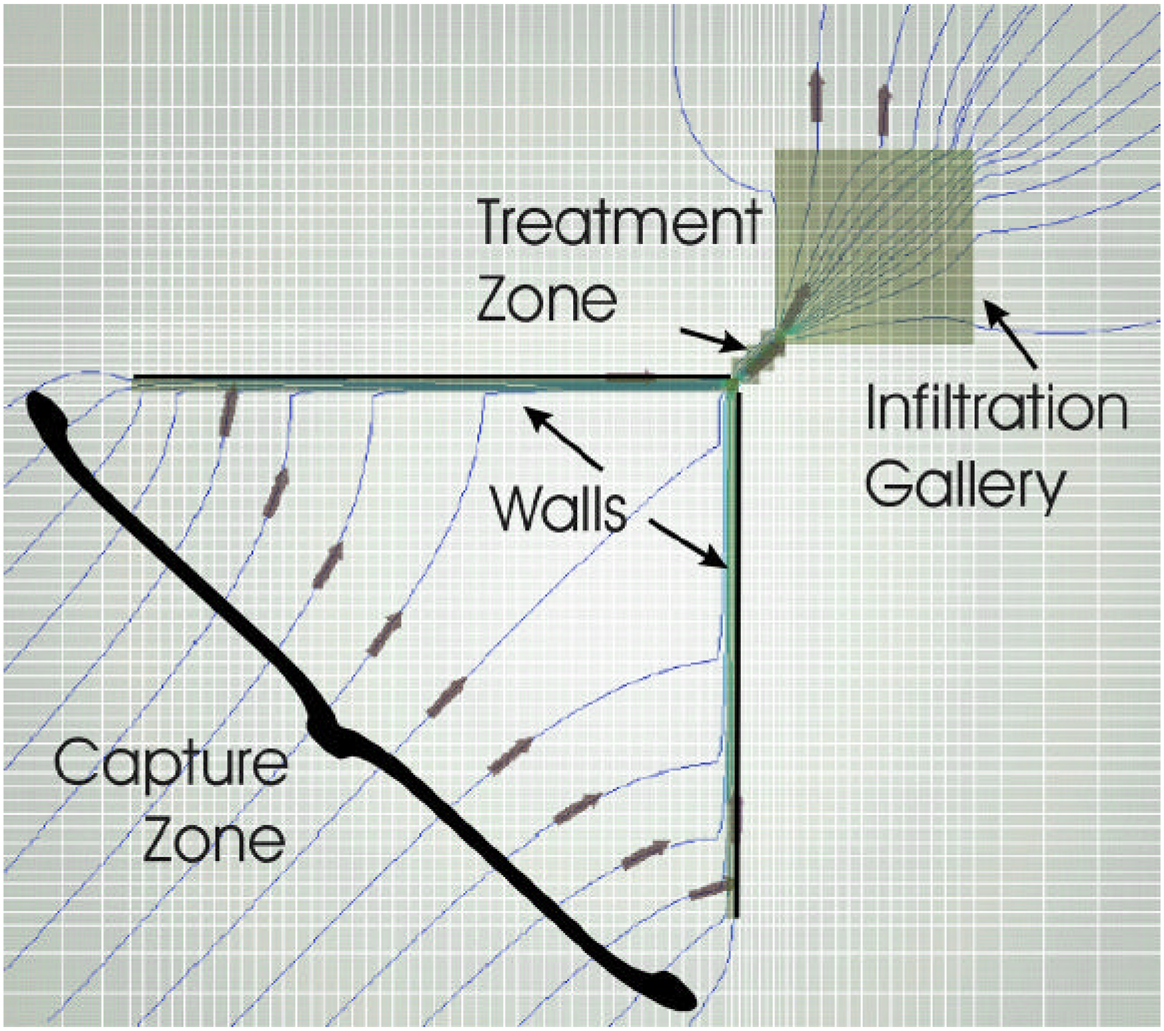


Figure 6-1 Plan View of Flow Field for the *Trench and Gate* System (Hoyne, in prep.).

As can be interpreted from the configuration of the capture zone, and as shown in Figure 6-2, the *Trench and Gate* system also has an effect on the contours of the potentiometric surface. The preferential flow path caused by the construction of the *Trench and Gate* causes a notable elongation, or pulling, of hydraulic head contours towards the apex of the funnel. This is balanced by a compression of contours around the ends of the trenches forming the funnel.

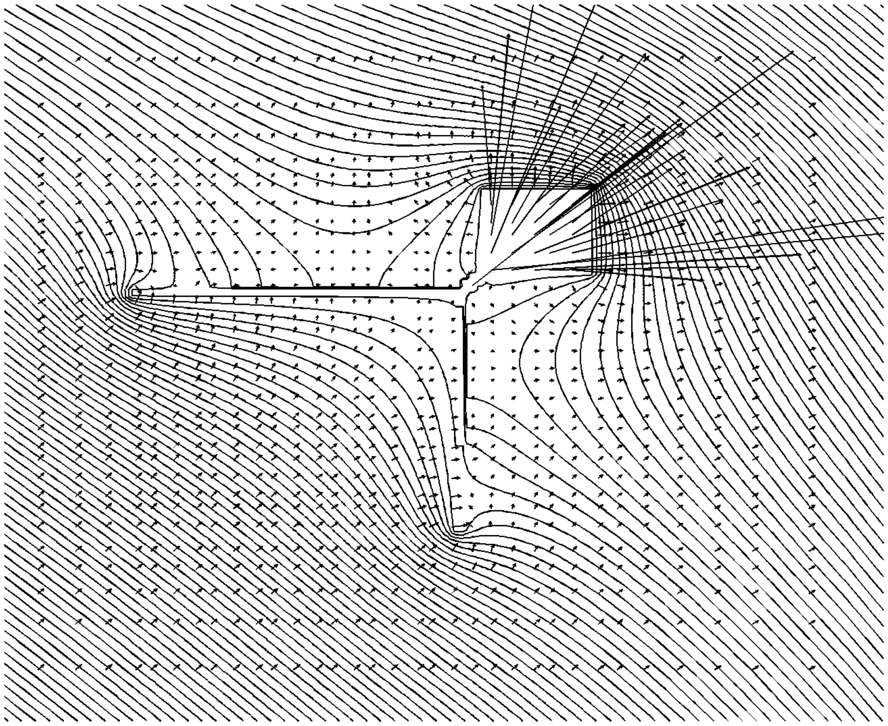


Figure 6-2 Plan View of the Potentiometric Surface and Flow Vectors for the *Trench and Gate* System (Hoyne, in prep.).

Modelling also confirmed that the *Trench and Gate* capture zone is wider than the width of the funnel mouth of the system. Other modelling runs have demonstrated that the *Trench and Gate* system works just as well in a hanging curtain configuration as it does when keyed into bedrock (Hoyne, in prep.). This is because the high permeability gravel trench focuses flow upwards thus preventing stream lines from short circuiting underneath the walls. The system also has some utility when installed without the impermeable barrier. However, while groundwater capture continues when the liner is removed, diffusion may permit down-gradient movement of contaminants across the trench. A three dimensional representation of the flow field for the *Trench and Gate* system with an impermeable barrier is shown in Figure 6-3.

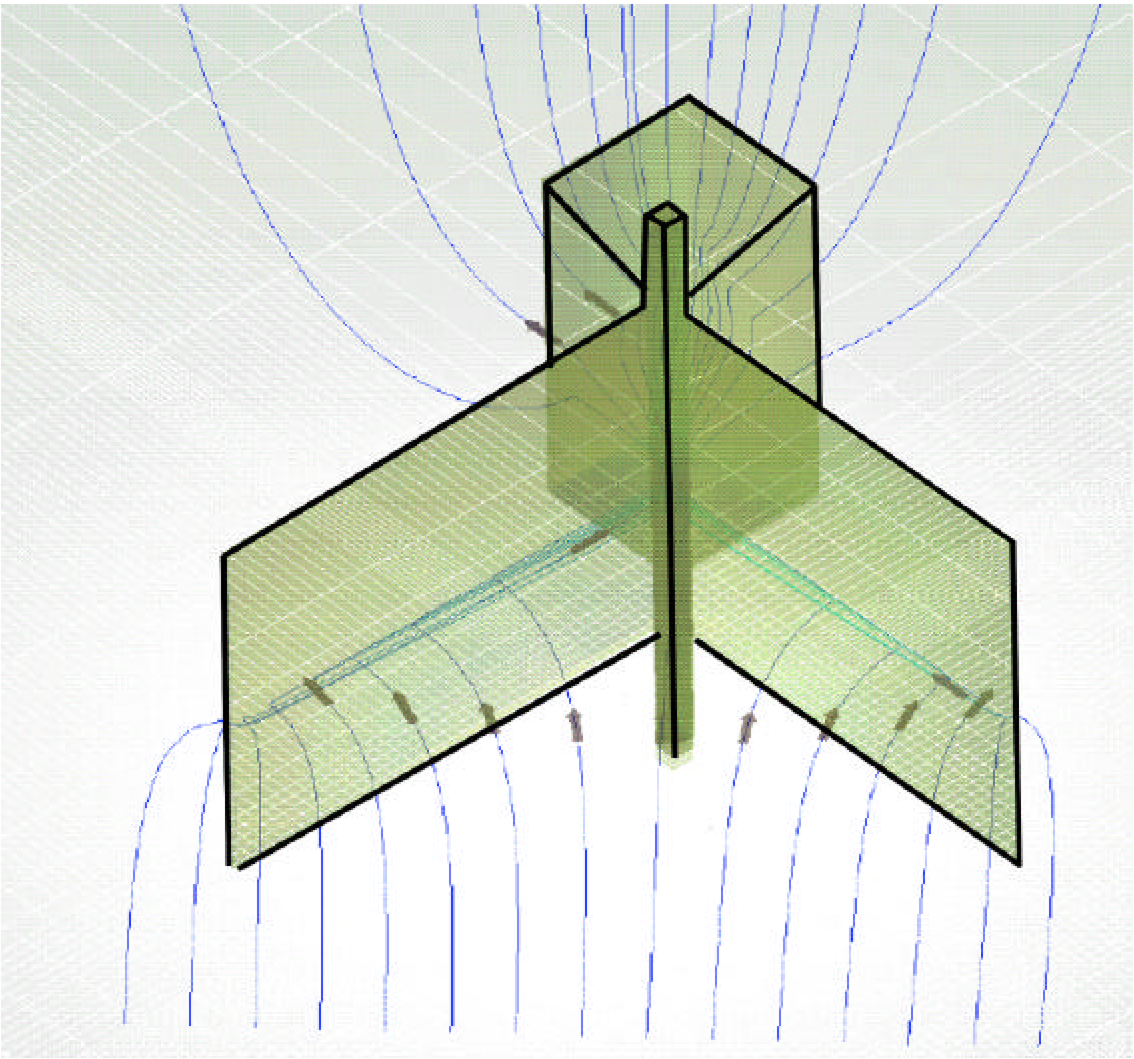


Figure 6-3 Three Dimensional Representation of Flow Field in the *Trench and Gate* System (Hoyne, in prep.).

Modelling has also confirmed that, as suspected, the capture zone for the Funnel and Gate system is narrower than the funnel width (Figure 6-4). The Funnel and Gate design essentially constricts flow in the area of the treatment gate and forces streamlines to short circuit underneath the funnel walls or to flow around the outside of the funnel walls, thus reducing both the horizontal and vertical extent of the capture zone.

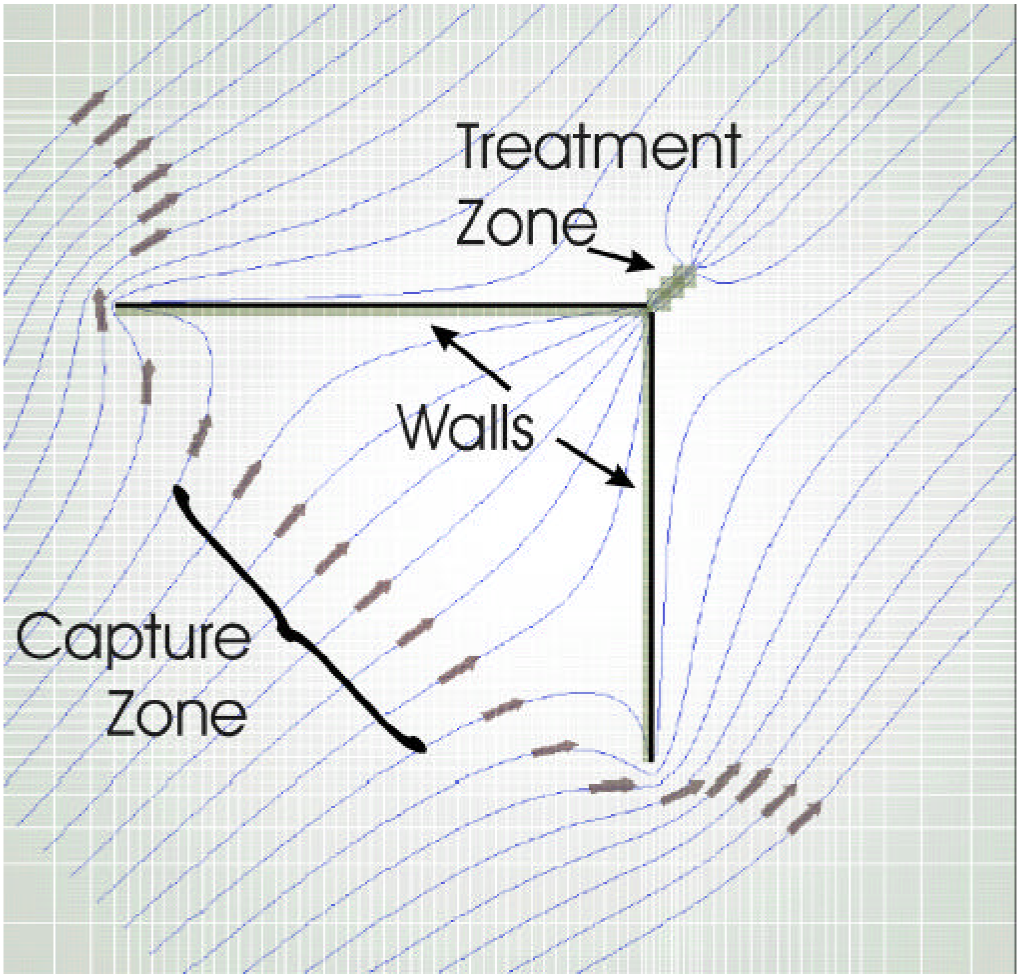


Figure 6-4 Plan View of Flow Field for the Funnel and Gate System (Hoyne, in prep.).

6.1.2 Hydraulic Response to Infiltration Events

Long term groundwater level monitoring at the East Garrington site has revealed that fluctuations in potentiometric surfaces, and hence gradients, are much more significant than previously suspected.

Inspection of groundwater level data (Appendix III, Table 1) shows that the horizontal hydraulic gradient across the site is seasonally dependent. During the winter, when there is no recharge, the gradient decreases and causes groundwater flow in the upper groundwater-bearing zone to slow considerably.

Figure 6-5 shows hydrographs for three piezometers (15A, 17A, and 20A) as well as rainfall, and temperature records for a one year period. Of note in the figure are the large increases in groundwater levels that correspond to warming trends in the spring (*i.e.,* snow melt) and infiltration following precipitation. Variability in magnitude of groundwater level fluctuations between piezometers is also of interest. For example, the first water level increase in late March is seen as a moderate increase in piezometers 17A and 20A, and as a large rise (nearly 1.5 m) in piezometer 15A. Groundwater recharge thus appears to be spatially variable.

Recharge variability is partially attributed to site heterogeneity, and topographic effects leading to depression focused recharge. However, the response in piezometer 15A is also likely in part attributable to the infrastructure of the *Trench and Gate* system itself. Depressions formed over the areas of the trenches as a result of settlement probably enhanced recharge directly into the trench during the spring melt. This effect would also be magnified by the increased permeability of the trench backfill material. Therefore, piezometers in the immediate area of the trench would likely have been affected by local groundwater mounding within the trench. Piezometers in this area are also installed in naturally more permeable sediments. As a result, it is difficult to distinguish between recharge due to the trench, and recharge due to the increased permeability of the till.

Hydraulic conductivity measurements for these three piezometers, as calculated from rising head tests, span more than an order of magnitude ranging from 2.8×10^{-7} for piezometer 20A to 1.2×10^{-8} for piezometer 17A (Appendix III - Table 1). Inspection of the results shows no direct correlation between hydraulic conductivity and the size of hydraulic head variations. This suggests that sedimentary heterogeneities and possibly fracturing in the till, play significant roles in the hydraulic head response of piezometers. However, piezometer 17A, the least permeable of the three, does show a slightly muted response to precipitation events as compared to the other two. The muted response could also be explained by its removed location relative to the trenches.

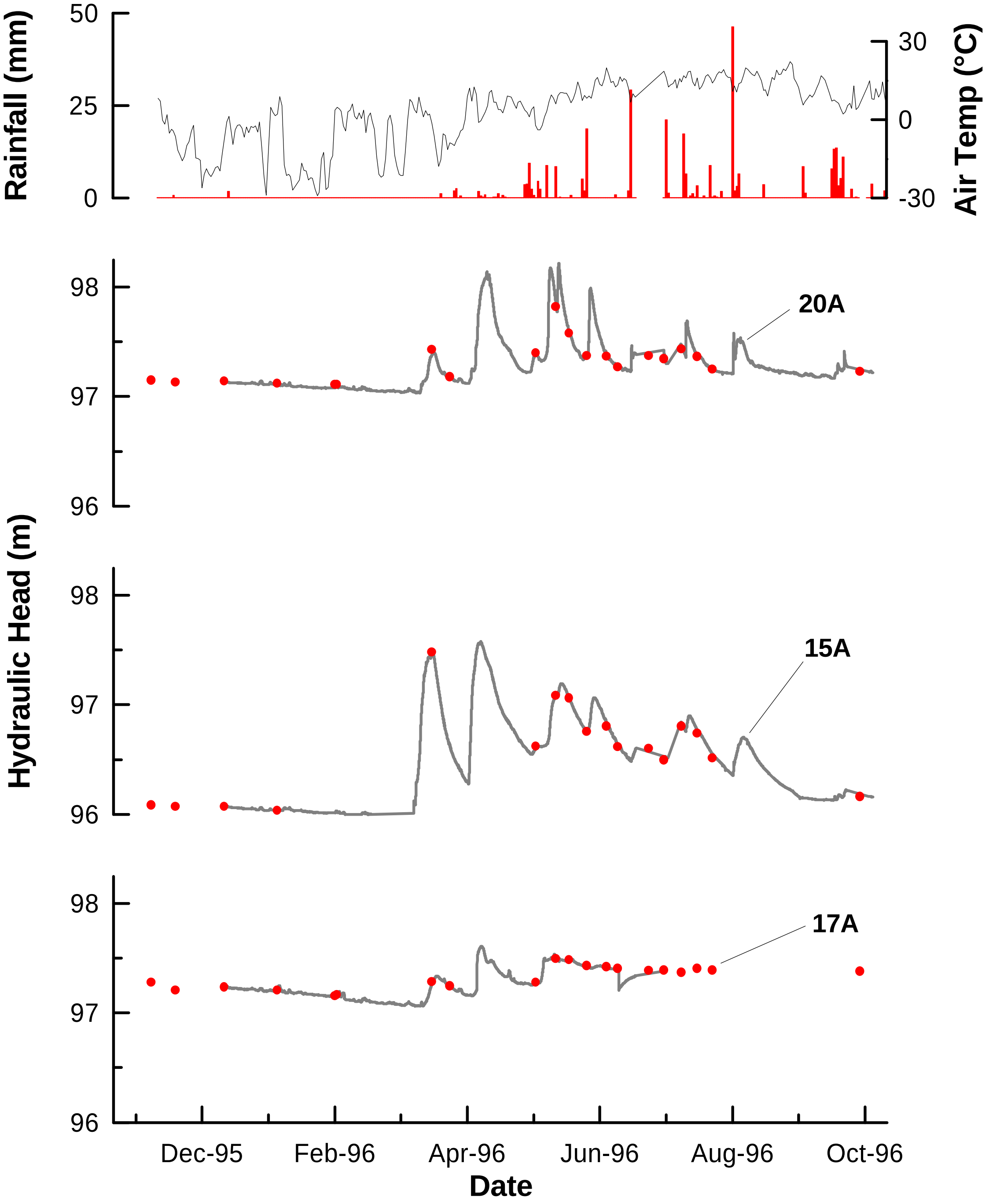


Figure 6-5 Hydrographs of Response to Melting and Infiltration Events (Thomas, in prep.).

Regardless of the cause, it is obvious that fluctuations in recharge and hence gradients will affect the flux through the *Trench and Gate* system. Since recharge is controlled by precipitation, it follows that there should be a direct correlation between major rainfall events and flux through the *Trench and Gate* system. This correlation is illustrated in Figure 6-6 which shows rainfall measurements in relation to fluxes flowing through the system as measured by the newly installed Controlotron flow meters.

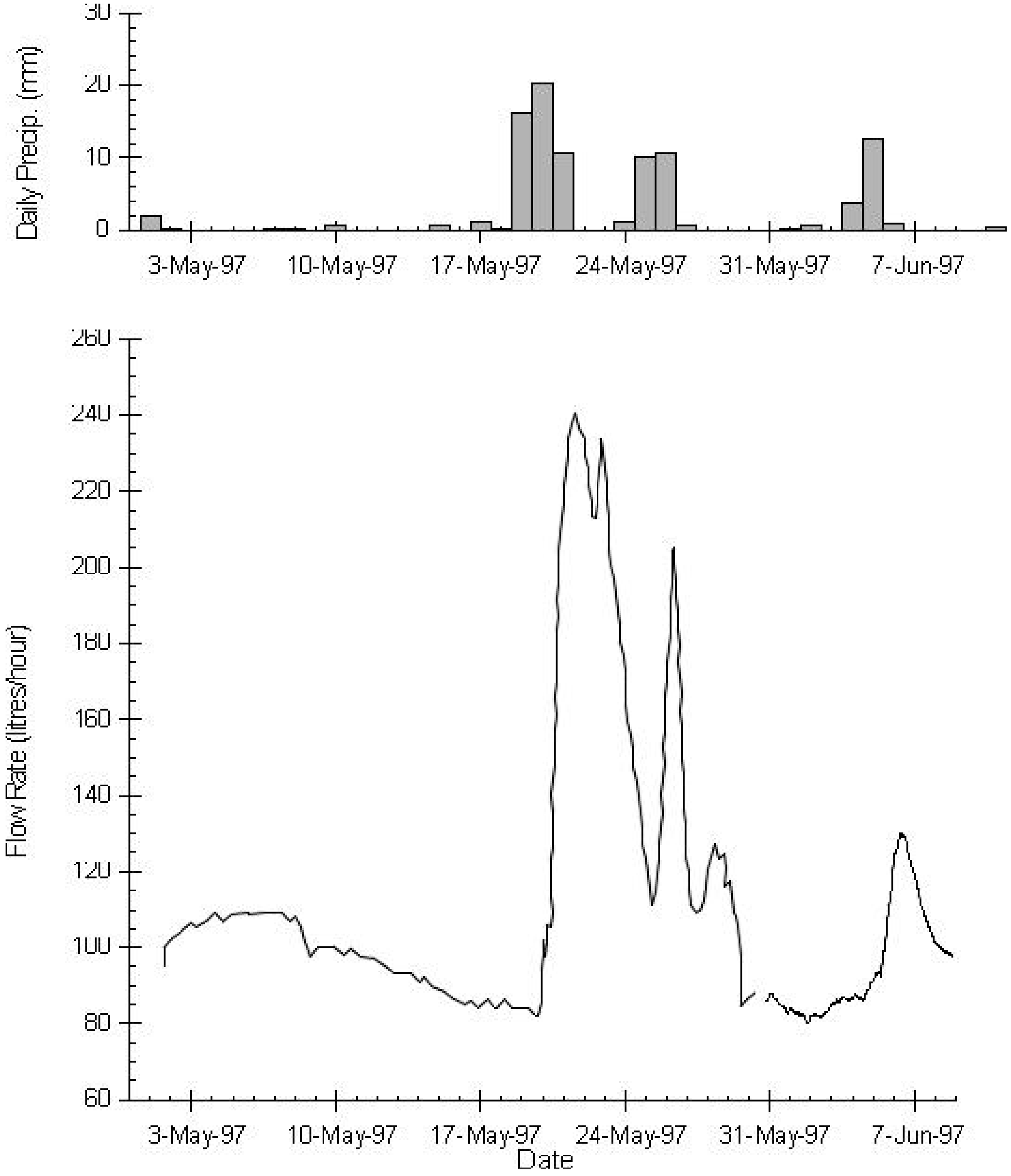


Figure 6-6 Correlation Between Measured Flow Rates Through the Gate and Precipitation (Thomas, in prep.).

The graph shows not only the delayed reaction to rainfall manifested as increased flow through the system, but also a significant variability in flow through the system.

Data from pressure transducers in nested pairs of piezometers has also shown that not only the magnitude, but also the direction, of the vertical hydraulic gradients changes in response to precipitation (Figure 6-7). Smaller scale variations in hydraulic head in unconfined piezometers have also been shown to be inversely related to changes in barometric pressure (Thomas, in prep.).

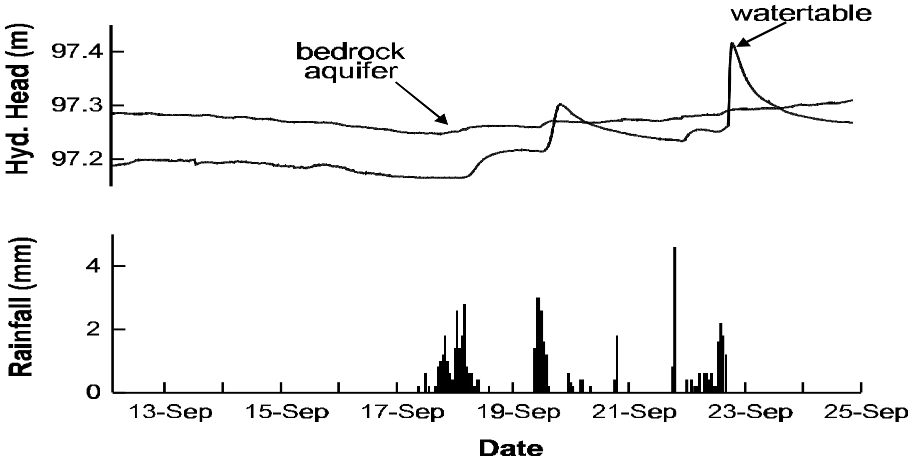


Figure 6-7 Changes in Vertical Hydraulic Gradient in Response to Precipitation Events (Thomas, in prep.).

6.1.3 Calculating Bulk Hydraulic Conductivity from Measured Flux

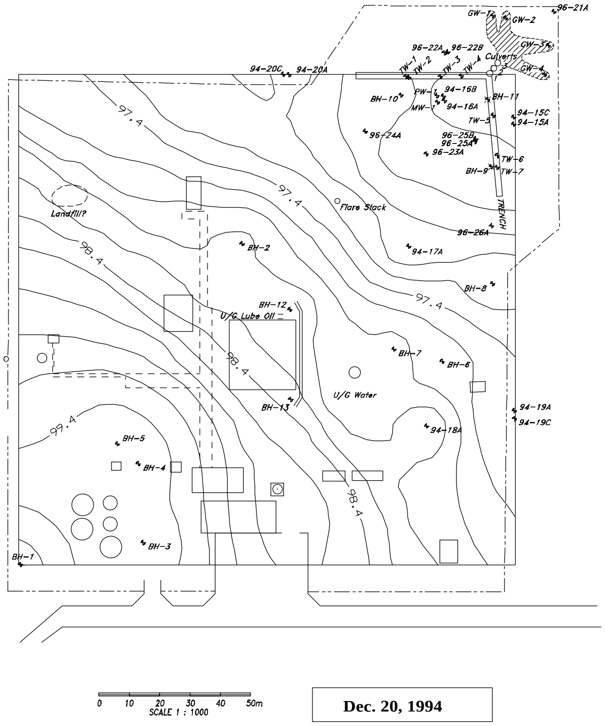
The measurement of treatment fluxes using the Controlotron flow meters has allowed for the calculation of a bulk hydraulic conductivity. Using an average flow rate through the system (*Q*) of approximately 100 litres per hour (Figure 6-6) then the bulk hydraulic conductivity of the sediments around the *Trench and Gate* system can be back-calculated using the same reasoning presented in Section 3.4. If the length (1) for calculating the area is assumed to be approximately 10% longer (*i.e.*, 68 m) to reflect the increased size of the capture zone relative to the funnel width, and the height (h = 4 m) and gradient (i = 0.035) are held constant, then substitution into the formula:

$$K = \frac{Q}{iA} \qquad \textbf{Equation 6-1}$$

yields a bulk hydraulic conductivity of 2.9 x 10^{-6} m/s or approximately one twentieth of the maximum expected K based on the worst case approximation.

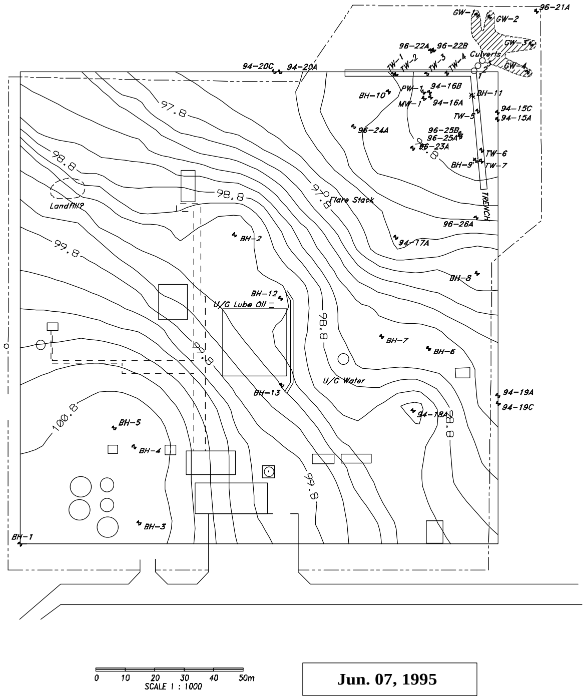
6.1.4 Field Measurement of Potentiometric Surfaces

In an attempt to confirm the modelling results, a number of piezometers were installed in and around the *Trench and Gate* infrastructure to see if the modelled flow field would match field measurements. Field measured hydraulic head distributions for winter and summer periods prior to installation of the *Trench and Gate* system are presented as Figure 6-8 and Figure 6-9, respectively. Similar contour maps for summer and winter periods following the installation of the *Trench and Gate* system are included as Figure 6-10 and Figure 6-11.



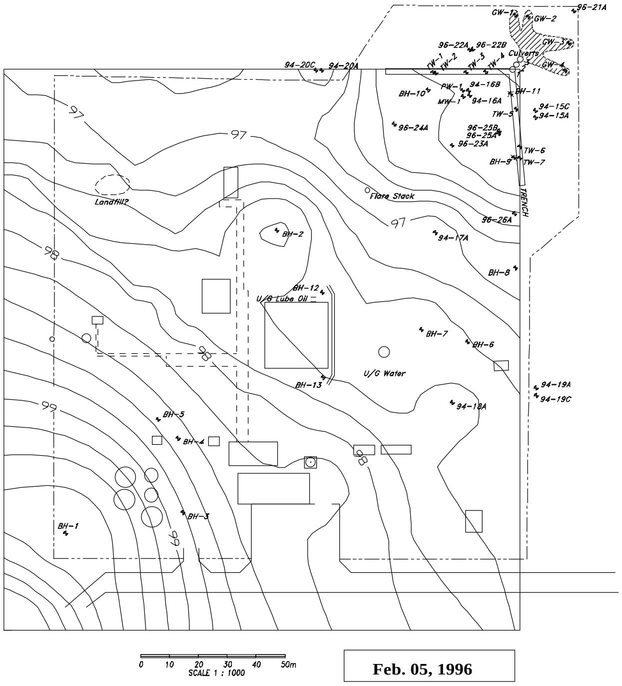
Dec. 20, 1994

Figure 6-8 Pre-*Trench and Gate* Uppermost Groundwater-Bearing Zone Potentiometric Contours, December, 1994.



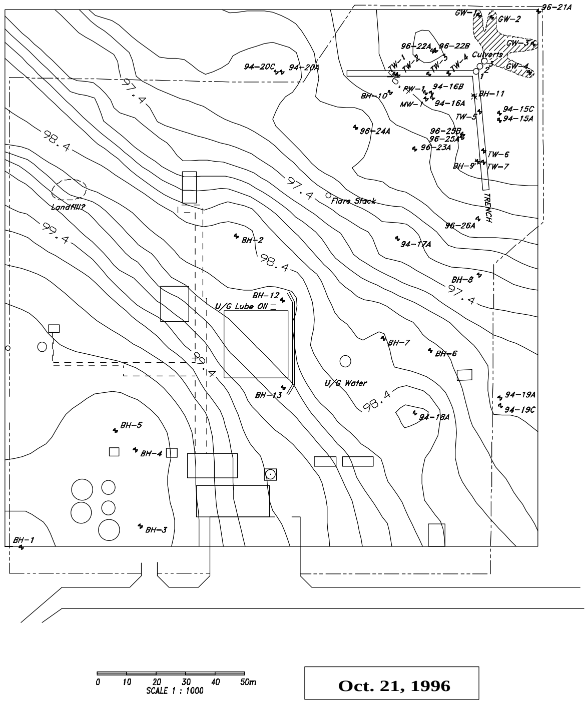
Jun. 07, 1995

Figure 6-9 **Pre-*Trench and Gate* Uppermost Groundwater-Bearing Zone Potentiometric Contours, June, 1995.**



Feb. 05, 1996

Figure 6-10 **Post-*Trench and Gate* Uppermost Groundwater-Bearing Zone Contours, February, 1996.**



Oct. 21, 1996

Figure 6-11 Post-*Trench and Gate* Uppermost Groundwater-Bearing Zone Potentiometric Contours, October, 1996.

Inspection of the flow field in these four figures leads to a number of observations:

- horizontal hydraulic gradients as measured during the winter are not as steep as those measured during the summer;
- perturbations in the water table around piezometers BH-2 and 94-18A persist through time and season and are tentatively attributed to surveying errors;
- the water table shows a natural flattening in the area of the *Trench and Gate* infrastructure prior to and after installation, reflecting the increased permeability of the cobble till in this area; and,
- post-installation groundwater surface contours curve inwards toward the apex of the trenches as predicted in the computer modelling. This

effect is particularly noticeable for the October 1996 data when the water table dropped into the less permeable classical till underlying the cobble till, thus allowing the system to operate in a manner more in keeping with the design parameters. This effect would be much more pronounced, and easier to see, if the contouring software could be programmed not to run contours through the impermeable trench walls. If they were made to run around the edges of the trench, as they are physically constrained to do, they would be compressed at the ends of the trenches as shown in the modelled scenario represented by Figure 6-2.

Thus it would appear, that under ideal conditions, the flow field in the area around the *Trench and Gate* infrastructure behaves as predicted. Differences between what has been observed and what was predicted are attributed to:

1. a poorer than expected hydraulic conductivity contrast between the cobble till and the trench backfill material; and,
2. site heterogeneity.

6.2 HYDROCHEMICAL EVALUATION

6.2.1 Field Procedures and Analytical Techniques

General Approach

Field programs sampling included the following:

1. Measurements of the depth to groundwater surface in all piezometers and at all sample points.
2. Where applicable, measurement of in-situ pre-purge parameters dissolved oxygen, redox potential, and sometimes temperature.

3. Purging of standing water from each piezometer to allow fresh groundwater to enter followed by sample collection. Either the piezometer was purged dry, or the equivalent of two borehole volumes of standing water was removed prior to sampling.

Field Measurements

Field measurements included the following and were measured as detailed below:

Water Levels: measured from the top of the piezometer PVC casing or other established point using a Solinist electric water level meter.
Temperature: measured in-situ using a dissolved oxygen meter or measured at surface using either a petroleum distillate-in-glass thermometer or a pH meter temperature probe.
pH: measured with a Hanna Instruments HI 8733 meter equipped with an HI 1230 gel-filled multi-purpose probe and calibrated using buffer solutions of pH 4 and pH 7.
E.C.: electrical conductivity (temperature corrected) measured with a Hanna Instruments HI 8733 conductivity meter, calibrated with standard KCl solution (≈ 1,413 μS/cm @ 25 °C).
D.O.: dissolved oxygen measured in-situ with either a YSI type 50B meter and YSI type 5739 probe (gold cathode, silver anode) calibrated in water saturated air or with an Oxyguard Handy MK II Dissolved Oxygen Meter (silver cathode, zinc anode) calibrated in air. Calibration of both units includes a correction for altitude.
Eh: redox potential measured in-situ using an Oxyguard Handy pH meter or at surface using a Hanna Instruments HI 8733 pH meter equipped with an HI 3430 platinum probe. Redox readings were checked against a standard ZoBell’s solution.

Sampling and Analyses

Groundwater samples were collected using dedicated PVC bailers with check valves used for volatile sampling or dedicated Waterra tubing equipped with inertial footvalves. Samples were collected in laboratory supplied bottles rinsed with sample water or in specially pre-cleaned bottles. If necessary, samples were filled in the field using Waterra disposable in-line filters and preserved with laboratory supplied preservatives. New bailing rope (where applicable) and disposable gloves were used at each sampling location and sampling equipment was thoroughly rinsed with distilled water between sampling stations to prevent cross contamination. Samples were transported in ice packed coolers to Maxxam Analytics Inc. (formerly Chemex Labs Alberta Inc.) or Amoco's Tulsa analytical facility for analysis. Standard chain of custody procedures were followed. Analytical results have been entered into the Amoco environmental database (AED) and original laboratory reports have been retained on file at the Komex office.

Analytical procedures for routine potability constituents {bicarbonate (HCO_3^-), calcium (Ca^{2+}), chloride (Cl^-), iron (Fe^{2+}), magnesium (Mg^{2+}), manganese (Mn^{2+}), nitrate plus nitrite nitrogen (NO_2^- + NO_3^- as N), potassium (K^+), sodium (Na^+), sulphate (SO_4^{2-}), and total dissolved solids (TDS)}, dissolved organic carbon (DOC), and dissolved metals/ metalloids followed standard methods for the examination of water as detailed in Table 6-1.

Analysis for dissolved volatile organic hydrocarbons {benzene, toluene, ethylbenzene, total xylenes (BTEX), total purgeable hydrocarbons as volatiles (TPH C_6-C_{11}) and semi-volatiles (TPH C_{12}-C_{22})} was completed by Amoco's Tulsa analytical services department using a GC-PID/FID freon extraction method (AMM8015) pioneered by Amoco. The method is described by Miller and Schmidt (1991) and yields a detection limit of 0.001 per BTEX component and 1.0 mg/L for volatile and semi-volatile components. Occasionally, BTEX components were also measured by gas chromatography - mass spectrometry (GC-MS) methods (USEPA Method 8260) by Maxxam Analytics Inc.. Samples analyzed by this method had an improved detection limit (0.0004 mg/L) and reported xylenes results represent a sum of the individual xylene components.

Table 6-1 Analytical Methods Summary

Analyte	**Technique**	**Naquadat Code**	**Method Detection Limit (mg/L)**
Aluminum[3]	ICP-MS/AES	13109L	0.001/0.01
Barium[3]	ICP-MS/AES	56101L	0.001/0.01
Beryllium[3]	ICP-MS/AES	04102L	0.0002/0.001
Bicarbonate[2]	Alkalinity	06201L	0.5
Boron[3]	ICP-AES	05107L	0.01
Cadmium[3]	ICP-MS	48102L	0.0002
Calcium[3]	ICP-AES	20311L	0.1
Chloride[1]	Ion Chromatography	17209L	0.5
Chromium[3]	ICP-MS/AES	24052L	0.001/0.002
Cobalt[3]	ICP-MS	27102L	0.0003
Copper[3]	ICP-MS/AES	29105L	0.0002/0.001
Dissolved Organic Carbon[5]	InfraRed	06104L	0.2
Iron[3]	ICP-AES	26104L	0.01
Lead[3]	ICP-MS	82103L	0.0003
Lithium[3]	ICP-AES	03101L	0.001
Magnesium[3]	ICP-AES	12311L	0.01
Manganese[3]	ICP-AES	25104L	0.001
Nickel[3]	ICP-MS/AES	28102L	0.0005/0.005
NO_2+NO_3 as N[4]	Colorimetric	07110L	0.003/0.03
Phosphorous[3]	ICP-AES	ICPPHO	0.1
Potassium[3]	ICP-AES	19111L	0.02
Silver[3]	ICP-MS	47102L	0.0001
Sodium[3]	ICP-AES	11311L	0.01
Strontium[3]	ICP-AES	38101L	0.002
Sulphate[1]	Ion Chromatography	16309L	0.1
Titanium[3]	ICP-AES	22009L	0.001/0.003
Total Dissolved Solids[6]	Gravimetric/Calculation	00201L	1.0
Uranium[3]	ICP-MS	102018L	0.0006
Vanadium[3]	ICP-AES	23102L	0.002
Zinc[3]	ICP-MS/AES	30105L	0.0006/0.001

Reference

1. Standard Methods for the Examination of Water and Wastewater, 19th ed., American Public Health Association, Washington, DC, 1995, Method 4110C.

2. Standard Methods for the Examination of Water and Wastewater, 19th ed., American Public Health Association, Washington, DC, 1995, Method 2320B.

   Methods for Chemical Analysis of Water and Wastes, U.S. Environmental Protection Agency, EMSL, Cincinnati, OH 45268, March, 1979 (EPA-600/4-79-020), Method 310.1.

3. Methods for Chemical Analysis of Water and Wastes, U.S. Environmental Protection Agency, EMSL, Cincinnati, OH 45268, March, 1979 (EPA-600/4-79-020), Method 200.7.

4. Standard Methods for the Examination of Water and Wastewater, 19th ed., American Public Health Association, Washington, DC, 1995, Method 4500-NO3E.

   Methods for Chemical Analysis of Water and Wastes, U.S. Environmental Protection Agency, EMSL, Cincinnati, OH 45268, March, 1979 (EPA-600/4-79-020), Method 353.2.

5. Standard Methods for the Examination of Water and Wastewater, 19th ed., American Public Health Association, Washington, DC, 1995, Method 505A.

   Methods for Chemical Analysis of Water and Wastes, U.S. Environmental Protection Agency, EMSL, Cincinnati, OH 45268, March, 1979 (EPA-600/4-79-020), Method 415.1.

6. Standard Methods for the Examination of Water and Wastewater, 16th ed., American Public Health Association, Washington, DC, 1985, Method 209B.

   Methods for Chemical Analysis of Water and Wastes, U.S. Environmental Protection Agency, EMSL, Cincinnati, OH 45268, March, 1979 (EPA-600/4-79-020), Method 160.1.

6.2.2 Field Measured Parameters

During the research program, field parameters were measured at regular intervals in observation wells and within the *Trench and Gate* system. A discussion of these measurements is presented below. Results are presented in Table 2 of Appendix III.

Electrical Conductivity

Electrical Conductivity (EC) readings recorded from monitoring wells on site range from 311 (BH-4) to 9300 µS/cm (96-23A). Most readings fall within the range of 800 to 1500 µS/cm. Readings below this range likely reflect dilution by large rainfall recharge events. Values above this range represent high groundwater chloride concentrations and are limited to the areas down-gradient of the flare pit and holding pond. High chloride concentrations presumably resulted from the disposal of produced water to the pit and pond and are in part identifiable from the electromagnetic survey (Figure 2-6).

pH

Values of pH, with the exception of the plant water well and piezometer 96-23A, span a range from 6.0 to 8.0, with most readings being around the expected median value of 7.0. The slightly higher values of approximately 8.5 from the water well reflect the influence of carbonate from the bedrock. The decrease in pH down-gradient of the flare pit (*i.e.*, 96-23A) is tentatively attributed to disposal of an acidic process chemical or possibly the breakdown of organic chemicals such as amines which yield an acidic intermediary daughter product.

Changes in pH were noted for water flowing through the treatment system. Field measured pH’s for inputs to the system (CW-1 and CW-2) as compared to system outputs (CW-7) are presented in Figure 6-12. Inspection of the graph reveals that the pH of the treated water is marginally but consistently elevated relative to the untreated water.

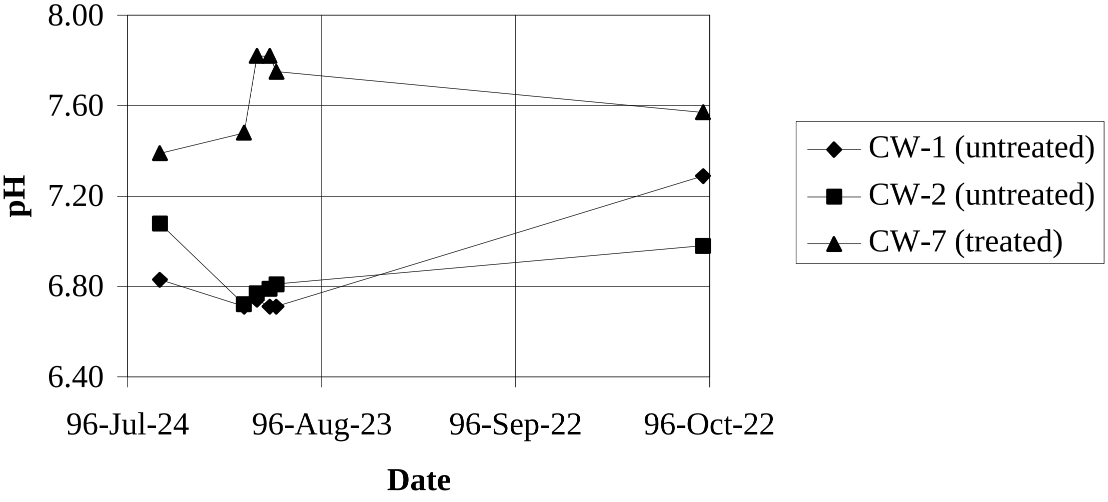


Figure 6-12 Temporal Variation in pH for Culvert Wells 1, 2, and 7.

The change in pH is attributed to oxidation of ferrous iron as evidenced by the accumulation of an iron precipitate on the walls of the culverts and the depletion of dissolved iron in samples from the third culvert (see Section 6.2.3). The proposed reaction is shown below. Transformation of the iron consumes protons (H^+) creating a surplus of OH^- thus driving the pH up.

$$\begin{array}{ccccccccc} 4Fe_{(aq)}^{2+} & + & O_2 & + & 4H^+ & + & 12OH^- & \rightarrow & 4Fe(OH)_{3\,(solid)} + 2H_2O \\ \textit{Ferrous} & + & \textit{Dissolved} & + & \textit{Proton} & + & \textit{Hydroxide} & \rightarrow & \textit{Ferric Hydroxide (amorphous)} \\ \textit{Iron} & & \textit{Oxygen} & & & & & & \textit{Ferrihydrite (if crystalline)} \end{array}$$

Dissolved Oxygen

Dissolved oxygen (DO) values across the site vary with location and temporal recharge conditions. Background values are typically less than 2.0 mg/L except immediately following a significant precipitation event where they can be seen to increase. Contaminated wells typically have negligible or zero DO concentrations as do the influent concentrations to the first culvert. Biosparging in the remediation system increases these values to fully saturated with respect to air or approximately 10 to 15 mg/L depending on temperature, mineralization, and other factors. Elevated dissolved oxygen concentrations persist into the infiltration gallery and results as high as 5.0 mg/L are not only common, but also provide indirect evidence of flow out of the treatment system. Variations in DO content within infiltration gallery wells also serve to illustrate how flow directions change through the year with groundwater discharge preferentially occurring down different fingers of the infiltration gallery. As can be seen in Table 6-2, near background DO concentrations in GW-3 and GW-4 at the end of May stand in contrast to the values from the other two wells, and to values in the same wells earlier in the month. This indicates that these infiltration gallery arms were receiving little oxygenated groundwater discharge flow from the Gates at this time but had been earlier.

Table 6-2 Dissolved Oxygen Values (mg/L) in Infiltration Gallery Piezometers

	Piezometer			
Date	**GW-1**	**GW-2**	**GW-3**	**GW-4**
96-May-16	9.6	5.7	7.2	7.2
96-May-31	7.3	3.3	0.8	0.4

Eh

Redox potential measurements span a broad range from -495 to 324 mV. Background values are typically in the 100 to 200 mV range while contaminated wells are more often in the -100 to -200 mV range. Eh values can be partially correlated to DO values, however, they appear to exhibit less short term variability and are not as easily altered by recharge. Groundwater Eh values show a concomitant increase with dissolved oxygen values as groundwater flows through and becomes oxygenated in the treatment system (Appendix III, Table 2).

6.2.3 Laboratory Analytical Data

Dissolved Hydrocarbons

Dissolved hydrocarbon analyses and dissolved organic carbon (DOC) concentrations, which serves as a general indicator of organic contamination, are presented in Table 4 of

Appendix III. Dissolved hydrocarbon analytical data has been collected since 1992. While different analytical techniques have been used to assess hydrocarbon concentrations (see Section 6.2.1) the majority of the samples were submitted for analysis of BTEX (benzene, toluene, ethylbenzene, and total xylenes), and total purgeable hydrocarbons (TPH) as volatiles (C_6-C_{11}) and semi-volatiles (C_{12}-C_{22}). Accordingly, the following discussion will be limited to these parameters.

Volatile and semi-volatile TPH detections generally do not exceed a few mg/L and are limited to piezometers immediately down-gradient of contaminant sources such as the underground water storage tank, the tank farm, and the flare pit.

BTEX concentrations, which represent the primary hydrocarbons of environmental concern, are discussed in terms of total BTEX concentrations (*i.e.,* benzene + toluene + ethylbenzene + total xylenes). However, it should be noted that at most locations the majority of the total BTEX component is composed of benzene. Therefore, the two terms can be used essentially interchangeably for the following discussion.

Total BTEX concentrations up to approximately 10 mg/L have been recorded for piezometer samples taken from down-gradient of the underground water storage tank (BH-7) and represent the most heavily hydrocarbon contaminated samples on site. Samples taken from piezometers down-gradient of the tank farm and flare pit yield lower BTEX concentrations in the 0.1 mg/l range. Thus, analytical data confirms the presence of multiple dissolved hydrocarbon plumes on site. The capture of the plume sourced from the underground storage tank by the *Trench and Gate* system is well illustrated by the significant increases in hydrocarbon concentrations in TW-7 and a concomitant increase at CW-1 over time.

In general, dissolved organic carbon concentrations serve as a good indicator of significant dissolved hydrocarbon concentrations at the East Garrington site. Background DOC values are typically less than approximately 10 mg/L while values over 15 mg/L can generally be correlated with hydrocarbon contamination. Values between 10 and 15 mg/L may represent background or contaminated samples. Notable for the DOC results is the high concentration measured in piezometer 96-23A, which exceeds 3000 mg/L. This is particularly anomalous because very little of this mass is accounted for by purgeable or extractable hydrocarbons and thus reflects the large quantities of organic material present in the flare pit, possibly as organic acids formed as a by-product of biodegradation.

To date, the highest measured total BTEX concentration treated by the system (not including the period when concentrations were artificially increased for experimental purposes) has been 0.183 mg/L. In this case, and as with most of the previous data, BTEX concentrations are reduced to less than the detection limit of 0.001 mg/L before the groundwater exits the third gate. For the three occasions where BTEX components were still detectable in the infiltration gallery after treatment (June and July, 1996), these concentrations were low enough, and dissolved oxygen concentrations were high enough, that any remaining hydrocarbons would have been degraded over a very short distance and time.

It appears that the treatment system has been able to degrade all incoming hydrocarbons despite the fact that bacterial growth is limited to the walls of the culvert. In settings with higher concentrations of hydrocarbons, it may be necessary to add a stationary growth medium to increase the surface area available for bacterial growth. While it is likely that some hydrocarbons are volatilized instead of degraded, this is likely to represent a relatively small fraction as suggested by the following:

1. Biosparging delivery pressure is kept to a minimum thus keeping agitation to a minimum.
2. Measurement of off-gasses from the sparging culvert using an organic vapour analyzer with an effective detection limit of 5 ppm, yield

background or near-background concentrations of petroleum hydrocarbons.

3. Biodegradation experiments (see Section 5.2.2) showed that most hydrocarbon mass destruction was attributable to biodegradation.

Indicators of Biodegradation

Indicators of contamination (chloride and total BTEX), indicators of biodegradation (*i.e.*, terminal electron acceptors $NO_2 + NO_3$ as N, manganese, iron, and sulphate), and nutrient (*i.e.*, phosphorous) concentrations are presented in Table 5 of Appendix III.

Analysis reveals that dissolved Fe and Mn concentrations are highest in piezometer 96-23A, the well with the highest DOC concentrations. Iron and manganese concentrations across the site are also generally higher in contaminated wells. Iron is removed from groundwater during treatment as evidenced by decreasing concentrations in samples taken from culvert wells CW-1 to CW-7 (Figure 6-13). This is supported by visual observations made during culvert inspections which confirmed the build-up of an iron precipitate on the sides of the culverts.

$NO_2 + NO_3$ as N concentrations exhibit no obvious depletion in contaminated wells.

Phosphorus concentrations are noticeably low across the site, indirectly supporting the argument that phosphorous is the limiting nutrient at the East Garrington site.

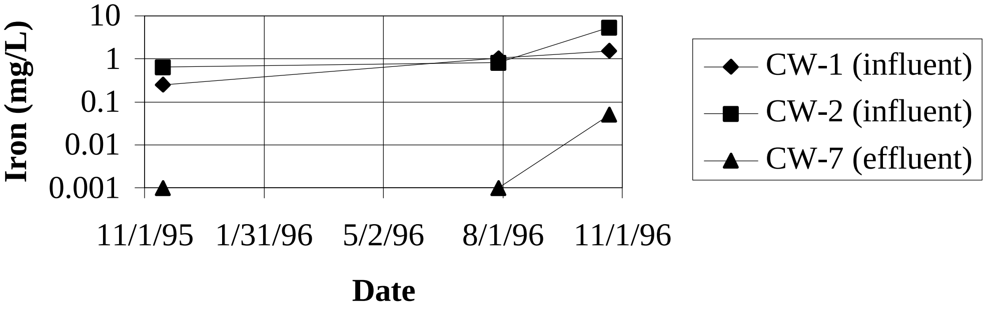
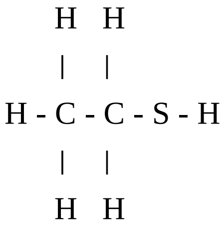


Figure 6-13 Temporal Variation in Dissolved Iron Concentrations for Culvert Wells 1, 2, and 7.

Sulphate concentrations are generally quite low across the site and small differences in concentrations may be attributed to natural sulphate variability within the tills (Hendry *et al.,* 1986). However, there is some evidence to indicate a decrease in sulphate concentrations down-gradient of the flare pit as discussed below.

Very strong sewage-like odours were detected in groundwater from piezometer 96-23A. In an effort to identify the cause of the odour, a volatile Gas Chromatograph-Mass Spectrometer open scan analysis of a water sample from this piezometer was conducted. The analysis yielded a concentration of 200 mg/L ethanethiol or ethyl mercaptan C_2H_6S (C_2H_5SH) as shown below:



$$\begin{array}{ccccccccc} & & H & & H & & & & \\ & & | & & | & & & & \\ H & - & C & - & C & - & S & - & H \\ & & | & & | & & & & \\ & & H & & H & & & & \end{array}$$

The mercaptan is believed to have resulted from an interaction between a polar organic such as alcohol and hydrogen sulphide (H_2S). Under the anaerobic conditions present in, and down-gradient of the flare pit, natural sulphate (SO_4^{2-}) dissolved in the groundwater is reduced to hydrogen sulphide (H_2S) by anaerobic bacteria possibly according to the following:

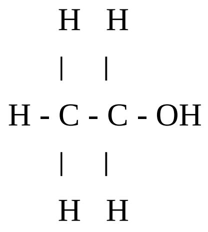
$$SO_4^{2-} + H_2O \xrightarrow[\textit{anaerobic bacteria}]{\qquad\qquad} H_2S + 2.5O_2$$

The excess O_2 is utilized by the bacteria. Decreased concentrations of dissolved sulphate in piezometers down-gradient of the flare pit tend to support this hypothesis. Following the breakdown of the sulphate by bacteria, the H_2S will then react with a polar organic to form the mercaptan according to the generic formula:

$$R\text{-}X + H_2S \longrightarrow R\text{-}SH$$

where R is the carbon parent chain and X is the substituent.

As an example, if we take the organic to be a straight chain aliphatic hydrocarbon or a compound such as ethanol (CH_3CH_2OH),

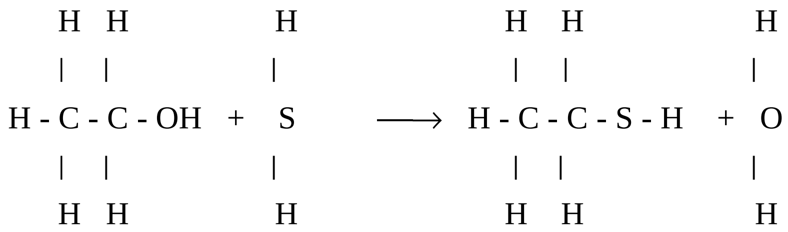


$$\begin{array}{ccccccc} & & H & & H & & \\ & & | & & | & & \\ H & - & C & - & C & - & OH \\ & & | & & | & & \\ & & H & & H & & \end{array}$$

it will react with the hydrogen sulphide according to the following:

$$CH_3CH_2OH \ + \ H_2S \longrightarrow C_2H_5SH + H_2O$$

<u>or</u>



$$\begin{array}{ccccccccccccccccccc} & & H & & H & & & & H & & & & H & & H & & & & H \\ & & | & & | & & & & | & & & & | & & | & & & & | \\ H & - & C & - & C & - & OH & + & S & \longrightarrow & H & - & C & - & C & - & S - H & + & O \\ & & | & & | & & & & | & & & & | & & | & & & & | \\ & & H & & H & & & & H & & & & H & & H & & & & H \end{array}$$

On emission to atmosphere (*i.e.*, during groundwater sampling) mercaptans will join together to form a disulphide (*e.g.*, carbon disulphide) which is even more pungent than a mercaptan:

$$R - SH + HS - R \longrightarrow R - S - S - R$$

After passing through the treatment gate and being aerated, aerobic bacteria will cleave the S atom from the mercaptan molecule. This molecule will then be degraded into CO_2 and H_2O.

Dissolved Metals

Dissolved metals analyses are presented in Table 6 of Appendix III. Most dissolved metal concentrations are quite low, as would be expected for a natural groundwater system. In all but a few cases, concentrations are also well below the Canadian drinking water guidelines (Health Canada, 1996) for parameters which have defined maximum acceptable concentrations. A notable exception to this generalization are the results from piezometer 96-23A which are significantly higher than all other samples. The higher concentrations of metals are at least partially due to a relatively lower pH. However, the high concentrations of DOC in the well suggest that organo-metallic complexing could also be a contributing factor (Davis *et al.*, 1994). Another notable exception are zinc values which appear to be elevated in the culvert wells (CW series). This is most likely due to dissolution of zinc from the galvanized culvert coating.

Piezometers 25A, 25B, and 26A also yielded some slightly elevated metal concentrations. The reason for this is not readily apparent.

6.3 PERFORMANCE EVALUATION

Costs for the construction of the basic *Trench and Gate* groundwater remediation system were compared to the costs of on-site landfarming or landfilling the same material (Komex, 1997). Results of the comparison indicate that the difference is significant, and that the *Trench and Gate* system can be built for less than half the cost of these routinely considered alternatives. The resultant savings are more than adequate to cover minimal annual routine maintenance costs for the system.

A long term installation also has the advantage of being able to treat new contamination without added cost. This assuages worries with regard to incurring additional clean-up costs for soils contaminated by new spills in the remediated area. However, the *Trench and Gate* system does require long term installation in order to be effective as it relies on natural flushing by groundwater flow to transport contaminants to the treatment zone.

7. CONCLUSIONS

Biodegradation experiments have identified a number of indigenous organisms capable of degrading dissolved hydrocarbons. These experiments also showed that under aerobic conditions, phosphorus is the limiting nutrient at the East Garrington site.

Research indicates that the flow regime within glacial sediments is significantly more dynamic than previously suspected. Infiltration and recharge rates can be extremely rapid and quite variable over small areas as illustrated by large short-term fluctuations in water table elevations. Variations in hydraulic head, and concomitant changes in horizontal gradients can change the flux through a cross-sectional area significantly and quickly. These results illustrate that a thorough characterization and understanding of site geological heterogeneities will significantly improve the chances of designing a successful remediation system.

Observations made during the initial period of operation confirm that the *Trench and Gate* system offers a viable, long-term remediation system capable of treating contaminated groundwater plumes hosted by low hydraulic conductivity sediments, and that the system can be equally well applied at numerous other sites. The system also offers several advantages in terms of increased vertical and horizontal capture zone size as compared with the Funnel and Gate system. This is illustrated by both field measurements and computer modelling results.

The *Trench and Gate* system is very flexible. Minor modifications to the open gate arrangement accommodate treatment of multiple contaminant types. The open gate configuration also facilitates routine maintenance. Additionally, operating expenses are minimal.

The *Trench and Gate* system has proved to be economical and effective in removing hydrocarbons from groundwater, especially as compared with other more traditional remediation methods. It has efficiently prevented off-site migration of contaminants. Controlled experiments have shown that the system is capable of degrading dissolved hydrocarbons at concentrations significantly higher than those present at the East Garrington site.

8. REFERENCES

Atlas, R.M., 1981. Microbial Degradation of Petroleum Hydrocarbons: an Environmental Perspective. Microbial Reviews, Vol. 45, pp.180-209.

Bear, J., 1979. Hydraulics of Groundwater, New York, McGraw-Hill Inc., 569 p.

Binks, Peter. R., S. Nicklin, and N.C. Bruce, 1995. Degradation of Haxahydro-1,3,5-Trinitro-1,3,5-Triazine (RDX) by Stenotrophomonas Maltophilia. Applied and Environmental Microbiology, Vol. 61, No. 4, pp.1318-1322.

Bostock, H.S., 1967. Physiographic Regions of Canada. Geological Survey of Canada, Map 1254A.

Bouwer, H. and R. C. Rice, 1976. A Slug Test for Determining Hydraulic Conductivity of Unconfined Aquifers with Completely or Partially Penetrating Wells. Water Resources Research, Vol. 12, pp. 423-428.

Bowles, M., L. Bentley, J. Barker, and J. Rathgeber. 1995. In-situ Remediation of Hydrocarbon Contaminated Groundwater in low Hydraulic Conductivity Media Using *Trench and Gate* Technology. Proceedings of the 5th Annual Symposium on Groundwater and Soil Remediation. Toronto, Ontario, Canada, October 2-6, 1995.

Bowles, M.W. and L.R. Bentley. 1995. Estimating Hydraulic Conductivity Using a Trench Pumping Test. Proceedings of the Scientific Meeting of the Canadian Geophysical Union. Banff, Alberta, Canada, May 22-26, 1995.

Bowles, M., L. Bentley, J. Barker, D. Thomas, D. Granger, and H. Jacobs. 1997. The East Garrington *Trench and Gate* Program: It Works. Proceedings of the 6th Annual Symposium on Groundwater and Soil Remediation. Montreal, Quebec, Canada, March 18-21, 1997.

Buscheck, T.E., D.C. Wickland, and D.L. Kuehne, 1996. Multiple Lines of Evidence to Demonstrate Natural Attenuation of Petroleum Hydrocarbons in Proceedings of the 1996 Petroleum Hydrocarbons & Organic Chemicals in Groundwater: Prevention, Detection, and Remediation, November 13-15, 1996. The Westin Galleria, Houston, Texas.

Cooper, H.H., J.D. Bredehoft, and I.S. Papadopulos, 1967. Response of a Finite-diameter Well to an Instantaneous Charge of Water. Water Resources Research, Vol. 3, pp. 263-269.

Darcy, H.P.G., 1856. Les fontaines publiques de la Ville de Dijon: Paris, Victor Dalmont.

D'Astous, A.Y., W.W. Ruland, J.R.G. Bruce, J.A. Cherry, and R.W. Gillham, 1989. Fracture effects in the shallow groundwater zone in weathered Sarnia-area clay. Canadian Geotechnical Journal, Vol. 26, pp. 43-56.

Davis, A., J. H. Kempton, and A. Nicholson, 1994. Groundwater transport of arsenic and chromium at a historical tannery, Woburn, Massachusetts, U.S.A.. Applied Geochemistry, Vol. 9, pp. 569-582.

De Marsily, G., 1986. Quantitative hydrogeology, Academic Press, London, p. 440.

Difco Laboratories, 1994. Difco Manual, 10th edition. Detroit: Difco Laboratories.

Domenico, P.A. and F.W. Schwartz, 1990. Physical and Chemical Hydrogeology. John Wiley & Sons, Toronto, 824 p.

Eaton, A.D., L.S. Clesceri and A.E. Greenbery (eds.), 1995. Standard Methods for the Examination of Water and Wastewater. American Public Health Association, American Water Works Association, and Water Environment Federation, Washington, D.C.

Environment Canada, 1991. Historical Streamflow Summary - Alberta, to 1990. Minister of Supply and Services, Cat. No. En36-418/1990-3, ISBN 0-662-58803-7. Government Printer.

Fitts, Charles R., 1997. Analytic Modeling of Impermeable and Resistant Barriers. Ground Water, Vol. 35, No. 2., March-April, 1997. pp. 312-317.

Freeze, R.A. and J.A. Cherry, 1979. Groundwater, Prentice Hall, Inc., New Jersey, 604 p.

Funk, H.B. and T.A. Krulwich, 1964. Preparation of Clear Silica Gels that can be Streaked. Journal of Bacteriology, Vol. 88, pp. 1200-1201.

Geraghty & Miller, Inc., 1996. AQTESOLV for Windows User's Guide. Hydrosolve Inc., Weston, VA.

Glass, D.J. (ed.), 1990. Lexicon of Canadian Stratigraphy, Volume 4 - Western Canada. Canadian Society of Petroleum Geologists, Calgary, Alberta, ISBN 0-920230-23-7, McAra, p. 772.

Granger, D.A., 1997. Nutrient Amendment to Enhance Aerobic Biodegradation Within a Funnel-And-Gate System. Master of Science Project. The University of Waterloo, Waterloo, Ontario, Canada.

Hazen, A., 1911. Discussion of "Dams on Soil Foundations", Trans. Amer. Soc. Civil Engrs., Vol. 73, p. 199.

Hazmacon, 1990a. Unpublished Letter Report to Amoco Canada Petroleum Company Ltd. on Phase 1 Site Investigation of the East Garrington Facility, November 10, 1990.

Hazmacon, 1990b. Soil Vapour Probe Analysis of East Garrington Site. Unpublished Report to Amoco Canada Petroleum Company Ltd., December 30, 1990.

Health Canada, 1996. Guidelines for Canadian Drinking Water Quality, Sixth Edition, Minister of Supply and Services Canada, Ottawa Canada Cat.: H48-10/1996E, ISBN 0-660-16295-4.

Hendry, M.J., J.A. Cherry, and E.I. Wallick, 1986. Origin and Distribution of Sulfate in a Fractured Till in Southern Alberta, Canada. Water Resources Research, Vol. 22, No. 1, pp. 45-61.

Harrison, B., E.A. Sudicky, and J.A. Cherry, 1992. Numerical Analysis of Solute Migration Through Fractured Clayey Deposits Into Underlying Aquifers. Water Resources Research, Vol. 28, No. 2, pp. 515-526.

Heald, S.C. and R.O. Jenkins, 1996. Expression and substrate specificity of the toluene dioxygenase of *Pseudomonas putida* NCIMB 11767. Appl. Microbiol. Biotechnol., No. 45, pp. 56-62.

Hinchee, Robert E. (ed.), 1994. Air Sparging for Site Remediation, Lewis Publishers, New York, p. 142.

Howard, P.H., R.S. Boethling, W.F. Jarvis, W.M. Meylan, and E.M. Michalenko, 1991. Handbook of Environmental Degradation Rates, Lewis Publishers, Inc., Michigan, 725 p.

Hoyne, B., (in prep.). Three Dimensional Flow and Transport of a Trench and Gate System in a Low Permeability Till, Master of Science thesis, University of Calgary, Department of Geology and Geophysics, Calgary, Alberta, Canada.

Hoyne, B. and Bentley, L., 1997. Simulating the performance of passive remediation designs in low permeability tills. Paper presented at the CSPG-SEPM 1997 Joint Convention, June 1- 6, 1997, Calgary, Alberta, Canada.

Keller, C.K., G. Van Der Kamp, and J.A. Cherry, 1988. Hydrogeology of two Saskatchewan tills, I. Fractures, bulk permeability, and spatial variability of downward flow. Journal of Hydrology, Vol. 101, pp. 97-121.

Komex International Ltd., 1993. Spring and Fall 1993 Groundwater monitoring Program at Amoco East Garrington Gas Plant. Unpublished Letter Report to Amoco Canada Petroleum Company Ltd. December, 1993.

Komex International Ltd., 1997. The *Trench and Gate* Remediation System. Unpublished Report Prepared for the GASReP Research Program, March, 1997.

Lord, D., J. Lei, M. Chapdelaine, J. Sansregret, and C. Benoit, 1995. In Situ Air Sparging for Bioremediation of Groundwater and Soils in In Situ Aeration: Air Sparging, Bioventing, and Related Remediation Processes, eds. R. Hinchee, R. Miller, Paul Johnson. Battelle Press, Columbus, Ohio, pp. 121 - 126.

Marconi, Andrea M, F. Beltrametti, G. Bestetti, F. Solinas, M. Ruzzi, E. Galli, and E. Zennaro, 1996. Cloning and Characterization of Styrene Catabolism Genes from Pseudomonas fluorescens ST. Applied and Environmental Microbiology, Vol. 62, No. 1, pp. 121-127.

Masai, Eiji, A. Yamada, J.M. Healy, T. Hatta, K. Kimbara, M. Fukuda, and K. Yano, 1995. Characterization of Biphenyl Catabolic Genes of Gram-Positive Polychlorinated Biphenyl Degrader Rhodococcus sp. Strain RHA1. Applied and Environmental Microbiology, Vol. 61, No. 6, pp. 2079-2085.

McKay, L.D., R.W. Gillham, and J.A. Cherry, 1993a. Field experiments in a fractured clay till. 1. Hydraulic conductivity and fracture aperture. Water Resources Research, Vol. 29, No. 4, pp. 1149-1162.

McKay, L.D., R.W. Gillham, and J.A. Cherry, 1993b. Field experiments in a fractured clay till. 2. Solute and colloid transport. Water Resources Research, Vol. 29, No. 12, pp. 3879-3890.

Miller, T.G. and G.W. Schmidt, 1991. Field-Freon Extraction of Dissolved Hydrocarbons in Groundwater. Proceedings of the Conference on Petroleum and Organic Chemicals in Groundwater. American Petroleum Institute / Association of Groundwater Scientists and Engineers Joint Conference, November 20th to 22nd, 1991, Houston, Texas. Water Well Journal Pub. Co. ISSN 1047-9023, pp. 45-57.

Montgomery and Welkom, 1989. Groundwater Chemicals Desk Reference, Lewis Publishers, Inc., Michigan, 640 p.

O'Connor Associates, 1991. Environmental Assessment, Garrington Gas Plant, 11-17-34-3-W5M. Unpublished Report prepared for Amoco Canada Petroleum Company Ltd. March, 1991.

O'Connor Associates, 1992. Environmental Site Monitoring, Amoco East Garrington Gas Plant, 11-17-34-3-W5M. Unpublished Report to Amoco Canada Petroleum Company Ltd., October, 1992.

Ozoray, G.F., and R. Barnes, 1977. Hydrogeology of the Calgary-Golden Area, Alberta. Alberta Research Council Report 77-2, p. 38.

Pankow, J.F., R.L. Johnson, and J.A. Cherry, 1993, Air Sparging in Gate Wells in Cutoff Walls and Trenches for Control of Plumes of Volatile Organic Compounds (VOCs). Groundwater Vol. 31, No. 4, July - August, 1993, pp. 654-663.

Rowe, R.K., and J.R. Booker, 1990. Contaminant migration through fractured till into an underlying aquifer. Canadian Geotechnical Journal, Vol. 27, No. 4, pp. 484-495.

Ruland, W.W., J.A. Cherry, and S. Feenstra, 1991. The depth of fractures and active ground-water flow in a clayey till plain in Southwestern Ontario. Ground Water, Vol.29, No. 3, pp. 405-417.

Shetson, I., 1987. Quaternary Geology, Southern Alberta. Alberta Research Council Map. Scale 1:500,000.

Shikaze, S.G. and C.D. Austrins, 1995. A 3-D Numerical Investigation of Groundwater Flow in the Vicinity of a Funnel-and-Gate System. Proceedings of the 5th Annual Symposium on Groundwater and Soil Remediation. Toronto, Ontario, Canada, October 2-6, 1995.

Snow, D.T., 1968. Rock fracture spacings, openings and porosities. J. Soil Mech. Found. Div. Am. Soc. Civ. Eng., 94 (SMI), pp. 73-91.

Snow, D. T., 1969. Anisotropic permeability of fractured media. Water Resources Research, Vol. 5, No. 6, pp. 1273-1289.

Starr, R.C., and J.C. Cherry, 1994. In-situ Remediation of Contaminated Ground Water: The Funnel-and-Gate System. Ground Water, Vol. 32, No. 3, pp. 465-476.

Shikaze, S.G., C.D. Austrins, D.J.A. Smyth, J.A. Cherry, J.F. Barker, and E.A. Sudicky. 1995. The Hydraulics of a Funnel-and-Gate System: A Three-Dimensional Numerical Analysis. Proceedings of the 5th International Association of Hydrogeologists. June 8-12. Edmonton, Alberta.

Su, J.J. and D. Kafkewitz. 1996 Toluene and Xylene Degradation by a Denitrifying Strain of *Xanthomonas maltophilia* with Limited or no Oxygen. Chemosphere. Vol. 32, No. 9, pp. 1843-1850.

Therrien, R., and E.A. Sudicky, 1996. Three-dimensional analysis of variably-saturated flow and solute transport in discretely-fractured porous media. Journal of Contaminant Hydrology, Vol. 23, pp. 1-44.

Thomas, David, (in prep.). Monitoring and Characterization of Water Fluxes at a Trench and Gate Groundwater Remediation Site, Master of Science thesis, University of Calgary, Department of Geology and Geophysics, Calgary, Alberta, Canada.

Wang, Ying, James Garnon, Diane Labbé, Hélène Bergeron, and Peter C.K. Lau, 1995. Sequence and Expression of the bpdC1C2BADE Genes Involved in the Initial Steps of Biphenyl/Chlorobiphenyl Degradation by Rhodococcus sp. M5. Gene, Vol. 164, pp. 117-122.

Weber, J.K. and J.F. Barker, 1994. Field-Scale Remediation of Hydrocarbon Contaminated Soil and Water Using an *In-Situ* Funnel-And-Gate Strategy. Proceedings of the 4th Annual Symposium on Groundwater and Soil Remediation. Calgary, Alberta, Canada, September 21-23, 1994, pp. 45-49.

APPENDIX I

BOREHOLE LOGS

AND

PIEZOMETER CONSTRUCTION DETAILS

(SEE HARD COPY)

APPENDIX II

HYDRAULIC CONDUCTIVITY DATA

AND

CALCULATIONS

(FOR GRAPHS, SEE HARD COPY)

HYDRAULIC CONDUCTIVITY TEST

AMOCO CANADA
East Garrington

Piezometer:	**BH-2**
Date	96/06/06
Hydraulic Conductivity (m/s)	5.34×10^{-7}
Piezometer Stick-up (m)	0.58
Screen Length (m)	3.6
Total depth below top of PVC (m)	5.18
Static water level (m below top of PVC)	1.9

Observations:

Elapsed Time (sec)	Water level (m)	Drawdown (m)
30	4.870	2.970
60	4.740	2.840
90	4.600	2.700
120	4.465	2.565
150	4.350	2.450
180	4.215	2.315
240	3.980	2.080
300	3.745	1.845
450	3.255	1.355
600	2.875	0.975
750	2.575	0.675
900	2.360	0.460
1800	2.165	0.265
2700	2.145	0.245
3600	2.130	0.230
5400	2.105	0.205
9000	2.080	0.180
12300	2.055	0.155

HYDRAULIC CONDUCTIVITY TEST

AMOCO CANADA
East Garrington

Piezometer:	**BH-6**
Date	96/5/31
Hydraulic Conductivity (m/s)	1.27 x 10^{-7}
Piezometer Stick-up (m)	0.65
Screen Length (m)	4.9
Total depth below top of PVC (m)	6.55
Static water level (m below top of PVC)	1.955

Observations:

Elapsed Time (sec)	Water level (m)	Drawdown (m)
30	5.220	3.265
60	5.170	3.215
90	5.110	3.155
120	5.055	3.100
150	4.995	3.040
180	4.955	3.000
240	4.845	2.890
300	4.735	2.780
450	4.455	2.500
600	4.165	2.210
750	3.885	1.930
900	3.610	1.655
1800	3.065	1.110
2700	2.690	0.735
3600	2.310	0.355
5400	1.960	0.005
9000	1.955	0.000

HYDRAULIC CONDUCTIVITY TEST

AMOCO CANADA
East Garrington

Piezometer:	**BH-8**
Date	95/05/23
Hydraulic Conductivity (m/s)	9.14 x 10^{-8}
Piezometer Stick-up (m)	0.77
Screen Length (m)	3.9
Total depth below top of PVC (m)	5.67
Static water level (m below top of PVC)	1.901

Observations:

Elapsed Time (sec)	Water level (m)	Drawdown (m)
15	5.640	3.739
30	5.610	3.709
45	5.585	3.684
60	5.555	3.654
75	5.515	3.614
90	5.495	3.594
120	5.470	3.569
150	5.440	3.539
180	5.385	3.484
210	5.335	3.434
240	5.230	3.329
300	5.130	3.229
360	5.045	3.144
420	4.960	3.059
480	4.880	2.979
600	4.740	2.839
900	4.450	2.549
1200	4.255	2.354
1800	3.963	2.062
3600	3.440	1.539
4680	3.150	1.249

Piezometer:	**BH-8**
Date	96/5/21
Hydraulic Conductivity (m/s)	1.31 x 10^{-7}
Piezometer Stick-up (m)	0.77
Screen Length (m)	3.9
Total depth below top of PVC (m)	5.67
Static water level (m below top of PVC)	1.875

Observations:

Elapsed Time (sec)	Water level (m)	Drawdown (m)
30	5.600	3.725
60	5.550	3.675
90	5.480	3.605
120	5.400	3.525
150	5.345	3.470
180	5.275	3.400
240	5.160	3.285
300	5.050	3.175
450	4.850	2.975
600	4.585	2.710
750	4.435	2.560
900	4.240	2.365
1800	3.645	1.770
2700	3.345	1.470
3600	3.125	1.250
5400	2.805	0.930
9000	2.430	0.555

HYDRAULIC CONDUCTIVITY TEST

AMOCO CANADA
East Garrington

Piezometer:	**BH-9**
Date	95/05/23
Hydraulic Conductivity (m/s)	8.93×10^{-8}
Piezometer Stick-up (m)	0.80
Screen Length (m)	4.3
Total depth below top of PVC (m)	6.1
Static water level (m below top of PVC)	3.302

Observations:

Elapsed Time (sec)	Water level (m)	Drawdown (m)
15	5.290	1.988
30	5.272	1.970
45	5.251	1.949
60	5.237	1.935
75	5.216	1.914
90	5.202	1.900
120	5.171	1.869
150	5.145	1.843
180	5.120	1.818
210	5.098	1.796
240	5.077	1.775
300	5.041	1.739
360	5.011	1.709
420	4.986	1.684
600	4.935	1.633
750	4.900	1.598
1200	4.880	1.578
1800	4.850	1.548
2400	4.820	1.518
3000	4.795	1.493

HYDRAULIC CONDUCTIVITY TEST

AMOCO CANADA
East Garrington

Piezometer:	**BH-10**
Date	96/06/14
Hydraulic Conductivity (m/s)	9.87×10^{-9}
Piezometer Stick-up (m)	0.95
Screen Length (m)	4.0
Total depth below top of PVC (m)	5.95
Static water level (m below top of PVC)	2.96

Observations:

Elapsed Time (sec)	Water level (m)	Drawdown (m)
30	5.630	2.675
60	5.535	2.580
90	5.460	2.505
120	5.410	2.455
150	5.375	2.420
180	5.350	2.395
240	5.325	2.370
300	5.310	2.355
450	5.280	2.325
600	5.260	2.305
750	5.245	2.290
900	5.225	2.270
1800	5.145	2.190
2700	5.090	2.135
3600	5.040	2.085
2700	4.960	2.005
9000	4.820	1.865
11100	4.740	1.785

HYDRAULIC CONDUCTIVITY TEST

AMOCO CANADA
East Garrington

Piezometer:	**BH-11**
Date	95/05/23
Hydraulic Conductivity (m/s)	1.66×10^{-7}
Piezometer Stick-up (m)	0.91
Screen Length (m)	3.3
Total depth below top of PVC (m)	5.21
Static water level (m below top of PVC)	3.65

Observations:

Elapsed Time (sec)	Water level (m)	Drawdown (m)
15	5.150	1.500
30	5.110	1.460
45	5.080	1.430
60	5.060	1.410
75	5.030	1.380
90	5.015	1.365
120	4.980	1.330
150	4.940	1.290
180	4.905	1.255
210	4.870	1.220
240	4.830	1.180
300	4.780	1.130
360	4.735	1.085
420	4.695	1.045
480	4.658	1.008
540	4.623	0.973
600	4.595	0.945
900	4.500	0.850
1500	4.436	0.786
2100	4.420	0.770
3480	4.400	0.750
9360	4.350	0.700

HYDRAULIC CONDUCTIVITY TEST

AMOCO CANADA
East Garrington

Piezometer:	**94-15A**
Date	94/12/20
Hydraulic Conductivity (m/s)	2.03×10^{-8}
Piezometer Stick-up (m)	0.65
Screen Length (m)	2.5
Total depth below top of PVC (m)	4.25
Static water level (m below top of PVC)	3.58

Observations:

Elapsed Time (sec)	Water level (m)	Drawdown (m)
60	4.130	0.550
90	4.120	0.540
120	4.114	0.534
150	4.110	0.530
180	4.108	0.528
240	4.102	0.522
300	4.098	0.518
360	4.097	0.517
420	4.093	0.513
480	4.092	0.512
900	4.082	0.502
1740	4.075	0.495
5220	4.065	0.485
7800	4.064	0.484
10860	4.058	0.478
13980	4.055	0.475
19500	4.050	0.470

HYDRAULIC CONDUCTIVITY TEST

AMOCO CANADA
East Garrington

Piezometer:	**94-15C**
Date	94/12/20
Hydraulic Conductivity (m/s)	4.67×10^{-8}
Piezometer Stick-up (m)	0.57
Screen Length (m)	1.5
Total depth below top of PVC (m)	12.17
Static water level (m below top of PVC)	2.93

Observations:

Elapsed Time (sec)	Water level (m)	Drawdown (m)
120	11.320	8.390
180	11.305	8.375
240	11.297	8.367
300	11.287	8.357
600	11.255	8.325
1920	11.150	8.220
3120	11.070	8.140
6360	10.890	7.960
8940	10.735	7.805
12300	10.062	7.132
15180	9.490	6.560
20640	8.500	5.570

T/b = K

$(4.2\text{x}10^{-8}\ \text{m}^2/\text{sec}) / 0.9\ \text{m} = 4.67\text{x}10^{-8}\ \text{m/s}$

HYDRAULIC CONDUCTIVITY TEST

AMOCO CANADA
East Garrington

Piezometer: **94-16A**

Date	95/06/07
Hydraulic Conductivity (m/s)	4.51×10^{-7}
Piezometer Stick-up (m)	0.54
Screen Length (m)	1.5
Total depth below top of PVC (m)	3.36
Static water level (m below top of PVC)	3.014

Observations:

Elapsed Time (sec)	Water level (m)	Drawdown (m)
30	3.270	0.256
45	3.250	0.236
60	3.240	0.226
90	3.220	0.206
120	3.205	0.191
180	3.180	0.166
240	3.160	0.146
300	3.140	0.126
360	3.120	0.106
420	3.105	0.091
480	3.095	0.081
540	3.083	0.069
660	3.067	0.053
900	3.045	0.031
1230	3.027	0.013

Piezometer: **94-16A**

Date	96/7/5
Hydraulic Conductivity (m/s)	9.53×10^{-7}
Piezometer Stick-up (m)	0.54
Screen Length (m)	1.5
Total depth below top of PVC (m)	3.345
Static water level (m below top of PVC)	2.89

Observations:

Elapsed Time (sec)	Water level (m)	Drawdown (m)
30	3.135	0.245
60	3.090	0.200
90	3.060	0.170
120	3.035	0.145
150	3.015	0.125
180	2.995	0.105
240	2.970	0.080
300	2.955	0.065
450	2.925	0.035
600	2.915	0.025
750	2.905	0.015
900	2.900	0.010
1800	2.895	0.005
2700	2.890	0.000

HYDRAULIC CONDUCTIVITY TEST

AMOCO CANADA
East Garrington

Piezometer:	**94-17A**
Date	94/12/20
Hydraulic Conductivity (m/s)	1.19 x 10^{-8}
Piezometer Stick-up (m)	0.58
Screen Length (m)	3.0
Total depth below top of PVC (m)	4.98
Static water level (m below top of PVC)	3.71

Observations:

Elapsed Time (sec)	Water level (m)	Drawdown (m)
30	4.870	1.160
60	4.864	1.154
150	4.860	1.150
180	4.857	1.147
210	4.852	1.142
240	4.849	1.139
270	4.847	1.137
300	4.843	1.133
360	4.839	1.129
420	4.835	1.125
480	4.832	1.122
540	4.829	1.119
660	4.820	1.110
900	4.814	1.104
1560	4.800	1.090
3540	4.785	1.075
5520	4.778	1.068

HYDRAULIC CONDUCTIVITY TEST

AMOCO CANADA
East Garrington

Piezometer:	**94-18A**
Date	94/12/20
Hydraulic Conductivity (m/s)	5.29 x 10^{-8}
Piezometer Stick-up (m)	0.54
Screen Length (m)	3.0
Total depth below top of PVC (m)	4.30
Static water level (m below top of PVC)	2.25

Observations:

Elapsed Time (sec)	Water level (m)	Drawdown (m)
60	3.810	1.560
90	3.795	1.545
120	3.772	1.522
150	3.756	1.506
180	3.738	1.488
210	3.722	1.472
240	3.707	1.457
300	3.675	1.425
360	3.650	1.400
420	3.623	1.373
480	3.603	1.353
600	3.565	1.315
720	3.530	1.280
900	3.486	1.236
2100	3.255	1.005
4380	2.965	0.715
4860	2.666	0.416

Piezometer:	**94-18A**
Date	96/6/4
Hydraulic Conductivity (m/s)	8.85 x 10^{-7}
Piezometer Stick-up (m)	0.54
Screen Length (m)	3.0
Total depth below top of PVC (m)	4.30
Static water level (m below top of PVC)	1.55

Observations:

Elapsed Time (sec)	Water level (m)	Drawdown (m)
30	3.570	2.025
60	3.480	1.935
90	3.390	1.845
150	3.185	1.640
180	3.060	1.515
240	2.825	1.280
300	2.605	1.060
450	2.165	0.620
600	1.885	0.340
750	1.730	0.185
900	1.645	0.100
1800	1.550	0.005
2700	1.545	0.000

HYDRAULIC CONDUCTIVITY TEST

AMOCO CANADA
East Garrington

Piezometer:	**94-19A**
Date	95/05/23
Hydraulic Conductivity (m/s)	3.28×10^{-6}
Piezometer Stick-up (m)	-0.06
Screen Length (m)	0.98
Total depth below top of PVC (m)	1.64
Static water level (m below top of PVC)	0.738

Observations:

Elapsed Time (sec)	Water level (m)	Drawdown (m)
15	1.440	0.702
30	1.410	0.672
45	1.385	0.647
60	1.360	0.622
75	1.335	0.597
90	1.290	0.552
120	1.245	0.507
150	1.170	0.432
180	1.110	0.372
210	1.060	0.322
240	1.005	0.267
300	0.922	0.184
360	0.854	0.116
420	0.808	0.070
480	0.780	0.042
540	0.763	0.025
600	0.760	0.022
720	0.755	0.017
900	0.754	0.016

HYDRAULIC CONDUCTIVITY TEST

AMOCO CANADA
East Garrington

Piezometer: **94-19C**

Date	94/12/20
Hydraulic Conductivity (m/s)	1.95 x 10^{-5}
Piezometer Stick-up (m)	-0.10
Screen Length (m)	1.4
Total depth below top of PVC (m)	8.54
Static water level (m below top of PVC)	1.49

Observations:

Elapsed Time (sec)	Water level (m)	Drawdown (m)
60	5.910	4.420
90	5.450	3.960
120	5.080	3.590
150	4.700	3.210
180	4.345	2.855
210	4.060	2.570
240	3.800	2.310
300	3.330	1.840
360	2.960	1.470
420	2.690	1.200
480	2.460	0.970
600	2.140	0.650
720	1.960	0.470
900	1.800	0.310
1200	1.690	0.200

T/b = K

(9.78×10^{-6} m^2/sec) / 0.5 m = 1.95×10^{-5} m/s

Piezometer: **94-19C**

Date	95/06/07
Hydraulic Conductivity (m/s)	2.26 x 10^{-5}
Piezometer Stick-up (m)	-0.10
Screen Length (m)	1.4
Total depth below top of PVC (m)	8.54
Static water level (m below top of PVC)	0.99

Observations:

Elapsed Time (sec)	Water level (m)	Drawdown (m)
30	5.250	4.263
45	5.020	4.033
60	4.800	3.813
90	4.410	3.423
120	4.050	3.063
150	3.740	2.753
180	3.440	2.453
210	3.190	2.203
240	2.980	1.993
270	2.770	1.783
300	2.590	1.603
330	2.420	1.433
360	2.300	1.313
390	2.170	1.183
420	2.050	1.063
450	1.960	0.973
480	1.870	0.883
570	1.670	0.683
600	1.630	0.643
900	1.350	0.363
1200	1.260	0.273

T/b = K

(1.13×10^{-5} m^2/sec) / 0.5 m = 2.26×10^{-5} m/s

HYDRAULIC CONDUCTIVITY TEST

AMOCO CANADA
East Garrington

Piezometer:	**94-20A**
Date	94/12/20
Hydraulic Conductivity (m/s)	2.81×10^{-7}
Piezometer Stick-up (m)	0.54
Screen Length (m)	1.0
Total depth below top of PVC (m)	3.20
Static water level (m below top of PVC)	2.26

Observations:

Elapsed Time (sec)	Water level (m)	Drawdown (m)
60	2.958	0.698
90	2.950	0.690
120	2.935	0.675
150	2.922	0.662
180	2.912	0.652
210	2.898	0.638
270	2.878	0.618
360	2.843	0.583
480	2.803	0.543
660	2.747	0.487
840	2.700	0.440
1080	2.637	0.377
1800	2.510	0.250
4740	2.320	0.060

HYDRAULIC CONDUCTIVITY TEST

AMOCO CANADA
East Garrington

Piezometer: **94-20C**

Date	94/12/20
Hydraulic Conductivity (m/s)	5.16×10^{-5}
Piezometer Stick-up (m)	0.52
Screen Length (m)	1.4
Total depth below top of PVC (m)	10.57
Static water level (m below top of PVC)	2.575

Observations:

Elapsed Time (sec)	Water level (m)	Drawdown (m)
30	3.880	1.305
60	3.130	0.555
90	2.840	0.265
120	2.735	0.160
150	2.705	0.130
180	2.690	0.115
210	2.685	0.110
300	2.672	0.097
330	2.670	0.095
510	2.665	0.090

T/b = K

$(5.68\text{x}10^{-5}\ \text{m}^2/\text{sec}) / 1.1\ \text{m} = 5.16\text{x}10^{-5}\ \text{m/s}$

HYDRAULIC CONDUCTIVITY TEST

AMOCO CANADA
East Garrington

Piezometer:	**96-22B**
Date	96/7/12
Hydraulic Conductivity (m/s)	5.68 x 10^{-8}
Piezometer Stick-up (m)	0.58
Screen Length (m)	0.38
Total depth below top of PVC (m)	3.56
Static water level (m below top of PVC)	2.055

Observations:

Elapsed Time (sec)	Water level (m)	Drawdown (m)
30	3.510	1.455
60	3.500	1.445
90	3.490	1.435
120	3.490	1.435
150	3.485	1.430
180	3.480	1.425
240	3.475	1.420
300	3.470	1.415
450	3.465	1.410
600	3.455	1.400
750	3.450	1.395
900	3.440	1.385
1800	3.395	1.340
2700	3.355	1.300
3600	3.315	1.260
5400	3.245	1.190
9000	2.960	0.905
12600	2.645	0.590

HYDRAULIC CONDUCTIVITY TEST

AMOCO CANADA
East Garrington

Piezometer:	**96-23A**
Date	96/06/27
Hydraulic Conductivity (m/s)	2.54×10^{-9}
Piezometer Stick-up (m)	0.63
Screen Length (m)	3.0
Total depth below top of PVC (m)	5.030
Static water level (m below top of PVC)	3.140

Observations:

Elapsed Time (sec)	Water level (m)	Drawdown (m)
30	4.875	1.735
60	4.860	1.720
90	4.850	1.710
120	4.845	1.705
150	4.840	1.700
180	4.835	1.695
240	4.830	1.690
300	4.820	1.680
450	4.815	1.675
600	4.805	1.665
750	4.795	1.655
1800	4.790	1.650
2700	4.760	1.620
3600	4.735	1.595
5400	4.715	1.575
9000	4.685	1.545
12600	4.635	1.495
16200	4.595	1.455

HYDRAULIC CONDUCTIVITY TEST

AMOCO CANADA
East Garrington

Piezometer:	**96-24A**
Date	96/06/27
Hydraulic Conductivity (m/s)	7.74×10^{-7}
Piezometer Stick-up (m)	0.59
Screen Length (m)	3.0
Total depth below top of PVC (m)	4.790
Static water level (m below top of PVC)	2.535

Observations:

Elapsed Time (sec)	Water level (m)	Drawdown (m)
30	4.650	2.115
60	4.445	1.910
90	4.235	1.700
120	4.050	1.515
150	3.885	1.350
180	3.800	1.265
240	3.640	1.105
300	3.490	0.955
450	3.170	0.635
600	2.985	0.450
750	2.875	0.340
900	2.775	0.240
1200	2.570	0.035
2700	2.545	0.010
3600	2.535	0.000

HYDRAULIC CONDUCTIVITY TEST

AMOCO CANADA
East Garrington

Piezometer:	**96-25B**
Date	96/06/28
Hydraulic Conductivity (m/s)	1.66 x 10^{-5}
Piezometer Stick-up (m)	0.41
Screen Length (m)	0.5
Total depth below top of PVC (m)	3.91
Static water level (m below top of PVC)	2.825

Observations:

Elapsed Time (sec)	Water level (m)	Drawdown (m)
30	3.680	0.855
60	3.385	0.560
90	3.165	0.340
120	3.020	0.195
150	2.935	0.110
180	2.895	0.070
240	2.855	0.030
300	2.835	0.010
450	2.830	0.005
600	2.825	0.000
750	2.825	0.000
900	2.825	0.000

HYDRAULIC CONDUCTIVITY TEST

AMOCO CANADA
East Garrington

Piezometer:	**96-26A**
Date	96/07/19
Hydraulic Conductivity (m/s)	1.22×10^{-6}
Piezometer Stick-up (m)	0.57
Screen Length (m)	3.0
Total depth below top of PVC (m)	3.87
Static water level (m below top of PVC)	2.395

Observations:

Elapsed Time (sec)	Water level (m)	Drawdown (m)
30	3.335	0.940
60	3.230	0.835
90	3.145	0.750
120	3.060	0.665
150	2.965	0.570
180	2.895	0.500
240	2.765	0.370
300	2.655	0.260
450	2.430	0.035
600	2.405	0.010
750	2.400	0.005
900	2.400	0.005
1800	2.400	0.005

APPENDIX III

HYDROGEOLOGICAL

AND

CHEMICAL DATA TABLES

TABLE 1
PIEZOMETER INSTALLATION DETAILS, DATUM/GROUNDWATER SURFACE ELEVATIONS, AND HYDRAULIC CONDUCTIVITIES

Monitoring Station	*Ground Elevation (m.a.s.l.)*	*Stick-up PVC Pipe (m)*	*Datum Elevation (top of PVC) (m.a.s.l.)*	*Depth of Piezo. (below ground) (m)*	*Depth Interval of Sand[1] (below ground) (m)*	*Date (y-m-d)*	*Depth to Water Below Datum (m)*	*Groundwater Surface Elevation (m.a.s.l.)*	*Hydraulic Conductivity (m/s)*	*Lithology*
BH-1	101.34	1.10	102.44	5.00	1.00 - 5.00	93-May-21	1.64	100.80	1.7×10^{-7}	Clay/silt/siltstone
						93-Nov-02	1.87	100.57		
						94-Jun-03	1.67	100.77		
						94-Jun-09	1.30	101.14		
						94-Dec-20	2.56	99.88		
						95-May-23	1.40	101.05		
						95-Jun-07	1.29	101.16		
						95-Aug-15	1.49	100.96		
						95-Sep-18	1.59	100.86		
						95-Nov-14	2.01	100.44		
						95-Nov-25	1.96	100.48		
						96-Feb-05	2.71	99.73		
						96-Mar-20	2.42	100.02		
						96-Mar-28	2.34	100.10		
						96-Apr-21	1.69	100.76		
						96-May-06	1.42	101.02		
						96-May-15	1.43	101.02		
						96-May-21	1.51	100.93		
						96-May-29	1.52	100.93		
						96-Jun-07	1.68	100.76		
						96-Jun-12	1.80	100.65		
						96-Jun-26	1.57	100.87		
						96-Jul-03	1.56	100.88		
						96-Jul-11	1.67	100.77		
						96-Jul-18	1.63	100.82		
						96-Jul-25	1.70	100.74		
						96-Sep-29	1.85	100.59		
						96-Oct-21	1.92	100.53		

TABLE 1
PIEZOMETER INSTALLATION DETAILS, DATUM/GROUNDWATER SURFACE ELEVATIONS, AND HYDRAULIC CONDUCTIVITIES

Monitoring Station	*Ground Elevation (m.a.s.l.)*	*Stick-up PVC Pipe (m)*	*Datum Elevation (top of PVC) (m.a.s.l.)*	*Depth of Piezo. (below ground) (m)*	*Depth Interval of Sand[1] (below ground) (m)*	*Date (y-m-d)*	*Depth to Water Below Datum (m)*	*Groundwater Surface Elevation (m.a.s.l.)*	*Hydraulic Conductivity (m/s)*	*Lithology*
GW-1	98.49	0.14	98.63	3.11	0.50 - 3.11	95-Nov-14	2.61	96.03	$>10^{-5}$	Gravel pack
						96-Feb-06	2.69	95.94		
						96-Apr-17	2.79	95.85		
						96-Apr-21	1.75	96.89		
						96-May-06	2.03	96.60		
						96-May-15	1.56	97.07		
						96-May-21	1.59	97.04		
						96-May-29	1.90	96.74		
						96-Jun-07	1.85	96.79		
						96-Jun-12	2.04	96.59		
						96-Jun-26	2.06	96.58		
						96-Jul-03	2.16	96.47		
						96-Jul-11	1.86	96.78		
						96-Jul-18	1.92	96.72		
						96-Jul-25	2.14	96.50		
						96-Sep-29	2.49	96.14		
						96-Oct-21	2.55	96.08		

TABLE 1
PIEZOMETER INSTALLATION DETAILS, DATUM/GROUNDWATER SURFACE ELEVATIONS, AND HYDRAULIC CONDUCTIVITIES

Monitoring Station	*Ground Elevation (m.a.s.l.)*	*Stick-up PVC Pipe (m)*	*Datum Elevation (top of PVC) (m.a.s.l.)*	*Depth of Piezo. (below ground) (m)*	*Depth Interval of Sand[1] (below ground) (m)*	*Date (y-m-d)*	*Depth to Water Below Datum (m)*	*Groundwater Surface Elevation (m.a.s.l.)*	*Hydraulic Conductivity (m/s)*	*Lithology*
MW-1	99.04	0.52	99.55	3.94	0.94 - 3.94	95-Jan-01	2.12	97.43	$>10^{-5}$	Gravel pack
						95-Jan-24	3.30	96.26		
						95-Mar-14	3.30	96.26		
						95-May-23	3.15	96.41		
						95-Jun-07	2.94	96.61		
						95-Aug-15	2.55	97.00		
						95-Sep-18	3.12	96.43		
						95-Nov-14	3.32	96.24		
						95-Nov-25	3.32	96.23		
						96-Feb-05	3.39	96.16		
						96-Mar-20	2.12	97.43		
						96-Mar-28	2.96	96.59		
						96-Apr-21	2.57	96.98		
						96-May-06	2.99	96.56		
						96-May-15	2.47	97.08		
						96-May-21	2.48	97.07		
						96-May-29	2.75	96.81		
						96-Jun-07	2.64	96.91		
						96-Jun-12	2.85	96.70		
						96-Jun-26	2.82	96.73		
						96-Jul-03	2.90	96.66		
						96-Jul-11	2.62	96.94		
						96-Jul-18	2.68	96.88		
						96-Jul-25	2.90	96.66		
						96-Sep-29	3.12	96.43		
						96-Oct-21	3.19	96.37		

TABLE 1
PIEZOMETER INSTALLATION DETAILS, DATUM/GROUNDWATER SURFACE ELEVATIONS, AND HYDRAULIC CONDUCTIVITIES

Monitoring Station	*Ground Elevation (m.a.s.l.)*	*Stick-up PVC Pipe (m)*	*Datum Elevation (top of PVC) (m.a.s.l.)*	*Depth of Piezo. (below ground) (m)*	*Depth Interval of Sand[1] (below ground) (m)*	*Date (y-m-d)*	*Depth to Water Below Datum (m)*	*Groundwater Surface Elevation (m.a.s.l.)*	*Hydraulic Conductivity (m/s)*	*Lithology*
PW-1	98.87	0.69	99.55	3.59	0.59 - 3.59	95-Jan-24	3.21	96.34	$>10^{-5}$	Gravel pack
						95-Mar-14	3.21	96.34		
						95-May-23	3.07	96.49		
						95-Jun-07	2.85	96.70		
						95-Aug-15	2.47	97.09		
						95-Sep-18	3.04	96.52		
						95-Nov-14	3.24	96.32		
						95-Nov-25	3.24	96.31		
						96-Feb-05	3.31	96.24		
						96-Mar-20	2.05	97.50		
						96-Mar-28	2.88	96.67		
						96-Apr-21	2.59	96.96		
						96-May-06	2.91	96.65		
						96-May-15	2.40	97.16		
						96-May-21	2.41	97.15		
						96-May-29	2.66	96.89		
						96-Jun-07	2.56	97.00		
						96-Jun-12	2.77	96.78		
						96-Jun-26	2.74	96.82		
						96-Jul-03	2.81	96.75		
						96-Jul-11	2.53	97.02		
						96-Jul-18	2.59	96.96		
						96-Jul-25	2.81	96.75		
						96-Sep-29	3.04	96.52		
						96-Oct-21	3.09	96.46		

TABLE 1
PIEZOMETER INSTALLATION DETAILS, DATUM/GROUNDWATER SURFACE ELEVATIONS, AND HYDRAULIC CONDUCTIVITIES

Monitoring Station	Ground Elevation (m.a.s.l.)	Stick-up PVC Pipe (m)	Datum Elevation (top of PVC) (m.a.s.l.)	Depth of Piezo. (below ground) (m)	Depth Interval of Sand [1] (below ground) (m)	Date (y-m-d)	Depth to Water Below Datum (m)	Groundwater Surface Elevation (m.a.s.l.)	Hydraulic Conductivity (m/s)	Lithology
TW-1	98.59	1.36	99.95	3.61	0.50 - 3.61	95-Nov-14	3.89	96.06	>10^{-5}	Gravel pack
						96-Feb-05	3.97	95.98		
						96-Mar-20	2.43	97.52		
						96-Mar-28	3.34	96.61		
						96-Apr-21	3.02	96.93		
						96-May-06	3.33	96.62		
						96-May-15	2.80	97.15		
						96-May-21	2.83	97.12		
						96-May-29	3.07	96.88		
						96-Jun-07	2.99	96.96		
						96-Jun-12	3.21	96.74		
						96-Jun-26	3.13	96.82		
						96-Jul-03	3.24	96.71		
						96-Jul-11	2.95	97.00		
						96-Jul-18	3.02	96.93		
						96-Jul-25	3.25	96.70		
						96-Sep-29	3.67	96.28		
						96-Oct-21	3.65	96.30		

TABLE 1
PIEZOMETER INSTALLATION DETAILS, DATUM/GROUNDWATER SURFACE ELEVATIONS, AND HYDRAULIC CONDUCTIVITIES

Monitoring Station	*Ground Elevation (m.a.s.l.)*	*Stick-up PVC Pipe (m)*	*Datum Elevation (top of PVC) (m.a.s.l.)*	*Depth of Piezo. (below ground) (m)*	*Depth Interval of Sand[1] (below ground) (m)*	*Date (y-m-d)*	*Depth to Water Below Datum (m)*	*Groundwater Surface Elevation (m.a.s.l.)*	*Hydraulic Conductivity (m/s)*	*Lithology*
BH-2	100.12	0.58	100.70	4.60	1.00 - 4.60	93-May-21	1.98	98.72	5.3 x 10^{-7}	Gravel/silt/siltstone
						93-Nov-02	2.35	98.35		
						94-Jun-03	1.89	98.81		
						94-Jun-09	1.34	99.36		
						94-Dec-20	2.65	98.05		
						95-May-23	1.61	99.09		
						95-Jun-07	1.32	99.39		
						95-Aug-15	1.59	99.11		
						95-Sep-18	0.84	99.86		
						95-Nov-14	2.49	98.22		
						95-Nov-25	2.51	98.19		
						96-Feb-05	2.84	97.86		
						96-Mar-20	1.90	98.80		
						96-Mar-28	2.25	98.45		
						96-Apr-21	2.10	98.61		
						96-May-06	1.86	98.85		
						96-May-15	1.67	99.03		
						96-May-21	1.76	98.95		
						96-May-29	1.96	98.74		
						96-Jun-07	1.90	98.80		
						96-Jun-12	2.03	98.67		
						96-Jun-26	1.82	98.88		
						96-Jul-03	1.40	99.30		
						96-Jul-11	1.89	98.82		
						96-Jul-18	1.91	98.80		
						96-Jul-25	2.01	98.69		
						96-Sep-29	1.93	98.77		
						96-Oct-21	2.20	98.51		

TABLE 1
PIEZOMETER INSTALLATION DETAILS, DATUM/GROUNDWATER SURFACE ELEVATIONS, AND HYDRAULIC CONDUCTIVITIES

Monitoring Station	***Ground Elevation (m.a.s.l.)***	***Stick-up PVC Pipe (m)***	***Datum Elevation (top of PVC) (m.a.s.l.)***	***Depth of Piezo. (below ground) (m)***	***Depth Interval of Sand[1] (below ground) (m)***	***Date (y-m-d)***	***Depth to Water Below Datum (m)***	***Groundwater Surface Elevation (m.a.s.l.)***	***Hydraulic Conductivity (m/s)***	***Lithology***
GW-2	98.41	0.02	98.43	4.15	1.15 - 4.15	95-Nov-14	2.40	96.03	>10^{-5}	Gravel pack
						96-Feb-06	2.48	95.95		
						96-Mar-20	0.97	97.46		
						96-Mar-28	1.85	96.58		
						96-Apr-21	1.55	96.88		
						96-May-06	1.83	96.60		
						96-May-15	1.36	97.07		
						96-May-21	1.39	97.04		
						96-May-29	1.69	96.74		
						96-Jun-07	1.64	96.79		
						96-Jun-12	1.84	96.59		
						96-Jun-26	1.85	96.58		
						96-Jul-03	1.96	96.47		
						96-Jul-11	1.65	96.78		
						96-Jul-18	1.71	96.72		
						96-Jul-25	1.93	96.50		
						96-Sep-29	2.29	96.14		
						96-Oct-21	2.35	96.08		

TABLE 1
PIEZOMETER INSTALLATION DETAILS, DATUM/GROUNDWATER SURFACE ELEVATIONS, AND HYDRAULIC CONDUCTIVITIES

Monitoring Station	*Ground Elevation (m.a.s.l.)*	*Stick-up PVC Pipe (m)*	*Datum Elevation (top of PVC) (m.a.s.l.)*	*Depth of Piezo. (below ground) (m)*	*Depth Interval of Sand*[1] *(below ground) (m)*	*Date (y-m-d)*	*Depth to Water Below Datum (m)*	*Groundwater Surface Elevation (m.a.s.l.)*	*Hydraulic Conductivity (m/s)*	*Lithology*
TW-2	98.54	1.21	99.76	2.56	0.50 - 2.56	95-Nov-14	3.75	96.01	$>10^{-5}$	Gravel pack
						96-Mar-20	2.25	97.51		
						96-Mar-28	3.16	96.60		
						96-Apr-21	2.84	96.92		
						96-May-06	3.13	96.63		
						96-May-15	2.61	97.15		
						96-May-21	2.64	97.12		
						96-May-29	2.89	96.87		
						96-Jun-07	2.81	96.95		
						96-Jun-12	3.03	96.73		
						96-Jun-26	2.95	96.81		
						96-Jul-03	3.06	96.70		
						96-Jul-11	2.77	96.99		
						96-Jul-18	2.84	96.92		
						96-Jul-25	3.07	96.69		
						96-Sep-29	3.36	96.40		
						96-Oct-21	3.47	96.29		

TABLE 1
PIEZOMETER INSTALLATION DETAILS, DATUM/GROUNDWATER SURFACE ELEVATIONS, AND HYDRAULIC CONDUCTIVITIES

Monitoring Station	*Ground Elevation (m.a.s.l.)*	*Stick-up PVC Pipe (m)*	*Datum Elevation (top of PVC) (m.a.s.l.)*	*Depth of Piezo. (below ground) (m)*	*Depth Interval of Sand[1] (below ground) (m)*	*Date (y-m-d)*	*Depth to Water Below Datum (m)*	*Groundwater Surface Elevation (m.a.s.l.)*	*Hydraulic Conductivity (m/s)*	*Lithology*
BH-3	101.32	0.02	101.34	6.40	1.00 - 6.40	93-May-21	0.82	100.52	1.4 x 10^{-7}	Silt/sand/clay/siltstone
						93-Nov-02	1.00	100.34		
						94-Jun-03	0.62	100.72		
						94-Jun-09	0.19	101.15		
						94-Dec-20	1.77	99.57		
						95-May-23	0.35	100.99		
						95-Jun-07	0.38	100.95		
						95-Aug-15	0.43	100.91		
						95-Sep-18	0.75	100.59		
						95-Nov-14	1.21	100.13		
						96-Mar-20	1.53	99.81		
						96-Mar-28	1.41	99.93		
						96-Apr-21	0.61	100.73		
						96-May-06	0.42	100.92		
						96-May-15	0.38	100.96		
						96-May-21	0.48	100.86		
						96-May-29	0.55	100.79		
						96-Jun-07	0.68	100.66		
						96-Jun-12	0.88	100.46		
						96-Jun-26	0.49	100.85		
						96-Jul-03	0.50	100.84		
						96-Jul-11	0.57	100.77		
						96-Jul-18	0.54	100.80		
						96-Jul-25	0.67	100.67		
						96-Sep-29	0.72	100.62		
						96-Oct-21	0.97	100.37		

TABLE 1
PIEZOMETER INSTALLATION DETAILS, DATUM/GROUNDWATER SURFACE ELEVATIONS, AND HYDRAULIC CONDUCTIVITIES

Monitoring Station	Ground Elevation (m.a.s.l.)	Stick-up PVC Pipe (m)	Datum Elevation (top of PVC) (m.a.s.l.)	Depth of Piezo. (below ground) (m)	Depth Interval of Sand[1] (below ground) (m)	Date (y-m-d)	Depth to Water Below Datum (m)	Groundwater Surface Elevation (m.a.s.l.)	Hydraulic Conductivity (m/s)	Lithology
GW-3	98.37	0.02	98.39	4.12	1.12 - 4.12	95-Nov-14	2.38	96.01	$>10^{-5}$	Gravel pack
						95-Nov-25	2.38	96.01		
						95-Dec-17	2.42	95.97		
						96-Jan-10	2.47	95.93		
						96-Feb-06	2.47	95.92		
						96-Mar-20	0.94	97.45		
						96-Mar-28	1.83	96.57		
						96-Apr-17	1.28	97.11		
						96-Apr-21	1.52	96.87		
						96-May-06	1.80	96.59		
						96-May-15	1.34	97.06		
						96-May-21	1.36	97.03		
						96-May-29	1.67	96.72		
						96-Jun-07	1.62	96.78		
						96-Jun-12	1.81	96.58		
						96-Jun-26	1.83	96.56		
						96-Jul-03	1.95	96.45		
						96-Jul-11	1.62	96.77		
						96-Jul-18	1.69	96.71		
						96-Jul-25	1.92	96.48		
						96-Sep-29	2.29	96.11		
						96-Oct-21	2.33	96.06		

TABLE 1
PIEZOMETER INSTALLATION DETAILS, DATUM/GROUNDWATER SURFACE ELEVATIONS, AND HYDRAULIC CONDUCTIVITIES

Monitoring Station	*Ground Elevation (m.a.s.l.)*	*Stick-up PVC Pipe (m)*	*Datum Elevation (top of PVC) (m.a.s.l.)*	*Depth of Piezo. (below ground) (m)*	*Depth Interval of Sand[1] (below ground) (m)*	*Date (y-m-d)*	*Depth to Water Below Datum (m)*	*Groundwater Surface Elevation (m.a.s.l.)*	*Hydraulic Conductivity (m/s)*	*Lithology*
TW-3	98.63	1.01	99.63	2.62	2.12 - 2.62	95-Nov-14	3.61	96.03	$>10^{-5}$	Gravel pack
						96-Mar-20	2.13	97.50		
						96-Mar-28	3.03	96.60		
						96-Apr-21	2.71	96.92		
						96-May-06	3.00	96.64		
						96-May-15	2.49	97.15		
						96-May-21	2.52	97.12		
						96-May-29	2.77	96.87		
						96-Jun-07	2.68	96.95		
						96-Jun-12	2.90	96.73		
						96-Jun-26	2.82	96.81		
						96-Jul-03	2.93	96.71		
						96-Jul-11	2.64	97.00		
						96-Jul-18	2.71	96.93		
						96-Jul-25	2.94	96.70		
						96-Sep-29	3.36	96.28		
						96-Oct-21	3.34	96.29		

TABLE 1
PIEZOMETER INSTALLATION DETAILS, DATUM/GROUNDWATER SURFACE ELEVATIONS, AND HYDRAULIC CONDUCTIVITIES

Monitoring Station	***Ground Elevation (m.a.s.l.)***	***Stick-up PVC Pipe (m)***	***Datum Elevation (top of PVC) (m.a.s.l.)***	***Depth of Piezo. (below ground) (m)***	***Depth Interval of Sand[1] (below ground) (m)***	***Date (y-m-d)***	***Depth to Water Below Datum (m)***	***Groundwater Surface Elevation (m.a.s.l.)***	***Hydraulic Conductivity (m/s)***	***Lithology***
BH-4	101.28	-0.18	101.10	5.00	1.00 - 5.00	93-May-21	0.69	100.41	1.5 x 10^{-7}	Sand/silt/clay/siltstone
						93-Nov-02	0.89	100.21		
						94-Jun-03	0.46	100.64		
						94-Jun-09	0.04	101.07		
						94-Dec-20	1.58	99.53		
						95-May-23	0.13	100.97		
						95-Jun-07	0.07	101.03		
						95-Aug-15	0.18	100.93		
						95-Nov-14	1.00	100.10		
						96-Mar-20	1.01	100.09		
						96-Mar-28	1.03	100.07		
						96-Apr-21	0.23	100.87		
						96-May-06	0.08	101.03		
						96-May-15	0.11	101.00		
						96-May-21	0.23	100.88		
						96-May-29	0.28	100.82		
						96-Jun-07	0.38	100.72		
						96-Jun-12	0.61	100.50		
						96-Jun-26	0.17	100.93		
						96-Jul-11	0.26	100.85		
						96-Jul-18	0.17	100.93		
						96-Jul-25	0.43	100.67		
						96-Sep-29	0.34	100.76		
						96-Oct-21	0.71	100.39		

TABLE 1

PIEZOMETER INSTALLATION DETAILS, DATUM/GROUNDWATER SURFACE ELEVATIONS, AND HYDRAULIC CONDUCTIVITIES

Monitoring Station	*Ground Elevation (m.a.s.l.)*	*Stick-up PVC Pipe (m)*	*Datum Elevation (top of PVC) (m.a.s.l.)*	*Depth of Piezo. (below ground) (m)*	*Depth Interval of Sand[1] (below ground) (m)*	*Date (y-m-d)*	*Depth to Water Below Datum (m)*	*Groundwater Surface Elevation (m.a.s.l.)*	*Hydraulic Conductivity (m/s)*	*Lithology*
GW-4	98.45	0.05	98.49	3.90	0.90 - 3.90	95-Nov-14	2.48	96.02	$>10^{-5}$	Gravel pack
						96-Feb-06	2.56	95.93		
						96-Mar-20	1.06	97.43		
						96-Mar-28	1.94	96.55		
						96-Apr-17	1.39	97.10		
						96-Apr-21	1.63	96.86		
						96-May-06	1.91	96.59		
						96-May-15	1.45	97.05		
						96-May-21	1.47	97.02		
						96-May-29	1.78	96.72		
						96-Jun-07	1.73	96.77		
						96-Jun-12	1.92	96.57		
						96-Jun-26	1.93	96.56		
						96-Jul-03	2.04	96.46		
						96-Jul-11	1.73	96.77		
						96-Jul-18	1.79	96.70		
						96-Jul-25	2.02	96.48		
						96-Sep-29	2.37	96.13		
						96-Oct-21	2.43	96.06		

TABLE 1
PIEZOMETER INSTALLATION DETAILS, DATUM/GROUNDWATER SURFACE ELEVATIONS, AND HYDRAULIC CONDUCTIVITIES

Monitoring Station	Ground Elevation (m.a.s.l.)	Stick-up PVC Pipe (m)	Datum Elevation (top of PVC) (m.a.s.l.)	Depth of Piezo. (below ground) (m)	Depth Interval of Sand[1] (below ground) (m)	Date (y-m-d)	Depth to Water Below Datum (m)	Groundwater Surface Elevation (m.a.s.l.)	Hydraulic Conductivity (m/s)	Lithology
TW-4	98.35	1.11	99.46	2.31	0.50 - 2.31	95-Nov-14	3.40	96.06	$>10^{-5}$	Gravel pack
						95-Nov-25	3.40	96.06		
						96-Feb-05	3.50	95.96		
						96-Mar-20	1.94	97.52		
						96-Mar-28	2.85	96.61		
						96-Apr-21	2.53	96.93		
						96-May-06	2.82	96.64		
						96-May-15	2.30	97.16		
						96-May-21	2.33	97.13		
						96-May-29	2.58	96.88		
						96-Jun-07	2.50	96.96		
						96-Jun-12	2.72	96.74		
						96-Jun-26	2.64	96.82		
						96-Jul-03	2.75	96.71		
						96-Jul-11	2.46	97.00		
						96-Jul-18	2.53	96.93		
						96-Jul-25	2.76	96.70		
						96-Sep-29	3.18	96.28		
						96-Oct-21	3.16	96.30		

TABLE 1
PIEZOMETER INSTALLATION DETAILS, DATUM/GROUNDWATER SURFACE ELEVATIONS, AND HYDRAULIC CONDUCTIVITIES

Monitoring Station	Ground Elevation (m.a.s.l.)	Stick-up PVC Pipe (m)	Datum Elevation (top of PVC) (m.a.s.l.)	Depth of Piezo. (below ground) (m)	Depth Interval of Sand[1] (below ground) (m)	Date (y-m-d)	Depth to Water Below Datum (m)	Groundwater Surface Elevation (m.a.s.l.)	Hydraulic Conductivity (m/s)	Lithology
BH-5	101.07	-0.08	100.99	5.00	1.00 - 5.00	93-May-21	0.63	100.36	9.0×10^{-8}	Silt/sand/siltstone
						93-Nov-02	0.78	100.21		
						94-Jun-03	0.42	100.57		
						94-Jun-09	0.08	100.91		
						94-Dec-20	1.46	99.53		
						95-May-23	0.13	100.86		
						95-Jun-07	0.06	100.94		
						95-Aug-15	0.18	100.82		
						95-Sep-18	0.42	100.57		
						95-Nov-14	0.94	100.06		
						96-Mar-20	1.13	99.86		
						96-Mar-28	1.00	99.99		
						96-Apr-21	0.25	100.74		
						96-May-06	0.17	100.83		
						96-May-15	0.14	100.86		
						96-May-21	0.25	100.75		
						96-May-29	0.26	100.73		
						96-Jun-07	0.43	100.57		
						96-Jun-12	0.60	100.40		
						96-Jun-26	0.22	100.78		
						96-Jul-03	0.25	100.74		
						96-Jul-11	0.30	100.70		
						96-Jul-18	0.27	100.73		
						96-Jul-25	0.39	100.61		
						96-Sep-29	0.42	100.57		
						96-Oct-21	0.66	100.33		

TABLE 1
PIEZOMETER INSTALLATION DETAILS, DATUM/GROUNDWATER SURFACE ELEVATIONS, AND HYDRAULIC CONDUCTIVITIES

Monitoring Station	*Ground Elevation (m.a.s.l.)*	*Stick-up PVC Pipe (m)*	*Datum Elevation (top of PVC) (m.a.s.l.)*	*Depth of Piezo. (below ground) (m)*	*Depth Interval of Sand[1] (below ground) (m)*	*Date (y-m-d)*	*Depth to Water Below Datum (m)*	*Groundwater Surface Elevation (m.a.s.l.)*	*Hydraulic Conductivity (m/s)*	*Lithology*
TW-5	98.54	0.98	99.52	2.97	0.50 - 2.97	95-Nov-14	3.46	96.06	$>10^{-5}$	Gravel pack
						95-Nov-25	3.45	96.07		
						96-Feb-05	3.54	95.98		
						96-Mar-20	2.01	97.51		
						96-Mar-28	2.92	96.60		
						96-Apr-21	2.60	96.92		
						96-May-06	2.88	96.64		
						96-May-15	2.37	97.15		
						96-May-21	2.40	97.12		
						96-May-29	2.65	96.87		
						96-Jun-07	2.57	96.95		
						96-Jun-12	2.78	96.74		
						96-Jun-26	2.71	96.81		
						96-Jul-03	2.81	96.71		
						96-Jul-11	2.53	96.99		
						96-Jul-18	2.60	96.92		
						96-Jul-25	2.82	96.70		
						96-Sep-29	3.24	96.28		
						96-Oct-21	3.22	96.30		

TABLE 1
PIEZOMETER INSTALLATION DETAILS, DATUM/GROUNDWATER SURFACE ELEVATIONS, AND HYDRAULIC CONDUCTIVITIES

Monitoring Station	*Ground Elevation (m.a.s.l.)*	*Stick-up PVC Pipe (m)*	*Datum Elevation (top of PVC) (m.a.s.l.)*	*Depth of Piezo. (below ground) (m)*	*Depth Interval of Sand[1] (below ground) (m)*	*Date (y-m-d)*	*Depth to Water Below Datum (m)*	*Groundwater Surface Elevation (m.a.s.l.)*	*Hydraulic Conductivity (m/s)*	*Lithology*
BH-6	99.70	0.65	100.35	5.90	1.00 - 5.90	93-May-21	2.20	98.16	1.3×10^{-7}	Silt/gravel/siltstone
						93-Nov-02	2.38	97.97		
						94-Jun-03	2.20	98.15		
						94-Jun-09	1.92	98.44		
						94-Dec-20	2.67	97.69		
						95-May-23	1.95	98.41		
						95-Jun-07	1.87	98.49		
						95-Aug-15	2.04	98.31		
						95-Sep-18	2.28	98.07		
						95-Nov-14	2.53	97.82		
						95-Nov-25	2.50	97.85		
						96-Feb-05	2.95	97.40		
						96-Mar-17	3.20	97.15		
						96-Mar-20	3.15	97.20		
						96-Mar-28	3.08	97.28		
						96-Apr-21	2.81	97.54		
						96-May-06	2.41	97.95		
						96-May-15	1.94	98.41		
						96-May-21	1.99	98.37		
						96-May-29	2.11	98.25		
						96-Jun-07	2.18	98.18		
						96-Jun-12	2.25	98.11		
						96-Jun-26	2.13	98.22		
						96-Jul-03	2.19	98.17		
						96-Jul-11	2.15	98.21		
						96-Jul-18	2.13	98.23		
						96-Jul-25	2.22	98.13		
						96-Sep-29	2.23	98.12		
						96-Oct-21	2.32	98.03		

TABLE 1
PIEZOMETER INSTALLATION DETAILS, DATUM/GROUNDWATER SURFACE ELEVATIONS, AND HYDRAULIC CONDUCTIVITIES

Monitoring Station	*Ground Elevation (m.a.s.l.)*	*Stick-up PVC Pipe (m)*	*Datum Elevation (top of PVC) (m.a.s.l.)*	*Depth of Piezo. (below ground) (m)*	*Depth Interval of Sand[1] (below ground) (m)*	*Date (y-m-d)*	*Depth to Water Below Datum (m)*	*Groundwater Surface Elevation (m.a.s.l.)*	*Hydraulic Conductivity (m/s)*	*Lithology*
TW-6	98.54	1.21	99.75	2.85	0.50 - 2.85	95-Nov-14	3.71	96.04	>10^{-5}	Gravel pack
						96-Feb-05	3.78	95.97		
						96-Mar-20	2.26	97.49		
						96-Mar-28	3.15	96.60		
						96-Apr-21	2.84	96.91		
						96-May-06	3.12	96.64		
						96-May-15	2.61	97.14		
						96-May-21	2.64	97.11		
						96-May-29	2.89	96.86		
						96-Jun-07	2.82	96.94		
						96-Jun-12	3.03	96.73		
						96-Jun-26	2.95	96.81		
						96-Jul-03	3.05	96.70		
						96-Jul-11	2.77	96.98		
						96-Jul-18	2.84	96.92		
						96-Jul-25	3.06	96.69		
						96-Sep-29	3.48	96.28		
						96-Oct-21	3.46	96.29		

TABLE 1
PIEZOMETER INSTALLATION DETAILS, DATUM/GROUNDWATER SURFACE ELEVATIONS, AND HYDRAULIC CONDUCTIVITIES

Monitoring Station	*Ground Elevation (m.a.s.l.)*	*Stick-up PVC Pipe (m)*	*Datum Elevation (top of PVC) (m.a.s.l.)*	*Depth of Piezo. (below ground) (m)*	*Depth Interval of Sand[1] (below ground) (m)*	*Date (y-m-d)*	*Depth to Water Below Datum (m)*	*Groundwater Surface Elevation (m.a.s.l.)*	*Hydraulic Conductivity (m/s)*	*Lithology*
BH-7	99.95	0.74	100.70	4.90	1.00 - 4.90	93-May-21	2.36	98.34	5.6×10^{-10}	Silt and siltstone
						93-Nov-02	2.52	98.18		
						94-Jun-03	2.39	98.31		
						94-Jun-09	2.28	98.42		
						94-Dec-20	2.82	97.88		
						95-May-23	2.47	98.23		
						95-Jun-07	2.28	98.42		
						95-Aug-15	2.29	98.41		
						95-Sep-18	2.47	98.23		
						95-Nov-14	2.68	98.02		
						95-Nov-25	5.65	95.05		
						96-Feb-05	3.12	97.58		
						96-Mar-17	3.41	97.29		
						96-Mar-20	3.36	97.34		
						96-Mar-28	3.24	97.46		
						96-Apr-21	2.95	97.75		
						96-May-06	2.60	98.10		
						96-May-15	2.30	98.40		
						96-May-21	2.33	98.37		
						96-May-29	2.35	98.35		
						96-Jun-07	2.35	98.35		
						96-Jun-12	2.40	98.30		
						96-Jun-26	2.35	98.35		
						96-Jul-03	2.37	98.33		
						96-Jul-11	2.37	98.33		
						96-Jul-18	2.33	98.37		
						96-Jul-25	2.40	98.30		
						96-Sep-29	2.45	98.25		
						96-Oct-21	2.45	98.25		

TABLE 1
PIEZOMETER INSTALLATION DETAILS, DATUM/GROUNDWATER SURFACE ELEVATIONS, AND HYDRAULIC CONDUCTIVITIES

Monitoring Station	*Ground Elevation (m.a.s.l.)*	*Stick-up PVC Pipe (m)*	*Datum Elevation (top of PVC) (m.a.s.l.)*	*Depth of Piezo. (below ground) (m)*	*Depth Interval of Sand[1] (below ground) (m)*	*Date (y-m-d)*	*Depth to Water Below Datum (m)*	*Groundwater Surface Elevation (m.a.s.l.)*	*Hydraulic Conductivity (m/s)*	*Lithology*
TW-7	98.53	1.38	99.91	3.83	0.83 - 3.83	95-Nov-14	3.86	96.05	$>10^{-5}$	Gravel pack
						96-Feb-05	3.94	95.97		
						96-Mar-20	2.41	97.50		
						96-Mar-28	3.31	96.60		
						96-Apr-17	2.76	97.15		
						96-Apr-21	2.99	96.92		
						96-May-06	3.27	96.64		
						96-May-15	2.76	97.15		
						96-May-21	2.79	97.12		
						96-May-29	3.04	96.87		
						96-Jun-07	2.97	96.94		
						96-Jun-12	3.18	96.73		
						96-Jun-26	3.10	96.81		
						96-Jul-03	3.20	96.71		
						96-Jul-11	2.91	97.00		
						96-Jul-18	2.98	96.93		
						96-Jul-25	3.22	96.69		
						96-Sep-29	3.63	96.28		
						96-Oct-21	3.62	96.29		

TABLE 1
PIEZOMETER INSTALLATION DETAILS, DATUM/GROUNDWATER SURFACE ELEVATIONS, AND HYDRAULIC CONDUCTIVITIES

Monitoring Station	*Ground Elevation (m.a.s.l.)*	*Stick-up PVC Pipe (m)*	*Datum Elevation (top of PVC) (m.a.s.l.)*	*Depth of Piezo. (below ground) (m)*	*Depth Interval of Sand[1] (below ground) (m)*	*Date (y-m-d)*	*Depth to Water Below Datum (m)*	*Groundwater Surface Elevation (m.a.s.l.)*	*Hydraulic Conductivity (m/s)*	*Lithology*
BH-8	98.47	0.77	99.25	4.90	1.00 - 4.90	93-May-21	2.00	97.25	9.1 x 10^{-8}	Silt and siltstone
						93-Nov-02	2.01	97.24		
						94-Jun-03	1.95	97.30		
						94-Jun-09	1.85	97.40		
						94-Dec-20	2.14	97.11		
						95-May-23	1.90	97.35		
						95-Jun-07	1.49	97.76		
						95-Aug-15	1.89	97.36		
						95-Sep-18	1.79	97.46		
						95-Nov-14	2.11	97.14		
						95-Nov-25	2.08	97.17		
						96-Feb-05	2.30	96.95		
						96-Mar-20	1.82	97.43		
						96-Mar-28	3.22	96.03		
						96-Apr-21	2.03	97.22		
						96-May-06	1.95	97.30		
						96-May-15	1.86	97.39		
						96-May-21	1.88	97.37		
						96-May-29	1.90	97.35		
						96-Jun-07	1.89	97.36		
						96-Jun-12	1.91	97.34		
						96-Jun-26	1.88	97.37		
						96-Jul-03	1.71	97.54		
						96-Jul-11	1.89	97.36		
						96-Jul-18	1.88	97.37		
						96-Jul-25	1.91	97.34		
						96-Sep-29	1.96	97.29		
						96-Oct-21	1.97	97.28		

TABLE 1
PIEZOMETER INSTALLATION DETAILS, DATUM/GROUNDWATER SURFACE ELEVATIONS, AND HYDRAULIC CONDUCTIVITIES

Monitoring Station	***Ground Elevation (m.a.s.l.)***	***Stick-up PVC Pipe (m)***	***Datum Elevation (top of PVC) (m.a.s.l.)***	***Depth of Piezo. (below ground) (m)***	***Depth Interval of Sand[1] (below ground) (m)***	***Date (y-m-d)***	***Depth to Water Below Datum (m)***	***Groundwater Surface Elevation (m.a.s.l.)***	***Hydraulic Conductivity (m/s)***	***Lithology***
BH-9	99.13	0.80	99.93	5.30	1.00 - 5.30	93-May-21	3.34	96.59	8.9 x 10^{-8}	Sand/silt/siltstone
						93-Nov-02	3.39	96.54		
						94-Jun-03	3.35	96.59		
						94-Jun-09	3.26	96.67		
						94-Dec-20	3.46	96.47		
						95-May-23	3.30	96.63		
						95-Jun-07	3.20	96.74		
						95-Aug-15	2.94	96.99		
						95-Sep-18	3.30	96.63		

TABLE 1
PIEZOMETER INSTALLATION DETAILS, DATUM/GROUNDWATER SURFACE ELEVATIONS, AND HYDRAULIC CONDUCTIVITIES

Monitoring Station	*Ground Elevation (m.a.s.l.)*	*Stick-up PVC Pipe (m)*	*Datum Elevation (top of PVC) (m.a.s.l.)*	*Depth of Piezo. (below ground) (m)*	*Depth Interval of Sand[1] (below ground) (m)*	*Date (y-m-d)*	*Depth to Water Below Datum (m)*	*Groundwater Surface Elevation (m.a.s.l.)*	*Hydraulic Conductivity (m/s)*	*Lithology*
BH-10	98.85	0.95	99.80	5.00	1.00 - 5.00	93-May-21	2.88	96.92	9.9 x 10^{-9}	Silt and siltstone
						93-Nov-02	2.97	96.83		
						94-Jun-03	2.84	96.96		
						94-Jun-09	2.70	97.10		
						94-Dec-20	3.04	96.76		
						95-Mar-14	3.13	96.67		
						95-May-23	2.81	96.98		
						95-Jun-07	2.56	97.24		
						95-Aug-15	2.56	97.24		
						95-Sep-18	2.84	96.96		
						95-Nov-14	3.16	96.64		
						95-Nov-25	3.19	96.61		
						96-Feb-05	3.29	96.51		
						96-Mar-20	2.30	97.50		
						96-Mar-28	3.00	96.80		
						96-Apr-21	2.82	96.98		
						96-May-06	2.91	96.89		
						96-May-15	2.60	97.20		
						96-May-21	2.65	97.15		
						96-May-29	2.85	96.95		
						96-Jun-07	2.80	97.00		
						96-Jun-12	2.91	96.89		
						96-Jun-26	2.85	96.95		
						96-Jul-03	2.88	96.92		
						96-Jul-11	2.75	97.05		
						96-Jul-18	2.78	97.02		
						96-Jul-25	2.90	96.90		
						96-Sep-29	2.94	96.86		
						96-Oct-21	3.10	96.70		

TABLE 1
PIEZOMETER INSTALLATION DETAILS, DATUM/GROUNDWATER SURFACE ELEVATIONS, AND HYDRAULIC CONDUCTIVITIES

Monitoring Station	*Ground Elevation (m.a.s.l.)*	*Stick-up PVC Pipe (m)*	*Datum Elevation (top of PVC) (m.a.s.l.)*	*Depth of Piezo. (below ground) (m)*	*Depth Interval of Sand[1] (below ground) (m)*	*Date (y-m-d)*	*Depth to Water Below Datum (m)*	*Groundwater Surface Elevation (m.a.s.l.)*	*Hydraulic Conductivity (m/s)*	*Lithology*
BH-11	99.06	0.91	99.97	4.30	1.00 - 4.30	93-May-21	3.60	96.37	1.7×10^{-7}	Silt and siltstone
						93-Nov-02	3.69	96.28		
						94-Jun-03	3.64	96.33		
						94-Jun-09	3.55	96.43		
						94-Dec-20	3.74	96.23		
						95-May-23	3.56	96.41		
						95-Jun-07	3.37	96.60		
						95-Aug-15	3.01	96.97		
						95-Sep-18	3.55	96.42		
BH-12	100.21	0.72	100.93	4.70	1.00 - 4.70	93-May-21	2.15	98.78	6.1×10^{-9}	Silt and siltstone
						93-Nov-02	2.38	98.56		
						94-Jun-03	1.99	98.94		
						94-Jun-09	1.76	99.17		
						94-Nov-25	2.47	98.47		
						94-Dec-20	2.80	98.13		
						95-May-23	1.80	99.13		
						95-Jun-07	1.67	99.26		
						95-Aug-15	1.61	99.32		
						95-Sep-18	2.00	98.93		
						95-Nov-14	2.40	98.53		
						96-Oct-21	2.22	98.71		

TABLE 1
PIEZOMETER INSTALLATION DETAILS, DATUM/GROUNDWATER SURFACE ELEVATIONS, AND HYDRAULIC CONDUCTIVITIES

Monitoring Station	*Ground Elevation (m.a.s.l.)*	*Stick-up PVC Pipe (m)*	*Datum Elevation (top of PVC) (m.a.s.l.)*	*Depth of Piezo. (below ground) (m)*	*Depth Interval of Sand[1] (below ground) (m)*	*Date (y-m-d)*	*Depth to Water Below Datum (m)*	*Groundwater Surface Elevation (m.a.s.l.)*	*Hydraulic Conductivity (m/s)*	*Lithology*
BH-13	100.57	0.56	101.13	5.00	1.00 - 5.00	93-May-21	1.72	99.42	7.0 x 10^{-9}	Silt and siltstone
						93-Nov-02	1.99	99.14		
						94-Jun-03	1.65	99.49		
						94-Jun-09	1.33	99.80		
						94-Dec-20	2.42	98.71		
						95-May-23	1.40	99.73		
						95-Jun-07	1.20	99.93		
						95-Aug-15	1.34	99.79		
						95-Sep-18	1.65	99.48		
						95-Nov-14	2.11	99.03		
						95-Nov-25	2.10	99.03		
						96-Feb-05	2.86	98.27		
						96-Mar-20	2.55	98.58		
						96-Mar-28	2.39	98.74		
						96-Apr-21	1.76	99.37		
						96-May-06	1.56	99.58		
						96-May-15	1.30	99.83		
						96-May-21	1.37	99.76		
						96-May-29	1.50	99.63		
						96-Jun-07	1.47	99.67		
						96-Jun-12	1.59	99.55		
						96-Jun-26	1.46	99.67		
						96-Jul-03	1.49	99.64		
						96-Jul-11	1.41	99.72		
						96-Jul-18	1.41	99.73		
						96-Jul-25	1.54	99.59		
						96-Sep-29	1.68	99.45		
						96-Oct-21	1.74	99.40		

TABLE 1
PIEZOMETER INSTALLATION DETAILS, DATUM/GROUNDWATER SURFACE ELEVATIONS, AND HYDRAULIC CONDUCTIVITIES

Monitoring Station	*Ground Elevation (m.a.s.l.)*	*Stick-up PVC Pipe (m)*	*Datum Elevation (top of PVC) (m.a.s.l.)*	*Depth of Piezo. (below ground) (m)*	*Depth Interval of Sand[1] (below ground) (m)*	*Date (y-m-d)*	*Depth to Water Below Datum (m)*	*Groundwater Surface Elevation (m.a.s.l.)*	*Hydraulic Conductivity (m/s)*	*Lithology*
BH-14	101.41	0.79	102.20	5.00	1.00 - 5.00	94-Jun-03	1.67	100.53	1.2 x 10^{-8}	Silt and siltstone
						94-Jun-09	1.12	101.08		
						94-Dec-20	2.26	99.94		
						95-May-23	1.30	100.90		
						95-Jun-07	1.10	101.10		
						95-Aug-15	0.91	101.29		
						95-Sep-18	1.07	101.13		
						95-Nov-14	1.71	100.49		
						96-Feb-05	2.36	99.84		
						96-Mar-28	3.51	98.69		
						96-May-06	1.65	100.56		
						96-May-15	1.22	100.99		
						96-May-21	1.19	101.02		
						96-May-29	1.09	101.11		
						96-Jun-07	1.32	100.89		
						96-Jun-12	1.46	100.74		
						96-Jun-26	1.03	101.17		
						96-Jul-03	0.99	101.22		
						96-Jul-11	1.18	101.03		
						96-Jul-18	1.12	101.09		
						96-Jul-25	1.12	101.08		
						96-Sep-29	1.36	100.84		
						96-Oct-21	1.54	100.66		

TABLE 1
PIEZOMETER INSTALLATION DETAILS, DATUM/GROUNDWATER SURFACE ELEVATIONS, AND HYDRAULIC CONDUCTIVITIES

Monitoring Station	***Ground Elevation (m.a.s.l.)***	***Stick-up PVC Pipe (m)***	***Datum Elevation (top of PVC) (m.a.s.l.)***	***Depth of Piezo. (below ground) (m)***	***Depth Interval of Sand[1] (below ground) (m)***	***Date (y-m-d)***	***Depth to Water Below Datum (m)***	***Groundwater Surface Elevation (m.a.s.l.)***	***Hydraulic Conductivity (m/s)***	***Lithology***
94-15A	99.01	0.65	99.66	3.60	1.80 - 3.60	94-Dec-20	3.58	96.08	$2.0 \text{ x } 10^{-8}$	Sand and gravel/silt till
						95-May-23	3.46	96.20		
						95-Jun-07	3.16	96.50		
						95-Aug-15	2.78	96.88		
						95-Sep-18	3.32	96.34		
						95-Nov-14	3.65	96.02		
						95-Nov-25	3.66	96.00		
						95-Dec-17	3.66	96.00		
						96-Jan-10	3.70	95.97		
						96-Mar-20	2.25	97.41		
						96-May-06	3.11	96.55		
						96-May-15	2.65	97.02		
						96-May-21	2.67	96.99		
						96-May-29	2.98	96.69		
						96-Jun-07	2.93	96.74		
						96-Jun-12	3.12	96.55		
						96-Jun-26	3.13	96.53		
						96-Jul-03	3.24	96.43		
						96-Jul-11	2.93	96.74		
						96-Jul-18	2.99	96.67		
						96-Jul-25	3.22	96.45		
						96-Sep-29	3.57	96.09		
						96-Oct-21	3.64	96.02		

TABLE 1
PIEZOMETER INSTALLATION DETAILS, DATUM/GROUNDWATER SURFACE ELEVATIONS, AND HYDRAULIC CONDUCTIVITIES

Monitoring Station	*Ground Elevation (m.a.s.l.)*	*Stick-up PVC Pipe (m)*	*Datum Elevation (top of PVC) (m.a.s.l.)*	*Depth of Piezo. (below ground) (m)*	*Depth Interval of Sand[1] (below ground) (m)*	*Date (y-m-d)*	*Depth to Water Below Datum (m)*	*Groundwater Surface Elevation (m.a.s.l.)*	*Hydraulic Conductivity (m/s)*	*Lithology*
94-15C	99.15	0.57	99.72	11.60	9.67 - 11.90	94-Dec-20	2.93	96.79	4.7×10^{-8}	Sandstone and shale
						95-May-23	2.92	96.80		
						95-Jun-07	2.73	97.00		
						95-Aug-15	2.28	97.45		
						95-Sep-18	2.28	97.45		
						95-Nov-14	2.57	97.15		
						95-Nov-25	2.59	97.13		
						96-Feb-05	2.97	96.75		
						96-Mar-20	2.90	96.82		
						96-Apr-21	2.58	97.14		
						96-May-06	2.53	97.20		
						96-May-15	2.37	97.36		
						96-May-21	2.24	97.48		
						96-May-29	2.31	97.42		
						96-Jun-07	2.26	97.46		
						96-Jun-12	2.35	97.37		
						96-Jun-26	2.39	97.34		
						96-Jul-03	2.40	97.32		
						96-Jul-11	2.30	97.43		
						96-Jul-18	2.27	97.46		
						96-Jul-25	2.35	97.38		
						96-Oct-21	2.58	97.14		

TABLE 1
PIEZOMETER INSTALLATION DETAILS, DATUM/GROUNDWATER SURFACE ELEVATIONS, AND HYDRAULIC CONDUCTIVITIES

Monitoring Station	*Ground Elevation (m.a.s.l.)*	*Stick-up PVC Pipe (m)*	*Datum Elevation (top of PVC) (m.a.s.l.)*	*Depth of Piezo. (below ground) (m)*	*Depth Interval of Sand[1] (below ground) (m)*	*Date (y-m-d)*	*Depth to Water Below Datum (m)*	*Groundwater Surface Elevation (m.a.s.l.)*	*Hydraulic Conductivity (m/s)*	*Lithology*
94-16A	99.18	0.54	99.72	2.82	1.07 - 2.82	94-Dec-20	3.36	96.36	4.5 x 10^{-7}	Sand/gravel/silt
						95-May-23	3.21	96.51		
						95-Jun-07	3.01	96.71		
						95-Aug-15	2.71	97.01		
						95-Sep-18	3.23	96.50		
						96-Mar-28	3.80	95.92		
						96-Apr-21	2.78	96.94		
						96-May-06	3.10	96.62		
						96-May-15	2.56	97.16		
						96-May-21	2.58	97.15		
						96-May-29	2.84	96.88		
						96-Jun-07	2.76	96.97		
						96-Jun-12	2.96	96.76		
						96-Jun-26	2.91	96.82		
						96-Jul-03	2.98	96.75		
						96-Jul-11	2.72	97.01		
						96-Jul-18	2.78	96.95		
						96-Jul-25	3.00	96.73		
						96-Sep-29	3.24	96.48		
						96-Oct-21	3.29	96.43		

TABLE 1
PIEZOMETER INSTALLATION DETAILS, DATUM/GROUNDWATER SURFACE ELEVATIONS, AND HYDRAULIC CONDUCTIVITIES

Monitoring Station	*Ground Elevation (m.a.s.l.)*	*Stick-up PVC Pipe (m)*	*Datum Elevation (top of PVC) (m.a.s.l.)*	*Depth of Piezo. (below ground) (m)*	*Depth Interval of Sand*[1] *(below ground) (m)*	*Date (y-m-d)*	*Depth to Water Below Datum (m)*	*Groundwater Surface Elevation (m.a.s.l.)*	*Hydraulic Conductivity (m/s)*	*Lithology*
94-16B	99.18	0.57	99.75	3.43	2.87 - 3.61	94-Dec-20	3.42	96.33	5.7×10^{-6}	Clayey silt till
						95-Jan-24	3.43	96.32		
						95-Mar-14	3.45	96.30		
						95-May-23	3.24	96.51		
						95-Jun-07	3.03	96.72		
						95-Aug-15	2.73	97.02		
						95-Sep-18	3.26	96.49		
						95-Nov-14	3.49	96.27		
						95-Nov-25	3.50	96.25		
						95-Dec-17	3.52	96.23		
						96-Jan-10	3.55	96.20		
						96-Feb-05	3.56	96.19		
						96-Feb-06	3.57	96.18		
						96-May-15	2.59	97.17		
						96-May-21	2.61	97.15		
						96-May-29	2.87	96.89		
						96-Jun-07	2.78	96.97		
						96-Jun-12	2.99	96.76		
						96-Jun-26	2.93	96.83		
						96-Jul-03	3.01	96.75		
						96-Jul-11	2.74	97.01		
						96-Jul-18	2.81	96.95		
						96-Jul-25	3.02	96.73		
						96-Sep-29	3.29	96.46		
						96-Oct-21	3.35	96.41		

TABLE 1

PIEZOMETER INSTALLATION DETAILS, DATUM/GROUNDWATER SURFACE ELEVATIONS, AND HYDRAULIC CONDUCTIVITIES

Monitoring Station	*Ground Elevation (m.a.s.l.)*	*Stick-up PVC Pipe (m)*	*Datum Elevation (top of PVC) (m.a.s.l.)*	*Depth of Piezo. (below ground) (m)*	*Depth Interval of Sand[1] (below ground) (m)*	*Date (y-m-d)*	*Depth to Water Below Datum (m)*	*Groundwater Surface Elevation (m.a.s.l.)*	*Hydraulic Conductivity (m/s)*	*Lithology*
94-17A	100.00	0.58	100.59	4.40	1.20 - 4.40	94-Dec-20	3.71	96.88	1.2 x 10^{-8}	Sandy/silty/gravel tills
						95-May-23	3.35	97.24		
						95-Jun-07	3.24	97.35		
						95-Aug-15	3.14	97.45		
						95-Sep-18	3.23	97.36		
						95-Nov-14	3.31	97.28		
						95-Nov-25	3.38	97.21		
						95-Dec-17	3.35	97.24		
						96-Jan-10	3.38	97.21		
						96-Feb-05	3.43	97.16		
						96-Feb-06	3.42	97.17		
						96-Mar-20	3.30	97.29		
						96-Mar-28	3.34	97.25		
						96-Apr-21	3.24	97.35		
						96-May-06	3.31	97.28		
						96-May-15	3.09	97.50		
						96-May-21	3.10	97.49		
						96-May-29	3.16	97.43		
						96-Jun-07	3.17	97.42		
						96-Jun-12	3.18	97.41		
						96-Jun-26	3.20	97.39		
						96-Jul-03	3.20	97.39		
						96-Jul-11	3.22	97.37		
						96-Jul-18	3.18	97.41		
						96-Jul-25	3.20	97.39		
						96-Sep-29	3.21	97.38		
						96-Oct-21	3.23	97.36		

TABLE 1

PIEZOMETER INSTALLATION DETAILS, DATUM/GROUNDWATER SURFACE ELEVATIONS, AND HYDRAULIC CONDUCTIVITIES

Monitoring Station	*Ground Elevation (m.a.s.l.)*	*Stick-up PVC Pipe (m)*	*Datum Elevation (top of PVC) (m.a.s.l.)*	*Depth of Piezo. (below ground) (m)*	*Depth Interval of Sand[1] (below ground) (m)*	*Date (y-m-d)*	*Depth to Water Below Datum (m)*	*Groundwater Surface Elevation (m.a.s.l.)*	*Hydraulic Conductivity (m/s)*	*Lithology*
94-18A	99.92	0.54	100.46	3.75	0.60 - 3.75	94-Dec-20	2.25	98.21	5.3×10^{-8}	Cobbles/clayey silt till
						95-May-23	1.46	99.00		
						95-Jun-07	1.15	99.31		
						95-Aug-15	1.37	99.09		
						95-Sep-18	1.67	98.79		
						95-Nov-14	2.03	98.43		
						95-Nov-25	1.95	98.51		
						96-Feb-05	2.74	97.72		
						96-Mar-17	3.09	97.37		
						96-Mar-20	3.05	97.41		
						96-Apr-21	2.42	98.04		
						96-May-06	1.68	98.78		
						96-May-15	1.47	98.99		
						96-May-21	1.53	98.93		
						96-May-29	1.55	98.91		
						96-Jun-07	1.61	98.85		
						96-Jun-12	1.68	98.78		
						96-Jun-26	1.47	98.99		
						96-Jul-03	1.48	98.98		
						96-Jul-11	1.49	98.97		
						96-Jul-18	1.49	98.97		
						96-Jul-25	1.51	98.95		
						96-Oct-21	1.74	98.72		

TABLE 1
PIEZOMETER INSTALLATION DETAILS, DATUM/GROUNDWATER SURFACE ELEVATIONS, AND HYDRAULIC CONDUCTIVITIES

Monitoring Station	*Ground Elevation (m.a.s.l.)*	*Stick-up PVC Pipe (m)*	*Datum Elevation (top of PVC) (m.a.s.l.)*	*Depth of Piezo. (below ground) (m)*	*Depth Interval of Sand[1] (below ground) (m)*	*Date (y-m-d)*	*Depth to Water Below Datum (m)*	*Groundwater Surface Elevation (m.a.s.l.)*	*Hydraulic Conductivity (m/s)*	*Lithology*
94-19A	98.85	-0.06	98.80	1.70	0.53 - 1.83	94-Dec-20	1.48	97.32	3.3×10^{-6}	Gravel & sand/silty till
						95-May-23	0.74	98.06		
						95-Jun-07	0.47	98.32		
						95-Aug-15	0.89	97.91		
						95-Sep-18	0.96	97.84		
						95-Nov-14	1.22	97.58		
						96-Apr-21	1.46	97.34		
						96-May-06	1.27	97.53		
						96-May-15	0.80	98.00		
						96-May-21	0.85	97.95		
						96-May-29	0.93	97.87		
						96-Jun-07	0.93	97.87		
						96-Jun-12	0.98	97.82		
						96-Jun-26	0.87	97.93		
						96-Jul-03	0.79	98.01		
						96-Jul-11	0.92	97.88		
						96-Jul-18	0.92	97.88		
						96-Jul-25	0.99	97.81		
						96-Sep-29	1.08	97.72		
						96-Oct-21	1.05	97.75		

TABLE 1
PIEZOMETER INSTALLATION DETAILS, DATUM/GROUNDWATER SURFACE ELEVATIONS, AND HYDRAULIC CONDUCTIVITIES

Monitoring Station	***Ground Elevation (m.a.s.l.)***	***Stick-up PVC Pipe (m)***	***Datum Elevation (top of PVC) (m.a.s.l.)***	***Depth of Piezo. (below ground) (m)***	***Depth Interval of Sand[1] (below ground) (m)***	***Date (y-m-d)***	***Depth to Water Below Datum (m)***	***Groundwater Surface Elevation (m.a.s.l.)***	***Hydraulic Conductivity (m/s)***	***Lithology***
94-19C	99.00	-0.10	98.89	8.64	6.72 - 8.92	94-Dec-20	1.49	97.40	1.1 x 10^{-5}	Siltstone/sandstone/shale
						95-May-23	1.12	97.77		
						95-Jun-07	0.99	97.91		
						95-Aug-15	0.57	98.32		
						95-Sep-18	0.97	97.93		
						95-Nov-14	1.18	97.71		
						96-Apr-21	1.46	97.43		
						96-May-06	1.25	97.64		
						96-May-15	0.86	98.04		
						96-May-21	0.78	98.12		
						96-May-29	0.82	98.08		
						96-Jun-07	0.81	98.08		
						96-Jun-12	0.90	98.00		
						96-Jun-26	0.90	98.00		
						96-Jul-03	0.89	98.01		
						96-Jul-11	0.84	98.05		
						96-Jul-18	0.83	98.07		
						96-Jul-25	0.90	98.00		
						96-Sep-29	1.09	97.80		
						96-Oct-21	1.08	97.81		

TABLE 1
PIEZOMETER INSTALLATION DETAILS, DATUM/GROUNDWATER SURFACE ELEVATIONS, AND HYDRAULIC CONDUCTIVITIES

Monitoring Station	*Ground Elevation (m.a.s.l.)*	*Stick-up PVC Pipe (m)*	*Datum Elevation (top of PVC) (m.a.s.l.)*	*Depth of Piezo. (below ground) (m)*	*Depth Interval of Sand[1] (below ground) (m)*	*Date (y-m-d)*	*Depth to Water Below Datum (m)*	*Groundwater Surface Elevation (m.a.s.l.)*	*Hydraulic Conductivity (m/s)*	*Lithology*
94-20A	98.85	0.54	99.39	2.65	1.37 - 2.70	94-Dec-20	2.26	97.13	2.8×10^{-7}	Clayey silt till
						95-May-23	2.45	96.94		
						95-Jun-07	1.90	97.49		
						95-Aug-15	1.85	97.54		
						95-Sep-18	2.14	97.25		
						95-Nov-14	2.24	97.15		
						95-Nov-25	2.26	97.13		
						95-Dec-17	2.25	97.14		
						96-Jan-10	2.27	97.12		
						96-Feb-05	2.28	97.11		
						96-Feb-06	2.28	97.11		
						96-Mar-20	1.96	97.43		
						96-Mar-28	2.21	97.18		
						96-Apr-21	1.95	97.44		
						96-May-06	1.99	97.40		
						96-May-15	1.57	97.82		
						96-May-21	1.81	97.58		
						96-May-29	2.02	97.37		
						96-Jun-07	2.02	97.37		
						96-Jun-12	2.12	97.27		
						96-Jun-26	2.02	97.37		
						96-Jul-03	2.05	97.34		
						96-Jul-11	1.96	97.43		
						96-Jul-18	2.03	97.36		
						96-Jul-25	2.14	97.25		
						96-Sep-29	2.17	97.22		
						96-Oct-21	2.19	97.20		

TABLE 1
PIEZOMETER INSTALLATION DETAILS, DATUM/GROUNDWATER SURFACE ELEVATIONS, AND HYDRAULIC CONDUCTIVITIES

Monitoring Station	*Ground Elevation (m.a.s.l.)*	*Stick-up PVC Pipe (m)*	*Datum Elevation (top of PVC) (m.a.s.l.)*	*Depth of Piezo. (below ground) (m)*	*Depth Interval of Sand[1] (below ground) (m)*	*Date (y-m-d)*	*Depth to Water Below Datum (m)*	*Groundwater Surface Elevation (m.a.s.l.)*	*Hydraulic Conductivity (m/s)*	*Lithology*
94-20C	98.97	0.52	99.49	10.05	8.10 - 10.05	94-Dec-20	2.58	96.92	5.2 x 10^{-5}	Shale and siltstone
						95-May-23	2.54	96.96		
						95-Jun-07	1.29	98.21		
						95-Aug-15	1.61	97.88		
						95-Sep-18	1.87	97.63		
						95-Nov-14	2.16	97.33		
						95-Nov-25	2.21	97.28		
						95-Dec-17	2.31	97.18		
						96-Jan-10	2.43	97.06		
						96-Feb-05	2.53	96.96		
						96-Feb-06	2.55	96.94		
						96-Mar-20	2.51	96.98		
						96-Mar-28	2.46	97.03		
						96-Apr-21	2.15	97.34		
						96-May-06	2.13	97.37		
						96-May-15	1.90	97.59		
						96-May-21	1.82	97.68		
						96-May-29	1.88	97.61		
						96-Jun-07	1.83	97.67		
						96-Jun-12	1.92	97.58		
						96-Jun-26	1.94	97.56		
						96-Jul-03	1.95	97.55		
						96-Jul-11	1.84	97.66		
						96-Jul-18	1.82	97.68		
						96-Jul-25	1.91	97.58		
						96-Sep-29	2.17	97.32		
						96-Oct-21	2.18	97.32		

TABLE 1
PIEZOMETER INSTALLATION DETAILS, DATUM/GROUNDWATER SURFACE ELEVATIONS, AND HYDRAULIC CONDUCTIVITIES

Monitoring Station	*Ground Elevation (m.a.s.l.)*	*Stick-up PVC Pipe (m)*	*Datum Elevation (top of PVC) (m.a.s.l.)*	*Depth of Piezo. (below ground) (m)*	*Depth Interval of Sand[1] (below ground) (m)*	*Date (y-m-d)*	*Depth to Water Below Datum (m)*	*Groundwater Surface Elevation (m.a.s.l.)*	*Hydraulic Conductivity (m/s)*	*Lithology*
96-21A	98.12	0.60	98.72	4.01	0.91 - 4.27	96-Jun-12	2.10	96.62	Not Tested	Sandy silt/cobble till
						96-Jun-26	2.12	96.60		
						96-Jul-03	2.22	96.50		
						96-Jul-11	1.92	96.80		
						96-Jul-18	1.98	96.74		
						96-Jul-25	2.20	96.52		
						96-Oct-21	2.61	96.11		
96-22A	98.52	0.58	99.10	2.13	1.00 - 2.20	96-Jun-26	2.12	96.99	Not Tested	Cobble/silt till
						96-Jul-03	2.27	96.83		
						96-Jul-11	2.05	97.06		
						96-Jul-18	2.11	96.99		
						96-Jul-25	2.29	96.81		
						96-Sep-29	2.29	96.81		
						96-Oct-21	2.50	96.60		
96-22B	98.54	0.58	99.11	2.98	2.44 - 3.04	96-Jun-26	2.17	96.94	5.7×10^{-8}	Cobble/silt till
						96-Jul-03	2.26	96.85		
						96-Jul-11	2.03	97.09		
						96-Jul-18	2.09	97.02		
						96-Jul-25	2.28	96.83		
						96-Sep-29	2.47	96.64		
						96-Oct-21	2.56	96.55		

TABLE 1
PIEZOMETER INSTALLATION DETAILS, DATUM/GROUNDWATER SURFACE ELEVATIONS, AND HYDRAULIC CONDUCTIVITIES

Monitoring Station	*Ground Elevation (m.a.s.l.)*	*Stick-up PVC Pipe (m)*	*Datum Elevation (top of PVC) (m.a.s.l.)*	*Depth of Piezo. (below ground) (m)*	*Depth Interval of Sand[1] (below ground) (m)*	*Date (y-m-d)*	*Depth to Water Below Datum (m)*	*Groundwater Surface Elevation (m.a.s.l.)*	*Hydraulic Conductivity (m/s)*	*Lithology*
96-23A	99.46	0.63	100.09	4.40	1.05 - 4.40	96-Jun-12	3.10	96.99	2.5×10^{-9}	Sandy silt till
						96-Jun-26	3.08	97.01		
						96-Jul-03	3.22	96.87		
						96-Jul-11	2.95	97.14		
						96-Jul-18	2.95	97.14		
						96-Jul-25	3.11	96.98		
						96-Sep-29	3.22	96.87		
						96-Oct-21	3.29	96.80		
96-24A	99.13	0.59	99.72	4.20	1.10 - 4.20	96-Jun-12	2.60	97.12	7.7×10^{-7}	Clayey/silty till
						96-Jun-26	2.53	97.19		
						96-Jul-03	2.59	97.13		
						96-Jul-11	2.43	97.29		
						96-Jul-18	2.46	97.26		
						96-Jul-25	2.59	97.13		
						96-Sep-29	2.59	97.13		
						96-Oct-21	2.66	97.06		
96-25A	99.09	0.57	99.66	2.70	0.80 - 2.70	96-Jun-26	2.84	96.82	Not Tested	Silty clay/cobble till
						96-Jul-03	2.92	96.74		
						96-Jul-11	2.66	97.00		
						96-Jul-18	2.73	96.93		
						96-Jul-25	2.94	96.72		
						96-Sep-29	3.08	96.58		
						96-Oct-21	3.15	96.51		

TABLE 1
PIEZOMETER INSTALLATION DETAILS, DATUM/GROUNDWATER SURFACE ELEVATIONS, AND HYDRAULIC CONDUCTIVITIES

Monitoring Station	*Ground Elevation (m.a.s.l.)*	*Stick-up PVC Pipe (m)*	*Datum Elevation (top of PVC) (m.a.s.l.)*	*Depth of Piezo. (below ground) (m)*	*Depth Interval of Sand[1] (below ground) (m)*	*Date (y-m-d)*	*Depth to Water Below Datum (m)*	*Groundwater Surface Elevation (m.a.s.l.)*	*Hydraulic Conductivity (m/s)*	*Lithology*
96-25B	99.22	0.41	99.63	3.50	2.70 - 3.50	96-Jun-26	2.82	96.82	1.7×10^{-5}	Silt till
						96-Jul-03	2.89	96.75		
						96-Jul-11	2.63	97.01		
						96-Jul-18	2.68	96.96		
						96-Jul-25	2.91	96.72		
						96-Sep-29	3.07	96.56		
						96-Oct-21	3.14	96.49		
96-26A	98.68	0.57	99.26	3.30	0.90 - 3.30	96-Jun-12	2.52	96.74	1.2×10^{-6}	Cobble till
						96-Jun-26	2.49	96.77		
						96-Jul-03	2.52	96.74		
						96-Jul-11	2.32	96.94		
						96-Jul-18	2.37	96.89		
						96-Jul-25	2.53	96.73		
						96-Sep-29	2.60	96.66		
						96-Oct-21	2.60	96.66		

TABLE 1

PIEZOMETER INSTALLATION DETAILS, DATUM/GROUNDWATER SURFACE ELEVATIONS, AND HYDRAULIC CONDUCTIVITIES

Monitoring Station	*Ground Elevation (m.a.s.l.)*	*Stick-up PVC Pipe (m)*	*Datum Elevation (top of PVC) (m.a.s.l.)*	*Depth of Piezo. (below ground) (m)*	*Depth Interval of Sand*[1] *(below ground) (m)*	*Date (y-m-d)*	*Depth to Water Below Datum (m)*	*Groundwater Surface Elevation (m.a.s.l.)*	*Hydraulic Conductivity (m/s)*	*Lithology*
CULVERT 1	98.29	0.85	99.14	4.95	0.16 - 4.46	95-Nov-14	3.07	96.07	Not applicable	Not applicable
						95-Nov-25	3.08	96.06		
						96-Feb-05	3.16	95.98		
						96-Mar-17	1.70	97.44		
						96-Mar-28	2.55	96.59		
						96-Apr-17	1.98	97.16		
						96-Apr-21	2.20	96.94		
						96-May-15	1.99	97.15		
						96-May-21	2.01	97.13		
						96-May-29	2.26	96.88		
						96-Jun-07	2.20	96.94		
						96-Jun-12	2.41	96.73		
						96-Jun-26	2.32	96.82		
						96-Jul-03	2.43	96.71		
						96-Jul-11	2.15	96.99		
						96-Jul-18	2.21	96.93		
						96-Jul-25	2.46	96.68		
						96-Aug-01	2.76	96.38		
						96-Aug-02	2.78	96.36		
						96-Aug-05	2.46	96.68		
						96-Aug-07	2.40	96.74		
						96-Aug-10	2.45	96.69		
						96-Aug-12	2.56	96.58		
						96-Aug-14	2.64	96.50		
						96-Aug-15	2.65	96.49		
						96-Aug-16	2.68	96.46		
						96-Sep-29	2.87	96.27		
						96-Oct-21	2.84	96.29		

TABLE 1
PIEZOMETER INSTALLATION DETAILS, DATUM/GROUNDWATER SURFACE ELEVATIONS, AND HYDRAULIC CONDUCTIVITIES

Monitoring Station	*Ground Elevation (m.a.s.l.)*	*Stick-up PVC Pipe (m)*	*Datum Elevation (top of PVC) (m.a.s.l.)*	*Depth of Piezo. (below ground) (m)*	*Depth Interval of Sand[1] (below ground) (m)*	*Date (y-m-d)*	*Depth to Water Below Datum (m)*	*Groundwater Surface Elevation (m.a.s.l.)*	*Hydraulic Conductivity (m/s)*	*Lithology*
CULVERT 2	98.29	0.90	99.18	4.96	N/A	95-Nov-14	3.12	96.06	Not applicable	Not applicable
						96-Mar-28	2.58	96.60		
						96-Apr-17	2.02	97.16		
						96-Apr-21	2.26	96.92		
						96-May-15	2.03	97.15		
						96-May-21	2.06	97.12		
						96-May-29	2.32	96.87		
						96-Jun-07	2.23	96.96		
						96-Jun-12	2.45	96.74		
						96-Jun-26	2.36	96.82		
						96-Jul-03	2.47	96.71		
						96-Jul-11	2.19	97.00		
						96-Jul-18	2.25	96.93		
						96-Jul-25	2.49	96.70		
						96-Aug-01	2.79	96.39		
						96-Aug-02	2.80	96.38		
						96-Aug-05	2.48	96.70		
						96-Aug-07	2.42	96.76		
						96-Aug-10	2.47	96.72		
						96-Aug-11	2.58	96.61		
						96-Aug-12	2.58	96.61		
						96-Aug-14	2.65	96.53		
						96-Aug-15	2.67	96.51		
						96-Aug-16	2.70	96.48		
						96-Sep-29	2.90	96.28		
						96-Oct-21	2.88	96.30		

TABLE 1
PIEZOMETER INSTALLATION DETAILS, DATUM/GROUNDWATER SURFACE ELEVATIONS, AND HYDRAULIC CONDUCTIVITIES

Monitoring Station	*Ground Elevation (m.a.s.l.)*	*Stick-up PVC Pipe (m)*	*Datum Elevation (top of PVC) (m.a.s.l.)*	*Depth of Piezo. (below ground) (m)*	*Depth Interval of Sand[1] (below ground) (m)*	*Date (y-m-d)*	*Depth to Water Below Datum (m)*	*Groundwater Surface Elevation (m.a.s.l.)*	*Hydraulic Conductivity (m/s)*	*Lithology*
CULVERT 3	98.30	0.88	99.17	4.93	N/A	95-Nov-14	3.11	96.07	Not applicable	Not applicable
						96-Mar-28	2.59	96.58		
						96-Apr-17	2.03	97.14		
						96-Apr-21	2.27	96.91		
						96-May-06	2.53	96.65		
						96-May-15	2.02	97.16		
						96-May-21	2.05	97.13		
						96-May-29	2.30	96.88		
						96-Jun-07	2.22	96.96		
						96-Jun-12	2.43	96.74		
						96-Jun-26	2.37	96.80		
						96-Jul-03	2.49	96.69		
						96-Jul-11	2.17	97.00		
						96-Jul-18	2.23	96.94		
						96-Jul-25	2.47	96.71		
						96-Aug-01	2.78	96.39		
						96-Aug-02	2.80	96.38		
						96-Aug-05	2.48	96.69		
						96-Aug-07	2.44	96.74		
						96-Aug-10	2.48	96.69		
						96-Aug-12	2.58	96.60		
						96-Aug-14	2.67	96.51		
						96-Aug-15	2.69	96.49		
						96-Sep-29	2.89	96.29		
						96-Oct-21	2.87	96.31		

TABLE 1
PIEZOMETER INSTALLATION DETAILS, DATUM/GROUNDWATER SURFACE ELEVATIONS, AND HYDRAULIC CONDUCTIVITIES

Monitoring Station	Ground Elevation (m.a.s.l.)	Stick-up PVC Pipe (m)	Datum Elevation (top of PVC) (m.a.s.l.)	Depth of Piezo. (below ground) (m)	Depth Interval of Sand [1] (below ground) (m)	Date (y-m-d)	Depth to Water Below Datum (m)	Groundwater Surface Elevation (m.a.s.l.)	Hydraulic Conductivity (m/s)	Lithology
REFERENCE ROD	N/A	N/A	101.79	N/A	N/A	96-Feb-05	1.02	100.77	Not applicable	Not applicable
						96-Mar-28	0.94	100.85		
						96-May-06	0.96	100.83		
						96-May-15	0.92	100.87		
						96-May-21	0.92	100.87		
						96-May-29	0.92	100.87		
						96-Jun-07	0.93	100.86		
						96-Jun-12	0.96	100.83		
						96-Jun-26	0.94	100.85		
						96-Jul-03	0.94	100.85		
						96-Jul-11	0.93	100.86		
						96-Jul-18	0.93	100.86		
						96-Jul-25	0.95	100.84		
						96-Sep-29	1.08	100.71		

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PIEZOMETER INSTALLATION DETAILS, DATUM/GROUNDWATER SURFACE ELEVATIONS, AND HYDRAULIC CONDUCTIVITIES

Monitoring Station	*Ground Elevation (m.a.s.l.)*	*Stick-up PVC Pipe (m)*	*Datum Elevation (top of PVC) (m.a.s.l.)*	*Depth of Piezo. (below ground) (m)*	*Depth Interval of Sand[1] (below ground) (m)*	*Date (y-m-d)*	*Depth to Water Below Datum (m)*	*Groundwater Surface Elevation (m.a.s.l.)*	*Hydraulic Conductivity (m/s)*	*Lithology*
SW CULVERT	N/A	N/A	101.95	N/A	N/A	96-Apr-21	0.96	100.99	Not applicable	Not applicable
						96-May-06	1.05	100.90		
						96-May-15	1.06	100.90		
						96-May-21	1.09	100.86		
						96-May-29	1.25	100.71		
						96-Jun-07	1.38	100.57		
						96-Jun-12	1.64	100.31		
						96-Jun-26	1.25	100.70		
						96-Jul-03	1.15	100.81		
						96-Jul-11	1.35	100.61		
						96-Jul-18	1.26	100.70		
						96-Jul-25	1.59	100.36		
						96-Sep-29	1.72	100.23		
						96-Oct-21	1.86	100.09		

Notes:

[1] For non-standard or previously installed monitoring wells, the screened interval is used instead of the sand interval.

N/A = Not applicable.

TABLE 2
FIELD MEASURED PARAMETERS

Monitoring Station	*Date (y-m-d)*	*Temp. (°C)*	*Electrical Conductivity (µS/cm)*	*pH (units)*	*Dissolved Oxygen (mg/L)*	*Eh (mV)*	*Comments*
BH-1	92-Jun-03	---	1090	7.50	---	---	Laboratory electrical conductivity
	93-May-21	8.5	1131	7.27	---	---	
	93-Nov-02	6.0	1036	6.90	---	---	
	94-Jun-10	9.0	1060	6.60	---	---	
	95-Jun-07	10.0	1196	7.03	---	---	
	95-Nov-14	6.0	985	7.00	---	---	
	96-Jul-29	12.0	1138	6.93	---	---	
	96-Oct-21	6.5	996	7.02	---	---	
CW-1	96-Jul-29	13.2	892	6.83	---	---	
	96-Aug-01	10.1	---	---	33.5	---	Oxygen sparging experiment in progress
	96-Aug-02	10.0	---	---	50.1	---	Oxygen sparging experiment in progress
	96-Aug-05	11.0	---	---	8.7	---	Oxygen sparging experiment in progress
	96-Aug-07	12.1	---	---	29	---	Oxygen sparging experiment in progress
	96-Aug-10	11.3	---	---	41.5	---	Oxygen sparging experiment in progress
	96-Aug-11	---	---	6.71	---	---	Oxygen sparging experiment in progress
	96-Aug-12	11.7	---	---	19.1	---	Oxygen sparging experiment in progress
	96-Aug-13	15.0	---	6.74	37.2	---	Oxygen sparging experiment in progress
	96-Aug-14	11.4	---	---	31.8	---	Oxygen sparging experiment in progress
	96-Aug-15	13.0	---	6.71	27.6	---	Oxygen sparging experiment in progress
	96-Aug-16	13.5	---	6.71	21.8	---	Oxygen sparging experiment in progress
	96-Oct-21	8.6	896	7.29	---	---	
GW-1	96-May-16	---	---	---	9.6	194	
	96-May-21	---	---	---	8.4	126	
	96-May-31	---	---	---	7.3	127	
	96-Jun-06	5.1	---	---	3.3	124	
	96-Jun-13	6.2	---	---	2.8	115	
	96-Jun-26	7.2	---	---	2.6	307	
	96-Jul-04	---	---	---	0.7	177	
	96-Jul-11	---	---	---	1.9	129	
	96-Jul-19	---	---	---	0.5	150	
	96-Jul-25	---	---	---	---	324	
	96-Jul-29	11.9	865	7.11	---	---	
	96-Aug-11	13.5	---	6.89	---	---	
	96-Oct-21	9.1	813	7.21	---	---	
MW-1	96-May-16	---	---	---	0.2	-48	
	96-May-21	---	---	---	0.1	-22	
	96-May-31	---	---	---	0.1	-114	
	96-Jun-06	3.1	---	---	0.3	-97	
	96-Jun-13	3.4	---	---	4.5	-70	
	96-Jun-26	5.4	---	---	0.1	-115	
	96-Jul-04	---	---	---	0.9	-66	
	96-Jul-11	---	---	---	0.1	-16	
	96-Jul-19	---	---	---	0.9	-184	
	96-Jul-25	---	---	---	---	-168	
	96-Jul-29	10.0	4110	6.70	---	---	
	96-Oct-21	9.4	4130	6.73	0.7	-108	

TABLE 2
FIELD MEASURED PARAMETERS

Monitoring Station	*Date (y-m-d)*	*Temp. (°C)*	*Electrical Conductivity (µS/cm)*	*pH (units)*	*Dissolved Oxygen (mg/L)*	*Eh (mV)*	*Comments*
PW-1	95-Jun-07	6.0	1880	6.96	---	---	
	96-May-16	---	---	---	0.1	45	
	96-May-21	---	---	---	1.6	-77	
	96-May-31	---	---	---	0.2	-126	
	96-Jun-06	2.8	---	---	2	-99	
	96-Jun-13	4.0	---	---	5.5	-39	
	96-Jun-26	5.6	---	---	0.1	-102	
	96-Jul-04	---	---	---	0.1	-53	
	96-Jul-11	---	---	---	0.1	-123	
	96-Jul-19	---	---	---	0.7	-154	
	96-Jul-25	---	---	---	---	-100	
	96-Jul-29	10.0	4680	6.78	---	---	
	96-Oct-21	9.3	3730	6.91	---	---	
TW-1	96-May-16	---	---	---	1.8	183	
	96-May-21	---	---	---	0.2	27	
	96-May-31	---	---	---	1.2	21	
	96-Jun-06	6.3	---	---	0.3	-18	
	96-Jun-13	7.6	---	---	2.6	66	
	96-Jun-26	9.1	---	---	0.4	20	
	96-Jul-04	---	---	---	0.7	59	
	96-Jul-11	---	---	---	0.4	-78	
	96-Jul-19	---	---	---	0.8	-31	
	96-Jul-25	---	---	---	---	-4	
	96-Jul-29	12.0	973	6.72	---	---	
	96-Oct-21	9.5	960	6.94	---	---	
BH-2	92-Jun-03	---	691	7.03	---	---	Laboratory electrical conductivity
	93-May-21	13.5	949	6.74	---	---	
	93-Nov-02	10.0	662	6.71	---	---	
	94-Jun-10	12.0	383	7.19	---	---	
	95-Jun-07	12.0	374	7.22	---	---	
	95-Nov-14	10.0	587	7.10	---	---	
	96-May-16	---	---	---	0.1	-152	
	96-May-21	---	---	---	0.1	-209	
	96-May-31	---	---	---	0.1	-243	
	96-Jun-06	8.5	---	---	0.1	-208	
	96-Jun-13	8.9	---	---	2.2	12	
	96-Jun-26	11.6	---	---	0.1	-1	
	96-Jul-04	---	---	---	0.1	48	
	96-Jul-11	---	---	---	0.1	-185	
	96-Jul-19	---	---	---	0.1	-49	
	96-Jul-25	---	---	---	---	-188	
	96-Jul-29	13.0	772	6.92	---	---	
	96-Oct-21	10.1	723	7.01	---	---	

TABLE 2
FIELD MEASURED PARAMETERS

Monitoring Station	***Date (y-m-d)***	***Temp. (°C)***	***Electrical Conductivity (µS/cm)***	***pH (units)***	***Dissolved Oxygen (mg/L)***	***Eh (mV)***	***Comments***
CW-2	96-Jul-29	11.6	943	7.08	---	---	
	96-Aug-01	10.1	---	---	36.3	---	Oxygen sparging experiment in progress
	96-Aug-02	10.0	---	---	48.8	---	Oxygen sparging experiment in progress
	96-Aug-05	11.3	---	---	9	---	Oxygen sparging experiment in progress
	96-Aug-07	11.7	---	---	29	---	Oxygen sparging experiment in progress
	96-Aug-10	11.4	---	---	43.6	---	Oxygen sparging experiment in progress
	96-Aug-11	15.0	---	6.72	---	---	Oxygen sparging experiment in progress
	96-Aug-12	11.1	---	---	24.1	---	Oxygen sparging experiment in progress
	96-Aug-13	15.0	---	6.77	37	---	Oxygen sparging experiment in progress
	96-Aug-14	11.2	---	---	32.4	---	Oxygen sparging experiment in progress
	96-Aug-15	13.0	---	6.79	27.8	---	Oxygen sparging experiment in progress
	96-Aug-16	13.5	---	6.81	22.8	---	Oxygen sparging experiment in progress
	96-Oct-21	8.6	885	6.98	---	---	
GW-2	96-May-16	---	---	---	5.7	193	
	96-May-21	---	---	---	5.6	128	
	96-May-31	---	---	---	3.3	130	
	96-Jun-06	4.5	---	---	1.3	144	
	96-Jun-13	5.0	---	---	2	126	
	96-Jun-26	6.3	---	---	0.1	284	
	96-Jul-04	---	---	---	0.1	137	
	96-Jul-11	---	---	---	0.1	124	
	96-Jul-19	---	---	---	0.1	126	
	96-Jul-25	---	---	---	---	212	
	96-Jul-29	10.9	904	7.19	---	---	
	96-Aug-11	14.5	---	7.02	---	---	
	96-Oct-21	9.4	908	7.28	---	---	
TW-2	96-May-16	---	---	---	1.9	174	
	96-May-21	---	---	---	0.2	54	
	96-May-31	---	---	---	0.3	35	
	96-Jun-06	6.6	---	---	0.4	-10	
	96-Jun-13	7.8	---	---	2.1	87	
	96-Jun-26	9.2	---	---	0.4	113	
	96-Jul-04	---	---	---	3	128	
	96-Jul-11	---	---	---	0.4	-115	
	96-Jul-19	---	---	---	0.6	-95	
	96-Jul-25	---	---	---	---	-9	
	96-Jul-29	13.0	868	6.81	---	---	
	96-Oct-21	8.9	830	6.92	---	---	
BH-3	92-Jun-03	---	696	7.40	---	---	Laboratory electrical conductivity
	93-May-21	5.5	873	6.93	---	---	Hydrocarbon sheen
	93-Nov-02	7.0	1018	6.78	---	---	
	94-Jun-10	13.0	391	7.02	---	---	
	95-Jun-07	12.0	408	7.09	---	---	
	95-Nov-14	4.5	760	7.28	---	---	Water may have gone into piezometer upon opening
	96-Jul-29	12.0	946	6.75	---	---	
	96-Oct-21	7.7	897	7.00	---	---	

TABLE 2
FIELD MEASURED PARAMETERS

Monitoring Station	Date (y-m-d)	Temp. (°C)	Electrical Conductivity (µS/cm)	pH (units)	Dissolved Oxygen (mg/L)	Eh (mV)	Comments
CW-3	96-Jul-29	12.2	926	7.10	---	---	
	96-Aug-01	10.2	---	---	35.9	---	Oxygen sparging experiment in progress
	96-Aug-02	10.0	---	---	51.7	---	Oxygen sparging experiment in progress
	96-Aug-05	11.1	---	---	7	---	Oxygen sparging experiment in progress
	96-Aug-07	11.7	---	---	29.5	---	Oxygen sparging experiment in progress
	96-Aug-10	11.3	---	---	43.9	---	Oxygen sparging experiment in progress
	96-Aug-11	14.5	---	6.69	---	---	Oxygen sparging experiment in progress
	96-Aug-12	11.1	---	---	18.7	---	Oxygen sparging experiment in progress
	96-Aug-13	14.0	---	6.76	36.6	---	Oxygen sparging experiment in progress
	96-Aug-14	11.1	---	---	34.5	---	Oxygen sparging experiment in progress
	96-Aug-15	13.0	---	6.78	27	---	Oxygen sparging experiment in progress
	96-Aug-16	14.0	---	6.87	20.7	---	Oxygen sparging experiment in progress
	96-Oct-21	8.6	930	7.56	---	---	
GW-3	96-May-16	---	---	---	7.2	198	
	96-May-21	---	---	---	4.2	134	
	96-May-31	---	---	---	0.8	117	
	96-Jun-06	5.1	---	---	1	-102	
	96-Jun-13	5.9	---	---	1.7	108	
	96-Jun-26	7.2	---	---	0.1	258	
	96-Jul-04	---	---	---	0.1	173	
	96-Jul-11	---	---	---	0.1	154	
	96-Jul-19	---	---	---	0.1	122	
	96-Jul-25	---	---	---	---	228	
	96-Jul-29	13.1	971	6.98	---	---	
	96-Aug-11	12.5	---	6.84	---	---	
	96-Oct-21	8.2	914	7.44	---	---	
TW-3	96-May-16	---	---	---	5.8	179	
	96-May-21	---	---	---	2	63	
	96-May-31	---	---	---	4.3	39	
	96-Jun-06	7.1	---	---	1	37	
	96-Jun-13	8.1	---	---	3.1	74	
	96-Jun-26	9.9	---	---	1.6	97	
	96-Jul-04	---	---	---	3.8	143	
	96-Jul-11	---	---	---	0.7	18	
	96-Jul-19	---	---	---	0.9	61	
	96-Jul-25	---	---	---	---	-10	
	96-Jul-29	12.0	845	6.98	---	---	
	96-Oct-21	9.0	797	7.13	---	---	
BH-4	92-Jun-03	---	1260	6.72	---	---	Laboratory electrical conductivity
	93-May-21	16.0	1003	6.89	---	---	Hydrocarbon sheen
	93-Nov-02	6.5	884	6.78	---	---	
	94-Jun-10	15.0	552	6.78	---	---	
	95-Jun-07	14.0	311	6.92	---	---	
	95-Nov-14	6.0	962	6.90	---	---	Hydrocarbon film on surface
	96-Jul-29	13.0	743	6.78	---	---	
	96-Oct-21	7.7	904	7.00	---	---	Strong hydrocarbon odour, trace free hydrocarbon

TABLE 2
FIELD MEASURED PARAMETERS

Monitoring Station	*Date (y-m-d)*	*Temp. (°C)*	*Electrical Conductivity (µS/cm)*	*pH (units)*	*Dissolved Oxygen (mg/L)*	*Eh (mV)*	*Comments*
CW-4	96-Jul-29	11.8	948	6.89	---	---	
	96-Aug-01	10.2	---	---	36.1	---	Oxygen sparging experiment in progress
	96-Aug-02	10.0	---	---	51.4	---	Oxygen sparging experiment in progress
	96-Aug-05	11.8	---	---	7.6	---	Oxygen sparging experiment in progress
	96-Aug-07	11.6	---	---	30.1	---	Oxygen sparging experiment in progress
	96-Aug-10	11.3	---	---	44.2	---	Oxygen sparging experiment in progress
	96-Aug-11	14.0	---	6.72	---	---	Oxygen sparging experiment in progress
	96-Aug-12	11.1	---	---	19.8	---	Oxygen sparging experiment in progress
	96-Aug-13	14.5	---	6.69	36.1	---	Oxygen sparging experiment in progress
	96-Aug-14	11.2	---	---	35.6	---	Oxygen sparging experiment in progress
	96-Aug-15	13.0	---	6.76	26.7	---	Oxygen sparging experiment in progress
	96-Aug-16	14.5	---	6.89	20.6	---	Oxygen sparging experiment in progress
GW-4	96-May-16	---	---	---	7.2	197	
	96-May-21	---	---	---	1.1	127	
	96-May-31	---	---	---	0.4	109	
	96-Jun-06	5.0	---	---	1	111	
	96-Jun-13	5.9	---	---	1.7	99	
	96-Jun-26	6.9	---	---	0.1	256	
	96-Jul-04	---	---	---	0.1	174	
	96-Jul-11	---	---	---	0.3	153	
	96-Jul-19	---	---	---	0.1	117	
	96-Jul-25	---	---	---	---	294	
	96-Jul-29	11.9	923	6.94	---	---	
	96-Aug-11	12.0	---	6.92	---	---	
	96-Oct-21	8.8	881	7.36	---	---	
TW-4	96-May-16	---	---	---	3.5	170	
	96-May-21	---	---	---	2	60	
	96-May-31	---	---	---	3	135	
	96-Jun-06	7.2	---	---	0.5	-19	
	96-Jun-13	8.7	---	---	2.7	65	
	96-Jun-26	9.6	---	---	1	49	
	96-Jul-04	---	---	---	2.9	138	
	96-Jul-11	---	---	---	0.3	-69	
	96-Jul-19	---	---	---	0.2	-50	
	96-Jul-25	---	---	---	---	-82	
	96-Jul-29	13.0	814	7.00	---	---	
	96-Oct-21	9.3	795	7.33	---	---	
BH-5	92-Jun-03	---	1250	6.96	---	---	Laboratory electrical conductivity
	93-May-21	11.0	1275	6.92	---	---	Hydrocarbon sheen
	93-Nov-02	7.0	1346	6.88	---	---	Free hydrocarbon
	94-Jun-10	14.0	1174	6.65	---	---	
	95-Jun-07	14.0	1205	6.81	---	---	
	95-Nov-14	5.5	963	6.95	---	---	Hydrocarbon film on surface
	96-Jul-29	15.0	1178	6.80	---	---	
	96-Oct-21	7.7	1050	7.10	---	---	Strong hydrocarbon odour, trace free hydrocarbon

TABLE 2
FIELD MEASURED PARAMETERS

Monitoring Station	*Date* (y-m-d)	*Temp.* (°C)	*Electrical Conductivity* (µS/cm)	*pH* (units)	*Dissolved Oxygen* (mg/L)	*Eh* (mV)	*Comments*
CW-5	96-Jul-29	12.2	949	7.38	---	---	
	96-Aug-01	10.5	---	---	11.4	---	Oxygen sparging experiment in progress
	96-Aug-11	13.0	---	7.12	---	---	Oxygen sparging experiment in progress
	96-Aug-13	14.0	---	7.76	---	---	Oxygen sparging experiment in progress
	96-Aug-15	13.5	---	7.50	---	---	Oxygen sparging experiment in progress
	96-Aug-16	14.5	---	7.29	---	---	Oxygen sparging experiment in progress
	96-Oct-21	8.6	914	7.59	---	---	
TW-5	96-May-16	---	---	---	0.2	144	
	96-May-21	---	---	---	0.4	83	
	96-May-31	---	---	---	0.2	99	
	96-Jun-06	5.8	---	---	0.2	115	
	96-Jun-13	6.1	---	---	2.5	76	
	96-Jun-26	7.9	---	---	0.1	8	
	96-Jul-04	---	---	---	0.1	138	
	96-Jul-11	---	---	---	0.2	-2	
	96-Jul-19	---	---	---	0.5	20	
	96-Jul-25	---	---	---	---	-3	
	96-Jul-29	14.0	883	6.96	---	---	
	96-Oct-21	9.8	820	6.93	---	---	
BH-6	92-Jun-03	---	1110	6.89	---	---	Laboratory electrical conductivity
	93-May-21	7.0	1083	6.80	---	---	
	93-Nov-02	8.0	1049	6.72	---	---	Hydrocarbon odour
	94-Jun-10	10.0	909	6.86	---	---	
	95-Jun-07	8.5	840	6.98	---	---	
	95-Nov-14	7.0	912	6.90	---	---	Hydrocarbon odour
	96-May-16	---	---	---	0.1	-160	
	96-May-21	---	---	---	0.1	-228	
	96-May-31	---	---	---	0.1	-291	
	96-Jun-06	4.2	---	---	0.1	-170	
	96-Jun-13	3.9	---	---	2.4	-162	
	96-Jun-26	6.4	---	---	0.1	-130	
	96-Jul-04	---	---	---	0.3	-181	
	96-Jul-11	---	---	---	0.1	-236	
	96-Jul-19	---	---	---	0.1	-165	
	96-Jul-25	---	---	---	---	-227	
	96-Jul-29	13.0	997	6.63	---	---	
	96-Oct-21	9.1	911	7.00	---	---	Moderate hydrocarbon odour
CW-6	96-Jul-29	14.0	944	7.45	---	---	
	96-Aug-01	10.6	---	---	11.3	---	Oxygen sparging experiment in progress
	96-Aug-11	13.5	---	7.43	---	---	Oxygen sparging experiment in progress
	96-Aug-13	14.5	---	7.67	---	---	Oxygen sparging experiment in progress
	96-Aug-15	13.5	---	7.34	---	---	Oxygen sparging experiment in progress
	96-Aug-16	14.5	---	7.31	---	---	Oxygen sparging experiment in progress

TABLE 2
FIELD MEASURED PARAMETERS

Monitoring Station	*Date (y-m-d)*	*Temp. (°C)*	*Electrical Conductivity (µS/cm)*	*pH (units)*	*Dissolved Oxygen (mg/L)*	*Eh (mV)*	*Comments*
TW-6	96-May-16	---	---	---	0.4	177	
	96-May-21	---	---	---	2.2	85	
	96-May-31	---	---	---	0.2	96	
	96-Jun-06	5.8	---	---	0.2	105	
	96-Jun-13	6.3	---	---	4.5	52	
	96-Jun-26	8.3	---	---	0.1	39	
	96-Jul-04	---	---	---	0.1	130	
	96-Jul-11	---	---	---	0.3	11	
	96-Jul-19	---	---	---	0.6	15	
	96-Jul-25	---	---	---	---	36	
	96-Jul-29	12.0	967	6.85	---	---	
	96-Oct-21	9.6	839	7.01	---	---	
BH-7	92-Jun-03	---	1090	6.91	---	---	Laboratory electrical conductivity
	93-May-21	6.0	1245	6.73	---	---	
	93-Nov-02	8.0	1222	6.58	---	---	Hydrocarbon odour
	94-Jun-10	9.0	1130	6.76	---	---	
	95-Jun-07	5.0	1138	6.92	---	---	
	95-Nov-14	7.0	1156	6.79	---	---	Hydrocarbon odour
	96-May-16	---	---	---	0.1	-145	
	96-May-21	---	---	---	0.1	-197	
	96-May-31	---	---	---	0.1	-271	
	96-Jun-06	4.1	---	---	0.1	-187	
	96-Jun-13	4.0	---	---	2.6	-77	
	96-Jun-26	5.2	---	---	0.1	-93	
	96-Jul-04	---	---	---	0.4	-182	
	96-Jul-11	---	---	---	0.1	-260	
	96-Jul-19	---	---	---	0.1	-159	
	96-Jul-25	---	---	---	---	-211	
	96-Jul-29	13.0	1235	6.62	---	---	
	96-Oct-21	8.0	1191	6.77	---	---	Strong hydrocarbon odour, trace free product
CW-7	96-Jul-29	13.5	---	7.39	---	---	
	96-Aug-01	10.4	---	---	11.3	---	Oxygen sparging experiment in progress
	96-Aug-11	13.0	---	7.48	---	---	Oxygen sparging experiment in progress
	96-Aug-13	15.0	---	7.82	---	---	Oxygen sparging experiment in progress
	96-Aug-15	14.0	---	7.82	---	---	Oxygen sparging experiment in progress
	96-Aug-16	14.5	---	7.75	---	---	Oxygen sparging experiment in progress
	96-Oct-21	8.6	921	7.57	---	---	
TW-7	96-May-16	---	---	---	1.7	186	
	96-May-21	---	---	---	0.3	89	
	96-May-31	---	---	---	0.8	98	
	96-Jun-06	4.7	---	---	0.3	60	
	96-Jun-13	5.1	---	---	10.1	80	
	96-Jun-26	6.6	---	---	0.1	-74	
	96-Jul-04	---	---	---	0.2	40	
	96-Jul-11	---	---	---	0.6	27	
	96-Jul-19	---	---	---	1.8	27	
	96-Jul-25	---	---	---	---	52	
	96-Jul-29	11.0	1143	6.86	---	---	
	96-Oct-21	9.2	1022	6.85	---	---	

TABLE 2
FIELD MEASURED PARAMETERS

Monitoring Station	*Date (y-m-d)*	*Temp. (°C)*	*Electrical Conductivity (µS/cm)*	*pH (units)*	*Dissolved Oxygen (mg/L)*	*Eh (mV)*	*Comments*
BH-8	92-Jun-03	---	867	7.45	---	---	Laboratory electrical conductivity
	93-May-21	7.0	788	7.25	---	---	
	93-Nov-02	7.0	800	6.99	---	---	
	94-Jun-10	10.0	769	7.01	---	---	
	95-Jun-07	9.0	510	7.30	---	---	
	95-Nov-14	6.5	766	7.24	---	---	
	96-May-16	---	---	---	0.1	28	
	96-May-21	---	---	---	0.1	29	
	96-May-31	---	---	---	0.4	153	
	96-Jun-06	4.9	---	---	0.1	-68	
	96-Jun-13	4.8	---	---	2.4	-47	
	96-Jun-26	5.3	---	---	0.1	98	
	96-Jul-04	---	---	---	0.6	28	
	96-Jul-11	---	---	---	0.1	31	
	96-Jul-19	---	---	---	0.1	81	
	96-Jul-25	---	---	---	---	-162	
	96-Jul-29	13.0	849	7.11	---	---	
	96-Oct-21	8.5	766	7.28	---	---	
BH-9	92-Jun-03	---	1230	7.16	---	---	Laboratory electrical conductivity
	93-May-21	8.0	1190	7.08	---	---	
	93-Nov-02	7.0	1151	6.98	---	---	
	94-Jun-10	8.0	1135	6.93	---	---	
	95-Jun-07	6.0	933	7.04	---	---	
	95-Nov-14	---	---	---	---	---	Abandoned
BH-10	92-Jun-03	---	2260	6.91	---	---	Laboratory electrical conductivity
	93-May-21	8.0	1595	6.78	---	---	
	93-Nov-02	7.0	1629	6.63	---	---	
	94-Jun-10	9.0	1190	6.44	---	---	
	95-Jun-07	6.0	1225	6.78	---	---	
	95-Nov-14	8.0	1288	6.81	---	---	
	96-May-16	---	---	---	0.1	7	
	96-May-21	---	---	---	0.1	-135	
	96-May-31	---	---	---	0.1	-91	
	96-Jun-06	2.8	---	---	0.1	-120	
	96-Jun-13	3.6	---	---	3.4	-26	
	96-Jun-26	4.9	---	---	0.1	-82	
	96-Jul-04	---	---	---	0.9	-63	
	96-Jul-11	---	---	---	0.2	-101	
	96-Jul-19	---	---	---	0.5	-121	
	96-Jul-25	---	---	---	---	-85	
	96-Jul-29	8.0	1520	6.90	---	---	
	96-Oct-21	8.6	1001	6.96	---	---	
BH-11	92-Jun-03	---	1080	7.64	---	---	Laboratory electrical conductivity
	93-May-21	8.0	1249	6.92	---	---	
	93-Nov-02	6.0	1441	6.89	---	---	
	94-Jun-10	8.0	1208	6.58	---	---	
	95-Jun-07	5.0	1287	6.81	---	---	
	95-Nov-14	---	---	---	---	---	Abandoned

TABLE 2
FIELD MEASURED PARAMETERS

Monitoring Station	*Date (y-m-d)*	*Temp. (°C)*	*Electrical Conductivity (µS/cm)*	*pH (units)*	*Dissolved Oxygen (mg/L)*	*Eh (mV)*	*Comments*
BH-12	92-Jun-03	---	---	---	---	---	10 mm free hydrocarbon
	92-Aug-04	---	---	---	---	---	5 mm free hydrocarbon
	93-May-21	12.5	1067	6.83	---	---	Free hydrocarbon present
	93-Nov-02	---	---	---	---	---	15 mm free hydrocarbon
	94-Jun-03	---	---	---	---	---	3 mm free hydrocarbon
	94-Jun-10	13.0	908	6.43	---	---	Free hydrocarbon present
	94-Nov-25	---	---	---	---	---	20 mm free hydrocarbon
	95-Jun-07	13.0	848	6.84	---	---	1 mm free hydrocarbon
	95-Nov-14	8.0	815	6.89	---	---	8 mm free hydrocarbon
	96-Jul-29	15.0	863	6.74	---	---	Free hydrocarbon present
	96-Oct-21	10.2	904	6.91	---	---	Free hydrocarbon present
BH-13	92-Jun-03	---	1010	7.20	---	---	Laboratory electrical conductivity
	93-May-21	12.5	916	7.06	---	---	
	93-Nov-02	10.0	816	6.93	---	---	Hydrocarbon odour
	94-Jun-10	12.0	877	6.71	---	---	
	95-Jun-07	15.0	900	6.91	---	---	
	95-Nov-14	10.5	759	7.16	---	---	
	96-May-16	---	---	---	0.1	-184	
	96-Jul-29	16.0	703	6.85	---	---	Slight hydrocarbon sheen
	96-Oct-21	9.5	712	7.17	---	---	
BH-14	92-Jun-03	---	1500	6.83	---	---	Laboratory electrical conductivity
	94-Jun-10	9.0	1443	6.34	---	---	
	95-Jun-07	6.0	1284	6.85	---	---	
	95-Nov-14	7.0	1241	6.74	---	---	
	96-May-16	---	---	---	1.7	93	
	96-Jul-29	8.0	1346	6.68	---	---	
	96-Oct-21	7.2	1266	6.79	---	---	
94-15A	94-Dec-20	5.5	1078	7.26	---	---	
	95-Jun-07	5.0	818	7.05	---	---	
	95-Nov-14	6.0	905	7.26	---	---	
	96-May-16	---	---	---	0.19	179	
	96-May-21	---	---	---	1.9	91	
	96-May-31	---	---	---	0.2	90	
	96-Jun-06	6.3	---	---	0.3	96	
	96-Jun-13	6.6	---	---	3.1	65	
	96-Jun-26	8.3	---	---	0.4	-233	
	96-Jul-04	---	---	---	0.1	132	
	96-Jul-11	---	---	---	0.3	5	
	96-Jul-19	---	---	---	0.5	21	
	96-Jul-25	---	---	---	---	12	
	96-Jul-29	11.0	933	6.92	---	---	
	96-Oct-21	9.6	1031	7.13	---	---	
94-15C	94-Dec-20	6.0	1198	7.09	---	---	
	95-Jun-07	7.0	1223	7.86	---	---	
	95-Nov-14	5.5	1150	7.81	---	---	
	96-May-16	---	---	---	0.1	166	
	96-Jul-29	9.0	1248	7.64	---	---	Slight hydrocarbon sheen
	96-Oct-21	6.2	1117	7.87	---	---	

TABLE 2
FIELD MEASURED PARAMETERS

Monitoring Station	*Date (y-m-d)*	*Temp. (°C)*	*Electrical Conductivity (µS/cm)*	*pH (units)*	*Dissolved Oxygen (mg/L)*	*Eh (mV)*	*Comments*
94-16A	95-Jun-07	6.0	1468	7.02	---	---	
	96-May-16	---	---	---	7.8	74	
	96-May-21	---	---	---	10.2	61	
	96-May-31	---	---	---	1.9	-7	
	96-Jun-06	3.9	---	---	3.5	-56	
	96-Jun-13	4.7	---	---	9.3	-14	
	96-Jun-26	7.4	---	---	2.4	-10	
	96-Jul-04	---	---	---	1.2	36	
	96-Jul-11	---	---	---	0.1	-53	
	96-Jul-19	---	---	---	0.4	-5	
	96-Jul-25	---	---	---	---	-73	
	96-Jul-29	12.0	1190	6.98	---	---	
	96-Oct-21	9.3	1232	7.09	---	---	
94-16B	94-Dec-20	5.5	2010	6.90	---	---	
	95-Jun-07	5.0	2072	6.99	---	---	
	95-Nov-14	6.0	1701	6.89	---	---	
	96-May-16	---	---	---	1.2	-42	
	96-May-21	---	---	---	0.6	-54	
	96-May-31	---	---	---	0.1	-74	
	96-Jun-06	4.5	---	---	1.1	-67	
	96-Jun-13	5.3	---	---	6.8	-25	
	96-Jun-26	7.8	---	---	0.7	-80	
	96-Jul-04	---	---	---	0.4	-17	
	96-Jul-11	---	---	---	0.3	-48	
	96-Jul-19	---	---	---	0.3	-66	
	96-Jul-25	---	---	---	---	-13	
	96-Jul-29	9.0	1664	6.90	---	---	
	96-Oct-21	9.3	1557	6.96	---	---	
94-17A	94-Dec-20	7.0	1064	7.07	---	---	Hydrocarbon odour
	95-Jun-07	6.0	1163	7.03	---	---	
	95-Nov-14	7.5	1024	6.87	---	---	Hydrocarbon sheen and odour
	96-May-16	---	---	---	0.1	-108	
	96-May-21	---	---	---	0.1	-201	
	96-May-31	---	---	---	0.1	-258	
	96-Jun-06	4.4	---	---	0.1	-132	
	96-Jun-13	4.7	---	---	3.7	-123	
	96-Jun-26	5.3	---	---	0.1	-100	
	96-Jul-04	---	---	---	0.4	-162	
	96-Jul-11	---	---	---	0.1	-177	
	96-Jul-19	---	---	---	0.1	-148	
	96-Jul-25	---	---	---	---	-203	
	96-Jul-29	9.0	1092	6.81	---	---	Slight hydrocarbon sheen
	96-Oct-21	7.5	963	7.00	---	---	
94-18A	94-Dec-20	4.5	1015	7.16	---	---	
	95-Jun-07	10.0	1008	6.96	---	---	
	95-Nov-14	7.0	627	7.17	---	---	
	96-May-16	---	---	---	0.1	-88	
	96-Jul-29	15.0	664	6.87	---	---	
	96-Oct-21	9.2	633	7.16	---	---	

TABLE 2
FIELD MEASURED PARAMETERS

Monitoring Station	*Date (y-m-d)*	*Temp. (°C)*	*Electrical Conductivity (µS/cm)*	*pH (units)*	*Dissolved Oxygen (mg/L)*	*Eh (mV)*	*Comments*
94-19A	95-Jun-07	9.0	593	7.18	---	---	
	95-Nov-14	5.0	963	7.40	---	---	
	96-Jul-29	14.0	838	7.07	---	---	
	96-Oct-21	6.9	765	7.25	---	---	
94-19C	94-Dec-20	5.0	1071	7.40	---	---	
	95-Jun-07	5.5	1086	7.43	---	---	
	95-Nov-14	7.0	1052	7.34	---	---	
	96-Jul-29	9.0	1032	7.24	---	---	Slight hydrocarbon sheen
	96-Oct-21	7.4	1066	7.41	---	---	
94-20A	94-Dec-20	5.5	975	7.15	---	---	
	95-Jun-07	7.0	916	7.10	---	---	
	95-Nov-14	7.0	920	7.04	---	---	
	96-May-21	---	---	---	1.5	81	
	96-May-31	---	---	---	2.3	86	
	96-Jun-06	8.7	---	---	1.2	135	
	96-Jun-13	8.4	---	---	4	288	
	96-Jun-26	9.6	---	---	0.7	223	
	96-Jul-04	---	---	---	2	140	
	96-Jul-11	---	---	---	2.4	182	
	96-Jul-19	---	---	---	0.3	328	
	96-Jul-25	---	---	---	---	128	
	96-Jul-29	12.0	970	7.01	---	---	
	96-Oct-21	7.8	880	7.16	---	---	
94-20C	94-Dec-20	6.0	1145	7.11	---	---	
	95-Jun-07	6.5	1176	7.27	---	---	
	95-Nov-14	6.0	1097	7.16	---	---	
	96-Jul-29	11.0	1174	7.11	---	---	
	96-Oct-21	7.7	1051	7.24	---	---	
96-21A	96-Jun-13	4.7	---	---	1.7	95	
	96-Jun-26	5.7	---	---	0.1	274	
	96-Jul-04	---	---	---	0.4	25	
	96-Jul-11	---	---	---	0.1	129	
	96-Jul-19	---	---	---	0.1	120	
	96-Jul-25	---	---	---	---	212	
	96-Jul-29	9.0	867	7.19	---	---	
	96-Aug-11	14.0	---	6.74	---	---	
	96-Oct-21	8.6	910	7.34	---	---	
96-22A	96-Jun-13	7.8	---	---	4.3	78	
	96-Jun-26	8.4	---	---	2.2	141	
	96-Jul-04	---	---	---	1.2	24	
	96-Jul-11	---	---	---	2	-7	
	96-Jul-19	---	---	---	0.5	38	
	96-Jul-25	---	---	---	---	148	
	96-Jul-29	14.0	910	6.95	---	---	
	96-Oct-21	9.1	927	7.12	---	---	

TABLE 2
FIELD MEASURED PARAMETERS

Monitoring Station	*Date (y-m-d)*	*Temp. (°C)*	*Electrical Conductivity (µS/cm)*	*pH (units)*	*Dissolved Oxygen (mg/L)*	*Eh (mV)*	*Comments*
96-22B	96-Jun-13	5.9	---	---	3.4	84	
	96-Jun-26	7.3	---	---	0.1	64	
	96-Jul-04	---	---	---	1	8	
	96-Jul-11	---	---	---	0.1	-47	
	96-Jul-19	---	---	---	2	13	
	96-Jul-25	---	---	---	---	105	
	96-Jul-29	12.0	1104	7.10	---	---	
	96-Oct-21	9.2	1084	7.16	---	---	
96-23A	96-Jun-13	4.0	---	---	10.2	14	
	96-Jun-26	5.1	---	---	0.8	33	
	96-Jul-04	---	---	---	0.9	-29	
	96-Jul-11	---	---	---	0.5	-51	
	96-Jul-19	---	---	---	1.5	-28	
	96-Jul-25	---	---	---	---	-35	
	96-Jul-29	8.0	9020	6.28	---	---	
	96-Oct-21	10.4	9300	5.90	---	---	
96-24A	96-Jun-13	4.4	---	---	2.6	-36	
	96-Jul-04	---	---	---	0.9	-58	
	96-Jul-11	---	---	---	0.1	-105	
	96-Jul-19	---	---	---	0.8	-52	
	96-Jul-25	---	---	---	---	-33	
	96-Jul-29	10.0	1083	6.85	---	---	
	96-Oct-21	8.7	870	6.93	---	---	
96-25A	96-Jun-13	4.3	---	---	7.2	-8	
	96-Jun-26	6.1	---	---	0.4	8	
	96-Jul-04	---	---	---	0.2	-14	
	96-Jul-11	---	---	---	0.5	-28	
	96-Jul-19	---	---	---	0.7	3	
	96-Jul-25	---	---	---	---	-61	
	96-Jul-29	12.0	946	6.61	---	---	
	96-Oct-21	8.9	974	6.89	---	---	
96-25B	96-Jun-13	4.1	---	---	6.4	-45	
	96-Jun-26	6.1	---	---	0.3	-33	
	96-Jul-04	---	---	---	0.1	-2	
	96-Jul-11	---	---	---	1.3	-17	
	96-Jul-19	---	---	---	0.7	-23	
	96-Jul-25	---	---	---	---	-26	
	96-Jul-29	11.0	1111	6.76	---	---	
	96-Oct-21	9.0	1008	6.78	---	---	
96-26A	96-Jun-13	5.1	---	---	2.7	35	
	96-Jun-26	7.4	---	---	0.4	232	
	96-Jul-04	---	---	---	1.1	-16	
	96-Jul-11	---	---	---	0.1	60	
	96-Jul-19	---	---	---	0.1	137	
	96-Jul-25	---	---	---	---	-109	
	96-Jul-29	11.0	1084	6.89	---	---	
	96-Oct-21	9.0	960	7.06	---	---	

TABLE 2
FIELD MEASURED PARAMETERS

Monitoring Station	*Date (y-m-d)*	*Temp. (°C)*	*Electrical Conductivity (µS/cm)*	*pH (units)*	*Dissolved Oxygen (mg/L)*	*Eh (mV)*	*Comments*
Culvert 1	96-May-16	---	---	---	1.6	121	
	96-May-21	---	---	---	0.1	69	
	96-May-31	---	---	---	0.1	-35	
	96-Jun-04	---	---	---	0.1	33	
	96-Jun-06	4.7	---	---	0.2	-175	
	96-Jun-07	---	---	---	---	-130	
	96-Jun-13	4.9	---	---	1.8	-98	
	96-Jun-26	6.6	---	---	7.3	-495	
	96-Jul-04	---	---	---	0.1	-181	
	96-Jul-11	---	---	---	0.1	-67	
	96-Jul-19	10.0	---	---	0.1	-209	
	96-Jul-25	---	---	---	---	-352	
Culvert 2	96-May-16	---	---	---	0.5	71	
	96-May-21	---	---	---	0.2	56	Hydrocarbon film on surface
	96-May-31	---	---	---	3.1	34	
	96-Jun-04	---	---	---	10.7	162	
	96-Jun-06	5.9	---	---	9.6	127	
	96-Jun-13	6.3	---	---	15.5	22	
	96-Jun-26	12.4	---	---	8	113	
	96-Jul-04	---	---	---	13.7	101	
	96-Jul-11	---	---	---	12.7	116	
	96-Jul-19	10.0	---	---	11.4	108	
	96-Jul-25	---	---	---	---	107	
	96-Aug-01	---	---	---	25	---	Oxygen sparging experiment in progress
	96-Aug-02	---	---	---	23	---	Oxygen sparging experiment in progress
	96-Aug-05	10.9	---	---	12.9	---	Oxygen sparging experiment in progress
	96-Aug-07	11.4	---	---	29	---	Oxygen sparging experiment in progress
	96-Aug-10	11.6	---	---	32.4	---	Oxygen sparging experiment in progress
	96-Aug-12	11.1	---	---	25	---	Oxygen sparging experiment in progress
	96-Aug-13	11.3	---	---	34	---	Oxygen sparging experiment in progress
	96-Aug-14	11.3	---	---	29.6	---	Oxygen sparging experiment in progress
	96-Aug-15	11.5	---	---	25.1	---	Oxygen sparging experiment in progress
	96-Aug-16	11.3	---	6.73	18.2	---	Oxygen sparging experiment in progress
	96-Oct-21	9.3	---	---	---	---	

TABLE 2
FIELD MEASURED PARAMETERS

Monitoring Station	*Date (y-m-d)*	*Temp. (°C)*	*Electrical Conductivity (µS/cm)*	*pH (units)*	*Dissolved Oxygen (mg/L)*	*Eh (mV)*	*Comments*
Culvert 3	96-May-16	---	---	---	8	167	
	96-May-21	---	---	---	9.4	147	
	96-May-31	---	---	---	3.4	71	
	96-Jun-04	---	---	---	1.5	153	
	96-Jun-06	4.8	---	---	2.9	28	
	96-Jun-13	5.4	---	---	8.6	90	
	96-Jun-26	6.2	---	---	0.1	29	
	96-Jul-04	---	---	---	8.4	195	
	96-Jul-11	---	---	---	5.1	121	
	96-Jul-19	---	---	---	2.1	136	
	96-Jul-25	---	---	---	---	165	
	96-Aug-02	---	---	---	10.6	---	Oxygen sparging experiment in progress
	96-Aug-05	10.7	---	---	12	---	Oxygen sparging experiment in progress
	96-Aug-07	11.5	---	---	12	---	Oxygen sparging experiment in progress
	96-Aug-10	11.4	---	---	13.6	---	Oxygen sparging experiment in progress
	96-Aug-12	11.2	---	---	14.2	---	Oxygen sparging experiment in progress
	96-Aug-13	12.6	---	---	13.5	---	Oxygen sparging experiment in progress
	96-Aug-14	11.9	---	---	13.3	---	Oxygen sparging experiment in progress
	96-Aug-15	13.5	---	---	12.4	---	Oxygen sparging experiment in progress
	96-Aug-16	12.0	---	---	12	---	Oxygen sparging experiment in progress
Reference Rod	96-Oct-21	1.0	860	7.06	---	---	
Water Well	94-Jun-10	8.0	1133	8.33	---	---	
	95-Jun-07	8.0	1259	8.70	---	---	
	96-Oct-21	7.4	1010	8.82	---	---	

Notes:
Electrical Conductivity normalized to 25 °C.

TABLE 3
MAJOR ION GROUNDWATER CHARACTERIZATION AND MINERALIZATION

Monitoring Station	***Date (y-m-d)***	***Calcium (mg/L)***	***Magnesium (mg/L)***	***Sodium (mg/L)***	***Potassium (mg/L)***	***Bicarbonate (mg/L)***	***Sulphate (mg/L)***	***Chloride (mg/L)***	***Ion Balance (balance)***	***TDS (mg/L)***
Water Quality Guidelines (mg/L)				*200*			*500*	*250*		*500*
BH-1	95-Nov-14	163	38.5	15.1	3.3	680	28.8	6.7	0.98	614*
	96-Jul-29	171	39.8	14.1	3.19	742	15.3	9.3	0.98	628*
	96-Oct-22	170	42.0	14.7	3.04	741	15.0	11.0	0.95	657*
CW-1	95-Nov-15	156	39.6	31.0	4.6	661	7.6	30.0	0.97	579*
	96-Jul-29	127	34.5	23.1	5.96	584	<0.1	7.8	1.05	492
	96-Oct-22	125	37.7	31.5	5.84	645	3.4	21.1	0.96	549*
GW-1	95-Nov-14	113	35.1	26.2	5.7	590	12.2	10.2	0.96	498
	96-Jul-29	115	29.4	19.7	8.1	538	0.2	10.3	0.99	464
	96-Oct-22	135	33.3	22.8	8.54	590	11.4	9.6	1.05	517*
MW-1	95-Nov-15	365	180	97.9	9.7	662	4.0	903*	1.03	1890*
	96-Jul-29	260	105	64.3	8.69	690	9.2	483*	0.98	1281*
	96-Oct-22	349	194	104	8.72	701	3.8	998*	0.96	2008*
PW-1	95-Jun-07	330	141	91.0	6.7	745	9.4	666*	1.03	1630*
	95-Nov-15	418	190	109	8.1	640	5.2	1020*	1.05	2070*
	96-Jul-29	299	140	74.9	7.76	594	10.9	730*	0.98	1565*
	96-Oct-22	332	182	99.3	8.55	646	6.0	976*	0.94	1927*
TW-1	95-Nov-15	165	43.7	31.5	4.0	657	6.4	46.9	1.09	626*
	96-Jul-30	139	36.8	23.0	5.31	645	<0.1	<0.5	1.05	527*
	96-Oct-22	142	40.5	30.1	4.14	639	2.5	31.8	1.04	570*

TABLE 3
MAJOR ION GROUNDWATER CHARACTERIZATION AND MINERALIZATION

Monitoring Station	***Date (y-m-d)***	***Calcium (mg/L)***	***Magnesium (mg/L)***	***Sodium (mg/L)***	***Potassium (mg/L)***	***Bicarbonate (mg/L)***	***Sulphate (mg/L)***	***Chloride (mg/L)***	***Ion Balance (balance)***	***TDS (mg/L)***
Water Quality Guidelines (mg/L)				*200*			*500*	*250*		*500*
BH-2	95-Nov-15	97.5	13.3	16.2	11.5	408	9.8	1.7	1.00	354
	96-Jul-29	128	12.4	9.15	10.5	491	<0.1	<0.5	1.00	406
	96-Oct-22	145	16.2	9.43	10.6	530	3.7	0.8	1.05	451
CW-2	95-Nov-15	157	37.1	37.1	4.4	668	10.1	36.7	0.99	606*
	96-Jul-29	133	35.1	22.3	5.75	624	<0.1	7.4	1.02	516*
	96-Oct-22	119	33.6	32.0	7.01	595	5.1	23.8	0.97	519*
GW-2	95-Nov-14	124	33.9	32.6	4.2	622	18.8	23.4	0.93	548*
	96-Jul-29	120	31.8	29.7	8.83	562	14.3	15.5	1.02	502*
	96-Oct-22	140	36.7	51.0	9.09	622	13.8	30.4	1.10	592*
TW-2	96-Jul-30	123	32.3	22.2	6.55	575	<0.1	<0.5	1.05	472
	96-Oct-22	130	36.5	25.4	3.96	618	2.8	6.2	1.03	518*
BH-3	95-Nov-14	84.3	14.9	69.9	1.5	432	23.8	44.0	0.94	467
	96-Jul-29	131	27.4	16.3	1.78	618	<0.1	10.6	0.91	497
	96-Oct-22	157	33.4	13.1	15.0	653	2.4	6.4	1.02	541*
CW-3	95-Nov-15	145	38.6	35.7	4.8	653	8.8	35.6	1.02	596*
	96-Jul-29	126	33.2	21.5	5.93	597	<0.1	7.8	1.01	495
	96-Oct-22	141	39.6	33.6	6.71	649	4.1	25.0	1.04	578*
GW-3	95-Nov-14	127	32.4	30.9	4.0	608	8.6	34.1	0.94	543*
	96-Jul-29	132	37.5	26.6	8.09	636	<0.1	16.5	1.01	539*
	96-Oct-22	147	40.9	36.9	8.33	713	5.5	23.7	1.00	620*

TABLE 3
MAJOR ION GROUNDWATER CHARACTERIZATION AND MINERALIZATION

Monitoring Station	*Date (y-m-d)*	*Calcium (mg/L)*	*Magnesium (mg/L)*	*Sodium (mg/L)*	*Potassium (mg/L)*	*Bicarbonate (mg/L)*	*Sulphate (mg/L)*	*Chloride (mg/L)*	*Ion Balance (balance)*	*TDS (mg/L)*
Water Quality Guidelines (mg/L)				*200*			*500*	*250*		*500*
TW-3	96-Jul-30	112	28.6	20.9	6.96	535	0.4	9.3	0.99	450
	96-Oct-22	122	30.1	25.4	7.36	518	14.0	17.9	1.06	479
BH-4	95-Nov-14	150	32.0	13.0	2.32	690	0.7	8.4	0.93	551*
	96-Jul-29	118	17.7	9.76	2.57	501	<0.1	<0.5	0.95	399
	96-Oct-22	151	27.7	12.1	2.17	627	2.3	4.8	0.99	513*
CW-4	95-Nov-15	146	39.7	36.9	4.8	659	9.1	35.2	1.02	602*
	96-Jul-29	129	35.2	22.7	6.00	614	<0.1	7.6	1.02	508*
GW-4	95-Nov-14	122	30.4	29.2	3.6	569	10.5	22.6	0.97	505*
	96-Jul-29	135	36.4	28.9	8.91	628	0.2	16.1	1.04	539*
	96-Oct-22	129	37.2	30.8	7.44	600	5.3	20.6	1.05	532*
TW-4	95-Nov-15	147	29.7	28.8	3.6	558	12.2	28.0	1.09	530*
	96-Jul-30	109	28.0	20.3	7.35	521	0.4	11.0	0.99	439
	96-Oct-22	112	22.8	50.7	8.28	433	21.0	58.0	1.07	491
BH-5	93-Nov-02	182	49.0	21.6	1.8	734	<0.1	65.2	1.02	687*
	94-Jun-10	155	43.0	20.6	2.05	720	1.1	18.3	0.99	600*
	95-Jun-07	170	44.2	19.5	1.9	763	0.2	18.9	1.00	636*
	95-Nov-14	134	39.6	17.8	2.0	641	4.3	9.0	0.99	527*
	96-Jul-29	158	41.1	20.8	2.38	752	1.0	11.7	0.96	611*
	96-Oct-22	155	42.5	20.1	2.43	683	1.2	12.9	1.05	576*

TABLE 3
MAJOR ION GROUNDWATER CHARACTERIZATION AND MINERALIZATION

Monitoring Station	***Date (y-m-d)***	***Calcium (mg/L)***	***Magnesium (mg/L)***	***Sodium (mg/L)***	***Potassium (mg/L)***	***Bicarbonate (mg/L)***	***Sulphate (mg/L)***	***Chloride (mg/L)***	***Ion Balance (balance)***	***TDS (mg/L)***
Water Quality Guidelines (mg/L)				*200*			*500*	*250*		*500*
CW-5	95-Nov-15	153	37.7	34.8	4.6	663	9.2	41.1	1.01	613*
	96-Jul-29	130	35.8	22.8	5.78	638	<0.1	7.3	0.99	521*
	96-Oct-22	135	38.5	33.3	6.95	629	5.5	25.3	1.03	562*
TW-5	95-Nov-15	158	33.7	34.2	3.9	624	12.9	34.2	1.07	591*
	96-Jul-30	118	30.6	22.9	7.41	566	0.4	<0.5	1.02	469
	96-Oct-22	116	31.7	27.0	8.27	539	9.4	12.2	1.04	474
BH-6	93-May-21	130	47.0	15.0	2.04	708	3.3	3.1	0.94	555*
	93-Nov-02	134	48.5	19.2	2.1	694	<0.1	4.0	1.01	555*
	94-Jun-10	130	38.9	15.1	1.25	655	2.5	2.4	0.96	517*
	95-Jun-07	97.6	25.5	8.1	0.9	545	2.0	4.2	---	411
	95-Nov-15	132	47.8	17.7	2.1	675	2.1	5.3	1.01	545*
	96-Jul-29	120	42.5	15.1	1.67	667	<0.1	<0.5	0.93	513*
	96-Oct-22	135	46.3	16.4	1.65	664	0.7	4.8	1.02	537*
CW-6	95-Nov-15	146	36.8	33.7	4.7	664	9.0	35.2	0.99	598*
	96-Jul-29	130	34.7	22.1	5.67	628	<0.1	7.1	1.00	514*
TW-6	95-Nov-15	147	31.0	32.3	3.3	631	15.6	25.0	1.00	572*
	96-Jul-30	118	31.6	22.7	6.92	622	0.4	12.6	0.91	505*
	96-Oct-22	131	33.9	27.3	8.52	568	15.9	13.7	1.06	519*

TABLE 3
MAJOR ION GROUNDWATER CHARACTERIZATION AND MINERALIZATION

Monitoring Station	***Date (y-m-d)***	***Calcium (mg/L)***	***Magnesium (mg/L)***	***Sodium (mg/L)***	***Potassium (mg/L)***	***Bicarbonate (mg/L)***	***Sulphate (mg/L)***	***Chloride (mg/L)***	***Ion Balance (balance)***	***TDS (mg/L)***
Water Quality Guidelines (mg/L)				*200*			*500*	*250*		*500*
BH-7	93-May-21	167	57.5	18.8	1.87	855	3.6	6.9	0.98	683*
	93-Nov-02	189	61.5	24.2	2.1	878	41.9	8.6	1.01	766*
	94-Jun-10	153	56.0	14.6	1.78	806	1.0	8.3	0.96	638*
	95-Jun-07	169	57.9	10.0	1.6	568	0.1	8.3	1.43	531*
	95-Nov-15	166	64.3	11.0	1.7	845	1.1	6.4	1.00	673*
	96-Jul-29	166	59.9	11.0	1.45	852	0.4	6.4	0.97	671*
	96-Oct-22	187	62.9	11.9	1.33	934	1.5	6.4	0.97	742*
CW-7	95-Nov-15	144	36.8	34.7	4.7	653	8.9	35.7	0.99	592*
	96-Jul-29	116	32.0	20.5	5.35	603	<0.1	7.3	0.94	484
	96-Oct-22	129	39.3	34.3	6.73	658	4.2	24.7	0.97	571*
TW-7	95-Nov-15	158	34.7	85.5	3.7	681	23.1	82.9	1.04	729*
	96-Jul-30	128	35.4	62.0	7.29	644	4.3	76.5	0.95	636*
	96-Oct-22	162	50.2	21.5	4.97	739	6.9	1.3	1.08	617*
BH-8	93-May-21	82.5	37.1	34.1	3.37	495	9.0	4.5	1.04	418
	93-Nov-02	76.5	43.0	38.2	3.9	545	8.9	5.4	0.98	448
	94-Jun-10	77.0	39.6	35.8	3.92	529	9.7	5.2	0.97	436
	95-Jun-07	58.4	21.9	10.2	2.8	271	8.2	3.0	1.04	261
	95-Nov-15	87.6	44.4	37.9	4.2	551	10.6	5.1	1.04	465
	96-Jul-29	75.2	41.5	36.5	3.64	549	<0.1	<0.5	0.98	432
	96-Oct-22	81.9	47.0	40.8	4.01	556	8.9	6.0	1.04	467

TABLE 3
MAJOR ION GROUNDWATER CHARACTERIZATION AND MINERALIZATION

Monitoring Station	*Date (y-m-d)*	*Calcium (mg/L)*	*Magnesium (mg/L)*	*Sodium (mg/L)*	*Potassium (mg/L)*	*Bicarbonate (mg/L)*	*Sulphate (mg/L)*	*Chloride (mg/L)*	*Ion Balance (balance)*	*TDS (mg/L)*
Water Quality Guidelines (mg/L)				*200*			*500*	*250*		*500*
BH-9	93-May-21	99.0	40.5	108	5.08	731	32.2	25.0	0.98	676*
	93-Nov-02	89.0	41.0	116	5.2	714	31.0	27.7	0.99	667*
	94-Jun-10	94.5	39.9	123	5.05	709	31.8	27.0	1.03	676*
	95-Jun-07	97.1	41.4	57.8	4.4	601	18.8	13.6	0.99	556*
BH-10	95-Nov-15	152	53.8	59.4	7.8	723	9.4	81.8	1.03	726*
	96-Jul-29	148	50.1	60.3	8.73	641	10.8	131	0.99	736*
	96-Oct-22	127	46.1	52.5	8.04	673	8.2	42.4	1.02	623*
BH-12	95-Nov-15	136	29.0	28.0	4.8	591	1.1	4.5	1.07	499
	96-Jul-29	116	24.8	23.9	5.64	566	<0.1	<0.5	0.97	453
	96-Oct-22	153	30.5	22.5	5.84	624	0.4	3.3	1.09	528*
BH-13	95-Nov-15	110	27.1	45.3	3.1	518	15.2	8.8	1.08	469
	96-Jul-29	91.6	18.8	22.7	3.49	419	0.2	<0.5	1.04	348
	96-Oct-22	110	24.8	29.1	3.44	483	10.2	7.5	1.06	427
BH-14	95-Nov-14	183	71.2	19.4	3.0	928	12.1	30.4	0.98	783*
	96-Jul-29	182	74.3	20.7	3.39	870	12.4	28.7	1.05	757*
	96-Oct-21	212	72.9	20.5	2.92	940	15.2	30.1	1.06	824*
94-15A	95-Nov-15	109	36.5	46.9	5.9	602	18.6	33.5	0.95	553*
	96-Jul-29	124	33.7	26.0	8.0	585	0.4	14.1	1.02	507*
	96-Oct-22	128	41.1	72.5	6.6	596	52.5	35.1	1.06	667*

TABLE 3
MAJOR ION GROUNDWATER CHARACTERIZATION AND MINERALIZATION

Monitoring Station	***Date (y-m-d)***	***Calcium (mg/L)***	***Magnesium (mg/L)***	***Sodium (mg/L)***	***Potassium (mg/L)***	***Bicarbonate (mg/L)***	***Sulphate (mg/L)***	***Chloride (mg/L)***	***Ion Balance (balance)***	***TDS (mg/L)***
Water Quality Guidelines (mg/L)				*200*			*500*	*250*		*500*
94-15C	95-Nov-15	17.7	6.9	295*	2.8	756	84.2	0.5	1.01	786*
	96-Jul-29	18.0	6.32	271*	2.4	758	79.5	<0.5	0.94	757*
	96-Oct-22	20.5	7.71	293*	2.67	745	83.7	0.5	1.04	781*
94-16A	96-Jul-29	174	35.9	30.8	10.5	714	15.9	33.1	1.00	675*
	96-Oct-22	183	42.8	41.2	15.7	880	11.0	29.7	0.94	780*
94-16B	95-Nov-15	216	56.5	65.8	11.0	852	25.2	159	0.98	960*
	96-Jul-29	196	53.9	69.5	9.54	759	20.0	171	0.99	900*
	96-Oct-22	195	51.3	63.5	10.2	907	15.4	90.2	0.96	880*
94-17A	95-Nov-15	143	47.8	31.5	4.1	729	1.2	11.4	1.02	604*
	96-Jul-29	146	49.7	26.4	4.26	762	0.7	9.0	0.99	617*
	96-Oct-22	145	50.4	29.8	3.88	730	0.7	4.7	1.05	600*
94-18A	95-Nov-15	104	19.8	16.0	1.2	440	16.0	4.7	0.98	382
	96-Jul-29	94.3	17.7	13.8	1.0	405	<0.1	<0.5	1.02	329
	96-Oct-22	100	19.7	14.6	0.95	442	10.6	4.6	0.96	372
94-19A	95-Nov-14	104	40.7	61.0	2.07	570	93.1	5.4	0.96	609*
	96-Jul-29	102	23.7	70.3	2.86	553	16.3	<0.5	1.07	499
	96-Oct-21	122	34.2	32.1	15.0	531	34.2	2.9	1.07	501*
94-19C	95-Nov-14	30.7	11.9	138	2.56	490	40.9	2.8	0.96	472
	96-Jul-29	40.6	17.3	188	3.35	698	39.2	1.6	0.95	640*
	96-Oct-21	47.1	19.1	207*	3.55	705	44.4	2.8	1.04	677*

TABLE 3
MAJOR ION GROUNDWATER CHARACTERIZATION AND MINERALIZATION

Monitoring Station	*Date (y-m-d)*	*Calcium (mg/L)*	*Magnesium (mg/L)*	*Sodium (mg/L)*	*Potassium (mg/L)*	*Bicarbonate (mg/L)*	*Sulphate (mg/L)*	*Chloride (mg/L)*	*Ion Balance (balance)*	*TDS (mg/L)*
Water Quality Guidelines (mg/L)				*200*			*500*	*250*		*500*
94-20A	95-Nov-14	136	37.3	20.3	4.67	677	10.2	8.1	0.94	556*
	96-Jul-29	131	34.4	20.5	5.25	620	0.2	7.7	1.00	510*
	96-Oct-21	156	39.7	20.2	5.17	647	7.7	7.1	1.10	562*
94-20C	95-Nov-14	67.2	36.1	162	4.5	803	27.8	<0.5	0.98	699*
	96-Jul-29	64.8	39.7	157	5.09	792	23.4	<0.5	1.00	687*
	96-Oct-21	81.6	37.5	166	4.59	811	25.2	0.5	1.05	721*
96-21A	96-Jul-29	112	32.9	16.7	9.35	539	0.2	22.7	0.98	464
	96-Oct-22	127	39.2	37.6	7.87	611	6.6	29.9	1.03	555*
96-22A	96-Jul-30	129	32.4	24.2	8.61	572	14.1	15.4	1.01	520*
	96-Oct-22	146	40.0	25.7	9.32	624	24.8	13.0	1.07	571*
96-22B	96-Jul-30	112	40.4	76.9	6.3	653	46.8	54.0	0.94	663*
	96-Oct-22	144	42.8	76.8	5.99	680	55.9	25.7	1.09	691*
96-23A	96-Jul-29	1260	543	123	14.1	2436	8.0	1770*	1.25	4936*
	96-Oct-22	1710	595	137	15.5	2926	8.1	1760*	1.44	5689*
96-24A	96-Jul-29	119	38.7	28.7	3.18	649	<0.1	9.8	0.96	524*
	96-Oct-22	120	42.5	30.1	3.58	640	1.3	9.8	1.01	527*
96-25A	96-Jul-30	108	35.3	36.1	12.9	608	<0.1	11.7	0.99	508*
	96-Oct-22	128	41.3	38.0	12.1	678	5.3	21.0	0.99	585*

TABLE 3
MAJOR ION GROUNDWATER CHARACTERIZATION AND MINERALIZATION

Monitoring Station	*Date (y-m-d)*	*Calcium (mg/L)*	*Magnesium (mg/L)*	*Sodium (mg/L)*	*Potassium (mg/L)*	*Bicarbonate (mg/L)*	*Sulphate (mg/L)*	*Chloride (mg/L)*	*Ion Balance (balance)*	*TDS (mg/L)*
Water Quality Guidelines (mg/L)				*200*			*500*	*250*		*500*
96-25B	96-Jul-30	124	41.0	65.4	11.4	701	6.4	22.1	1.04	621*
	96-Oct-22	138	43.4	44.0	6.99	695	3.1	30.5	1.02	613*
96-26A	96-Jul-30	145	49.4	29.8	6.95	725	4.4	19.6	1.02	618*
	96-Oct-22	140	46.5	42.5	7.47	691	8.2	15.2	1.08	606*
Reference Rod	96-Oct-22	145	38.1	31.2	6.26	605	0.8	29.7	1.10	554*
Water Well	94-Jun-10	2	0.3	274*	1.03	678	35.7	5.2	0.94	681*
	95-Jun-07	1.6	0.7	292*	1.1	680	30.9	4.7	1.01	696*
	95-Nov-15	2	0.4	293*	0.9	680	39.7	5.2	1.01	702*
	96-Oct-22	1.95	0.46	284*	0.94	678	38.4	5.2	0.99	687*

Notes:

1.* Denotes Values That Exceed Water Quality Guidelines (mg/L).

2. Carbonate concentrations are less than the detection limit of 0.5 mg/L for all analyses except the water well, which averages approximately 20 mg/L.

TABLE 4
DISSOLVED HYDROCARBONS AND DISSOLVED ORGANIC CARBON

Monitoring Station	*Date*	*Benzene (mg/L)*	*Ethylbenzene (mg/L)*	*Toluene (mg/L)*	*Xylenes (total) (mg/L)*	*BTEX (total) (mg/L)*	*DOC (mg/L)*	*TPH Vol. (C_6-C_{11}) (mg/L)*	*TPH Semi-Vol. (C_{12}-C_{22}) (mg/L)*
Water Quality Guidelines (mg/L)		*0.005*	*£ 0.0024*	*£ 0.024*	*£ 0.3*				
BH-1	92-Aug-06	<0.001	<0.001	<0.001	<0.001			<1	<1
	93-May-21	<0.001	<0.001	<0.001	<0.001			<1	<1
	93-Nov-02	<0.001	<0.001	<0.001	<0.001			<1	<1
	94-Jun-10	<0.001	<0.001	<0.001	0.001	0.001		<1	<1
	95-Jun-07	<0.001	<0.001	<0.001	<0.001			<1	<1
	95-Nov-14	<0.001	<0.001	<0.001	<0.001		9.6	<1	<1
	96-Jul-30	<0.001	<0.001	<0.001	<0.001			<1	<1
	96-Oct-21	<0.001	<0.001	<0.001	<0.001			<1	<1
	96-Oct-22						12.5		
BH-1 Dup.	96-Oct-21	<0.001	<0.001	<0.001	<0.001			<1	<1
CW-1	95-Nov-15	0.009*	<0.001	<0.001	0.001	0.010*	8.2	<1	<1
	96-Apr-21	0.006*	<0.001	0.001	<0.001	0.007*		<1	<1
	96-May-05	<0.001	<0.001	<0.001	<0.001			<1	<1
	96-May-15	0.013*	<0.001	0.003	0.002	0.018*		<1	<1
	96-Jun-12	0.009*	<0.001	<0.001	0.002	0.011*		<1	<1
	96-Jul-03	0.013*	0.001	<0.001	0.003	0.017*		<1	<1
	96-Jul-29	0.0073*	<0.0004	<0.0004	<0.0008	0.0073*			
	96-Jul-30	0.036*	0.001	<0.001	0.001	0.038*		<1	<1
	96-Oct-21	0.011*	<0.001	<0.001	<0.001	0.011*		<1	<1
	96-Oct-22						11.0		
CW-1 Dup.	95-Nov-15	0.008*	<0.001	<0.001	0.001	0.009*		<1	<1
	96-May-15	0.007*	<0.001	0.002	<0.001	0.009*		<1	<1
	96-Jul-03	0.012*	<0.001	<0.001	0.002	0.014*		<1	<1
	96-Oct-21	0.017*	<0.001	<0.001	<0.001	0.017*		<1	<1

TABLE 4
DISSOLVED HYDROCARBONS AND DISSOLVED ORGANIC CARBON

Monitoring Station	*Date*	*Benzene (mg/L)*	*Ethylbenzene (mg/L)*	*Toluene (mg/L)*	*Xylenes (total) (mg/L)*	*BTEX (total) (mg/L)*	*DOC (mg/L)*	*TPH Vol. (C_6-C_{11}) (mg/L)*	*TPH Semi-Vol. (C_{12}-C_{22}) (mg/L)*
Water Quality Guidelines (mg/L)		*0.005*	*£ 0.0024*	*£ 0.024*	*£ 0.3*				
DW-1	96-May-15	<0.001	<0.001	<0.001	<0.001			<1	<1
	96-Jun-12	<0.001	<0.001	<0.001	<0.001			<1	<1
	96-Jul-03	<0.001	<0.001	<0.001	<0.001			<1	<1
	96-Jul-30	<0.001	<0.001	<0.001	<0.001			<1	<1
DW-1 Dup.	96-May-15	<0.001	<0.001	<0.001	<0.001			<1	<1
GW-1	95-Nov-14						7.3		
	95-Nov-15	<0.001	<0.001	<0.001	<0.001			<1	<1
	96-Apr-21	<0.001	<0.001	<0.001	<0.001			<1	<1
	96-May-05	<0.001	<0.001	<0.001	<0.001			<1	<1
	96-May-15	<0.001	<0.001	<0.001	<0.001			<1	<1
	96-Jun-12	<0.001	<0.001	<0.001	<0.001			<1	<1
	96-Jul-03	<0.001	<0.001	<0.001	<0.001			<1	<1
	96-Jul-30	<0.001	<0.001	<0.001	<0.001			<1	<1
	96-Aug-18	<0.001	<0.001	<0.001	<0.001			<1	<1
	96-Aug-27	<0.001	<0.001	<0.001	<0.001			<1	<1
	96-Oct-22						8.7		
	96-Oct-28	<0.001	<0.001	<0.001	<0.001			<1	<1
MW-1	95-Nov-15	<0.001	<0.001	<0.001	<0.001		8.6	<1	<1
	96-May-15	0.004	<0.001	<0.001	<0.001	0.004		<1	<1
	96-Jun-12	0.002	<0.001	<0.001	<0.001	0.002		<1	<1
	96-Jul-03	0.006*	<0.001	<0.001	<0.001	0.006*		<1	<1
	96-Jul-30	<0.001	<0.001	<0.001	<0.001			<1	<1
	96-Oct-21	<0.001	<0.001	<0.001	<0.001			<1	<1
	96-Oct-22						8.4		

TABLE 4
DISSOLVED HYDROCARBONS AND DISSOLVED ORGANIC CARBON

Monitoring Station	***Date***	***Benzene (mg/L)***	***Ethylbenzene (mg/L)***	***Toluene (mg/L)***	***Xylenes (total) (mg/L)***	***BTEX (total) (mg/L)***	***DOC (mg/L)***	***TPH Vol. (C_6-C_{11}) (mg/L)***	***TPH Semi-Vol. (C_{12}-C_{22}) (mg/L)***
Water Quality Guidelines (mg/L)		*0.005*	*£ 0.0024*	*£ 0.024*	*£ 0.3*				
PW-1	95-Jun-07	<0.001	<0.001	<0.001	<0.001		12.9	<1	<1
	95-Nov-15	<0.001	<0.001	<0.001	<0.001		6.6	<1	<1
	96-May-15	<0.001	<0.001	<0.001	<0.001			<1	<1
	96-Jun-12	<0.001	<0.001	<0.001	<0.001			<1	<1
	96-Jul-03	<0.001	<0.001	<0.001	<0.001			<1	<1
	96-Jul-30	<0.001	<0.001	<0.001	<0.001			<1	<1
	96-Oct-21	<0.001	<0.001	<0.001	<0.001			<1	<1
	96-Oct-22						7.5		
PW-1 Dup.	96-Jul-30	<0.001	<0.001	<0.001	<0.001			<1	<1
TW-1	95-Nov-15	0.007*	<0.001	<0.001	<0.001	0.007*	8.1	<1	<1
	96-Apr-21	0.066*	0.001	0.016	0.012	0.095*		<1	<1
	96-May-15	0.043*	0.001	0.011	0.013	0.068*		<1	<1
	96-Jun-12	0.064*	0.005*	<0.001	0.021	0.090*		<1	<1
	96-Jul-03	0.065*	0.004*	<0.001	0.015	0.084*		<1	<1
	96-Jul-30	0.045*	0.002	<0.001	0.004	0.051*		<1	<1
	96-Aug-18	0.046*	0.002	<0.001	0.005	0.053*		<1	<1
	96-Aug-27	0.037*	0.002	<0.001	0.003	0.042*		<1	<1
	96-Oct-21	0.035*	0.002	<0.001	<0.001	0.037*		<1	<1
	96-Oct-22						10.3		

TABLE 4
DISSOLVED HYDROCARBONS AND DISSOLVED ORGANIC CARBON

Monitoring Station	*Date*	*Benzene (mg/L)*	*Ethylbenzene (mg/L)*	*Toluene (mg/L)*	*Xylenes (total) (mg/L)*	*BTEX (total) (mg/L)*	*DOC (mg/L)*	*TPH Vol. (C_6-C_{11}) (mg/L)*	*TPH Semi-Vol. (C_{12}-C_{22}) (mg/L)*
Water Quality Guidelines (mg/L)		*0.005*	*£ 0.0024*	*£ 0.024*	*£ 0.3*				
BH-2	92-Aug-06	0.010*	0.001	0.002	0.003	0.016*		<1	<1
	93-May-21	0.077*	0.004*	<0.001	0.008	0.089*		<1	<1
	93-Nov-02	0.002	<0.001	<0.001	<0.001	0.002		<1	<1
	94-Jun-10	<0.001	<0.001	<0.001	<0.001			<1	<1
	95-Jun-07	<0.001	<0.001	<0.001	<0.001			<1	<1
	95-Nov-14	<0.001	<0.001	<0.001	<0.001			<1	<1
	95-Nov-15						5.5		
	96-Jul-30	0.001	<0.001	<0.001	<0.001	0.001		<1	<1
	96-Oct-21	0.006*	<0.001	<0.001	<0.001	0.006*		<1	<1
	96-Oct-22						12.4		
CW-2	95-Nov-15	0.039*	<0.001	<0.001	0.002	0.041*	6.7	<1	<1
	96-Apr-21	0.020*	<0.001	0.004	0.003	0.027*		<1	<1
	96-May-05	0.004	<0.001	0.001	<0.001	0.005		<1	<1
	96-May-15	0.023*	<0.001	0.005	0.006	0.034*		<1	<1
	96-Jun-12	0.006*	<0.001	<0.001	0.001	0.007*		<1	<1
	96-Jul-03	0.020*	0.001	<0.001	0.004	0.025*		<1	<1
	96-Jul-29	<0.0004	<0.0004	<0.0004	<0.0008				
	96-Jul-30	0.016*	<0.001	<0.001	<0.001	0.016*		<1	<1
	96-Oct-21	0.176*	0.003*	<0.001	0.004	0.183*		<1	<1
	96-Oct-22						10.2		
CW-2 Dup.	95-Nov-15	0.033*	<0.001	<0.001	0.001	0.034*		<1	<1
	96-Jul-03	0.019*	0.001	<0.001	0.004	0.024*		<1	<1

TABLE 4
DISSOLVED HYDROCARBONS AND DISSOLVED ORGANIC CARBON

Monitoring Station	*Date*	*Benzene (mg/L)*	*Ethylbenzene (mg/L)*	*Toluene (mg/L)*	*Xylenes (total) (mg/L)*	*BTEX (total) (mg/L)*	*DOC (mg/L)*	*TPH Vol. (C_6-C_{11}) (mg/L)*	*TPH Semi-Vol. (C_{12}-C_{22}) (mg/L)*
Water Quality Guidelines (mg/L)		*0.005*	*£ 0.0024*	*£ 0.024*	*£ 0.3*				
GW-2	95-Nov-14						6.8		
	95-Nov-15	<0.001	<0.001	<0.001	<0.001			<1	<1
	96-May-05	<0.001	<0.001	<0.001	<0.001			<1	<1
	96-May-15	<0.001	<0.001	<0.001	<0.001			<1	<1
	96-Jun-12	<0.001	<0.001	<0.001	<0.001			<1	<1
	96-Jul-03	<0.001	<0.001	<0.001	<0.001			<1	<1
	96-Jul-29	<0.0004	<0.0004	<0.0004	<0.0008				
	96-Jul-30	<0.001	<0.001	<0.001	<0.001			<1	<1
	96-Aug-18	<0.001	<0.001	<0.001	<0.001			<1	<1
	96-Aug-27	<0.001	<0.001	<0.001	<0.001			<1	<1
	96-Oct-22						8.8		
	96-Oct-28	<0.001	<0.001	<0.001	<0.001			<1	<1
TW-2	96-May-15	<0.001	<0.001	<0.001	<0.001			<1	<1
	96-Jun-12	<0.001	<0.001	<0.001	<0.001			<1	<1
	96-Jul-03	0.005	<0.001	<0.001	<0.001	0.005		<1	<1
	96-Jul-30	0.057*	0.002	<0.001	0.002	0.061*		<1	<1
	96-Aug-18	0.072*	0.003*	<0.001	0.010	0.085*		<1	<1
	96-Oct-21	0.037*	<0.001	<0.001	<0.001	0.037*		<1	<1
	96-Oct-22						11.2		
BH-3	93-May-21	0.166*	0.020*	0.098*	0.076	0.360*		<1	<1
	93-Nov-02	0.029*	0.020*	0.001	0.021	0.071*		<1	<1
	94-Jun-10	<0.001	<0.001	<0.001	0.005	0.005		<1	<1
	95-Jun-07	0.003	<0.001	<0.001	<0.001	0.003		<1	<1
	95-Nov-14	<0.001	<0.001	<0.001	<0.001		16.9	<1	<1
	96-Jul-30	0.030*	0.003*	<0.001	0.005	0.038*		<1	<1
	96-Oct-21	0.054*	0.002	<0.001	0.003	0.059*		<1	<1
	96-Oct-22						16.1		
BH-3 Dup.	93-May-21	0.173*	0.020*	0.106*	0.082	0.381*		<1	<1

TABLE 4
DISSOLVED HYDROCARBONS AND DISSOLVED ORGANIC CARBON

Monitoring Station	***Date***	***Benzene (mg/L)***	***Ethylbenzene (mg/L)***	***Toluene (mg/L)***	***Xylenes (total) (mg/L)***	***BTEX (total) (mg/L)***	***DOC (mg/L)***	***TPH Vol. (C_6-C_{11}) (mg/L)***	***TPH Semi-Vol. (C_{12}-C_{22}) (mg/L)***
Water Quality Guidelines (mg/L)		*0.005*	*£ 0.0024*	*£ 0.024*	*£ 0.3*				
CW-3	95-Nov-15	0.003	<0.001	<0.001	<0.001	0.003	7.8	<1	<1
	96-Apr-21	0.031*	<0.001	0.007	0.006	0.044*		<1	<1
	96-May-15	0.019*	<0.001	0.004	0.005	0.028*		<1	<1
	96-Jun-12	0.001	<0.001	<0.001	<0.001	0.001		<1	<1
	96-Jul-03	0.018*	0.001	<0.001	0.004	0.023*		<1	<1
	96-Jul-29	<0.0004	<0.0004	<0.0004	<0.0008				
	96-Jul-30	0.010*	<0.001	<0.001	<0.001	0.010*		<1	<1
	96-Oct-21	0.005	<0.001	<0.001	<0.001	0.005		<1	<1
	96-Oct-22						11.6		
GW-3	95-Nov-14						7.9		
	95-Nov-15	<0.001	<0.001	<0.001	<0.001			<1	<1
	96-Apr-21	<0.001	<0.001	<0.001	<0.001			<1	<1
	96-May-05	<0.001	<0.001	<0.001	<0.001			<1	<1
	96-May-15	<0.001	<0.001	<0.001	<0.001			<1	<1
	96-Jun-12	0.011*	<0.001	<0.001	<0.001	0.011*		<1	<1
	96-Jul-03	0.006*	<0.001	<0.001	<0.001	0.006*		<1	<1
	96-Jul-29	<0.0004	<0.0004	<0.0004	<0.0008				
	96-Jul-30	0.002	<0.001	<0.001	<0.001	0.002		<1	<1
	96-Aug-18	<0.001	<0.001	<0.001	<0.001			<1	<1
	96-Aug-27	<0.001	<0.001	<0.001	<0.001			<1	<1
	96-Oct-22						10.8		
	96-Oct-28	<0.001	<0.001	<0.001	<0.001			<1	<1
GW-3 Dup.	96-May-05	<0.001	<0.001	<0.001	<0.001			<1	<1
	96-Oct-28	<0.001	<0.001	<0.001	<0.001			<1	<1

TABLE 4
DISSOLVED HYDROCARBONS AND DISSOLVED ORGANIC CARBON

Monitoring Station	*Date*	*Benzene* (mg/L)	*Ethylbenzene* (mg/L)	*Toluene* (mg/L)	*Xylenes (total)* (mg/L)	*BTEX (total)* (mg/L)	*DOC* (mg/L)	*TPH Vol.* (C_6-C_{11}) (mg/L)	*TPH Semi-Vol.* (C_{12}-C_{22}) (mg/L)
Water Quality Guidelines (mg/L)		*0.005*	*£ 0.0024*	*£ 0.024*	*£ 0.3*				
TW-3	96-May-15	<0.001	<0.001	<0.001	<0.001			<1	<1
	96-Jun-12	<0.001	<0.001	<0.001	<0.001			<1	<1
	96-Jul-03	<0.001	<0.001	<0.001	<0.001			<1	<1
	96-Jul-30	<0.001	<0.001	<0.001	<0.001			<1	<1
	96-Aug-18	<0.001	<0.001	<0.001	<0.001			<1	<1
	96-Oct-21	0.001	<0.001	<0.001	<0.001	0.001		<1	<1
	96-Oct-22						7.8		
BH-4	92-Aug-06	0.740*	0.028*	0.003	0.127	0.898*		2	<1
	93-May-21	0.444*	0.051*	0.003	0.121	0.619*		<1	<1
	93-Nov-02	0.688*	0.065*	0.003	0.078	0.834*		1	<1
	94-Jun-10	0.111*	0.015*	0.002	0.029	0.157*		<1	<1
	95-Jun-07	0.142*	0.082*	<0.001	0.113	0.337*		11	187
	95-Nov-14	0.544*	0.058*	<0.001	0.015	0.617*	25.8	1	7
	96-Jul-30	0.272*	0.029*	<0.001	0.003	0.304*		<1	<1
	96-Oct-21	0.737*	0.050*	<0.001	0.005	0.792*		1	<1
	96-Oct-22						25.9		
BH-4 Dup.	92-Aug-06	0.754*	0.036*	0.002	0.159	0.951*		2	<1
	93-Nov-02	0.637*	0.059*	0.001	0.064	0.761*		1	<1
CW-4	95-Nov-15	0.003	<0.001	<0.001	<0.001	0.003	8.0	<1	<1
	96-May-15	0.026*	<0.001	0.006	0.006	0.038*		<1	<1
	96-Jun-12	0.013*	0.001	<0.001	0.004	0.018*		<1	<1
	96-Jul-03	0.018*	0.001	<0.001	0.004	0.023*		<1	<1
	96-Jul-29	<0.0004	<0.0004	<0.0004	<0.0008				
	96-Jul-30	0.013*	<0.001	<0.001	<0.001	0.013*		<1	<1

TABLE 4
DISSOLVED HYDROCARBONS AND DISSOLVED ORGANIC CARBON

Monitoring Station	***Date***	***Benzene (mg/L)***	***Ethylbenzene (mg/L)***	***Toluene (mg/L)***	***Xylenes (total) (mg/L)***	***BTEX (total) (mg/L)***	***DOC (mg/L)***	***TPH Vol. (C_6-C_{11}) (mg/L)***	***TPH Semi-Vol. (C_{12}-C_{22}) (mg/L)***
Water Quality Guidelines (mg/L)		*0.005*	*£ 0.0024*	*£ 0.024*	*£ 0.3*				
GW-4	95-Nov-14						7.4		
	95-Nov-15	<0.001	<0.001	<0.001	<0.001			<1	<1
	96-Apr-21	<0.001	<0.001	<0.001	<0.001			<1	<1
	96-May-05	<0.001	<0.001	<0.001	<0.001			<1	<1
	96-May-15	<0.001	<0.001	<0.001	<0.001			<1	<1
	96-Jun-12	0.001	<0.001	<0.001	<0.001	0.001		<1	<1
	96-Jul-03	<0.001	<0.001	<0.001	<0.001			<1	<1
	96-Jul-30	0.001	<0.001	<0.001	<0.001	0.001		<1	<1
	96-Aug-18	<0.001	<0.001	<0.001	<0.001			<1	<1
	96-Aug-27	<0.001	<0.001	<0.001	<0.001			<1	<1
	96-Oct-22						9.5		
	96-Oct-28	<0.001	<0.001	<0.001	<0.001			<1	<1
GW-4 Dup.	96-Jul-03	<0.001	<0.001	<0.001	<0.001			<1	<1
	96-Aug-27	<0.001	<0.001	<0.001	<0.001			<1	<1
TW-4	95-Nov-15	<0.001	<0.001	<0.001	<0.001		8.2	<1	<1
	96-Jun-12	<0.001	<0.001	<0.001	<0.001			<1	<1
	96-Jul-03	<0.001	<0.001	<0.001	<0.001			<1	<1
	96-Jul-30	<0.001	<0.001	<0.001	<0.001			<1	<1
	96-Aug-18	<0.001	<0.001	<0.001	<0.001			<1	<1
	96-Aug-27	0.003	<0.001	<0.001	<0.001	0.003		<1	<1
	96-Oct-21	0.001	<0.001	<0.001	<0.001	0.001		<1	<1
	96-Oct-22						7.6		
TW-4 Dup.	95-Nov-15	<0.001	<0.001	<0.001	<0.001			<1	<1
	96-Jun-12	<0.001	<0.001	<0.001	<0.001			<1	<1
	96-Jul-30	<0.001	<0.001	<0.001	<0.001			<1	<1
	96-Oct-21	<0.001	<0.001	<0.001	<0.001			<1	<1

TABLE 4
DISSOLVED HYDROCARBONS AND DISSOLVED ORGANIC CARBON

Monitoring Station	*Date*	*Benzene (mg/L)*	*Ethylbenzene (mg/L)*	*Toluene (mg/L)*	*Xylenes (total) (mg/L)*	*BTEX (total) (mg/L)*	*DOC (mg/L)*	*TPH Vol. (C_6-C_{11}) (mg/L)*	*TPH Semi-Vol. (C_{12}-C_{22}) (mg/L)*
Water Quality Guidelines (mg/L)		*0.005*	*£ 0.0024*	*£ 0.024*	*£ 0.3*				
BH-5	92-Aug-06	0.178*	0.085*	0.003	0.120	0.386*		<1	<1
	93-May-21	0.155*	0.091*	0.005	0.195	0.446*		1	<1
	93-Nov-02	0.307*	0.101*	0.004	0.220	0.632*	31.7	2	<1
	94-Jun-10	0.053*	0.065*	0.003	0.093	0.214*	17.2	<1	<1
	95-Jun-07	0.076*	0.038*	0.039*	0.048	0.201*	16.8	<1	1
	95-Nov-14						15.6		
	95-Nov-15	0.002	0.020*	<0.001	0.032	0.054*		<1	<1
	96-Jul-30	0.004	0.015*	<0.001	0.023	0.042*		<1	<1
	96-Oct-21	0.074*	0.017*	<0.001	0.017	0.108*		<1	<1
	96-Oct-22						19.0		
CW-5	95-Nov-15	0.001	<0.001	<0.001	<0.001	0.001	8.2	<1	<1
	96-Apr-21	0.029*	<0.001	0.006	0.006	0.041*		<1	<1
	96-May-15	0.030*	<0.001	0.006	0.009	0.045*		<1	<1
	96-Jun-12	0.016*	0.001	<0.001	0.005	0.022*		<1	<1
	96-Jul-03	0.010*	<0.001	<0.001	0.002	0.012*		<1	<1
	96-Jul-29	<0.0004	<0.0004	<0.0004	<0.0008				
	96-Jul-30	0.003	<0.001	<0.001	<0.001	0.003		<1	<1
	96-Oct-21	<0.001	<0.001	<0.001	<0.001			<1	<1
	96-Oct-22						10.7		

TABLE 4
DISSOLVED HYDROCARBONS AND DISSOLVED ORGANIC CARBON

Monitoring Station	***Date***	***Benzene (mg/L)***	***Ethylbenzene (mg/L)***	***Toluene (mg/L)***	***Xylenes (total) (mg/L)***	***BTEX (total) (mg/L)***	***DOC (mg/L)***	***TPH Vol. (C_6-C_{11}) (mg/L)***	***TPH Semi-Vol. (C_{12}-C_{22}) (mg/L)***
Water Quality Guidelines (mg/L)		*0.005*	*£ 0.0024*	*£ 0.024*	*£ 0.3*				
TW-5	95-Nov-15	<0.001	<0.001	<0.001	<0.001		7.6	<1	<1
	96-Jun-12	0.033*	<0.001	<0.001	0.006	0.039*		<1	<1
	96-Jul-03	0.003	<0.001	0.001	<0.001	0.004		<1	<1
	96-Jul-30	0.012*	<0.001	0.005	0.002	0.019*		<1	<1
	96-Aug-18	0.121*	0.002	<0.001	0.005	0.128*		<1	<1
	96-Aug-27	0.145*	0.004*	<0.001	0.011	0.160*		<1	<1
	96-Oct-21	0.093*	<0.001	<0.001	<0.001	0.093*		<1	<1
	96-Oct-22						9.9		
	96-Oct-28	0.122*	0.001	<0.001	<0.001	0.123*		<1	<1
TW-5 Dup.	96-Jul-30	0.006*	<0.001	0.002	<0.001	0.008*		<1	<1
	96-Oct-28	0.123*	0.001	<0.001	<0.001	0.124*		<1	<1
BH-6	91-Jan-10	0.155*	0.027*	0.014	0.138	0.334*			
	92-Jun-03						18.9		
	92-Aug-06	0.363*	0.064*	0.005	0.362*	0.794*		2	<1
	93-May-21	1.070*	0.078*	0.008	0.341*	1.497*	29.2	3	<1
	93-Nov-02	0.400*	0.071*	0.005	0.180	0.656*	13.0	2	<1
	94-Jun-10	0.410*	0.060*	0.005	0.562*	1.037*	17.6	3	<1
	95-Jun-07	0.304*	0.091*	0.002	0.588*	0.985*	16.1	3	<1
	95-Nov-15	0.106*	0.022*	0.001	0.040	0.169*	8.6	1	<1
	96-May-15	0.634*	0.061*	<0.001	0.272	0.967*		3	<1
	96-Jun-12	0.261*	0.058*	0.001	0.373*	0.693*		3	<1
	96-Jul-03	0.312*	0.057*	0.001	0.284	0.654*		3	<1
	96-Jul-30	0.246*	0.026*	0.001	0.147	0.420*		1	<1
	96-Oct-21	0.139*	0.031*	<0.001	0.089	0.259*		1	<1
	96-Oct-22						11.4		
BH-6 Dup.	94-Jun-10	0.413*	0.061*	0.005	0.563*	1.042*		3	<1

TABLE 4
DISSOLVED HYDROCARBONS AND DISSOLVED ORGANIC CARBON

Monitoring Station	Date	Benzene (mg/L)	Ethylbenzene (mg/L)	Toluene (mg/L)	Xylenes (total) (mg/L)	BTEX (total) (mg/L)	DOC (mg/L)	TPH Vol. (C_6-C_{11}) (mg/L)	TPH Semi-Vol. (C_{12}-C_{22}) (mg/L)
Water Quality Guidelines (mg/L)		*0.005*	*£ 0.0024*	*£ 0.024*	*£ 0.3*				
CW-6	95-Nov-15	<0.001	<0.001	<0.001	<0.001		7.9	<1	<1
	96-May-15	0.028*	<0.001	0.006	0.008	0.042*		<1	<1
	96-Jun-12	0.016*	0.001	<0.001	0.006	0.023*		<1	<1
	96-Jul-03	0.010*	<0.001	<0.001	0.002	0.012*		<1	<1
	96-Jul-29	<0.0004	<0.0004	<0.0004	<0.0008				
	96-Jul-30	0.003	<0.001	<0.001	<0.001	0.003		<1	<1
TW-6	95-Nov-15	0.001	<0.001	<0.001	<0.001	0.001	7.1	<1	<1
	96-May-15	<0.001	<0.001	<0.001	<0.001			<1	<1
	96-Jun-12	0.011*	<0.001	<0.001	0.002	0.013*		<1	<1
	96-Jul-03	0.006*	<0.001	<0.001	<0.001	0.006*		<1	<1
	96-Jul-30	0.040*	<0.001	0.004	<0.001	0.044*		<1	<1
	96-Aug-18	0.017*	<0.001	<0.001	<0.001	0.017*		<1	<1
	96-Oct-22						8.8		
	96-Oct-28	0.091*	<0.001	<0.001	<0.001	0.091*		<1	<1
TW-6 Dup.	96-Aug-18	0.017*	<0.001	<0.001	<0.001	0.017*		<1	<1

TABLE 4
DISSOLVED HYDROCARBONS AND DISSOLVED ORGANIC CARBON

Monitoring Station	*Date*	*Benzene (mg/L)*	*Ethylbenzene (mg/L)*	*Toluene (mg/L)*	*Xylenes (total) (mg/L)*	*BTEX (total) (mg/L)*	*DOC (mg/L)*	*TPH Vol. (C_6-C_{11}) (mg/L)*	*TPH Semi-Vol. (C_{12}-C_{22}) (mg/L)*
Water Quality Guidelines (mg/L)		*0.005*	*£ 0.0024*	*£ 0.024*	*£ 0.3*				
BH-7	91-Jan-10	0.498*	0.060*	1.040*	0.476*	2.07*			
	92-Jun-03						30.6		
	92-Aug-06	6.230*	0.096*	0.721*	0.805*	7.85*		9	<1
	93-May-21	8.340*	0.048*	1.150*	0.985*	10.52*	26.5	14	<1
	93-Nov-02	9.020*	0.085*	1.470*	1.430*	12.00*	20.5	16	<1
	94-Jun-10	3.310*	0.042*	0.277*	0.333*	3.96*	25.0	6	<1
	95-Jun-07	2.690*	0.022*	0.134*	0.283	3.13*	24.4	5	<1
	95-Nov-15	3.660*	0.031*	0.169*	0.572*	4.43*	13.2	7	<1
	96-May-15	3.680*	0.016*	0.175*	0.392*	4.26*		7	<1
	96-Jun-12	5.540*	0.033*	0.131*	0.366*	6.07*		10	<1
	96-Jul-03	6.670*	0.026*	0.209*	0.494*	7.40*		10	<1
	96-Jul-30	4.710*	0.022*	0.150*	0.400*	5.28*		7	<1
	96-Oct-21	7.550*	0.077*	0.502*	1.630*	9.76*		10	<1
	96-Oct-22						28.9		
BH-7 Dup.	92-Aug-06	6.430*	0.094*	0.737*	0.772*	8.03*		9	<1
	93-Nov-02	8.970*	0.085*	1.470*	1.430*	11.96*		16	<1
CW-7	95-Nov-15	<0.001	<0.001	<0.001	<0.001		8.0	<1	<1
	96-Apr-21	0.025*	<0.001	0.005	0.005	0.035*		<1	<1
	96-May-05	0.008*	<0.001	0.002	0.004	0.014*		<1	<1
	96-May-15	0.024*	<0.001	0.005	0.007	0.036*		<1	<1
	96-Jun-12	0.016*	0.001	<0.001	0.005	0.022*		<1	<1
	96-Jul-03	0.009*	<0.001	<0.001	0.001	0.010*		<1	<1
	96-Jul-29	<0.0004	<0.0004	<0.0004	<0.0008				
	96-Jul-30	0.003	<0.001	<0.001	<0.001	0.003		<1	<1
	96-Oct-21	<0.001	<0.001	<0.001	<0.001			<1	<1
	96-Oct-22						12.4		

TABLE 4
DISSOLVED HYDROCARBONS AND DISSOLVED ORGANIC CARBON

Monitoring Station	***Date***	***Benzene (mg/L)***	***Ethylbenzene (mg/L)***	***Toluene (mg/L)***	***Xylenes (total) (mg/L)***	***BTEX (total) (mg/L)***	***DOC (mg/L)***	***TPH Vol. (C_6-C_{11}) (mg/L)***	***TPH Semi-Vol. (C_{12}-C_{22}) (mg/L)***
Water Quality Guidelines (mg/L)		*0.005*	*£ 0.0024*	*£ 0.024*	*£ 0.3*				
CW-7 Dup.	96-May-15	0.027*	<0.001	0.005	0.008	0.040*		<1	<1
	96-Jun-12	0.016*	0.001	<0.001	0.005	0.022*		<1	<1
	96-Jul-30	0.003	<0.001	<0.001	<0.001	0.003		<1	<1
TW-7	95-Nov-15	0.060*	<0.001	<0.001	<0.001	0.060*	6.7	<1	<1
	96-Apr-21	0.007*	<0.001	<0.001	<0.001	0.007*		<1	<1
	96-May-15	0.032*	<0.001	0.007	0.009	0.048*		<1	<1
	96-Jun-12	0.018*	<0.001	<0.001	0.005	0.023*		<1	<1
	96-Jul-03	0.014*	<0.001	<0.001	<0.001	0.014*		<1	<1
	96-Jul-30	0.083*	0.008*	0.102*	0.059	0.252*		<1	<1
	96-Aug-18	1.160*	0.001	<0.001	0.027	1.19*		1	<1
	96-Aug-27	1.060*	<0.001	<0.001	0.018	1.08*		1	<1
	96-Oct-22						9.7		
	96-Oct-28	0.727*	0.005*	<0.001	0.033	0.765*		<1	<1
BH-8	91-Jan-10	0.035*	0.004*	0.018	0.022	0.079*			
	92-Jun-03						7.4		
	92-Aug-06	0.001	<0.001	0.002	0.003	0.006		<1	<1
	93-May-21	<0.001	<0.001	<0.001	<0.001		2.8	<1	<1
	93-Nov-02	<0.001	<0.001	<0.001	<0.001		3.1	<1	<1
	94-Jun-10	<0.001	<0.001	<0.001	<0.001		3.3	<1	<1
	95-Jun-07	<0.001	<0.001	<0.001	<0.001		2.6	<1	<1
	95-Nov-15	<0.001	<0.001	<0.001	<0.001		2.7	<1	<1
	96-May-15	<0.001	<0.001	<0.001	<0.001			<1	<1
	96-Jun-12	<0.001	<0.001	<0.001	<0.001			<1	<1
	96-Jul-03	<0.001	<0.001	<0.001	<0.001			<1	<1
	96-Jul-30	<0.001	<0.001	<0.001	<0.001			<1	<1
	96-Oct-21	<0.001	<0.001	<0.001	<0.001			<1	<1
	96-Oct-22						3.0		

TABLE 4
DISSOLVED HYDROCARBONS AND DISSOLVED ORGANIC CARBON

Monitoring Station	*Date*	*Benzene (mg/L)*	*Ethylbenzene (mg/L)*	*Toluene (mg/L)*	*Xylenes (total) (mg/L)*	*BTEX (total) (mg/L)*	*DOC (mg/L)*	*TPH Vol. (C_6-C_{11}) (mg/L)*	*TPH Semi-Vol. (C_{12}-C_{22}) (mg/L)*
Water Quality Guidelines (mg/L)		*0.005*	*£ 0.0024*	*£ 0.024*	*£ 0.3*				
BH-8 Dup.	91-Jan-10	0.038*	0.004*	0.019	0.023	0.084*			
	96-Jun-12	<0.001	<0.001	<0.001	<0.001			<1	<1
	96-Oct-21	<0.001	<0.001	<0.001	<0.001			<1	<1
BH-9	91-Jan-10	<0.001	<0.001	<0.001	<0.001				
	92-Jun-03						7.9		
	92-Aug-06	0.076*	<0.001	<0.001	0.002	0.078*		<1	<1
	93-May-21	<0.001	<0.001	<0.001	0.001	0.001	7.3	<1	<1
	93-Nov-02	<0.001	<0.001	<0.001	<0.001		5.6	<1	<1
	94-Jun-10	<0.001	<0.001	<0.001	<0.001		6.9	<1	<1
	95-Jun-07	0.081*	0.003*	<0.001	0.024	0.108*	5.4	<1	<1
BH-10	92-Aug-06	0.089*	<0.001	<0.001	<0.001	0.089*		<1	<1
	93-May-21	0.074*	0.001	<0.001	0.003	0.078*		<1	<1
	93-Nov-02	0.012*	<0.001	<0.001	<0.001	0.012*		<1	<1
	94-Jun-10	0.298*	0.016*	0.001	0.058	0.373*		<1	<1
	95-Jun-07	0.112*	0.006*	<0.001	0.031	0.149*		<1	<1
	95-Nov-14	0.003	<0.001	<0.001	<0.001	0.003		<1	<1
	95-Nov-15						13.4		
	96-Jun-12	0.008*	<0.001	<0.001	<0.001	0.008*		<1	<1
	96-Jul-03	0.014*	<0.001	<0.001	0.001	0.015*		<1	<1
	96-Jul-30	0.004	<0.001	<0.001	<0.001	0.004		<1	<1
	96-Oct-21	0.021*	<0.001	<0.001	<0.001	0.021*		<1	<1
	96-Oct-22						13.1		
BH-10 Dup.	94-Jun-10	0.297*	0.015*	0.001	0.057	0.370*		<1	<1

TABLE 4
DISSOLVED HYDROCARBONS AND DISSOLVED ORGANIC CARBON

Monitoring Station	*Date*	*Benzene (mg/L)*	*Ethylbenzene (mg/L)*	*Toluene (mg/L)*	*Xylenes (total) (mg/L)*	*BTEX (total) (mg/L)*	*DOC (mg/L)*	*TPH Vol. (C_6-C_{11}) (mg/L)*	*TPH Semi-Vol. (C_{12}-C_{22}) (mg/L)*
Water Quality Guidelines (mg/L)		*0.005*	*£ 0.0024*	*£ 0.024*	*£ 0.3*				
BH-11	92-Aug-06	0.035*	<0.001	0.002	0.003	0.040*		<1	<1
	93-May-21	0.131*	0.007*	0.004	0.019	0.161*		<1	<1
	93-Nov-02	0.002	<0.001	<0.001	<0.001	0.002		<1	<1
	94-Jun-10	0.068*	0.007*	<0.001	0.030	0.105*		<1	<1
	95-Jun-07	0.060*	0.003*	<0.001	0.019	0.082*		<1	<1
BH-11 Dup.	95-Jun-07	0.054*	0.003*	<0.001	0.017	0.074*		<1	<1
BH-12	93-May-21	<0.001	0.001	0.001	0.006	0.008		<1	<1
	94-Jun-10	<0.001	<0.001	<0.001	<0.001			<1	<1
	95-Jun-07	<0.001	<0.001	<0.001	<0.001			<1	<1
	95-Nov-14	<0.001	<0.001	<0.001	<0.001			<1	<1
	95-Nov-15						19.8		
	96-Jul-30	<0.001	<0.001	<0.001	0.002	0.002		<1	<1
	96-Oct-21	<0.001	<0.001	<0.001	<0.001			<1	<1
	96-Oct-22						29.7		
BH-12 Dup.	93-May-21	<0.001	0.002	<0.001	0.007	0.009		<1	<1
BH-13	92-Aug-06	0.002	0.001	<0.001	0.002	0.005		<1	<1
	93-May-21	<0.001	<0.001	<0.001	<0.001			<1	<1
	93-Nov-02	<0.001	<0.001	<0.001	<0.001			<1	<1
	94-Jun-10	<0.001	<0.001	<0.001	<0.001			<1	<1
	95-Jun-07	<0.001	<0.001	<0.001	<0.001			<1	<1
	95-Nov-14	<0.001	<0.001	<0.001	<0.001			<1	<1
	95-Nov-15						5.2		
	96-Jul-30	<0.001	<0.001	<0.001	<0.001			<1	<1
	96-Oct-21	<0.001	<0.001	<0.001	<0.001			<1	<1
	96-Oct-22						5.5		

TABLE 4
DISSOLVED HYDROCARBONS AND DISSOLVED ORGANIC CARBON

Monitoring Station	*Date*	*Benzene (mg/L)*	*Ethylbenzene (mg/L)*	*Toluene (mg/L)*	*Xylenes (total) (mg/L)*	*BTEX (total) (mg/L)*	*DOC (mg/L)*	*TPH Vol. (C_6-C_{11}) (mg/L)*	*TPH Semi-Vol. (C_{12}-C_{22}) (mg/L)*
Water Quality Guidelines (mg/L)		*0.005*	*£ 0.0024*	*£ 0.024*	*£ 0.3*				
BH-14	92-Aug-06	0.001	<0.001	0.001	<0.001	0.002		<1	<1
	94-Jun-10	<0.001	<0.001	<0.001	<0.001			<1	<1
	95-Jun-07	<0.001	<0.001	<0.001	<0.001			<1	<1
	95-Nov-14	<0.001	<0.001	<0.001	<0.001		12.3	<1	<1
	96-Jul-30	<0.001	<0.001	<0.001	<0.001			<1	<1
	96-Oct-21	<0.001	<0.001	<0.001	<0.001		13.6	<1	<1
94-15A	94-Dec-22	<0.001	<0.001	<0.001	<0.001			<1	<1
	95-Jun-07	0.002	<0.001	<0.001	<0.001	0.002		<1	<1
	95-Nov-15	0.006*	<0.001	<0.001	<0.001	0.006*	8.1	<1	<1
	96-Jul-03	<0.001	<0.001	<0.001	<0.001			<1	<1
	96-Jul-30	<0.001	<0.001	<0.001	<0.001			<1	<1
	96-Oct-21	<0.001	<0.001	<0.001	<0.001			<1	<1
	96-Oct-22						7.9		
94-15C	94-Dec-22	<0.001	<0.001	<0.001	<0.001			<1	<1
	95-Jun-07	<0.001	<0.001	<0.001	<0.001			<1	<1
	95-Nov-15	<0.001	<0.001	<0.001	<0.001		5.6	<1	<1
	96-Jul-30	<0.001	<0.001	<0.001	<0.001			<1	<1
	96-Oct-21	<0.001	<0.001	<0.001	<0.001			<1	<1
	96-Oct-22						6.0		
94-16A	95-Jun-07	0.009*	<0.001	<0.001	<0.001	0.009*		<1	<1
	96-Jun-12	<0.001	<0.001	<0.001	<0.001			<1	<1
	96-Jul-03	<0.001	<0.001	<0.001	<0.001			<1	<1
	96-Jul-30	<0.001	<0.001	<0.001	<0.001			<1	<1
	96-Oct-21	0.016*	<0.001	<0.001	<0.001	0.016*		<1	<1
	96-Oct-22						12.3		

TABLE 4
DISSOLVED HYDROCARBONS AND DISSOLVED ORGANIC CARBON

Monitoring Station	*Date*	*Benzene (mg/L)*	*Ethylbenzene (mg/L)*	*Toluene (mg/L)*	*Xylenes (total) (mg/L)*	*BTEX (total) (mg/L)*	*DOC (mg/L)*	*TPH Vol. (C_6-C_{11}) (mg/L)*	*TPH Semi-Vol. (C_{12}-C_{22}) (mg/L)*
Water Quality Guidelines (mg/L)		*0.005*	*£ 0.0024*	*£ 0.024*	*£ 0.3*				
94-16B	94-Dec-22	<0.001	<0.001	<0.001	<0.001			<1	<1
	95-Jun-07	0.002	<0.001	<0.001	<0.001	0.002		<1	<1
	95-Nov-15	0.011*	<0.001	<0.001	<0.001	0.011*	13.5	<1	<1
	96-May-15	<0.001	<0.001	<0.001	<0.001			<1	<1
	96-Jun-12	<0.001	<0.001	<0.001	<0.001			<1	<1
	96-Jul-03	<0.001	<0.001	<0.001	<0.001			<1	<1
	96-Jul-30	<0.001	<0.001	<0.001	<0.001			<1	<1
	96-Oct-21	0.008*	<0.001	<0.001	<0.001	0.008*		<1	<1
	96-Oct-22						10.9		
94-16B Dup.	94-Dec-22	<0.001	<0.001	<0.001	<0.001			<1	<1
94-17A	94-Dec-22	0.076*	0.046*	0.001	0.256	0.379*		<1	<1
	95-Jun-07	0.075*	0.029*	<0.001	0.120	0.224*		<1	<1
	95-Nov-15	0.064*	0.027*	<0.001	0.140	0.231*	11.6	1	<1
	96-May-15	0.061*	0.016*	<0.001	0.204	0.281*		2	4
	96-Jun-12	0.058*	0.026*	<0.001	0.257	0.341*		3	8
	96-Jul-03	0.067*	0.025*	<0.001	0.268	0.360*		2	6
	96-Jul-30	0.040*	0.009*	<0.001	0.088	0.137*		<1	<1
	96-Oct-21	0.033*	0.010*	<0.001	0.129	0.172*		<1	<1
	96-Oct-22						11.7		
94-17A Dup.	95-Jun-07	0.076*	0.029*	<0.001	0.117	0.222*		<1	<1
94-18A	94-Dec-22	<0.001	<0.001	<0.001	<0.001			<1	<1
	95-Jun-07	<0.001	<0.001	<0.001	<0.001			<1	<1
	95-Nov-15	<0.001	<0.001	<0.001	<0.001		2.5	<1	<1
	96-Jul-30	<0.001	<0.001	<0.001	<0.001			<1	<1
	96-Oct-21	<0.001	<0.001	<0.001	<0.001			<1	<1
	96-Oct-22						4.0		
94-18A Dup.	95-Jun-07	<0.001	<0.001	<0.001	<0.001			<1	<1

TABLE 4
DISSOLVED HYDROCARBONS AND DISSOLVED ORGANIC CARBON

Monitoring Station	Date	Benzene (mg/L)	Ethylbenzene (mg/L)	Toluene (mg/L)	Xylenes (total) (mg/L)	BTEX (total) (mg/L)	DOC (mg/L)	TPH Vol. (C_6-C_{11}) (mg/L)	TPH Semi-Vol. (C_{12}-C_{22}) (mg/L)
Water Quality Guidelines (mg/L)		*0.005*	*£ 0.0024*	*£ 0.024*	*£ 0.3*				
94-19A	94-Dec-22	<0.001	<0.001	<0.001	<0.001			<1	<1
	95-Jun-07	<0.001	<0.001	<0.001	<0.001			<1	<1
	95-Nov-14						7.1		
	95-Nov-15	<0.001	<0.001	<0.001	<0.001			<1	<1
	96-Jul-30	<0.001	<0.001	<0.001	<0.001			<1	<1
	96-Oct-21						3.5		
	96-Oct-28	<0.001	<0.001	<0.001	<0.001			<1	<1
94-19C	94-Dec-22	<0.001	<0.001	<0.001	<0.001			<1	<1
	95-Jun-07	<0.001	<0.001	<0.001	<0.001			<1	<1
	95-Nov-14						5.1		
	95-Nov-15	<0.001	<0.001	<0.001	<0.001			<1	<1
	96-Jul-30	<0.001	<0.001	<0.001	<0.001			<1	<1
	96-Oct-21						4.7		
	96-Oct-28	<0.001	<0.001	<0.001	<0.001			<1	<1
94-20A	94-Dec-22	<0.001	<0.001	<0.001	<0.001			<1	<1
	95-Jun-07	0.004	<0.001	<0.001	0.001	0.005		<1	<1
	95-Nov-14						5.6		
	95-Nov-15	0.003	<0.001	<0.001	<0.001	0.003		<1	<1
	96-Jul-30	0.003	<0.001	<0.001	<0.001	0.003		<1	<1
	96-Oct-21	<0.001	<0.001	<0.001	<0.001		4.9	<1	<1
	96-Oct-28	<0.001	<0.001	<0.001	<0.001			<1	<1

TABLE 4
DISSOLVED HYDROCARBONS AND DISSOLVED ORGANIC CARBON

Monitoring Station	*Date*	*Benzene (mg/L)*	*Ethylbenzene (mg/L)*	*Toluene (mg/L)*	*Xylenes (total) (mg/L)*	*BTEX (total) (mg/L)*	*DOC (mg/L)*	*TPH Vol. (C_6-C_{11}) (mg/L)*	*TPH Semi-Vol. (C_{12}-C_{22}) (mg/L)*
Water Quality Guidelines (mg/L)		*0.005*	*£ 0.0024*	*£ 0.024*	*£ 0.3*				
94-20C	94-Dec-22	<0.001	<0.001	<0.001	<0.001			<1	<1
	95-Jun-07	<0.001	<0.001	<0.001	<0.001			<1	<1
	95-Nov-14						5.7		
	95-Nov-15	<0.001	<0.001	<0.001	<0.001			<1	<1
	96-Jul-30	<0.001	<0.001	<0.001	<0.001			<1	<1
	96-Oct-21						5.4		
	96-Oct-28	<0.001	<0.001	<0.001	<0.001			<1	<1
94-20C Dup.	96-Jul-30	<0.001	<0.001	<0.001	<0.001			<1	<1
96-21A	96-Jun-12	<0.001	<0.001	<0.001	<0.001			<1	<1
	96-Jul-03	<0.001	<0.001	0.001	<0.001	0.001		<1	<1
	96-Jul-29	<0.0004	<0.0004	<0.0004	<0.0008				
	96-Jul-30	<0.001	<0.001	<0.001	<0.001			<1	<1
	96-Aug-18	<0.001	<0.001	<0.001	<0.001			<1	<1
	96-Aug-27	<0.001	<0.001	<0.001	<0.001			<1	<1
	96-Oct-22						9.1		
	96-Oct-28	<0.001	<0.001	<0.001	<0.001			<1	<1
96-21A Dup.	96-Jun-12	<0.001	<0.001	<0.001	<0.001			<1	<1
	96-Aug-27	<0.001	<0.001	<0.001	<0.001			<1	<1
96-22A	96-Jun-12	<0.001	<0.001	<0.001	<0.001			<1	<1
	96-Jul-03	<0.001	<0.001	0.001	<0.001	0.001		<1	<1
	96-Jul-30	<0.001	<0.001	<0.001	<0.001			<1	<1
	96-Oct-21	<0.001	<0.001	<0.001	<0.001			<1	<1
	96-Oct-22						9.2		

TABLE 4
DISSOLVED HYDROCARBONS AND DISSOLVED ORGANIC CARBON

Monitoring Station	***Date***	***Benzene (mg/L)***	***Ethylbenzene (mg/L)***	***Toluene (mg/L)***	***Xylenes (total) (mg/L)***	***BTEX (total) (mg/L)***	***DOC (mg/L)***	***TPH Vol. (C_6-C_{11}) (mg/L)***	***TPH Semi-Vol. (C_{12}-C_{22}) (mg/L)***
Water Quality Guidelines (mg/L)		*0.005*	*£ 0.0024*	*£ 0.024*	*£ 0.3*				
96-22B	96-Jun-12	0.001	<0.001	<0.001	<0.001	0.001		<1	<1
	96-Jul-03	<0.001	<0.001	<0.001	<0.001			<1	<1
	96-Jul-30	<0.001	<0.001	<0.001	<0.001			<1	<1
	96-Oct-21	<0.001	<0.001	<0.001	<0.001			<1	<1
	96-Oct-22						8.0		
96-22B Dup.	96-Jul-03	<0.001	<0.001	0.001	<0.001	0.001		<1	<1
96-23A	96-Jun-12	0.076*	0.034*	0.001	0.051	0.162*		2	<1
	96-Jul-03	0.082*	0.037*	0.002	0.042	0.163*		2	<1
	96-Jul-29								
	96-Jul-30	0.068*	0.023*	0.002	0.018	0.111*		2	<1
	96-Oct-21	0.093*	0.044*	<0.001	0.032	0.169*		2	<1
	96-Oct-22	<0.061	<0.061	<0.061	<0.122		3840		
96-23A Dup.	96-Oct-21	0.092*	0.046*	0.001	0.034	0.173*		2	<1
96-24A	96-Jun-12	0.083*	0.002	<0.001	0.003	0.088*		<1	<1
	96-Jul-03	0.077*	0.004*	<0.001	0.004	0.085*		<1	<1
	96-Jul-30	0.013*	0.001	<0.001	0.001	0.015*		<1	<1
	96-Oct-21	0.009*	<0.001	<0.001	<0.001	0.009*		<1	<1
	96-Oct-22						11.3		
96-25A	96-Jun-12	<0.001	<0.001	<0.001	<0.001			1	7
	96-Jul-03	0.086*	0.002	0.001	0.008	0.097*		<1	<1
	96-Jul-30	0.102*	0.006*	<0.001	0.017	0.125*		<1	<1
	96-Oct-21	0.026*	<0.001	<0.001	<0.001	0.026*		<1	<1
	96-Oct-22						16.1		

TABLE 4
DISSOLVED HYDROCARBONS AND DISSOLVED ORGANIC CARBON

Monitoring Station	***Date***	***Benzene (mg/L)***	***Ethylbenzene (mg/L)***	***Toluene (mg/L)***	***Xylenes (total) (mg/L)***	***BTEX (total) (mg/L)***	***DOC (mg/L)***	***TPH Vol. (C_6-C_{11}) (mg/L)***	***TPH Semi-Vol. (C_{12}-C_{22}) (mg/L)***
Water Quality Guidelines (mg/L)		*0.005*	*£ 0.0024*	*£ 0.024*	*£ 0.3*				
96-25B	96-Jun-12	0.080*	<0.001	<0.001	0.007	0.087*		<1	<1
	96-Jul-03	0.090*	<0.001	<0.001	0.004	0.094*		<1	<1
	96-Jul-30	0.108*	0.002	<0.001	0.007	0.117*		<1	<1
	96-Oct-21	0.493*	0.002	<0.001	0.013	0.508*		<1	<1
	96-Oct-22						14.6		
96-26A	96-Jun-12	0.001	<0.001	<0.001	<0.001	0.001		<1	<1
	96-Jul-03	0.058*	<0.001	0.001	0.003	0.062*		<1	<1
	96-Jul-30	0.007*	<0.001	<0.001	0.001	0.008*		<1	<1
	96-Oct-21	0.006*	<0.001	<0.001	<0.001	0.006*		<1	<1
	96-Oct-22						7.6		
Equipment Blank	94-Jun-10	<0.001	<0.001	<0.001	<0.001			<1	<1
	94-Dec-22	<0.001	<0.001	<0.001	<0.001			<1	<1
	95-Jun-07	<0.001	<0.001	<0.001	<0.001			<1	<1
	95-Nov-15	<0.001	<0.001	<0.001	<0.001			<1	<1
	96-Oct-21	<0.001	<0.001	<0.001	<0.001			<1	<1
Freon Blank	94-Jun-10	<0.001	<0.001	<0.001	<0.001			<1	<1
	94-Dec-22	<0.001	<0.001	<0.001	<0.001			<1	<1
	95-Jun-07	<0.001	<0.001	<0.001	<0.001			<1	<1
	95-Nov-15	<0.001	<0.001	<0.001	<0.001			<1	<1
Reference Rod	96-Oct-22						49		

TABLE 4
DISSOLVED HYDROCARBONS AND DISSOLVED ORGANIC CARBON

Monitoring Station	*Date*	*Benzene (mg/L)*	*Ethylbenzene (mg/L)*	*Toluene (mg/L)*	*Xylenes (total) (mg/L)*	*BTEX (total) (mg/L)*	*DOC (mg/L)*	*TPH Vol. (C_6-C_{11}) (mg/L)*	*TPH Semi-Vol. (C_{12}-C_{22}) (mg/L)*
Water Quality Guidelines (mg/L)		*0.005*	*£ 0.0024*	*£ 0.024*	*£ 0.3*				
Trip Blank	91-Jan-10	<0.001	<0.001	<0.001	<0.001				
	93-May-21	<0.001	<0.001	<0.001	<0.001			<1	<1
	93-Nov-02	<0.001	<0.001	<0.001	<0.001			<1	<1
	95-Nov-14	<0.001	<0.001	<0.001	<0.001			<1	<1
	96-Oct-21	<0.001	<0.001	<0.001	<0.001			<1	<1

Notes:
* Denotes Values That Exceed Water Quality Guidelines (mg/L).

TABLE 5
INDICATORS OF CONTAMINATION, BIODEGRADATION, AND NUTRIENTS

Monitoring Station	*Date*	*Chloride*	*BTEX (total)*	*NO_2+NO_3 as N*	*Manganese*	*Iron*	*Sulphate*	*Phosphorus*
		(mg/L)	*(mg/L)*	*(mg/L)*	*(mg/L)*	*(mg/L)*	*(mg/L)*	*(mg/L)*
Water Quality Guidelines (mg/L)		*250*		*10*	*0.05*	*0.3*	*500*	
BH-1	94-Jun-10		0.001					
	95-Nov-14	6.7		4.23	0.014	<0.01	28.8	
	96-Jul-29	9.3		0.961	0.015	<0.01	15.3	
	96-Oct-22	11		6.85	0.016	<0.01	15	
CW-1	95-Nov-15	30	0.01*	0.086	2.71*	0.25	7.6	0.1
	96-Apr-21		0.007*					
	96-May-15		0.018*					
	96-Jun-12		0.011*					
	96-Jul-03		0.017*					
	96-Jul-29	7.8	0.0073*	0.294	2.92*	1.03*	<0.1	<0.1
	96-Jul-30		0.038*					
	96-Oct-21		0.011*					
	96-Oct-22	21.1		0.398	3.5*	1.52*	3.4	<0.1
GW-1	95-Nov-14	10.2		0.139	0.132*	0.02	12.2	
	96-Jul-29	10.3		2.83	0.004	<0.01	0.2	<0.1
	96-Oct-22	9.6		0.32	0.015	<0.01	11.4	<0.1
MW-1	95-Nov-15	903*		0.013	3.22*	5.73*	4	
	96-May-15		0.004*					
	96-Jun-12		0.002*					
	96-Jul-03		0.006*					
	96-Jul-29	483*		1.25	2.22*	<0.01	9.2	
	96-Oct-22	998*		0.065	3.38*	<0.01	3.8	
PW-1	95-Jun-07	666*		2.5	3.52*	0.04	9.4	
	95-Nov-15	1020*		0.023	4.37*	3.39*	5.2	
	96-Jul-29	730*		1.33	2.99*	<0.01	10.9	
	96-Oct-22	976*		0.014	3.55*	<0.01	6	
TW-1	95-Nov-15	46.9	0.007*	0.03	2.72*	0.09	6.4	
	96-Apr-21		0.095*					
	96-May-15		0.068*					
	96-Jun-12		0.09*					
	96-Jul-03		0.084*					
	96-Jul-30	<0.5	0.051*	0.019	3.41*	3.48*	<0.1	<0.1
	96-Aug-18		0.053*					
	96-Aug-27		0.042*					
	96-Oct-21		0.037*					
	96-Oct-22	31.8		0.013	3.99*	10.2*	2.5	0.1
BH-2	92-Aug-06		0.016*					
	93-May-21		0.089*					
	93-Nov-02		0.002*					
	95-Nov-15	1.7		0.06	0.321*	<0.01	9.8	
	96-Jul-29	<0.5		0.019	0.352*	<0.01	<0.1	
	96-Jul-30		0.001*					
	96-Oct-21		0.006*					
	96-Oct-22	0.8		0.029	1.34*	<0.01	3.7	

TABLE 5
INDICATORS OF CONTAMINATION, BIODEGRADATION, AND NUTRIENTS

Monitoring Station	*Date*	*Chloride (mg/L)*	*BTEX (total) (mg/L)*	*NO_2+NO_3 as N (mg/L)*	*Manganese (mg/L)*	*Iron (mg/L)*	*Sulphate (mg/L)*	*Phosphorus (mg/L)*
Water Quality Guidelines (mg/L)		*250*		*10*	*0.05*	*0.3*	*500*	
CW-2	95-Nov-15	36.7	0.041*	0.129	0.983*	0.64*	10.1	0.1
	96-Apr-21		0.027*					
	96-May-05		0.005*					
	96-May-15		0.034*					
	96-Jun-12		0.007*					
	96-Jul-03		0.025*					
	96-Jul-29	7.4		0.123	3.05*	0.81*	<0.1	<0.1
	96-Jul-30		0.016*					
	96-Oct-21		0.183*					
	96-Oct-22	23.8		0.35	3.24*	5.29*	5.1	0.1
CW-2 Dup.	95-Nov-15		0.034*					
	96-Jul-03		0.024*					
GW-2	95-Nov-14	23.4		0.059	0.015	0.01	18.8	
	96-Jul-29	15.5		0.12	0.045	<0.01	14.3	<0.1
	96-Oct-22	30.4		0.117	0.14*	<0.01	13.8	<0.1
TW-2	96-Jul-03		0.005*					
	96-Jul-30	<0.5	0.061*	0.053	3.85*	0.18	<0.1	<0.1
	96-Aug-18		0.085*					
	96-Oct-21		0.037*					
	96-Oct-22	6.2		0.852	2.98*	<0.01	2.8	
BH-3	93-May-21		0.36*					
	93-Nov-02		0.071*					
	94-Jun-10		0.005*					
	95-Jun-07		0.003*					
	95-Nov-14	44		2.88	0.141*	<0.01	23.8	
	96-Jul-29	10.6		0.144	0.967*	<0.01	<0.1	
	96-Jul-30		0.038*					
	96-Oct-21		0.059*					
	96-Oct-22	6.4		0.03	0.799*	<0.01	2.4	
BH-3 Dup.	93-May-21		0.381*					
CW-3	95-Nov-15	35.6	0.003*	0.124	1.45*	0.04	8.8	
	96-Apr-21		0.044*					
	96-May-15		0.028*					
	96-Jun-12		0.001*					
	96-Jul-03		0.023*					
	96-Jul-29	7.8		0.327	2.64*	0.38*	<0.1	<0.1
	96-Jul-30		0.01*					
	96-Oct-21		0.005*					
	96-Oct-22	25		0.75	3.67*	<0.01	4.1	<0.1
GW-3	95-Nov-14	34.1		0.463	0.003	<0.01	8.6	
	96-Jun-12		0.011*					
	96-Jul-03		0.006*					
	96-Jul-29	16.5		0.024	0.3*	<0.01	<0.1	0.1
	96-Jul-30		0.002*					
	96-Oct-22	23.7		0.303	0.394*	<0.01	5.5	<0.1

TABLE 5
INDICATORS OF CONTAMINATION, BIODEGRADATION, AND NUTRIENTS

Monitoring Station	*Date*	*Chloride (mg/L)*	*BTEX (total) (mg/L)*	*NO_2+NO_3 as N (mg/L)*	*Manganese (mg/L)*	*Iron (mg/L)*	*Sulphate (mg/L)*	*Phosphorus (mg/L)*
Water Quality Guidelines (mg/L)		*250*		*10*	*0.05*	*0.3*	*500*	
TW-3	96-Jul-30	9.3		0.855	0.141*	<0.01	0.4	<0.1
	96-Oct-21		0.001*					
	96-Oct-22	17.9		0.769	<0.001	<0.01	14	
BH-4	92-Aug-06		0.898*					
	93-May-21		0.619*					
	93-Nov-02		0.834*					
	94-Jun-10		0.157*					
	95-Jun-07		0.337*					
	95-Nov-14	8.4	0.617*	0.011	0.915*	14.2*	0.7	
	96-Jul-29	<0.5		0.025	0.823*	0.03	<0.1	
	96-Jul-30		0.304*					
	96-Oct-21		0.792*					
	96-Oct-22	4.8		<0.003	1.09*	<0.01	2.3	
BH-4 Dup.	92-Aug-06		0.951*					
	93-Nov-02		0.761*					
CW-4	95-Nov-15	35.2	0.003*	0.123	1.46*	<0.01	9.1	
	96-May-15		0.038*					
	96-Jun-12		0.018*					
	96-Jul-03		0.023*					
	96-Jul-29	7.6		0.17	2.86*	0.42*	<0.1	<0.1
	96-Jul-30		0.013*					
GW-4	95-Nov-14	22.6		0.408	0.003	<0.01	10.5	
	96-Jun-12		0.001*					
	96-Jul-29	16.1		<0.003	0.163*	<0.01	0.2	<0.1
	96-Jul-30		0.001*					
	96-Oct-21							
	96-Oct-22	20.6		0.326	0.244*	<0.01	5.3	<0.1
TW-4	95-Nov-15	28		0.392	0.017	<0.01	12.2	
	96-Jul-30	11		0.625	0.089*	<0.01	0.4	<0.1
	96-Aug-27		0.003*					
	96-Oct-21		0.001*					
	96-Oct-22	58		0.44	0.39*	<0.01	21	<0.1
BH-5	92-Aug-06		0.386*					
	93-May-21		0.446*					
	93-Nov-02	65.2	0.632*	0.004	0.54*	34.4*	<0.1	
	94-Jun-10	18.3	0.214*	<0.03	0.733*	7.86*	1.1	
	95-Jun-07	18.9	0.201*	0.006	0.729*	5.51*	0.2	
	95-Nov-14	9		0.019	6.43*	19.9*	4.3	
	95-Nov-15		0.054*					
	96-Jul-29	11.7		0.019	0.785*	7.65*	1	
	96-Jul-30		0.042*					
	96-Oct-21		0.108*					
	96-Oct-22	12.9		0.073	0.772*	<0.01	1.2	

TABLE 5
INDICATORS OF CONTAMINATION, BIODEGRADATION, AND NUTRIENTS

Monitoring Station	*Date*	*Chloride (mg/L)*	*BTEX (total) (mg/L)*	*NO_2+NO_3 as N (mg/L)*	*Manganese (mg/L)*	*Iron (mg/L)*	*Sulphate (mg/L)*	*Phosphorus (mg/L)*
Water Quality Guidelines (mg/L)		*250*		*10*	*0.05*	*0.3*	*500*	
CW-5	95-Nov-15	41.1	0.001*	0.177	1.46*	0.01	9.2	
	96-Apr-21		0.041*					
	96-May-15		0.045*					
	96-Jun-12		0.022*					
	96-Jul-03		0.012*					
	96-Jul-29	7.3		0.114	2.94*	<0.01	<0.1	<0.1
	96-Jul-30		0.003*					
	96-Oct-22	25.3		0.676	3.38*	<0.01	5.5	0.1
TW-5	95-Nov-15	34.2		0.453	0.048	<0.01	12.9	
	96-Jun-12		0.039*					
	96-Jul-03		0.004*					
	96-Jul-30	<0.5	0.019*	1.47	0.492*	<0.01	0.4	<0.1
	96-Aug-18		0.128*					
	96-Aug-27		0.16*					
	96-Oct-21		0.093*					
	96-Oct-22	12.2		0.005	1.16*	<0.01	9.4	<0.1
	96-Oct-28		0.123*					
TW-5 Dup.	96-Jul-30		0.008*					
	96-Oct-28		0.124*					
BH-6	91-Jan-10		0.334*					
	92-Jun-03	4.6		0.013			<0.5	
	92-Aug-06		0.794*					
	93-May-21	3.1	1.497*	0.011	1.75*	7.83*	3.3	
	93-Nov-02	4	0.656*	0.003	1.4*	8.38*	<0.1	
	94-Jun-10	2.4	1.037*	0.008	1.95*	0.1	2.5	
	95-Jun-07	4.2	0.985*	0.029	1.1*	0.04	2	
	95-Nov-15	5.3	0.169*	0.005	1.1*	0.09	2.1	
	96-May-15		0.967*					
	96-Jun-12		0.693*					
	96-Jul-03		0.654*					
	96-Jul-29	<0.5		<0.003	1.29*	<0.01	<0.1	
	96-Jul-30		0.42*					
	96-Oct-21		0.259*					
	96-Oct-22	4.8		<0.003	1.36*	<0.01	0.7	
BH-6 Dup.	94-Jun-10		1.042*					
CW-6	95-Nov-15	35.2		0.151	1.32*	<0.01	9	
	96-May-15		0.042*					
	96-Jun-12		0.023*					
	96-Jul-03		0.012*					
	96-Jul-29	7.1		0.119	2.84*	0.01	<0.1	<0.1
	96-Jul-30		0.003*					

TABLE 5
INDICATORS OF CONTAMINATION, BIODEGRADATION, AND NUTRIENTS

Monitoring Station	*Date*	*Chloride (mg/L)*	*BTEX (total) (mg/L)*	*NO_2+NO_3 as N (mg/L)*	*Manganese (mg/L)*	*Iron (mg/L)*	*Sulphate (mg/L)*	*Phosphorus (mg/L)*
Water Quality Guidelines (mg/L)		*250*		*10*	*0.05*	*0.3*	*500*	
TW-6	95-Nov-15	25	0.001*	0.417	0.016	<0.01	15.6	
	96-Jun-12		0.013*					
	96-Jul-03		0.006*					
	96-Jul-30	12.6	0.044*	0.529	1.15*	<0.01	0.4	<0.1
	96-Aug-18		0.017*					
	96-Oct-22	13.7		1.12	0.621*	<0.01	15.9	
	96-Oct-28		0.091*					
TW-6 Dup.	96-Aug-18		0.017*					
BH-7	92-Jun-03	6.6		0.098			35	
	92-Aug-06		7.852*					
	93-May-21	6.9	10.523*	0.012	1.88*	9.34*	3.6	
	93-Nov-02	8.6	12.005*	0.005	1.82*	11.7*	41.9	
	94-Jun-10	8.3	3.962*	<0.03	1.64*	6.43*	1	
	95-Jun-07	8.3	3.129*	<0.003	1.5*	4.69*	0.1	
	95-Nov-15	6.4	4.432*	0.005	1.82*	8.8*	1.1	
	96-May-15		4.263*					
	96-Jun-12		6.07*					
	96-Jul-03		7.399*					
	96-Jul-29	6.4		0.016	1.68*	6.95*	0.4	
	96-Jul-30		5.282*					
	96-Oct-21		9.759*					
	96-Oct-22	6.4		0.977	1.91*	0.7*	1.5	
BH-7 Dup.	92-Aug-06		8.033*					
	93-Nov-02		11.955*					
CW-7	95-Nov-15	35.7		0.204	0.982*	<0.01	8.9	
	96-Apr-21		0.035*					
	96-May-05		0.014*					
	96-May-15		0.036*					
	96-Jun-12		0.022*					
	96-Jul-03		0.01*					
	96-Jul-29	7.3		0.199	2.44*	<0.01	<0.1	<0.1
	96-Jul-30		0.003*					
	96-Oct-22	24.7		0.85	3.39*	0.05	4.2	<0.1
CW-7 Dup.	96-May-15		0.04*					
	96-Jun-12		0.022*					
	96-Jul-30		0.003*					
TW-7	95-Nov-15	82.9	0.06*	0.017	0.163*	0.02	23.1	
	96-Apr-21		0.007*					
	96-May-15		0.048*					
	96-Jun-12		0.023*					
	96-Jul-03		0.014*					
	96-Jul-30	76.5	0.252*	0.091	2.6*	0.18	4.3	<0.1
	96-Aug-18		1.188*					
	96-Aug-27		1.078*					
	96-Oct-22	1.3		0.285	1.86*	<0.01	6.9	0.1
	96-Oct-28		0.765*					

TABLE 5
INDICATORS OF CONTAMINATION, BIODEGRADATION, AND NUTRIENTS

Monitoring Station	*Date*	*Chloride (mg/L)*	*BTEX (total) (mg/L)*	*NO_2+NO_3 as N (mg/L)*	*Manganese (mg/L)*	*Iron (mg/L)*	*Sulphate (mg/L)*	*Phosphorus (mg/L)*
Water Quality Guidelines (mg/L)		*250*		*10*	*0.05*	*0.3*	*500*	
BH-8	91-Jan-10	6.3	0.079*	0.017			43.1	
	92-Jun-03	4.6		0.379			13.2	
	92-Aug-06		0.006*					
	93-May-21	4.5		0.109	0.1*	0.01	9	
	93-Nov-02	5.4		0.022	0.12*	0.03	8.9	
	94-Jun-10	5.2		0.316	0.077*	0.03	9.7	
	95-Jun-07	3		4.77	0.016	0.02	8.2	
	95-Nov-15	5.1		0.044	0.045	0.01	10.6	
	96-Jul-29	<0.5		0.091	0.042	<0.01	<0.1	
	96-Oct-22	6		0.08	0.015	<0.01	8.9	
BH-8 Dup.	91-Jan-10		0.084*					
BH-9	92-Jun-03	39.8		1.18			30.9	
	92-Aug-06		0.078*					
	93-May-21	25	0.001*	0.156	0.385*	0.09	32.2	
	93-Nov-02	27.7		0.05	0.53*	0.02	31	
	94-Jun-10	27		0.168	0.349*	<0.01	31.8	
	95-Jun-07	13.6	0.108*	5.05	0.257*	0.03	18.8	
BH-10	92-Aug-06		0.089*					
	93-May-21		0.078*					
	93-Nov-02		0.012*					
	94-Jun-10		0.373*					
	95-Jun-07		0.149*					
	95-Nov-14		0.003*					
	95-Nov-15	81.8		0.036	1.68*	0.02	9.4	
	96-Jun-12		0.008*					
	96-Jul-03		0.015*					
	96-Jul-29	131		1.37	1.93*	<0.01	10.8	
	96-Jul-30		0.004*					
	96-Oct-21		0.021*					
	96-Oct-22	42.4		0.5	1.52*	<0.01	8.2	
BH-10 Dup.	94-Jun-10		0.37*					
BH-11	92-Aug-06		0.04*					
	93-May-21		0.161*					
	93-Nov-02		0.002*					
	94-Jun-10		0.105*					
	95-Jun-07		0.082*					
BH-11 Dup.	95-Jun-07		0.074*					
BH-12	93-May-21		0.008*					
	95-Nov-15	4.5		<0.003	1.27*	1.97*	1.1	
	96-Jul-29	<0.5		0.021	1.22*	1.03*	<0.1	
	96-Jul-30		0.002*					
	96-Oct-22	3.3		<0.003	1.49*	<0.01	0.4	
BH-12 Dup.	93-May-21		0.009*					

TABLE 5
INDICATORS OF CONTAMINATION, BIODEGRADATION, AND NUTRIENTS

Monitoring Station	*Date*	*Chloride (mg/L)*	*BTEX (total) (mg/L)*	*NO_2+NO_3 as N (mg/L)*	*Manganese (mg/L)*	*Iron (mg/L)*	*Sulphate (mg/L)*	*Phosphorus (mg/L)*
Water Quality Guidelines (mg/L)		*250*		*10*	*0.05*	*0.3*	*500*	
BH-13	92-Aug-06		0.005*					
	95-Nov-15	8.8		0.007	0.476*	0.01	15.2	
	96-Jul-29	<0.5		0.357	0.484*	<0.01	0.2	
	96-Oct-22	7.5		0.224	0.368*	<0.01	10.2	
BH-14	92-Aug-06		0.002*					
	95-Nov-14	30.4		0.018	0.56*	0.22	12.1	
	96-Jul-29	28.7		0.154	0.298*	<0.01	12.4	
	96-Oct-21	30.1		0.089	0.337*	<0.01	15.2	
94-15A	95-Jun-07		0.002*					
	95-Nov-15	33.5	0.006*	0.353	0.693*	<0.01	18.6	
	96-Jul-29	14.1		1.75	0.215*	<0.01	0.4	
	96-Oct-22	35.1		7.5	0.153*	<0.01	52.5	
94-15C	95-Nov-15	0.5		0.195	0.092*	0.17	84.2	
	96-Jul-29	<0.5		0.195	0.096*	<0.01	79.5	
	96-Oct-22	0.5		0.096	0.121*	<0.01	83.7	
94-16A	95-Jun-07		0.009*					
	96-Jul-29	33.1		3.91	0.05	<0.01	15.9	
	96-Oct-21							
	96-Oct-22	29.7	0.016*	3.65	0.318*	<0.01	11	
94-16B	95-Jun-07		0.002*					
	95-Nov-15	159	0.011*	0.058	2.12*	0.28	25.2	
	96-Jul-29	171		0.085	1.39*	<0.01	20	
	96-Oct-21		0.008*					
	96-Oct-22	90.2		0.138	1.54*	<0.01	15.4	
94-17A	94-Dec-22		0.379*					
	95-Jun-07		0.224*					
	95-Nov-15	11.4	0.231*	0.009	1.52*	0.12	1.2	
	96-May-15		0.281*					
	96-Jun-12		0.341*					
	96-Jul-03		0.36*					
	96-Jul-29	9		0.013	1.75*	<0.01	0.7	
	96-Jul-30		0.137*					
	96-Oct-21		0.172*					
	96-Oct-22	4.7		0.076	1.38*	0.01	0.7	
94-17A Dup.	95-Jun-07		0.222*					
94-18A	95-Nov-15	4.7		0.007	0.498*	0.06	16	
	96-Jul-29	<0.5		0.017	0.712*	<0.01	<0.1	
	96-Oct-22	4.6		0.036	0.833*	<0.01	10.6	
94-19A	95-Nov-14	5.4		3.94	0.022	<0.01	93.1	
	96-Jul-29	<0.5		1.67	0.006	<0.01	16.3	
	96-Oct-21	2.9		1.78	0.008	<0.01	34.2	

TABLE 5
INDICATORS OF CONTAMINATION, BIODEGRADATION, AND NUTRIENTS

Monitoring Station	*Date*	*Chloride (mg/L)*	*BTEX (total) (mg/L)*	*NO_2+NO_3 as N (mg/L)*	*Manganese (mg/L)*	*Iron (mg/L)*	*Sulphate (mg/L)*	*Phosphorus (mg/L)*
Water Quality Guidelines (mg/L)		*250*		*10*	*0.05*	*0.3*	*500*	
94-19C	95-Nov-14	2.8		0.078	0.049	<0.01	40.9	
	96-Jul-29	1.6		0.084	0.073*	0.05	39.2	
	96-Oct-21	2.8		0.087	0.047	0.19	44.4	
94-20A	95-Jun-07		0.005*					
	95-Nov-14	8.1		0.328	0.477*	<0.01	10.2	
	95-Nov-15		0.003*					
	96-Jul-29	7.7		0.129	0.266*	<0.01	0.2	
	96-Jul-30		0.003*					
	96-Oct-21	7.1		0.452	0.088*	<0.01	7.7	
94-20C	95-Nov-14	<0.5		0.013	0.111*	<0.01	27.8	
	96-Jul-29	<0.5		0.213	0.13*	<0.01	23.4	
	96-Oct-21	0.5		0.006	0.236*	<0.01	25.2	
96-21A	96-Jul-03		0.001*					
	96-Jul-29	22.7		0.282	0.245*	<0.01	0.2	<0.1
	96-Oct-22	29.9		0.372	0.071*	<0.01	6.6	<0.1
96-22A	96-Jul-03		0.001*					
	96-Jul-30	15.4		2.37	0.082*	<0.01	14.1	
	96-Oct-22	13		0.024	0.009	<0.01	24.8	
96-22B	96-Jun-12		0.001*					
	96-Jul-30	54		0.048	1.72*	<0.01	46.8	
	96-Oct-22	25.7		0.034	2.02*	<0.01	55.9	
96-22B Dup.	96-Jul-03		0.001*					
96-23A	96-Jun-12		0.162*					
	96-Jul-03		0.163*					
	96-Jul-29	1770*		0.028	21.7*	29.2*	8	<0.1
	96-Jul-30		0.111*					
	96-Oct-21		0.169*					
	96-Oct-22	1760*		0.08	33.5*	129*	8.1	0.5
96-23A Dup.	96-Oct-21		0.173*					
96-24A	96-Jun-12		0.088*					
	96-Jul-03		0.085*					
	96-Jul-29	9.8		0.029	4.75*	2.29*	<0.1	
	96-Jul-30		0.015*					
	96-Oct-21		0.009*					
	96-Oct-22	9.8		0.038	3.22*	<0.01	1.3	
96-25A	96-Jul-03		0.097*					
	96-Jul-30	11.7	0.125*	0.018	3.53*	8.13*	<0.1	<0.1
	96-Oct-21		0.026*					
	96-Oct-22	21		0.078	3.51*	<0.01	5.3	

TABLE 5
INDICATORS OF CONTAMINATION, BIODEGRADATION, AND NUTRIENTS

Monitoring Station	*Date*	*Chloride (mg/L)*	*BTEX (total) (mg/L)*	*$NO_2 + NO_3$ as N (mg/L)*	*Manganese (mg/L)*	*Iron (mg/L)*	*Sulphate (mg/L)*	*Phosphorus (mg/L)*
Water Quality Guidelines (mg/L)		*250*		*10*	*0.05*	*0.3*	*500*	
96-25B	96-Jun-12		0.087*					
	96-Jul-03		0.094*					
	96-Jul-30	22.1	0.117*	0.043	4.67*	3.68*	6.4	<0.1
	96-Oct-21		0.508*					
	96-Oct-22	30.5		<0.03	3.18*	<0.01	3.1	
96-26A	96-Jun-12		0.001*					
	96-Jul-03		0.062*					
	96-Jul-30	19.6	0.008*	0.028	1.86*	0.38*	4.4	0.1
	96-Oct-21		0.006*					
	96-Oct-22	15.2		0.047	0.395*	<0.01	8.2	
Reference Rod	96-Oct-22	29.7		0.03	0.85*	0.08	0.8	

Notes:
* Denotes Values That Exceed Water Quality Guidelines (mg/L).

TABLE 6
DISSOLVED METALS

Monitoring Station	***Date***	***Aluminum (mg/L)***	***Barium (mg/L)***	***Beryllium (mg/L)***	***Boron (mg/L)***	***Cadmium (mg/L)***	***Chromium (mg/L)***	***Cobalt (mg/L)***	***Copper (mg/L)***	***Lead (mg/L)***
Water Quality Guidelines (mg/L)			*1*		*5*	*0.005*	*0.05*		*1*	*0.01*
CW-1	95-Nov-15	0.34	0.44	<0.001	0.15	0.0037	<0.002	0.0162	0.011	0.0100
	96-Jul-29	<0.001	0.80	<0.0002	0.20	0.0003	0.003	0.0054	0.004	<0.0003
	96-Oct-22	0.02	0.75	<0.001	0.14	<0.0002	<0.002	0.004	<0.001	<0.0003
GW-1	96-Jul-29	0.01	0.57	<0.0002	0.05	0.0002	<0.002	0.0012	0.0038	<0.0003
	96-Oct-22	0.01	0.71	<0.001	0.10	<0.0002	<0.002	0.0030	<0.001	<0.0003
TW-1	96-Jul-30	0.005	0.79	<0.0002	0.26	0.0002	<0.002	0.0057	0.0017	<0.0003
	96-Oct-22	0.03	0.96	0.002	0.19	<0.0002	<0.002	0.0048	0.005	<0.0003
CW-2	95-Nov-15	0.61	0.42	<0.001	---	0.0039	<0.002	0.0099	0.013	0.0107*
	96-Jul-29	<0.001	0.78	<0.0002	0.24	<0.0002	0.003	0.0054	0.0018	<0.0003
	96-Oct-22	0.06	0.75	0.003	0.08	<0.0002	<0.002	0.0031	0.001	<0.0003
GW-2	96-Jul-29	0.01	0.38	<0.0002	0.12	<0.0002	<0.002	0.0013	0.0019	<0.0003
	96-Oct-22	<0.01	0.43	<0.001	0.12	0.0004	<0.002	0.0020	<0.001	<0.0003
TW-2	96-Jul-30	0.052	0.67	<0.0002	0.20	0.0002	<0.002	0.0053	0.0009	<0.0003
CW-3	96-Jul-29	<0.001	0.74	<0.0002	0.22	0.0002	0.006	0.0048	0.0037	<0.0003
	96-Oct-22	0.03	0.79	0.002	0.13	<0.0002	<0.002	0.0035	0.006	<0.0003
GW-3	96-Jul-29	<0.001	0.64	<0.0002	0.13	0.0002	<0.002	0.0017	0.0038	<0.0003
	96-Oct-22	0.01	0.47	<0.001	0.14	<0.0002	<0.002	0.0025	<0.001	<0.0003
TW-3	96-Jul-30	0.016	0.43	<0.0002	0.11	0.0004	<0.002	0.0020	0.0012	<0.0003
CW-4	96-Jul-29	<0.001	0.77	<0.0002	0.24	0.0002	0.005	0.0048	0.0037	<0.0003
GW-4	96-Jul-29	<0.001	0.70	<0.0002	0.15	<0.0002	0.003	0.0018	0.0017	<0.0003
	96-Oct-22	<0.01	0.55	<0.001	0.10	<0.0002	<0.002	0.0012	<0.001	<0.0003

TABLE 6
DISSOLVED METALS

Monitoring Station	***Date***	***Aluminum (mg/L)***	***Barium (mg/L)***	***Beryllium (mg/L)***	***Boron (mg/L)***	***Cadmium (mg/L)***	***Chromium (mg/L)***	***Cobalt (mg/L)***	***Copper (mg/L)***	***Lead (mg/L)***
Water Quality Guidelines (mg/L)			*1*		*5*	*0.005*	*0.05*		*1*	*0.01*
TW-4	96-Jul-30	0.007	0.39	<0.0002	0.09	0.0002	0.005	0.0010	0.0018	<0.0003
	96-Oct-22	0.01	0.35	<0.001	0.05	<0.0002	<0.002	0.0022	<0.001	<0.0003
CW-5	96-Jul-29	<0.001	0.78	<0.0002	0.27	0.0002	0.004	0.0049	0.002	<0.0003
	96-Oct-22	0.01	0.76	0.002	0.13	<0.0002	<0.002	0.0033	0.005	0.0011
TW-5	96-Jul-30	0.003	0.43	<0.0002	0.10	0.0003	0.003	0.0020	0.0017	<0.0003
	96-Oct-22	<0.01	0.53	<0.001	0.06	<0.0002	0.003	0.0026	<0.001	<0.0003
CW-6	96-Jul-29	<0.001	0.74	<0.0002	0.24	<0.0002	<0.002	0.0047	0.0021	<0.0003
TW-6	96-Jul-30	0.017	0.46	<0.0002	0.16	0.0002	<0.002	<0.0003	0.0018	<0.0003
CW-7	96-Jul-29	<0.001	0.66	<0.0002	0.23	0.0003	<0.002	0.0041	0.0018	<0.0003
	96-Oct-22	0.03	0.75	<0.001	0.12	<0.0002	<0.002	0.0037	<0.001	<0.0003
TW-7	96-Jul-30	0.003	0.66	<0.0002	0.18	<0.0002	<0.002	0.0045	0.0015	<0.0003
	96-Oct-22	<0.01	0.58	<0.001	0.05	<0.0002	<0.002	0.0055	<0.001	<0.0003
96-21A	96-Jul-29	0.017	0.299	<0.0002	0.05	<0.0002	<0.002	0.0022	0.0018	<0.0003
	96-Oct-22	0.008	0.425	<0.0002	0.04	<0.0002	<0.001	0.0018	<0.0002	<0.0003
96-23A	96-Jul-29	0.164	7.1*	0.0005	<0.01	0.0027	0.005	0.121	0.0179	0.0015
	96-Oct-22	0.017	10.7*	<0.0002	0.06	<0.0002	0.752*	0.172	0.0863	0.0011
96-25A	96-Jul-30	0.024	1.84*	<0.0002	0.09	0.0004	<0.002	0.0069	0.0007	<0.0003
96-25B	96-Jul-30	0.029	1.16*	<0.0002	0.10	0.0002	<0.002	0.0084	0.0039	<0.0003
96-26A	96-Jul-30	0.293	0.49	<0.0002	0.06	0.0002	<0.002	0.0037	0.0026	0.0009

TABLE 6
DISSOLVED METALS

Monitoring Station	*Date*	*Lithium (mg/L)*	*Nickel (mg/L)*	*Strontium (mg/L)*	*Silver (mg/L)*	*Titanium (mg/L)*	*Uranium (mg/L)*	*Vanadium (mg/L)*	*Zinc (mg/L)*
Water Quality Guidelines (mg/L)							*0.1*		*5*
CW-1	95-Nov-15	0.007	0.640	0.532	<0.0002	0.014	0.0078	0.195	0.857
	96-Jul-29	0.009	<0.005	0.446	<0.0001	0.002	0.0007	<0.002	1.67
	96-Oct-22	0.011	<0.0005	0.557	<0.0001	<0.003	0.0008	<0.002	0.838
GW-1	96-Jul-29	0.007	<0.005	0.347	<0.0001	0.001	0.0020	<0.002	0.0157
	96-Oct-22	0.009	0.0158	0.437	<0.0001	<0.003	0.0019	<0.002	<0.001
TW-1	96-Jul-30	0.010	<0.005	0.464	<0.0001	<0.001	0.0007	<0.002	0.143
	96-Oct-22	0.011	<0.0005	0.649	<0.0001	<0.003	0.0006	0.008	0.003
CW-2	95-Nov-15	0.006	0.105	0.464	<0.0002	0.013	0.0114	0.192	2.19
	96-Jul-29	0.01	<0.005	0.456	<0.0001	<0.001	0.0009	<0.002	4.65
	96-Oct-22	0.01	<0.0005	0.518	<0.0001	<0.003	0.0008	0.004	0.446
GW-2	96-Jul-29	0.006	<0.005	0.393	<0.0001	0.002	0.0022	<0.002	0.0045
	96-Oct-22	0.007	<0.0005	0.494	<0.0001	<0.003	0.0021	<0.002	0.003
TW-2	96-Jul-30	0.008	<0.005	0.373	<0.0001	0.001	0.0011	<0.002	0.0136
CW-3	96-Jul-29	0.009	<0.005	0.431	<0.0001	<0.001	0.0008	0.003	4.50
	96-Oct-22	0.010	<0.0005	0.613	<0.0001	<0.003	0.0010	0.009	1.31
GW-3	96-Jul-29	0.009	<0.005	0.492	<0.0001	<0.001	0.0012	<0.002	0.0355
	96-Oct-22	0.010	0.0013	0.572	<0.0001	<0.003	0.0016	<0.002	0.028
TW-3	96-Jul-30	0.007	<0.005	0.350	<0.0001	0.001	0.0015	0.003	0.0053
CW-4	96-Jul-29	0.009	<0.005	0.446	<0.0001	<0.001	0.0009	<0.002	5.05*
GW-4	96-Jul-29	0.009	<0.005	0.502	<0.0001	<0.001	0.0010	<0.002	0.0403
	96-Oct-22	0.009	<0.0005	0.489	<0.0001	<0.003	0.0014	<0.002	0.009

TABLE 6
DISSOLVED METALS

Monitoring Station	*Date*	*Lithium (mg/L)*	*Nickel (mg/L)*	*Strontium (mg/L)*	*Silver (mg/L)*	*Titanium (mg/L)*	*Uranium (mg/L)*	*Vanadium (mg/L)*	*Zinc (mg/L)*
Water Quality Guidelines (mg/L)							*0.1*		*5*
TW-4	96-Jul-30	0.006	<0.005	0.35	<0.0001	<0.001	0.0014	<0.002	0.005
	96-Oct-22	0.005	<0.0005	0.365	<0.0001	<0.003	0.0019	<0.002	0.002
CW-5	96-Jul-29	0.01	<0.005	0.453	<0.0001	<0.001	0.0005	0.003	6.12*
	96-Oct-22	0.011	<0.0005	0.587	<0.0001	<0.003	0.0008	0.008	1.34
TW-5	96-Jul-30	0.007	<0.005	0.408	<0.0001	0.001	0.0017	<0.002	0.238
	96-Oct-22	0.006	<0.0005	0.431	<0.0001	<0.003	0.0009	<0.002	0.008
CW-6	96-Jul-29	0.01	<0.005	0.434	<0.0001	<0.001	0.0009	<0.002	6.15*
TW-6	96-Jul-30	0.007	<0.005	0.417	<0.0001	0.002	0.0012	<0.002	0.0424
CW-7	96-Jul-29	0.009	<0.005	0.388	<0.0001	<0.001	0.0005	<0.002	5.43*
	96-Oct-22	0.011	<0.0005	0.589	<0.0001	<0.003	0.0009	<0.002	1.82
TW-7	96-Jul-30	0.01	<0.005	0.42	<0.0001	0.005	0.0004	<0.002	7.01*
	96-Oct-22	0.013	0.0078	0.787	<0.0001	<0.003	0.0012	0.003	0.037
96-21A	96-Jul-29	0.01	<0.005	0.512	<0.0001	0.002	0.0018	<0.002	0.004
	96-Oct-22	0.012	<0.0005	0.538	<0.0001	0.001	0.0024	<0.001	0.0029
96-23A	96-Jul-29	0.057	0.02	9.8	<0.0001	0.004	0.008	<0.002	0.0406
	96-Oct-22	0.069	0.365	9.17	0.0012	0.937	0.0113	0.211	0.0304
96-25A	96-Jul-30	0.009	<0.005	0.522	<0.0001	<0.001	0.0005	<0.002	0.0125
96-25B	96-Jul-30	0.018	<0.005	0.681	<0.0001	0.004	0.0013	<0.002	0.0149
96-26A	96-Jul-30	0.02	0.014	0.863	<0.0001	0.006	0.0038	0.003	0.0124

Notes:
* Denotes Values That Exceed Water Quality Guidelines (mg/L).

APPENDIX IV

CONSTRUCTION TECHNIQUES
AND
SCHEDULE

Construction Techniques and Schedule

Construction of the *Trench and Gate* was undertaken during the period September 18 to 27, 1995. Having chosen a standard construction technique, the first step was to begin de-watering the existing excavation made during the initial attempt to install the system. This was accomplished using a trash pump installed in an excavated sump near the down-gradient corner of the gate excavation. The pump de-watered the excavation in short order and continued operating during the balance of the project. Top soil in the area of the construction had already been scraped off during the initial installation attempt and thus construction proceeded according to the schedule below:

Sept. 19: Excavation of the hole for gate construction was accomplished using an Hitachi backhoe. This step included the construction of an access ramp for personnel and equipment. The excavated hole was approximately 6 m deep, several metres below the water table. During excavation it was discovered that walls excavated through the till underlying the cobble unit would hold up for days, providing the overlying cobble unit was cut back at approximately 45°. When this methodology was used, the walls remained relatively stable except for areas of high groundwater influx (particularly permeable cobble lenses).

Sept. 20: The excavation for the gate installation was finished and construction of the cribbing to form the cement pad was undertaken. This generally followed standard construction techniques except that drainage ditches had to be dug around the outside of the form.

Sept. 21: The culverts were set into place inside the cribbing using a picker truck. Due to the width of the hole and the awkward shape of the culverts it was necessary to have a heavy duty picker with a long reach. Once set in place, rebar was threaded through the culverts and throughout the pad. This was followed by pouring of the 2% calcium cement using a cement pumping truck with an articulated arm. In order to pour the cement inside the base of the culverts, operations had to be guided by employees working from a basket suspended from the picker arm. After the culverts were cemented in place, the first lift for the east arm of the trench was made.

Sept. 22: Activities on this day consisted of digging the slit trench for the east arm, installing the liner and PVC piping, backfilling of the trench with gravel and welding together the pipes that connect the three culverts. Welding had to be carried out from both inside and outside of the culverts. It was soon discovered that the brass fittings originally chosen for the valve extension arms were not strong enough to stand up to the torque of opening the valve from 5 m above. In future these fittings should be made of steel if it is determined that spark reduction is not a necessary component of the design. Welding inside the vertical culverts was accomplished using the picker truck and a basket. Welding operations were hampered by not having radio communications between the picker operator and the welders. Future programs should definitely have walkie talkies for this sort of work. Installation of the liner proved a difficult, although not insurmountable task. Due to the weight of the liner it had to be stretched out using a small backhoe and manhandled into place. The liner was stretched out across the trench by tying rope around rocks folded into the edge of the liner. Installation was also hindered by the difficulty of adjusting the liner once it was in place. In hindsight, having eyelets sewn into the edges of the liner would have made the task easier to complete. Also, giving some thought to how the liner should be folded for ease of installation would have made the job go faster. Keeping the liner in the correct position while backfilling was also a challenge that would have been simplified by incorporating eyelets into the liner. Losses due to folds and wrinkles were also slightly greater than the estimated 15%. Future designers should consider incorporating a 20 to 25% loss factor for shorter sections. Losses along the long direction of the liner were much less significant. Backfilling around the liner had to be accomplished by alternately adding material from one side and then the other in order to keep it more or less vertical. Installation of large diameter PVC drainage tile was also hindered by the shear weight of the unit as it had to be pre-assembled outside of the trench and lowered in by rope. In future consideration should be given to using steel pipe for the section closest to the gate to reduce sagging of the unsupported portion during back-filling and natural compaction.

Sept. 23: Excavation of the second (north) trench arm proceeded using the same methodology developed during the previous day.

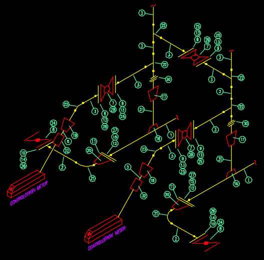
Sept. 24: The objective for this day was to seal together the two trench liners behind the back of the first culvert. This proved to be one of the most difficult and frustrating tasks of the entire operation. Overlapping of the liners around the back of the culvert was accomplished by tying ropes to the corners of the liner, pulling them across the excavation and then tying them off. This task would also have been easier if eyelets had been installed in the liner or preferably if a cable has been sewn in along the top of the liner. This would also have helped prevent liner sagging during backfilling. The liners then had to be joined together to create a water tight seal. PVC liner cannot be glued together and thus the two sheets had to be joined using the solvent tetrahydrofuran which actually melts the PVC. In order to do this properly, short sections must be joined together and rolled. A plank was installed behind the joint of the two PVC liners and a rolling pin was used to press the two sheets together. This proved to be a difficult task to complete due to the vertical alignment of the liners, and the necessity of working from ladders. Since the tetrahydrofuran takes up to an hour to create a good join between PVC sheets, the effort proved very difficult because gravity would cause the sheets to separate before they could bond. Efforts may also have been frustrated by high humidity affecting the solvent or degraded tetrahydrofuran. Other activities on this day included excavation of the first of the infiltration gallery slit trenches. This was relatively straight forward but necessitated having the drain rock backfill available on short notice as the trenches began sloughing shortly after excavation. The use of prefabricated base plates (which had worked well during the construction of the test pit) for the piezometers installed in the infiltration gallery actually made the job slightly harder, as the PVC became unmanageable at depth and one of the base plates snapped off during installation. During backfilling, piezometers were held in place by ropes. In future the base plate should be dropped in favour of a simple cap.

Sept. 25: Efforts to join the liners continued on this day. At the suggestion of the suppliers, we tried preheating the liners using a hot air gun followed by application of the tetrahydrofuran. While this method did meet with some success it was immediately discontinued when it resulted in a small flash vapour explosion. No personnel were injured as a result, however the two employees using the solvent were somewhat shaken. An incident report was filed with an Amoco representative (Helen Jacobs of Quest). Since pre-heating of the PVC is an accepted technique it must be assumed that vapours were able to build up to concentrations above the LEL because the work was being carried out at the bottom of the excavation. Future efforts to join liners under these sorts of circumstances should be conducted under the guidance of the liner manufacturer and preferably by employees of the manufacturer who are familiar with the techniques. If heat guns are again required to complete the bond, a portable fan should be used to disperse the fumes and continuous atmospheric testing should be undertaken. When the liner was finally sealed later in the day, backfilling of the area around the gate excavation commenced. Work continued until dark. At this point the pump had to be turned off to prevent the liner from being unduly stressed on the up-gradient side by a build-up of water. In future it would be prudent to start backfilling early in the morning so the job can be finished in short order without having to let everything stand over night.

Sept. 26: Backfilling of the excavation was completed and the last of the infiltration gallery trenches was dug.

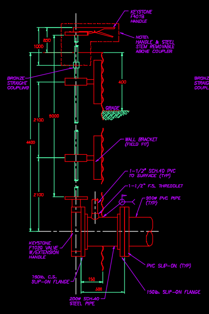
Sept. 27: Clean up of the site was undertaken and the perimeter fence was reinstalled.

Drawings

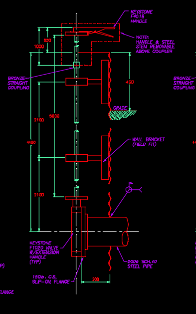


	ITEM	QTY.	RATING/W.T.	SIZE/O.D.	TYPE/DESCRIPTION	REMARKS/MAT.SPEC.
PIPE	1	–	SCH.40	219.1	STEEL	EXISTING
	2	1m	SCH.80	114.3	PVC PIPE	–
	3	3m	SCH.80	60.3	PVC PIPE	–
	4	1m	SCH.80	48.3	PVC PIPE	–
	5	1m	SCH.80	26.7	PVC PIPE	–
	6	1m	SCH.80	17.1	PVC PIPE	–
VALVES	7	3	150 ANSI	60.3	VALVE,BALL,FULL PORT,STEEL,FLGD.	–
	8	2	150 ANSI	114.3	VALVE,BUTTERFLY,STEEL,WAFFER STYLE	KEYSTONE F1020
FLANGES	9	6	150 ANSI	60.3	FLANGE,SOC,PVC	–
	10	2	150 ANSI	114.3	FLANGE,SOC,PVC	–
	11	1	150 ANSI	219.1	FLANGE,SOC,PVC	–
	12	1	150 ANSI	219.1	FLANGE,FF,SLIP–ON,STEEL	
	13	6	150 ANSI	60.3	GASKET,RF, W/ BACK UP RING	–
	14	2	150 ANSI	114.3	GASKET,RF, W/ BACK UP RING	–
	15	2	150 ANSI	219.1	GASKET,FF	–
FITTINGS	16	2	SCH.40	48.3	THREADOLET,STEEL	EXISTING
	17	2	SCH.80	60.3 X 48.3	RED.BUSH,CONC,SPXSOC,PVC	–
	18	1	SCH.80	60.3 X 17.1	RED.BUSH,CONC,SPXSOC,PVC	–
	19	1	SCH.80	60.3 X 26.7	RED.BUSH,CONC,SPXSOC,PVC	–
	20	2	SCH.40	219.1 X 114.3	RED.BUSH,CONC,SPXSOC,PVC	–
	21	2	SCH.80	114.3	ELL,90°,SOC,PVC	–
	22	4	SCH.80	60.3X60.3	TEE,SOCXSOCXSOC,PVC	–
	23	2	SCH.80	60.3	ELL,45°,SOC,PVC	–
MISC.	24	2	–	4100LG	VALVE HANDLE c/w STEM EXTENTION	TO FIT ITEM 8
	25	24	–	14mmøX70mmLG	FLANGE BOLT c/w NUT & 2 WASHERS	
	26	16	–	14mmøX83mmLG	FLANGE BOLT c/w NUT & 2 WASHERS	
	27	16	–	19mmøX102mmLG	FLANGE BOLT c/w NUT & 2 WASHERS	
	28	2	–	3900LG	LONG VALVE STEM EXTENSION	TO FIT ITEM 7
	29	1	–	3460LG	LONG VALVE STEM EXTENSION	TO FIT ITEM 7
	30	2	SCH.80	60.3	UNION,SOCXSOC,PVC	–
	31	2	SCH.80	48.3	NIPPLE,P.E.XT.E.,PVC	–
	32	1	SCH.80	26.7	MALE ADAPTOR,SOCXM.T.,PVC	–
	33	1	SCH.80	17.1	MALE ADAPTOR,SOCXM.T.,PVC	–

* SUPPORT PIPING AS REQUIRED



A P-01 HANDLE AND BRACKET DETAIL
SCALE 1 : 10



B P-01 HANDLE AND BRACKET DETAIL
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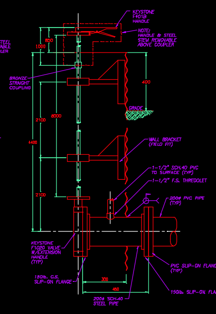

C P-01 HANDLE AND BRACKET DETAIL
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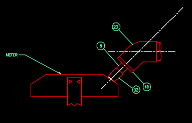
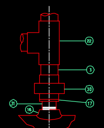


DETAIL A
SCALE 1 : 5



DETAIL B
SCALE 1 : 5

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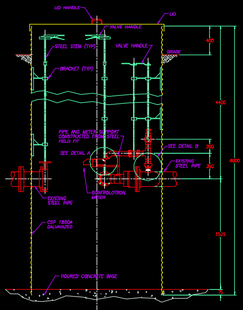
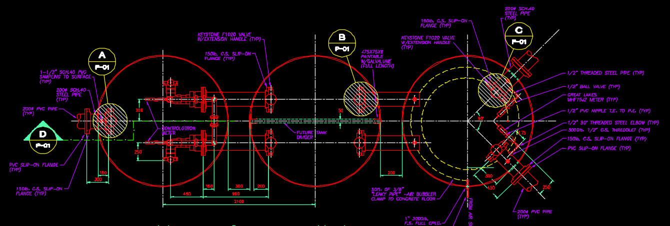
REV	DATE	DESCRIPTION
E	96-12-18	DETAILS
D	96-11-01	VALVE HANDLES
C	96-10-29	VALVE STEM EXTENSIONS
B	96-10-17	ADDITION OF METER AND RELATED PIPING
A	95-07-07	ISSUED FOR CONSTRUCTION

PREPARED SOLELY FOR THE USE OF OUR CLIENT AND NO REPRESENTATION OF ANY KIND IS MADE TO OTHER PARTIES WITH WHICH KOMEX INTERNATIONAL LTD. HAS NOT ENTERED INTO A CONTRACT.



D P-01 WELL SECTION
SCALE 1 : 50



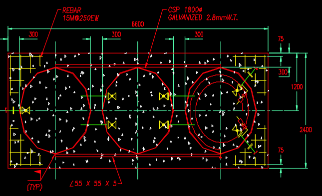
WELL ARRANGEMENT -PLAN VIEW
SCALE 1 : 20

KOMEX INTERNATIONAL LTD.
ENVIRONMENTAL AND ENGINEERING CONSULTANTS

AMOCO CANADA PETROLEUM CO. LTD.

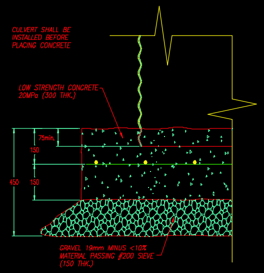
EAST GARRINGTON
TRENCH & GATE
PIPING DETAILS

DRAWN BY: M.Z.	DATE: 95-07-07	SCALE: AS NOTED
REVISED BY: P.S	DATE: 96-12-18	REVISION No: E
APPROVED BY: A.C.S.	DATE: 95-07-07	DRAWING No: P-01



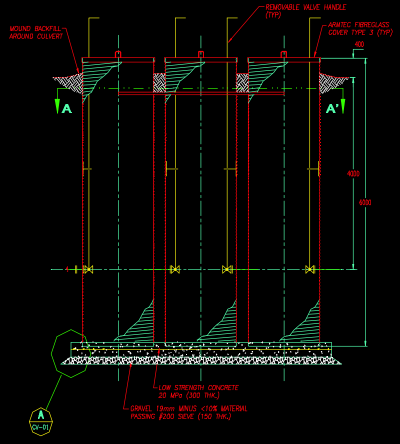
CROSS-SECTION A-A'

SCALE 1 : 50



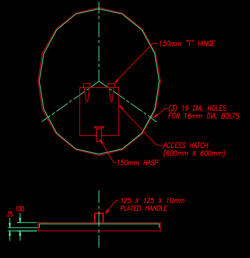
A CV-01 CULVERT PLACEMENT DETAIL

SCALE 1 : 10



ELEVATION VIEW

SCALE 1 : 50



LID DETAIL

SCALE 1 : 30

CONSTRUCTION SPECIFICATIONS

BACKFILL AROUND CULVERTS SHALL BE COMPACTED TO 90% OF MAXIMUM DRY DENSITY.

BACKFILL MATERIAL SHALL BE FREE OF ROCKS, FROZEN LUMPS, AND FOREIGN MATERIAL. IT MUST BE PLACED SYMMETRICALLY ON EACH SIDE OF THE CULVERTS IN 150-200mm LOOSE LIFTS. EACH LIFT SHALL BE COMPACTED TO 90% OF DRY DENSITY.

ANGLES SHALL BE WELDED TO CULVERTS.

BACKFILL BENEATH PIPES PENETRATING CULVERTS SHALL BE HAND COMPACTED TO 95% MAXIMUM DRY DENSITY TO UNDERSIDE OF PIPE.

REV	DATE	DESCRIPTION
	–	
A	95-07-07	ISSUED FOR CONSTRUCTION

PREPARED SOLELY FOR THE USE OF OUR CLIENT AND NO REPRESENTATION OF ANY KIND IS MADE TO OTHER PARTIES WITH WHICH KOMEX INTERNATIONAL LTD. HAS NOT ENTERED INTO A CONTRACT.

KOMEX INTERNATIONAL LTD.
ENVIRONMENTAL AND ENGINEERING CONSULTANTS

AMOCO CANADA PETROLEUM CO. LTD.

EAST GARRINGTON
TRENCH & GATE
CIVIL DETAILS

DRAWN BY: M.ZAGORSKY	DATE: 95-07-07	SCALE: AS NOTED
REVISED BY:	DATE:	REVISION No: A
APPROVED BY: M.THOMPSON	DATE: 95-07-07	DRAWING No: 2

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