CONTAMINATED GROUNDWATER FLOW CONTROL ACROSS AN INVERTED GROUNDWATER DIVIDE WITH THREE GROUNDWATER CONTROL SYSTEMS

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The potential impacts from legacy, unlined landfills to surrounding hydrological systems are substantial challenges in the management of waste and water quality. Because these landfills do not have passive controls (i.e. liners), groundwater controls (pumping wells, trenches, etc.) can be necessary to minimize impacts. However, the function and interaction of multiple groundwater control devices in combination with complicated hydrogeologic settings are poorly characterized. Most research on groundwater control device interactions relies on simulation experiments and either measures the effectiveness of a system using a limited set of groundwater control devices or focuses on a single aquifer. This thesis examines three groundwater control devices (a slurry wall, a pumping trench, and a pumping well) installed near an active legacy landfill to evaluate changes in the flow of contaminated groundwater off site. This system of control devices was evaluated using monthly water quality data from a spring where changes in water quality were observed prior to installation of the groundwater control system. The water geochemical results indicate that the contaminated groundwater flows primarily through the fractured rock in the ridge (contrary to expectations), and therefore the collection trench is more effective in contaminant flux reductions. The groundwater pumping well, designed to capture contaminated groundwater flow through the coal seams and sandstone, is less effective, likely due to limited transport through the coal aquifers. Although the groundwater control system reduces the amount of contaminated groundwater flow off site, these controls must operate until the landfill is closed and a permanent control (i.e. installation of a clay cap which will reduce infiltration and should result in reduced groundwater elevations) can be installed which may take decades. The results provide fundamental information for future application of groundwater control in complicated field sites.

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1.0 INTRODUCTION

In 2013, the US population, on average, produced 2 kilograms of trash per day per person (USEPA, 2015). This average has increased from an average of 1.2 kilograms per day per person in 1960 (USEPA, 2015). During this period, waste disposal methods have varied, but historically one of the most common methods has been landfill disposal. Landfilling of waste is a common waste management practice and is one of the cheapest methods for organized waste management in most of the world (El-Fadel et al, 1997). In 1983 the United States Environmental Protection Agency (USEPA) inventoried approximately 2,079 open dumps (EPA, 1983). Open dumps had little to no government oversight monitoring their construction or operation. Poorly designed landfills without groundwater control devices can contaminate groundwater, and groundwater contamination is the most commonly reported danger to human health from landfills (Odunlami, 2012). Numerous studies have shown that unlined landfills contaminate groundwater (LaMaskin, 2003; Reddy, 2011; Yadav, 2014).

Newer landfills generally rely on engineered control barriers, that is, barriers constructed from a combination of earthen and polymeric liners, designed to slow the rate of contaminant released to the environment (Yeboah, 2011). Newer landfills are regulated by the United States Environmental Protection Agency (USEPA), or by the state environmental agency where they operate. Legacy open dumps, which started operations before the Solid Waste Disposal Act of 1965 when governmental oversight began, are much more likely to become sources of groundwater contamination. These landfills cannot be retroactively fitted with liners, so groundwater control devices are likely instrumental in groundwater contamination prevention.

Landfills with no liner system cause water to pool and the water levels in the landfill can impact groundwater quality, recharge area, geomorphic changes, and storage of an aquifer. The primary effect of water pooling in landfills is on flow direction and groundwater levels. For example, changes in groundwater flow direction were observed following the construction of Lake Diefenbaker on the Saskatchewan River (Schmid, 2003). Prior to construction of the dam, groundwater flow direction was toward the river valley in a generally flat topography. After the reservoir was filled, the flow direction reversed and generally flowed away from the river valley up to 5 kilometers upstream of the dam. Additionally, the water levels in the dam caused groundwater levels in the bedrock aquifer through both increased infiltration and the rise in hydraulic base level (Wildi, 2010). In general, this rise in groundwater levels causes the changes in groundwater flow direction. Increased water elevations in the groundwater aquifer were observed in the Riverhurst section of the Lake Diefenbaker dam. When water levels in the lake rose by 40 m, water levels in the bedrock aquifer were observed to rise by 3 m to 33 m depending on the section of the lake (Schmid, 2003). Landfills and dams can dramatically change the groundwater levels and flow direction in aquifers. These altered groundwater flow dynamics generally complicate groundwater control efforts.

Groundwater control devices are installed to capture/prevent movement of contaminated groundwater. These devices can be installed as separate systems or combined at sites where a higher volume of groundwater needs to be controlled and one system alone is not likely to effectively control groundwater flow. Groundwater control is achieved by both passive and active systems. Passive interceptor trenches prevent contaminant migration offsite without causing cones of depression and intervening zones of low velocity, in which contaminants linger (EPA, 1989). Similarly, passive slurry walls are vertical barriers comprised of a material with a low permeability constructed downgradient of a contamination source. This low permeable material prevents contaminated groundwater from flowing downgradient and allows additional time to extract the contaminated groundwater. In contrast, an active system like a groundwater pumping well continuously pumps groundwater out of the system, creating a cone of depression in the groundwater table. The cone of depression funnels contaminated groundwater to the pumping well and prevents continued contaminant flow downstream through the aquifer. Whether passive or active, groundwater controls require careful design and evaluation to ensure they are effective.

1.1 PURPOSE

This research examines how three groundwater control devices interact and the implications for prevention of contaminated groundwater flow from a legacy landfill. Without these controls to manage the contaminated groundwater, the water will likely flow from the landfill and down gradient to other downstream receptors. This task is complicated by elevated groundwater levels that have overtopped groundwater divides, removing natural barriers that would prevent leachate from flowing offsite under normal groundwater elevations. The resulting flow has impacted groundwater and surface water, creating the need for groundwater control. Three groundwater control devices (a groundwater pumping trench, groundwater pumping well, and slurry wall,) were installed and this study will use water chemistry at a spring to evaluate the effectiveness of these controls in the prevention of groundwater flow offsite. Groundwater control devices are typically installed to control groundwater in a single aquifer system and interactions among multiple control devices installed to address complicated aquifer systems are rare to non-existent. Some studies have examined the effectiveness of multiple groundwater control systems with models (Bayer 2004, Bayer 2006, Avci 1992). However, the research presented in this study is one of the only to evaluate these systems through field measurements. The results provide fundamental information for future application of groundwater control in complicated field sites.

1.2 REVIEW OF PREVIOUS RESEARCH

1.2.1 Surficial Landfills

When disposing of solid waste, the most common practice is surficial disposal. This type of disposal generally relies on engineered control barriers, that is, barriers constructed from a combination of earthen and polymeric liners, designed to slow the rate of contaminant releases to the surrounding environment (Yeboah, 2011). In particular, these engineered designs minimize liquid flow through the solid waste and the potential mobilization of leached material into local groundwater. Historically, unregulated (i.e. no environmental oversight from a regulatory agency) waste dumps were frequently placed in naturally occurring, low lying surface depressions, and typically were not lined (Yeboah, 2011). Furthermore, additional volume for waste disposal is often added during landfill operation through the construction of dikes around the surface impoundment (Yeboah, 2011). Legacy landfills had little or no controls installed when constructed, therefore these landfills are much more likely to contaminate groundwater. Ultimately this contamination from legacy landfills has to be addressed with more complicated groundwater control strategies.

1.2.2 Pumping Trench Groundwater Control

One of the simplest and most effective configurations for a passive interceptor trench is a linear trench, installed perpendicular to groundwater flow, spanning the maximum width of a hydraulically up gradient contaminant plume (Hudak, 2005). The pumping trench is backfilled with sand or gravel (McMurtry and Elton, 1985), and groundwater that collects in the trench is pumped to a treatment plant. This type of system utilizes prevailing groundwater flow which requires less energy and maintenance than pumping groundwater at several locations to the land surface, treating it, and injecting it back into an aquifer. In some cases, installing a collection trench directly downgradient of the contamination source is not feasible due to property access limitations or complicated plume structures. Fundamentally, the effectiveness of the pumping trench is dependent on the boundary conditions at the site (Avci, 1992). The primary boundary condition identified by Avci (1992) is the impermeable layer under the aquifer. The pumping trench requires the trench to span entire depth of the aquifer. This configuration is not always feasible, particularly when aquifer may be too thick for a trench to be installed across its entire depth.

Avci (1992) examined several scenarios for an interceptor trench near a lake. The goal was to use models to determine how to prevent contaminated groundwater from flowing into the lake. Avci (1992) used measured data from the lake site to populate the simulations including the baseline scenario which used a collection trench next to a lake. Numerical and analytical models were then used to simulate different scenarios and predict if hydraulic barriers in conjunction with the interceptor trench were more effective at capturing contaminated groundwater than the interceptor trench alone. The second scenario simulated the impact of changing lake water levels. When the water levels decreased in the lake, the amount of water that could be removed with the pumping trench decreased and reduced treatment effectiveness. The third scenario examined the impact of varying aquifer thickness. When the thickness of the aquifer increased the aquifer transmissivity increased and caused a smaller drawdown from the pumping trench. This allowed more groundwater to flow past the pumping trench. The fourth scenario examined the impact of a partially penetrating impermeable flow boundary. This scenario had a slurry wall down gradient of the interceptor trench and upgradient of the lake. In this case, the same amount of groundwater was predicted to flow to the interceptor trench as during baseline conditions. Avci (1992) determined that the use of simulations and models were a quick way to establish initial interceptor trench effectiveness using assumptions regarding boundary conditions, but field tests are required to determine how actual boundary conditions will influence the interceptor trench.

Hudak (2005) looked at the most effective size and set back distance of an interceptor trench. The further the interceptor trench is from the contaminated area, the wider the trench size and longer the time period necessary to capture the contaminant plume. Hudak (2005) suggests that interceptor trenches oriented perpendicularly to regional groundwater flow should be located close to the leading tip of a contaminant plume and be slightly wider than the maximum width of the plume. This trench configuration is not always feasible due to the arrangement of local topography or the contaminant plume. For example, if the contaminant plume is under a building, a trench likely cannot be installed at the leading tip of the plume. Or, if a contamination source is too wide, installation of an interceptor trench may be prohibitively expensive. Hudak (2005) determined that because wider trenches and farther setbacks increased capture time, quicker recovery was possible if a shorter setback distance could be implemented.

1.2.3 Pumping Wells

Pump-and-treat is the most widely used remediation technology for groundwater contamination. Pump-and-treat has been used both as a stand-alone treatment system and in conjunction with complementary technologies. Conventional pump-and-treat methods focus on the extraction of contaminated groundwater to the surface for subsequent treatment. Such systems have been used in about 75% of Superfund cleanup actions where groundwater was contaminated (NRC, 1994). The treated groundwater may be re-injected into the subsurface or discharged into a receiving water body or a municipal wastewater collection system (Damera, 2007).

An important design objective of a groundwater extraction system may be the hydraulic control of groundwater to prevent offsite migration of the contaminant plume during reclamation efforts. Properly located extraction wells can remove water from the aquifer by creating a capture zone for migrating contaminants. As water is extracted, a capture zone curve develops upstream from the well (Figure 1). Groundwater inside the capture zone is extracted by the well, while the water outside is not (Damera, 2007). The figure below shows an idealized two-dimensional capture zone envelope for a well extending the entire depth of an aquifer and pumping at a constant rate, or head value, to extract groundwater equally at all levels (Damera, 2007).

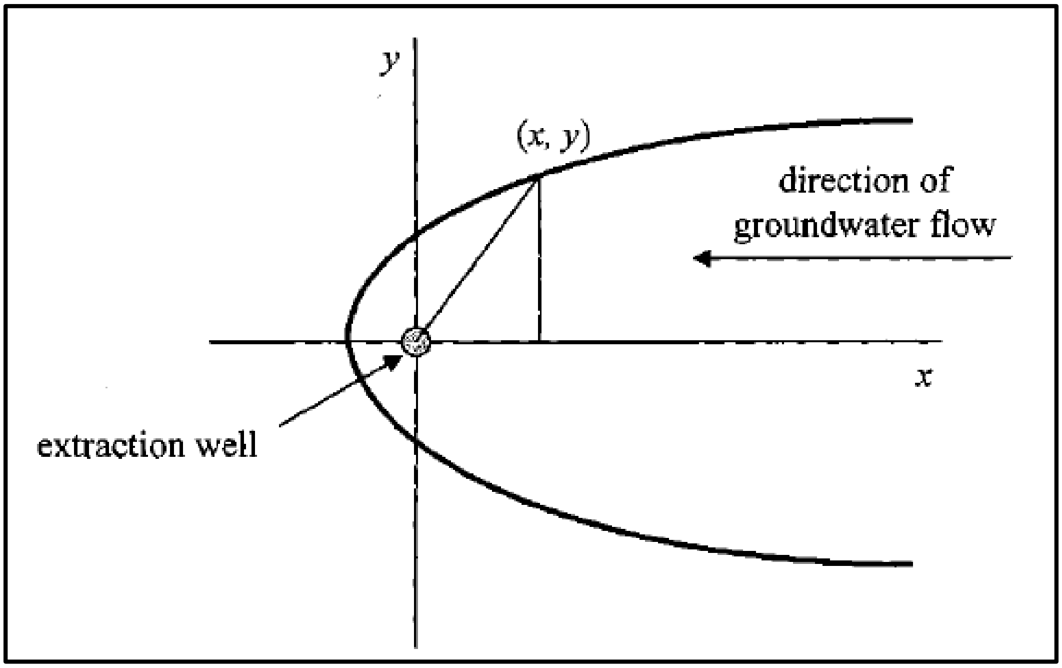

Figure 1. Groundwater Pumping Well Capture Zone

(Damera, 2007)

The objective of many pump-and-treat systems is to lower groundwater contamination concentration below cleanup standards, ultimately allowed the pumping system to be shut down. In some cases, the source of the contamination cannot be completely removed and pumping is required for the foreseeable future.

Duda (2014) examined the water chemistry records of 46 groundwater pumping wells at one of the largest mine tailings disposal sites in Poland to determine reductions in groundwater chloride, sodium, calcium, and sulfate concentrations. Duda (2014) sought to determine a new quantitative criterion for evaluating drainage barrier effects on contaminant transport reduction, and use the criterion to assess pumping well influences on groundwater protection. A material budget approach was used to determine the flux of chloride, sodium, calcium, and sulfate off site and thereby evaluate the effectiveness of the pumping wells. Additional pumping wells were installed until the network surrounded the entire facility and a hydraulic divide between the site and downgradient receptors was created. The network of pumping wells was effective at capturing contaminated groundwater that flowed off site. However, not all wells removed contaminated groundwater equally. Duda (2014) found wells that were positioned in preferential groundwater pathways removed the bulk of the contaminated groundwater.

1.2.4 Slurry Walls

Vertical barriers are constructed by digging a trench and backfilling it with a slurry-type mixture of water, soil, and bentonite clay. These barriers are keyed into a low-permeability layer such as clay or bedrock (Fetter, 2001). Cutoff walls profoundly alter groundwater flow fields, increasing pumping well efficiency in contaminated groundwater removal. Slurry walls primarily control seepage flow. Slurry walls are now being installed around landfills to prevent contaminant migration off site (Hudak, 2004). Fine sediment content of native soils controls the initial permeability (i.e., more fines, less permeable). As the trench is excavated the materials are mixed and pumped back into the excavation to prevent cave ins. Davis (1988) has shown that the higher the amount of bentonite in the slurry mixture, the lower the hydraulic permeability is of the wall. Davis (1988) also shows that hydraulic permeability varies minimally among the different types of bentonite. The bentonite expands the slurry mixture and minimizes macropore formation that can reduce the effectiveness of the slurry wall. Moreover, if cracking does occur during dry periods, the bentonite will re-expand once the system gets wets again, swells up and reseals. Slurry walls, while effective, require relatively specialized aquifer and plume geometries to be effective in isolation.

1.2.5 Multi-System Design

Sometimes a contamination source is too large or the aquifer system too complicated for a single groundwater control system to be effective. In these cases, multiple groundwater control systems can be installed in tandem to control the groundwater flux. However, these systems will interact and can cause unexpected flow patterns.

Bayer (2004) examined the potential of partial containment strategies to reduce the pumping rate required for the pump-and-treat measure. This work used MODFLOW (McDonald and Harbaugh 1988) to conduct simulation experiments.

Five scenarios were examined (Figure 2);

1. A traditional pump-and-treat system downgradient of the contaminated area (Figure 2A)
2. A hydraulic barrier upgradient of the contaminated area, and the pumping well downgradient of the contaminated area (Figure 2B)
3. A hydraulic barrier downgradient of the contaminated area, and upgradient of the pumping well (Figure 2C)
4. A hydraulic barrier upgradient of the contaminated area, a hydraulic barrier downgradient of the contaminated area, and the pumping well downgradient of both hydraulic barriers and the contaminated area (Figure 2D)
5. A hydraulic barrier upgradient and on both sides of the contaminated area parallel to groundwater flow direction, and the pumping well down gradient of the contaminated area (Figure 2E).

Bayer (2004) determined that combinations of barriers and pumping wells (Figure 2D and 2E) were the most effective at capturing groundwater flow from the contaminated area. When barrier widths are twice the width of the contaminated area, pumping rates from the pumping well can be reduced by 25% to 50% compared to a standard pump-and-treat system (Bayer, 2004). While multiple flow controls seem to be promising in terms of improving flow control, these simulated systems focus on relatively simple field conditions.

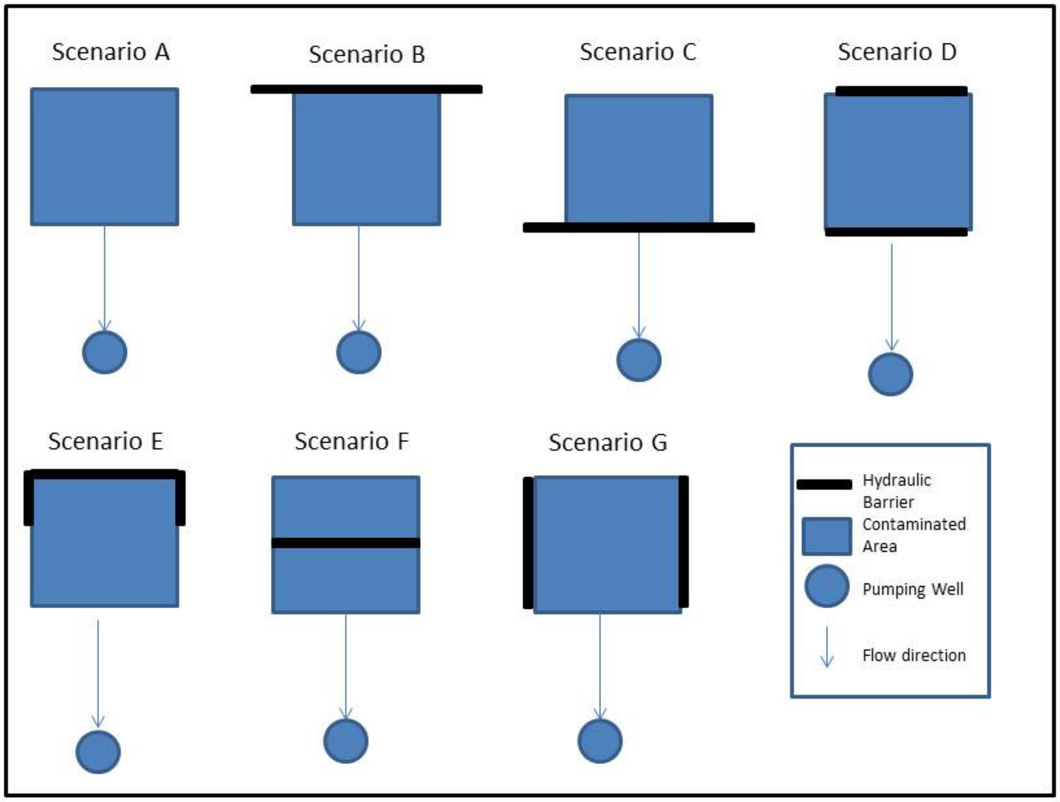

Figure 2. Pump and Treat Systems with a Slurry Wall

Showing 7 different types of pump and treat systems with a slurry wall installed at different locations in respect to the contamination zone.

Bayer (2006) built on this simulation experiment to incorporate uncertainty in the regional flow direction and highly heterogeneous aquifer transmissivity distributions into the simulation experiments. These simulations assume that the operating costs for a pumping system are directly proportional to pumping rates (Bayer, 2006). System designs requiring the minimal pumping rates were therefore the most economical to operate. This study analyzed two additional well-barrier scenarios (Bayer 2206):

1. A hydraulic barrier through the center of the contaminated zone perpendicular to groundwater flow, and the pumping well downgradient of the contaminated area (Figure 2F)
2. Two hydraulic barriers on both sides of the contaminated area and parallel to groundwater flow with the pumping well downgradient of the contaminated area (Figure 2G).

Heterogeneous aquifer transmissivity was simulated with a Monte Carlo approach; 500 random aquifer realizations were generated with an unconditional sequential Gaussian Simulation (SGS). The SGS is used to estimate probability distributions of aquifer transmissivities. A 3 dimensional transmissivity model was created for each realization, and the minimal pumping rate required for capture of the contaminant plume was evaluated for each scenario. All of the 500 simulated aquifers indicated that pairing a hydraulic barrier with a pumping well would reduce the pumping rate in the well and still capture the contaminated groundwater flow when compared to the standalone pump-and-treat systems. Further, even if groundwater flow direction was poorly predicted and the system was not directly downgradient of the contaminant source, the hydraulic barrier still improved system efficiency. The study found that containment on both the up and down gradient side of the contamination and a downstream pumping well (Figure 2D) reduced the pumping rate necessary to capture the contaminated groundwater flow by 80%.

In the case of unlined landfills with leachable contaminants, the question is not *if* groundwater contamination will occur, but *how much* will the landfill impact groundwater quality. Large, unlined landfills generally will require a multi-approach system to minimize contaminant flux from the landfill. If the landfill is too large for a groundwater capture system that surrounds the entire area or local aquifers too thick to effectively install a barrier, a focused approach can be employed to capture contaminated groundwater flow through preferential pathways. However, field-scale data from this type of system is rare, limiting our ability to assess redundant systems used to control large contaminant sources. This research examines a three system approach designed to prevent contaminated groundwater from migrating off site through complicated strata geology. This research will help determine if a multi-approach system is effective, and what parts of the system are most effective so that those components can be incorporated into future system design.

2.0 METHODS

2.1 BACKGROUND

2.1.1 Site Description

The research area (Site) for this study is in Western Pennsylvania. The Site is an unlined, solid waste landfill located in a former stream valley. The eastern and western sides are bounded by ridges. The north side is bounded by an earthen dam. Due to the Site configuration within valley walls, dikes typically constructed around a landfill were not installed. This research focuses on a portion of the Site on the eastern ridge (Figure 3). The ridge acts as a local groundwater divide with two coal seams (Brush Creek and Mahoning) running nearly horizontal through the ridge (Figure 3). Disposal at the landfill does not occur continuously across available landfill area. Rather, disposal occurs in one section of the landfill for 1-3 months. This system of varied disposal areas ensures that one section of the landfill does not have a large mound that rising higher than the rest of the site.

Prior to the disposal of waste, we assume that groundwater flowed in both directions from the ridge (northeast toward Spring-2 and southwest toward the present day landfill, Figure 3). However, once the groundwater levels in the impoundment rose higher than the bedrock aquifer, groundwater flowed predominantly toward the northeast and out of the landfill. Groundwater elevation data for the bedrock aquifer on the ridge prior to solid waste disposal does not exist, however, the effects of the solid waste on the groundwater table are reasonable assumptions though they that cannot be confirmed with available data. Springs are common along coal seam outcrops on the eastern side of the ridge. In particular, two specific springs, Spring-1 and Spring-2, were examined for this study. In 2012 groundwater levels in the research area exceeded an expected tipping point (i.e. groundwater levels rose above the base of the fractured bedrock zone) and concentration of chloride, sulfate, calcium, and magnesium increased in Spring-2. These concentrations peaked in October 2012. At this point in time waste disposal was redirected to other portions of the landfill. During this period of disposal distant from the ridge, groundwater levels returned to elevations below the fractured bedrock. Likewise, following this drop in groundwater elevation, spring water chemistry returned to concentrations observed prior to October 2012.

Following the period of elevated Cl, SO_4, Ca, Mg concentrations in Spring-2, it was determined that groundwater flow controls would be necessary to prevent additional groundwater contamination through the saddle in the ridge (Figure 3) during future periods of waste disposal near the research area.

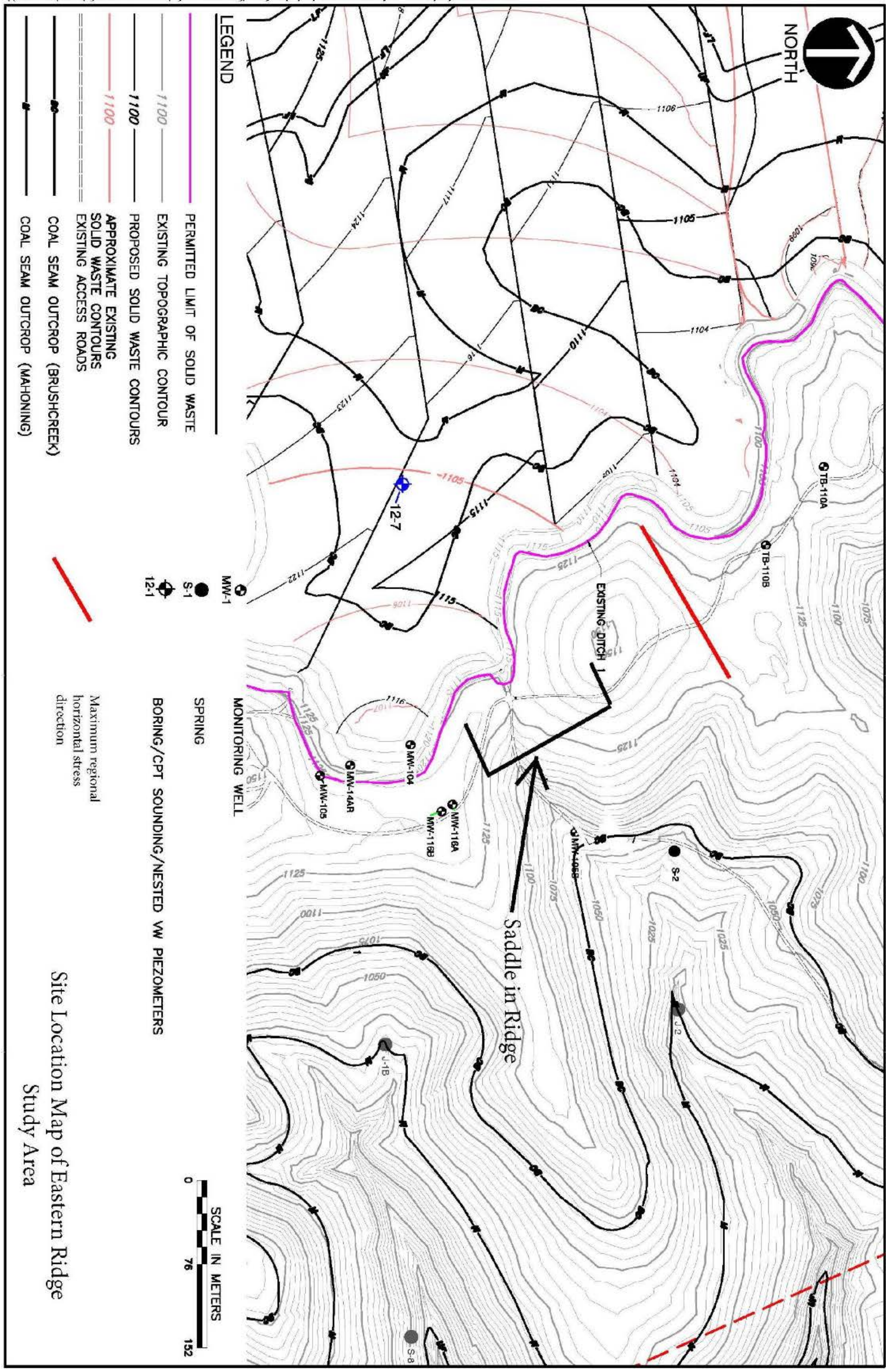

Figure 3. Research Area

Research Area showing the saddle in the ridge.

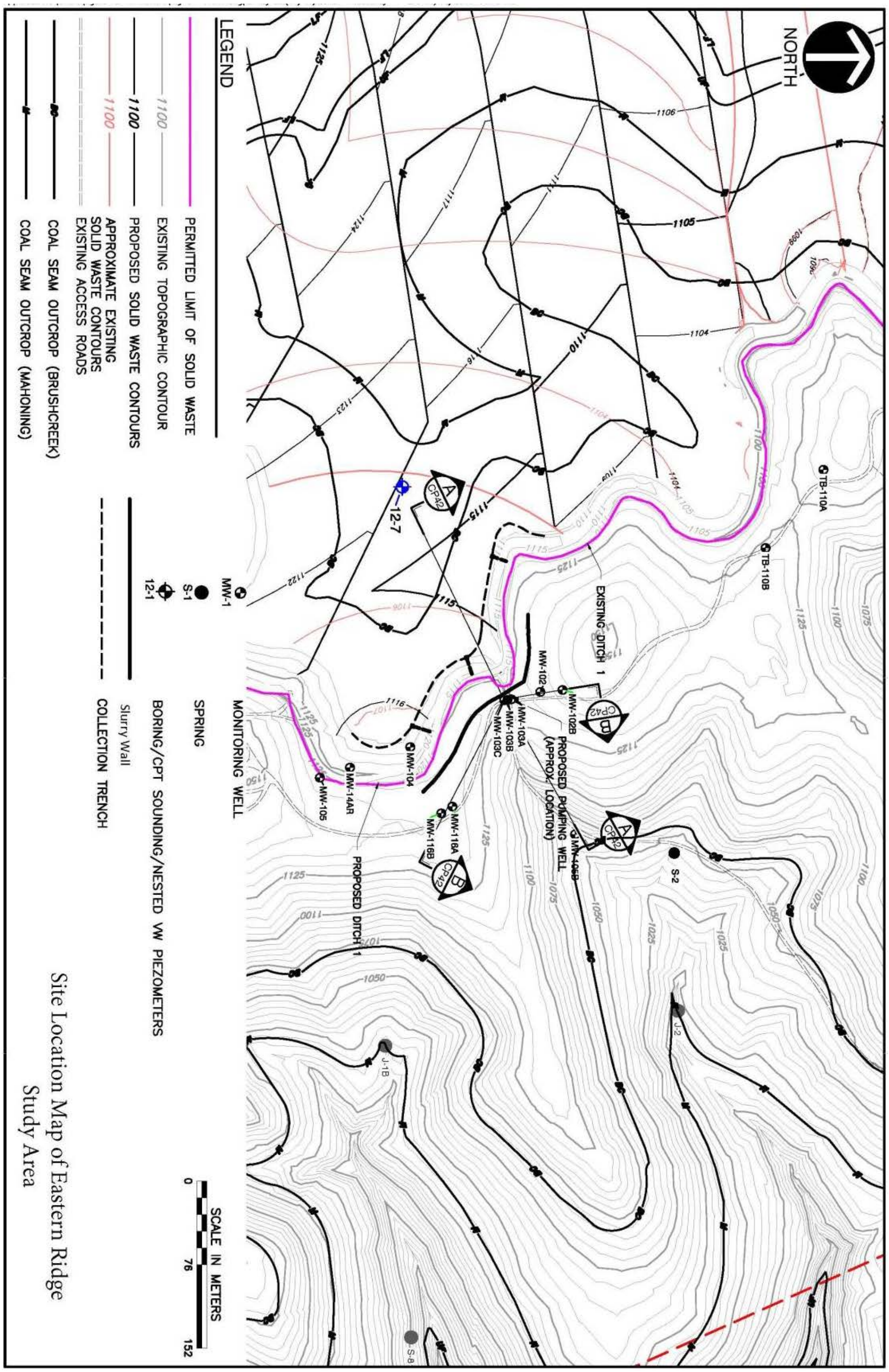

Figure 4. Research Area with Groundwater Controls

Site location for study area showing the coal seam outcrops, solid waste limits, groundwater monitoring wells and spring sampling locations.

The initial plan was to install groundwater pumping wells along the saddle in the ridge. However, it became clear that this system would not cost effectively control groundwater flow in the area. The second plan involved only installing a slurry wall to act as a hydraulic barrier. A slurry wall would only be effective if it could completely prevent groundwater flow through the ridge. With plans for continued disposal in the landfill, the groundwater elevation would also continue to rise, requiring either a pumping well or collection trench to work in conjunction with the slurry wall. The collection trench was chosen as it could be installed lower in elevation than the planned final grade of the landfill, on the edge of the current solid waste, and in the fractured rock (which is believed to be the primary conduit for contaminated groundwater). Moreover, a collection trench would be more cost effective than multiple pumping wells. As the landfill material level rises, the collection trench will be covered and is expected to continue to collect of groundwater flowing horizontally from the landfill as well as vertically from the material above the trench. Optimally, a pumping trench is installed downgradient of the contamination source spanning the entire width and depth of the source. In this case, the solid waste is too massive for these dimensions to be feasible. The pumping trench at the research area cannot feasibly be installed around the entire landfill or through all relevant aquifers. Therefore, this trench is designed to limit flow through the saddle only. Further, due to equipment limitations, the collection trench is not as deep as the coal seams. When the final design of the collection trench and slurry wall was finished there was concern that the collection trench was too far from the slurry wall, so to add redundancy and to remove water from the coal seam a single pumping well was added to the trench system.

The three groundwater control devices were installed at the study area to prevent contaminated groundwater from flowing through the saddle in the ridge and toward Spring-2 (Figure 4 and 5). Directly down gradient of the landfill an interceptor trench was installed. A pumping well was installed down gradient of the landfill, and directly up gradient of the slurry wall. A slurry wall was installed in the topographic low area of the ridge between the solid waste landfill and Spring-2. The pumping trench primarily controls groundwater flow through the fractured bedrock, and relies on the pumping well to control groundwater flow through the sandstone and coal seams.

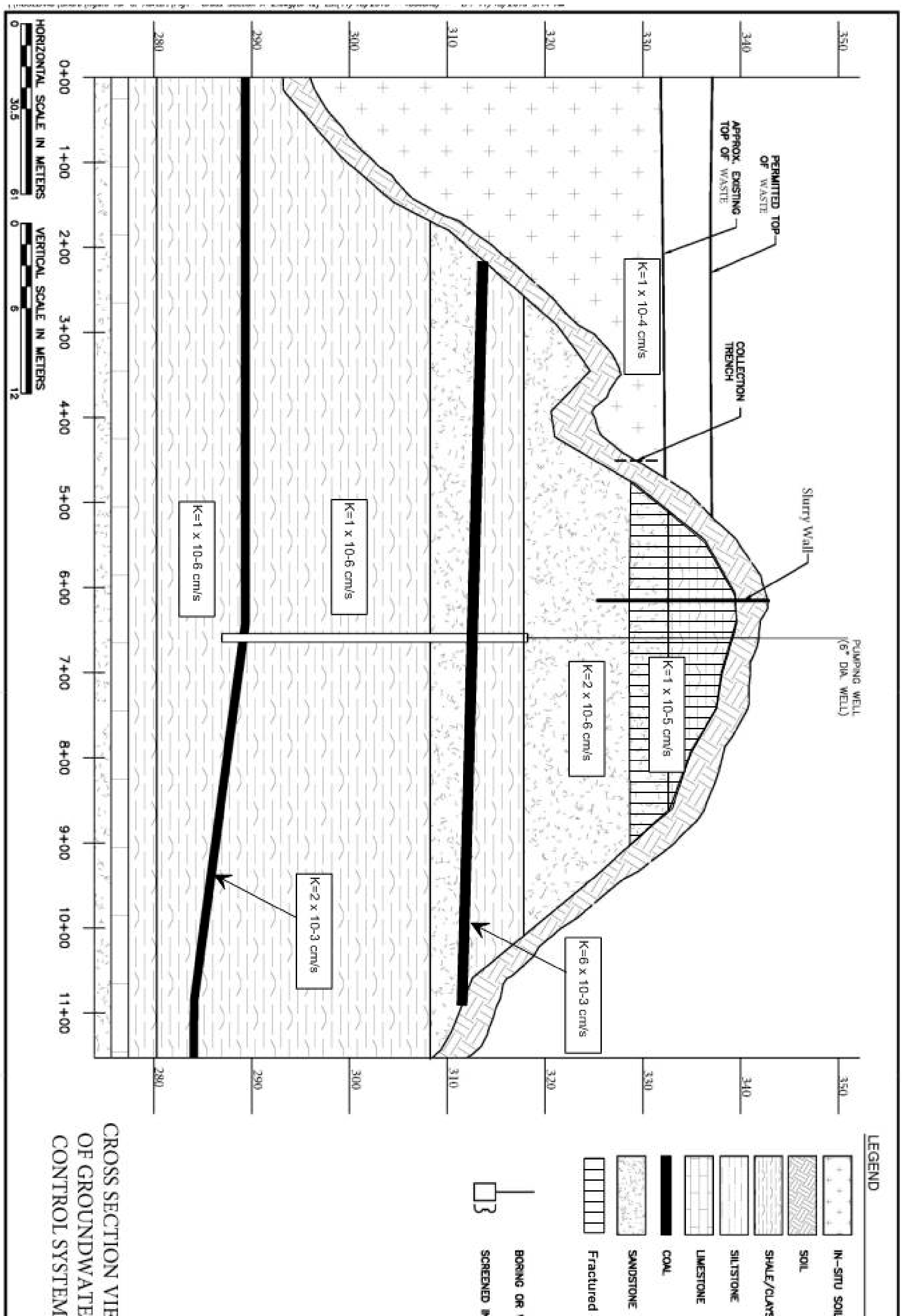

Figure 5. Cross Section A of Research Area

Cross section view of study area showing the solid waste limit, the elevation solid waste will end up at, locations of the pumping trench, slurry wall, and pumping well and the rock units each intercepts.

Water quality at Spring-1 and Spring-2 was similar in 2010 and 2011 (Figure 6). Spring-2 is directly down gradient of the three groundwater control devices and outcrops at the Brush Creek coal seam. The groundwater that feeds Spring-2 is believed to flow from the landfill and through the saddle in the ridge. Water quality samples were collected monthly to measure contaminant concentrations in Spring-2. Contaminant concentrations in Spring-2 are used to indicate if the three groundwater control devices effectively prevent contaminated groundwater from flowing through the saddle off site as water levels rise in the landfill.

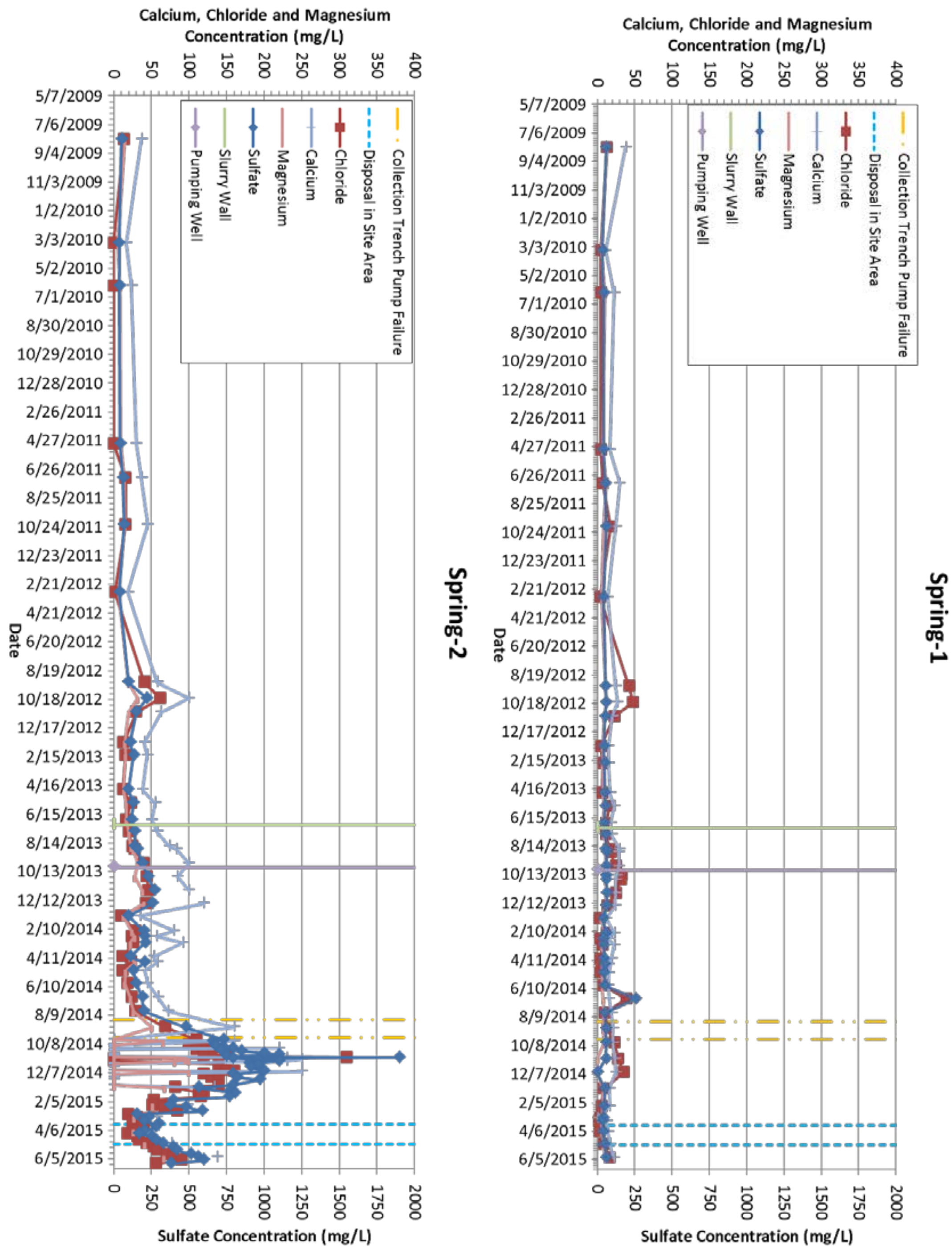

Figure 6. Water Quality at Spring-1 and Spring-2

Water quality at Spring-1 and Spring-2 over time showing similar water quality in 2010 and 2011.

2.1.2 Local Geology

2.1.2.1 Geography & Climate

The Site lies within the Allegheny Plateau physiographic province (Van, 1951) of western Pennsylvania. The mean annual air temperature is 11°C with an average annual precipitation of 97 centimeters (Van, 1951).

2.1.2.2 Geology

The Allegheny Plateau physiographic province is characterized by gently dipping coal measures of complex stratigraphy. No major fold or faults are present in the area. The upper stratigraphic unit on site is the Glenshaw formation (Figure 7).

The lower Mahoning sandstone is the lowest formation considered for this research. This unit is comprised of fine to medium fine-grained micaceous quartz sandstone. The lower Mahoning sandstone has numerous fractures. The lower Mahoning sandstone is overlaid by an unnamed shale unit. The Mahoning Coal overlies the unnamed shale unit. The upper Mahoning overlays the Mahoning coal seam. It is comprised of very fine-grained, gray, silty, micaceous sandstone. This unit directly overlies the Mahoning coal and is overlain by the Brush Creek coal. The Brush Creek coal seam is an important aquifer system at this Site. The Brush Creek coal is generally 35 to 71 centimeters (cm) thick, ranked as high-volatile A bituminous (Petterson, 1963). The Brush Creek coal has a high heat value with a moisture content ranging from 1.8 to 6.8 percent, volatile matter from 30.2 to 41.1 percent, an average sulfur content of 2.8 percent, and average ash content of 9.4 percent (Petterson, 1963). According to the County Coal Resources report, the Brush Creek coal primarily crops out near the tops of hills but is generally thin and discontinuous. The Brush Creek coal is not economically minable in the vicinity of the Site. Alternating units of unnamed shale and sandstone overlie the Brush Creek Coal. The sandstones are calcareous sandstones and/or contain limestone lenses.

Surficial residuum ranges up to 7.3 m in thickness and consists of residual clay, silt, sand, and weathered rock.

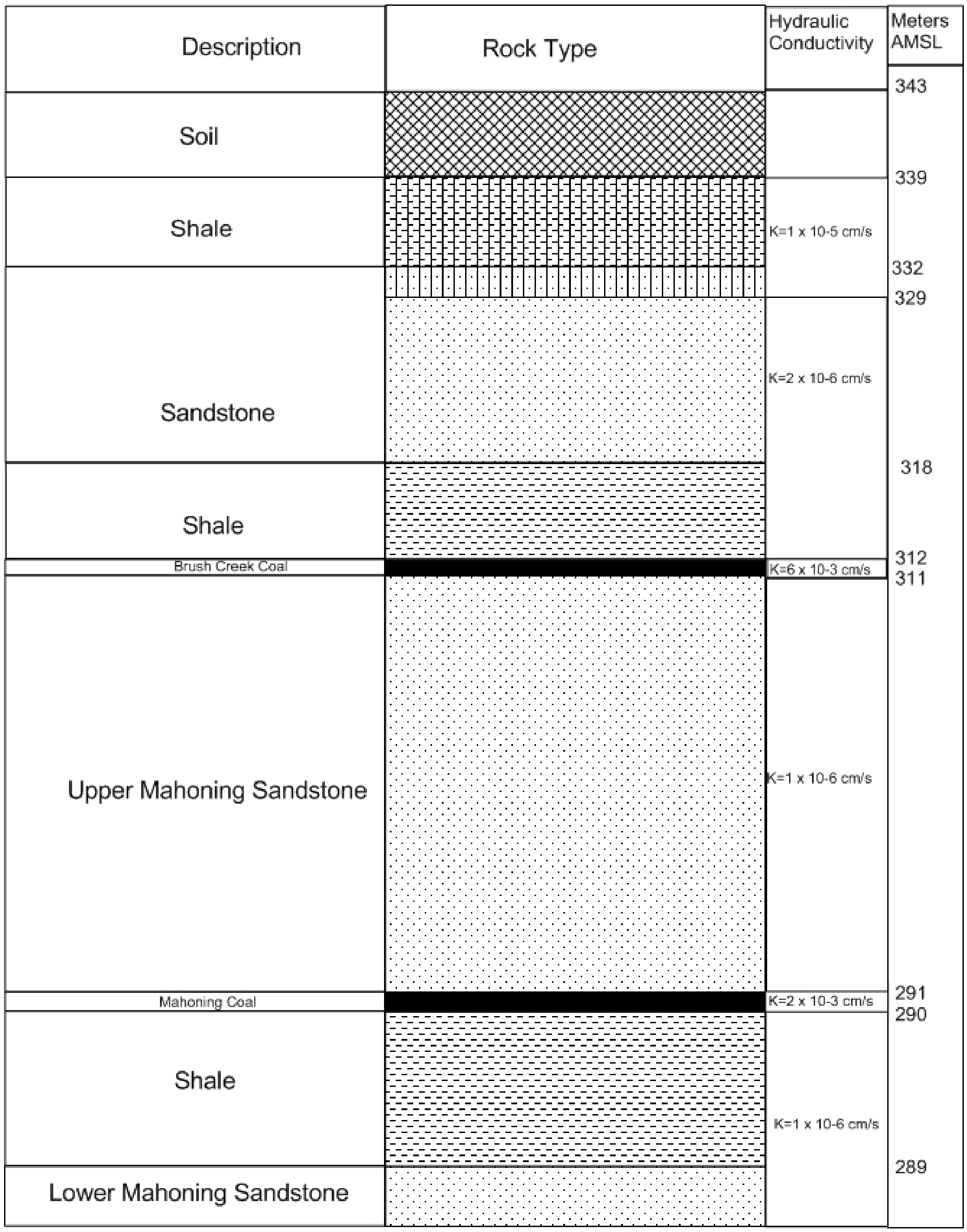

Figure 7. Stratigraphic Section

Generalized stratigraphic section of the Glenshaw Formation. Hydraulic conductivities correspond to those determined in section 3.1

2.1.2.3 Groundwater

The stratigraphic units present at the Site vary in permeability. The permeable strata, generally sandstones and coals, act as aquifers and transmit groundwater. The less permeable strata, such as shales, siltstones, claystones, and underclays are aquitards which restrict flow. The

Middle Glenshaw aquifer, the shallowest bedrock aquifer at the Site, is located in the Brush Creek coal, upper Mahoning sandstone, and the Mahoning coal. The aquifer is located in multiple rock formations due to the similar hydraulic conductivities. These strata crop out on the ridge at elevations between 290 and 312 m AMSL. The Middle Glenshaw Aquifer is separated from the lower aquifers by confining siltstones, shales and claystones.

2.1.3 Background Water Quality

Background water quality for the Site and surrounding county was synthesized from multiple sources. The County Groundwater Resources Report includes analysis of water from 26 wells across the county (Patterson, 1963). These samples were a collected primarily by water companies (Table 1). The water collected during the reporting period in 1946 is relatively neutral, with low levels of metals and a moderately high level of total dissolved solids (TDS).

The second source of background water quality for the area, sampled mine drainage from the Brush Creek coal in 1995 (Hornberger, 2004, shown in Table 1). The limited parameters collected show constituent composition is similar if not lower than the average water quality collected for the entire county. The water is neutral with low levels of metals and a low total suspended solid (TSS).

The third source of background water quality is from a spring on the study site (Spring-1) which is not believed to be impacted by the solid waste. Water quality samples have been collected from this location on a regular basis starting on March 11, 2010 (Table 1). Parameters like pH, iron, manganese, and bicarbonate are similar to average county wide groundwater quality background water quality sources. The water quality at Spring-1 for calcium, magnesium, sulfate, chloride, nitrate, TDS, and alkalinity are lower than the other background water measurements.

Table 1. Water Quality Comparison

Water quality comparison between the 26 samples from the Groundwater Resources Report (Patterson, 1963), mine drainage from the Brush Creek Coal (Hornberger 2004), and the two springs in the study area.

Location	**1946 County Quality**			**Mine Drainage**	**Spring-1**	**Spring-2**
	minimum	**average**	**maximum**	**7/12/1995**	**3/11/2010**	**3/11/2010**
Parameter						
pH (S.U.)	6.1	7.2	7.8	6.9	6.31	6.43
Silica (mg/L)	6.0	10.0	14.0			
Manganese (mg/L)	0.0	0.3	1.6	0.4	0.55	6
Iron (mg/L)	0.0	0.5	5.0	0.21	0.75	0.1
Calcium (mg/L)	24.0	81.0	175.0		11	17
Magnesium (mg/L)	7.0	22.0	78.0		5.9	6
Bicarbonate (mg/L)	63.0	83.0	96.0		6.8	21
Sulfate (mg/L)	25.0	108.0	325.0	68	35	36
Chloride (mg/L)	14.0	35.0	103.0		5	0
Nitrate(mg/L)	3.5	5.4	8.0		2.3	1.8
TDS (mg/L)	260.0	478.0	670.0		80	96
Total Hardness (mg/L)	93.0	260.0	528.0			
Alkalinity (mg/L)	98.0	178.0	253.0	189	6.8	21
Acidity (mg/L)	0.0	8.4	20.0			
Aluminum (mg/L)				0.07		
TSS (mg/L)				1		

The fourth source of background water quality is Spring-2 which, though later affected by changes in groundwater quality caused by the landfill, is considered "background" water quality from August 2009 through September 2012 when the groundwater elevation in the landfill was below the fractured bedrock. The sample from March 11, 2010 was used to represent pre-impact water quality at Spring-2 and evaluate water quality changes followed subsequent disposal of solid waste. The entire water quality record for Spring-2 is shown in Appendix A and pre-impact data included in Table 1. Parameters like pH, iron, and bicarbonate are similar to other background water quality sources. Similar to Spring-1, the Spring-2 calcium, magnesium, sulfate, chloride, nitrate, TDS and alkalinity concentrations are lower than those reported in the other background water quality data. However, pre-impact manganese levels at Spring-2 are higher than the other background water chemistry samples.

Table 2. Site Water Quality Compared to Background

Spring-1 and Spring-2 10/16/2012 data compared to background water quality

Location	Spring-2		Spring-1		1946 County quality	Mine Drainage	Landfill water
	3/11/2010	10/16/2012	3/11/2010	10/16/2012			
Parameter	pre-impact		pre-impact				
pH (S.U.)	6.43	6.72	6.31	6.95	7.2	6.9	7.25
Silica (mg/l)					10		
Manganese (mg/l)	<0.005	0.36	0.55	0.17	0.28	0.4	0.001
Iron (mg/l)	0.1	0.83	0.75	0.09	0.47	0.21	0.018
Calcium (mg/l)	17	100	11	27	81		480
Magnesium (mg/l)	6	32	5.9	12	22		86
Bicarbonate (mg/l)	21	170	6.8	33	83		150
Sulfate (mg/l)	36	220	35	59	108	68	2400
Chloride (mg/l)	0	62	5	48	35		370
Nitrate (mg/l)	1.8	0.12	2.3	0.05	5.4		1.4
TDS (mg/l)	96	490	80	210	478		4400
Hardness (mg/l)					260		
Alkalinity (mg/l)	21	170	6.8	33	178	189	150
Acidity					8.4		
Aluminum (mg/l)						0.07	0.0033
TSS (mg/l)						1	

2.2 WATER QUALITY IMPACTS

During the October 16, 2012 sampling event, high levels of chloride, calcium, sulfate, and magnesium were detected in Spring-2 (Figure 6) compared to background water quality (Table 2). This was believed to be caused by the high groundwater levels in the landfill creating sufficient head to push groundwater through the Brush Creek Coal seam and fractured upper bedrock zone and therefore across the groundwater divide. Calcium increased from 17 mg/L to 100 mg/L, chloride increased from 16 mg/L to 62 mg/L, magnesium increased from 6 mg/L to 32 mg/L, and sulfate increased from 36 mg/L to 220 mg/L. In addition to these increases, TDS increased from 96 mg/L to 490 mg/L and alkalinity increased from 21 mg/L to 170 mg/L. The increase is clearly larger than the small increase observed at Spring-1 as the October 16, 2012 sample from Spring-1 had only slightly elevated levels of calcium, chloride, magnesium and sulfate. The impacts to Spring-2 during this sampling event suggested that contaminated groundwater was flowing through the ridge, and because additional solid waste was going to be placed in this area it was believed that concentrations of calcium, magnesium, chloride and sulfate would increase. It was decided that a groundwater control system was required to reduce, if not prevent, contaminated groundwater from flowing through the ridge to downstream receptors.

2.3 AQUIFER PROPERTIES

2.3.1 Hydraulic Properties

Rising head and falling head single well hydraulic conductivity tests (slug tests), single well and multi-well pumping tests were conducted in bedrock and in the waste material to calculate the hydraulic conductivity, transmissivity, specific yield and storativity of the rock units on Site. Tests conducted in the fractured bedrock were assumed to be under unconfined conditions, and tests conducted in the Brush Creek coal seam and below were assumed to be under confined conditions.

In development of the conceptual model for the site, the stratigraphic units were considered based on their hydraulic properties as determined by single-well permeability testing results, pump test results and lithology. Lithologic units with similar hydraulic permeabilities were grouped together as hydrostratigraphic units.

Evaluations of all hydraulic property tests were conducted using Aqtesolv Pro (Version 4.0; Duffy, 2015). Inputs into the system include, well construction information water height in well, displacement observed, and the water levels collected during the test.

2.3.2 Piezometer Installation

2.3.2.1 Solid Waste Piezometers

Piezometers were installed in the solid waste landfill to collect groundwater elevations data, perform slug tests, and to perform pumping tests.

Each piezometer boring was advanced by 16 cm diameter hollow stem augers (HSA) through the entire the solid waste. The pumping well, 12-10, was advanced to 37 m deep. The observation piezometers, 12-10A and 12-10B, were advanced 6 m deep each. The piezometer used as the pumping well for the study, 12-10 was constructed of 5 cm diameter PVC with 0.025 cm slot screened across the entire water table (7-37 m below ground surface (bgs)). The observation piezometers, 12-10A and 12-10B, were constructed with 5 cm diameter PVC casing and 3 m of 0.025 cm slot screen. The annulus around the screen was filled with clean quartz sand and capped with a hydrated bentonite seal. The remaining annulus was filled to the ground surface with hydrated bentonite chips. The piezometers were completed with a steel protective cover and 0.75 m diameter concrete pad. Well construction details are shown on Table 3 and the boring logs are attached as Appendix B.

Table 3. Piezometer Construction Details

Piezometer construction details for the monitoring wells and piezometers were installed for the study.

Well	Depth	Elevation		Screen Interval						Location	Completion Zone
		Ground	Casing	Depth			Elevation				
	m	*m MSL*	*m MSL*	*m*			*m MSL*				
MW-101	14.54	343.83	344.59	14.54	-	11.52	329.29	-	332.31	Ridgeline	First water, undesignated
MW-102	14.08		345.70	14.11	-	11.06	330.98	-	334.03	Ridgeline	First water, undesignated
MW-103A	11.58	343.47	344.19	11.58	-	8.53	331.89	-	334.94	Ridgeline	First water, undesignated
MW-103C	43.37	343.52	344.28	43.37	-	40.33	300.15	-	303.20	Ridgeline	Lower Glenshaw aquifer
MW-104	7.62		340.54	7.62	-	4.57	332.31	-	335.36	Ridgeline	First water, undesignated
MW-105	10.06	344.58	345.34	10.06	-	7.01	334.52	-	337.57	Ridgeline	First water, undesignated
MW-106	8.53		352.65	8.53	-	5.49	343.50	-	346.55	Ridgeline	First water, undesignated
MW-107A	12.19	351.02	351.78	12.19	-	9.14	338.83	-	341.88	Ridgeline	First water, undesignated
MW-107B	39.90	351.06	351.82	39.90	-	36.85	311.16	-	314.21	Ridgeline	Mahoning coal
MW-107C	44.90	350.95	351.71	44.90	-	41.85	306.06	-	309.10	Ridgeline	Glenshaw Formation
MW-108	11.64		353.27	11.64	-	8.60	341.02	-	344.07	Ridgeline	First water, undesignated
MW-110	17.56		343.36	17.56	-	14.51	325.19	-	328.24	Ridgeline	First water, undesignated
MW-111	7.01	354.02	354.78	7.01	-	3.96	347.01	-	350.05	Ridgeline	First water, undesignated
OW-112B	15.54	342.76	343.45	12.50	-	15.54	330.27	-	327.22	Ridgeline	Brush Creek coal
P-1(220)	67.06	333.79	334.40	67.06	-	0.00	266.73	-	333.79	Landfill	Solid Waste
P-1(150)	45.72	333.82	334.26	45.72	-	42.67	288.10	-	291.14	Landfill	Solid Waste
P-1(50)	15.24	333.79	334.48	15.24	-	12.19	318.55	-	321.60	Landfill	Solid Waste
12-10A	6.10	338.27	338.90	6.10	-	1.52	332.18	-	336.75	Landfill	Solid Waste

2.3.2.2 Bedrock Piezometers

Piezometers were installed and screened at varying depths in bedrock to collect groundwater elevation data, perform slug tests, and to perform pumping tests.

Each piezometer boring was advanced by 16 cm diameter HSA to bedrock refusal. Once the piezometer borings could no longer be advanced using HSA, air rotary or “HQ” (6.3 cm diameter) coring was used to advance the borehole to the desired depth. The piezometers were constructed with 5 cm diameter PVC casing and 3 meters of 0.025 cm slot screen. Table 3 shows where each piezometer was installed (by specific rock formation, or when groundwater was first encountered). The annulus around the screen was filled with clean quartz sand and capped with a hydrated bentonite seal. The remaining annulus was filled to the ground surface with hydrated bentonite chips. The piezometers were completed with a steel protective cover and 0.75 m diameter concrete pad.

2.3.3 Slug Tests

2.3.3.1 Solid Waste

Slug tests were conducted on four piezometers completed in the solid waste material to estimate in-situ hydraulic conductivities. Tests were evaluated using either the Bower-Rice or Cooper-Bredehoeft-Papadopulos method, depending on the trend of the recovery data. The best fit lines for multiple methods like the Bower-Rice, Copper-Bredehoeft-Papadopulos, Hvorslev, and KGS models were used to determine which method fit the best. Once the best method was determined the best fit line was adjusted to match data patterns. For example, Figure 8 shows a Bouwer-Rice solution. However, the best fit line takes all of the data into account and the fit line does not match with the data curve. To improve the fit, a line is chosen based on one of the three sections of data: 1) the early data (first 75 seconds on Figure 8). This section of data is generally considered to reflect drainage of the filter pack. Therefore, the early data are usually not included in the best fit line. 2) The second data section (75 second to 480 second range on Figure 8). These data are usually the section used for the best fit line due to the size of the differential head (water level change between the formation and the water level in the well) and the resulting maximum in flow. 3) The third data section (>480 second on Figure 8) is usually the longest section. The hydraulic conductivity changes from 8.5 x 10^{-4} cm/sec (the initial best fit for all of the data) to 3.5 x 10^{-4} cm/sec when the best fit line is adjusted to the most appropriate data.

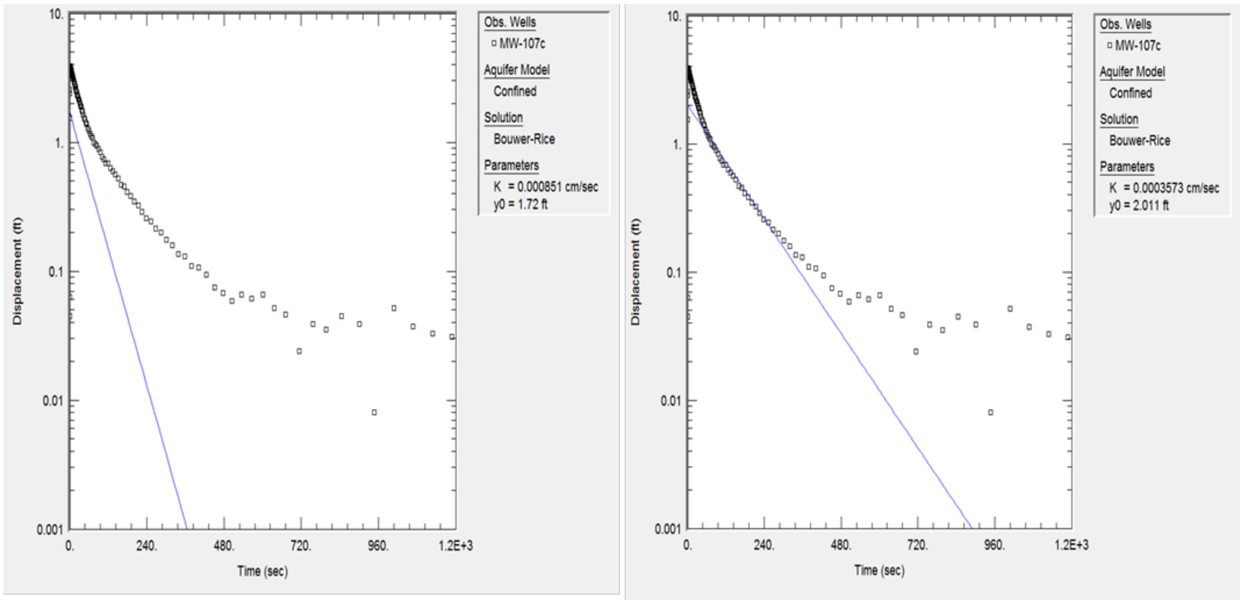

Figure 8. Hydraulic Conductivity Determination

Uncorrected slug test data from monitoring well MW-107 on the left and the same data on the right after visual compensation

2.3.3.2 Bedrock

Slug tests were conducted on 12 wells located along the ridge of the site to estimate hydraulic conductivities. Tests were primarily analyzed using the Bower-Rice method for unconfined aquifers with the exception of piezometer MW-107C which was analyzed using the KGS model. Most of these piezometers targeted the uppermost occurrence of groundwater, without regard for geologic stratum. Exceptions were MW-107B, which was completed in the Mahoning coal, and MW-107C, which was completed in a lower portion of the Glenshaw Formation.

2.3.4 Single Well Pumping Test

A single well pumping test was conducted at piezometer MW-103B to assess the properties of the Mahoning coal seam along the ridge.

The test was initiated on November 2, 2012 and lasted 90 minutes. After pumping stopped the recovery was measured and test data was evaluated using the This recovery solution for a confined aquifer.

2.3.5 Multi-Well Pumping Test

2.3.5.1 Solid Waste

A pumping test was conducted at piezometer 12-10 to assess the in-situ aquifer properties of the solid waste material. Observation wells for the tests were piezometers 12-10A, located 3.9 m from the pumping well, and 12-10B, located 8 m from the pumping well. All piezometers were equipped with transducers and data loggers to record drawdowns.

The test was initiated on October 3, 2012 at 8:31 AM, and continued for 52 hours. The pumping rate was maintained between 26.4 and 29.1 liters per minute (lpm) for most of the test, after ramping up from an initial 21.9 lpm. Drawdowns at the end of the test appeared to have reached steady state. Test data was evaluated for wells 12-10A and 12-10B using the Cooper-Jacob solution for an unconfined aquifer.

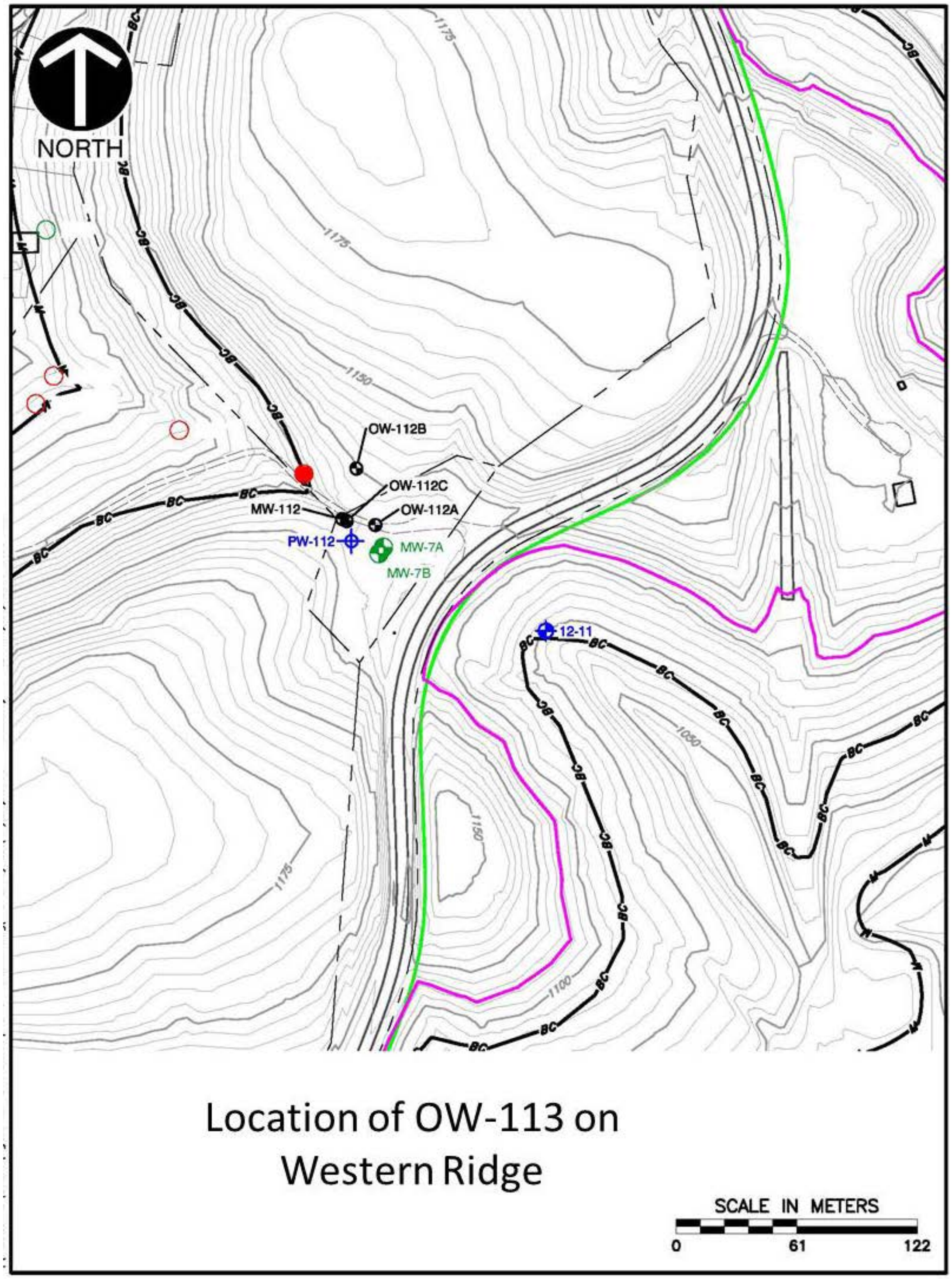

Figure 9. Location Map of OW-112b

The location on the West side of the solid waste landfill where the slug test of the Brush Creek Coal was conducted at OW-112b.

2.3.5.2 Bedrock

A pumping test was conducted at piezometer MW-103B to assess the properties of the rock units along the ridge. Observations wells for the test were piezometers MW-102B located 52 m, MW-105B located 135 m, MW-107B located 548 m, and MW-116B located 122 m from the pumping well. All piezometers were equipped with transducers and data loggers to record drawdowns.

The test was initiated on December 5, 2012 and continued for 47 hours. The pumping rate was maintained at 28.4 lpm. This test specifically targeted the Mahoning coal, to test whether this stratum was carrying a disproportionate amount of the groundwater beneath the ridge. The coal is approximately 1.5 m thick in this area.

An additional pumping test was conducted at piezometer MW-112 on the opposite side of the solid waste landfill from the study area (Figure 9). This pumping test had an observation piezometer, OW-112B which was screened across the Brush Creek coal seam. The test was initiated on October 8, 2012 and continued for 44 hours. The pumping rate was maintained at 5.7 lpm. This test was screened across multiple formations, but observation piezometer OW-112B was screened in the Brush Creek coal seam.

2.4 GROUNDWATER CONTROL INSTALLATIONS

2.4.1 Slurry Wall

Approximately 215 linear meters of soil-bentonite slurry wall was installed on the ridge (Figure 4 and 5). The wall was installed to elevation 332 m AMSL, approximately 12 m below ground surface at the crest of the topographic saddle near MW-103. The wall was installed between June 6, 2013 and July 7, 2013. Hydraulic conductivity testing on the trial mixes was performed to determine conformance with the specified permeability of 10^{-7} cm/sec. Laboratory testing of samples was performed to confirm the hydraulic conductivity of the placed material. The hydraulic conductivity ranged from 2.2×10^{-8} to 7.6×10^{-8} cm/sec.

2.4.2 Collection Trench

Approximately 426 linear meters of groundwater collection trench was installed 15 m from the solid waste 3 m deep (Figure 4 and 5). The collection trench was installed between June 3 and June 19, 2013. The drain includes three HDPE slope riser pipes and pumps to remove collected water. The pumps installed in the slope risers are EPG 17-2 Sump Drainer pumps with level sensors that are controlled by individual EPG Pumpmaster Controllers. The slope risers are fitted with disconnects to allow for removal and servicing of the pumps. The pumps discharge to the treatment system via individual 7.6 cm HDPE force mains. Pumping in the slope risers commenced on June 26, 2013 in the middle slope riser utilizing a temporary pump. Final pump installation occurred on September 4, 2013. A failure of the pumping trench occurred August 18 to October 6, 2014 and is discussed in section 3.2.

2.4.3 Pumping Well

Pumping well PW-103 was installed after completion of the barrier wall and collection trench (Figure 4).

The boring was advanced by 16 cm diameter HSA to bedrock refusal. Once the borings could no longer be advanced using HSA, air rotary was used to advance the borehole to the Mahoning Coal seam. The well was constructed with 10 cm diameter PVC casing and 0.025 cm slot screen. The annulus around the screen was filled with clean quartz sand and capped with a hydrated bentonite seal. The remaining annulus was filled to the ground surface with hydrated bentonite chips. The piezometers were completed with a steel protective cover and 0.75 m diameter concrete pad.

The pumping well is screened across the Brush Creek and Mahoning Coal seams to intercept any constituents which migrate through the permeable units (Figure 5). The pumping well screen was constructed from approximate elevation 325 to 300 m AMSL. A Grundfos Redi-flo3 SQE-NE submersible pump was installed in the well. The flow from the well is estimated to be less than 38 lpm and discharges to the treatment plant via 7.6 cm HDPE pipe. The pumping rate and water level is controlled with a Grundfos CU 300 control unit with a submersible pressure transducer.

3.0 RESULTS

3.1 AQUIFER PROPERTIES

3.1.1 Slug Tests

3.1.1.1 Solid Waste

The wells completed to intersect the top of the water table exhibit a range of hydraulic conductivity from 7 x 10^{-7} to 4 x 10^{-5} cm/sec, with a median of 1 x 10^{-5} cm/sec. The results of the slug test analyses shown on Table 4. Complete Aqtesolv spreadsheets are attached in Appendix C.

3.1.1.2 Bedrock

The wells completed at first water exhibit a range of hydraulic conductivity from 7 x 10^{-7} to 4 x 10^{-5} cm/sec, with a median of 1 x 10^{-5} cm/sec. The results of the slug test analyses are shown on Table 4 and depicted on Figures 10 and 11. Complete Aqtesolv spreadsheets are attached in Appendix C.

Table 4. Slug Test Results

Slug test results, the solution used for each analysis and how well the curve matched the data.

Well	Location	Completion Zone	Hydraulic Conductivity *cm/sec*	Solution	Match Quality
12-10A	Landfill	Solid Waste	4.E-05	Bouwer-Rice	Very good
P-1(50)	Landfill	Solid Waste	9.E-07	Cooper-Brdehoeft-Papadopulos	Fair/poor
P-1(150)	Landfill	Solid Waste	1.E-06	Cooper-Brdehoeft-Papadopulos	Fair/poor
P-1(220)	Landfill	Solid Waste	1.E-03	Bouwer-Rice	Very good
MW-101	Ridgeline	First water, undesignated	2.E-06	Bouwer-Rice	Very good
MW-103A	Ridgeline	First water, undesignated	3.E-06	Bouwer-Rice	Fair
MW-103C	Ridgeline	Lower Glenshaw aquifer	2.E-06	Bouwer-Rice	Very good
MW-105	Ridgeline	First water, undesignated	1.E-05	Bouwer-Rice	Good
MW-107A	Ridgeline	First water, undesignated	2.E-06	Bouwer-Rice	Good
MW-107B	Ridgeline	Mahoning coal	9.E-05	Bouwer-Rice	Very good
MW-107C	Ridgeline	Glenshaw Formation	9.E-04	KGS Model	Fair
MW-110	Ridgeline	First water, undesignated	7.E-07	Bouwer-Rice	Good
MW-111	Ridgeline	First water, undesignated	2.E-05	Bouwer-Rice	Fair
MW-113	Ridgeline		2.E-05	Bouwer-Rice	Fair/poor
MW-114A	Ridgeline		2.E-05	Bouwer-Rice	Good
MW-114B	Ridgeline		3.E-04	Bouwer-Rice	Fair

3.1.2 Single Well Pumping Test

The transmissivity obtained from the single well pumping test was 0.57 cm^2/sec (Table 5, Figure 10 and 11) which is in reasonable agreement with the multi-well pumping test transmissivity of 0.3 cm^2/sec at MW-103B and the transmissivity of 0.2884 cm^2/sec at MW-112 discussed below.

3.1.3 Multi-Well Pumping Test

3.1.3.1 Solid Waste

The transmissivity obtained for both observation wells was 3 cm^2/sec and are shown on Table 5 and depicted on appropriate units in Figures 10 and 11. Complete Aqtesolv spreadsheets are attached in Appendix C. The specific yield values based on the pumping test results were 2.8 and 3.8%. These values are relatively low for specific yields in general, but are considered typical for the solid waste material in this study (silt and clay sized particles). At a typical porosity of 78% for the solid waste, 75% of the material would consist of non-drainable pore space.

Because the steady state was achieved during the test, the final drawdowns can be used to compute a radius of influence for the pumping well. The steady state radius of influence is estimated at 70 m based on the final drawdown data.

Table 5. Pumping Test Results

Pumping test results, the solution used for each test and how well the curve matched the data.

Well	Location	Test Type	Transmissivity cm^2/sec	Solution	Match Quality
12-10	Landfill	Multi-well Pumping Test	2.E-01	Neuman	Very good
12-10A	Landfill	Multi-well Pumping Test	3.E+00	Cooper-Jacob	Good
12-10b	Landfill	Multi-well Pumping Test	3.E+00	Cooper-Jacob	Good
MW-103B	Ridgeline	Single well Pumping Test	6.E-01	Theis	Very good
MW-103B	Ridgeline	Multi-well Pumping Test	3.E-01	Theis	Fair
MW-102B	Ridgeline	Multi-well Pumping Test	3.E-01	Cooper-Jacob	Very good
MW-105B	Ridgeline	Multi-well Pumping Test	4.E-01	Theis	Good
MW-107B	Ridgeline	Multi-well Pumping Test	3.E-01	Theis	Good
MW-116B	Ridgeline	Multi-well Pumping Test	4.E-01	Theis	Good
OW-112B	Ridgeline	Multi-well Pumping Test	3.E-01	Theis	Good

3.1.3.2 Bedrock

Drawdowns during the MW-103B pumping test, which is screened in the coal seam, did not achieve steady state during the pumping test in bedrock. The wells completed in the coal exhibited a transmissivity of 0.3 cm^2/sec. Using the thickness of the Mahoning coal at the individual well locations, the transmissivities translate to a hydraulic conductivity of 2 x 10^{-3} cm/sec. The low storage coefficient is consistent with confined conditions. A steady-state radius of influence cannot be accurately projected because steady-state conditions were not achieved. However, the drawdowns that were observed indicate that such a radius will be substantial, in excess of 460 m (Figure 12).

Drawdown during the MW-112 pumping test, which is screened across multiple layers, achieved steady state. Observation piezometers OW-112B, which is screened in the Brush Creek coal seam, showed a transmissivity of 0.2884 cm^2/sec. Using this transmissivity, and the thickness of the Brush Creek coal seam in the investigation area the transmissivity translates to a hydraulic conductivity range of 4 x 10^{-3} to 8 x 10^{-3} cm/sec.

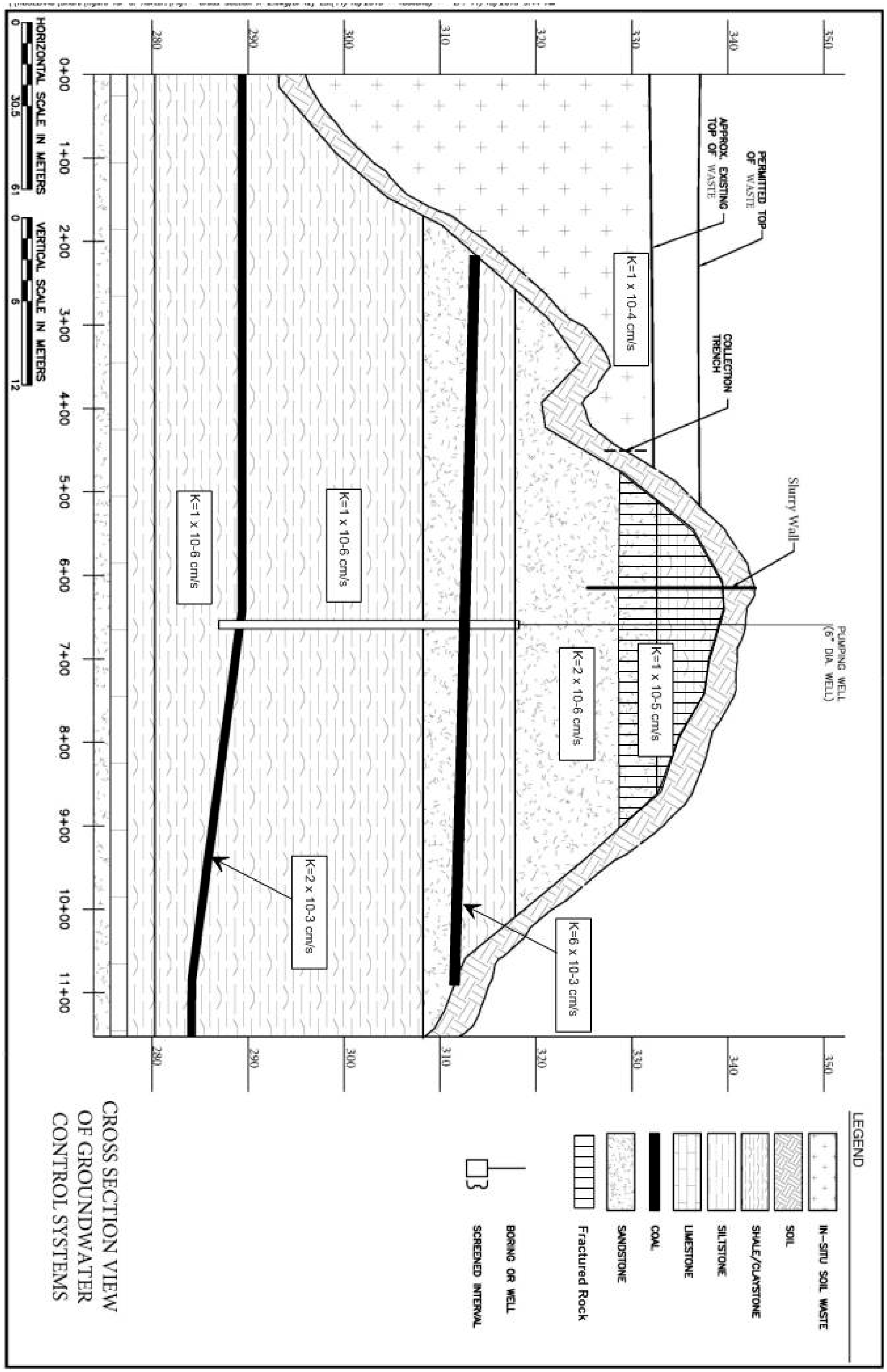

Figure 10. Cross Section A of Research Area

Cross Section A from Figure 4 showing the calculated hydraulic conductivities for tested wells.

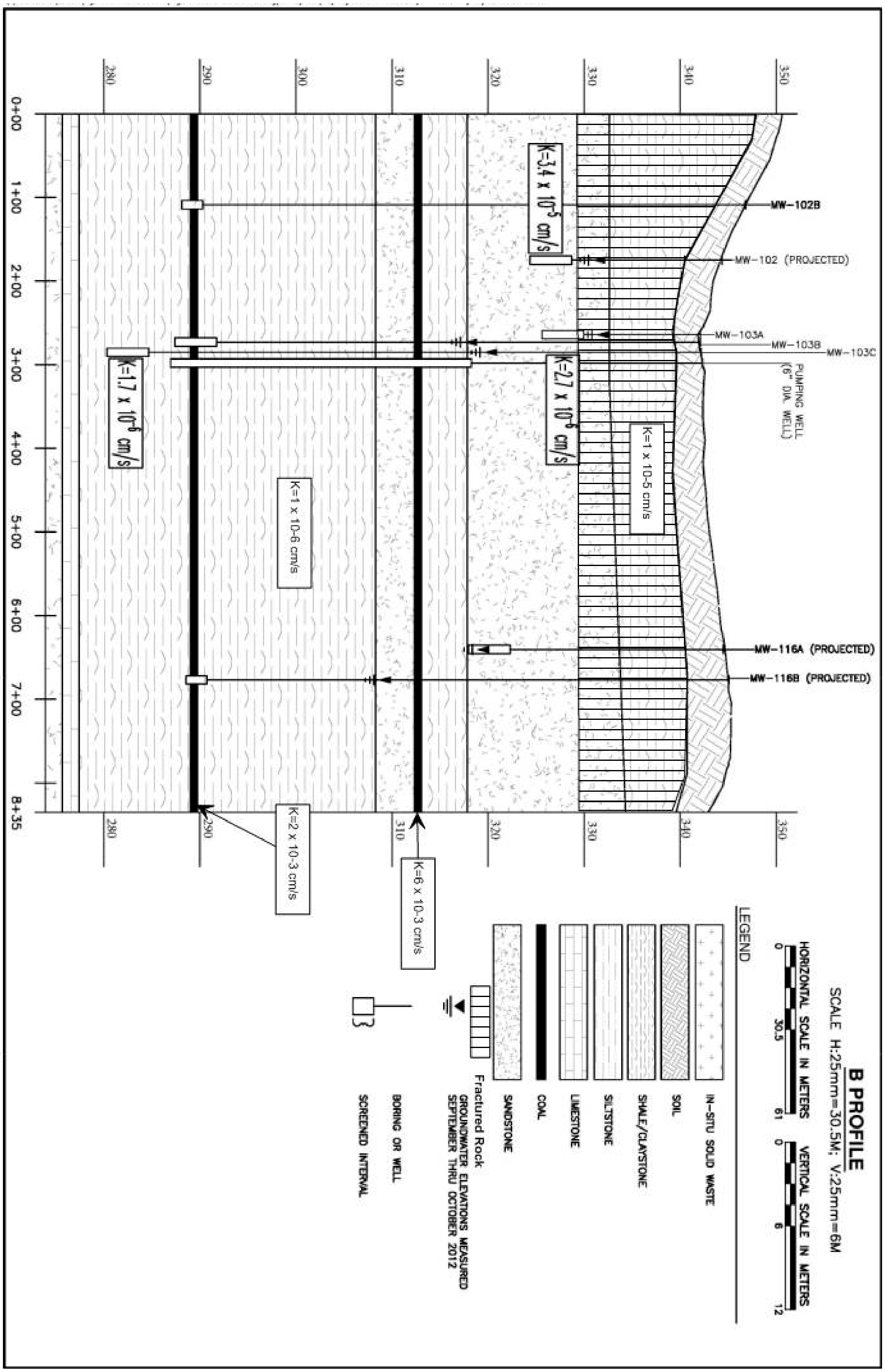

Figure 11. Cross Section B of Research Area

Cross Section B from Figure 4 showing calculated hydraulic conductivities from tested wells.

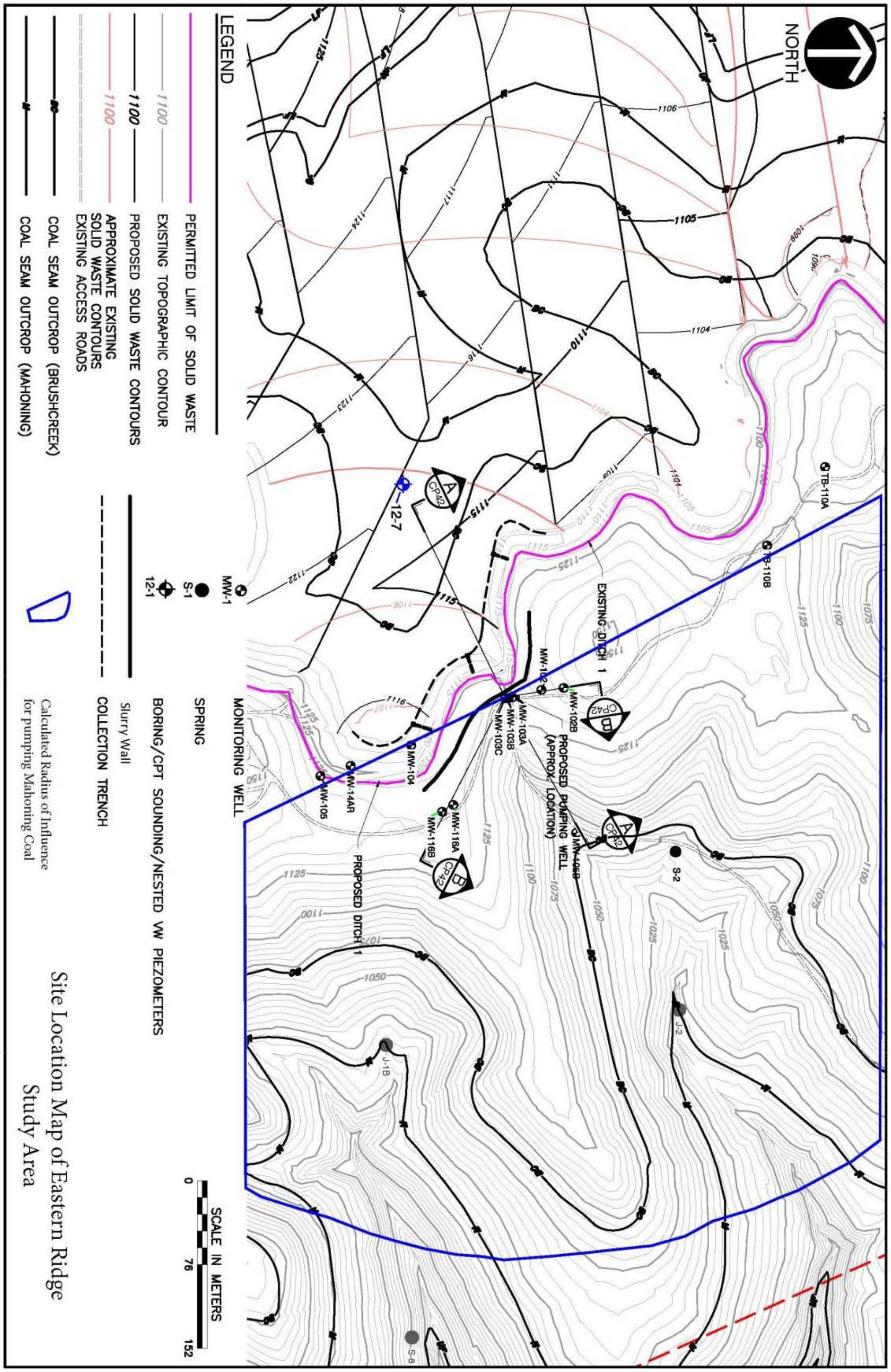

Figure 12. Radius of Influence Map

Radius of influence from pumping test in Mahoning Coal seam.

3.2 PERTURBATIONS IN GROUNDWATER CONTROL TECHNOLOGIES

3.2.1 Pumping Trench

On August 18, 2014 the two pumps in the pumping trench stopped working and the trench was only pumped on the northern and southern edge. The pumps were not reinstalled until October 6, 2014. In the months following the pumping trench failure, Spring-2 water chemical concentrations increased for chloride, calcium, magnesium and sulfate (Figure 13). In contrast, concentrations in Spring-1 stayed relatively stable (Figure 13).

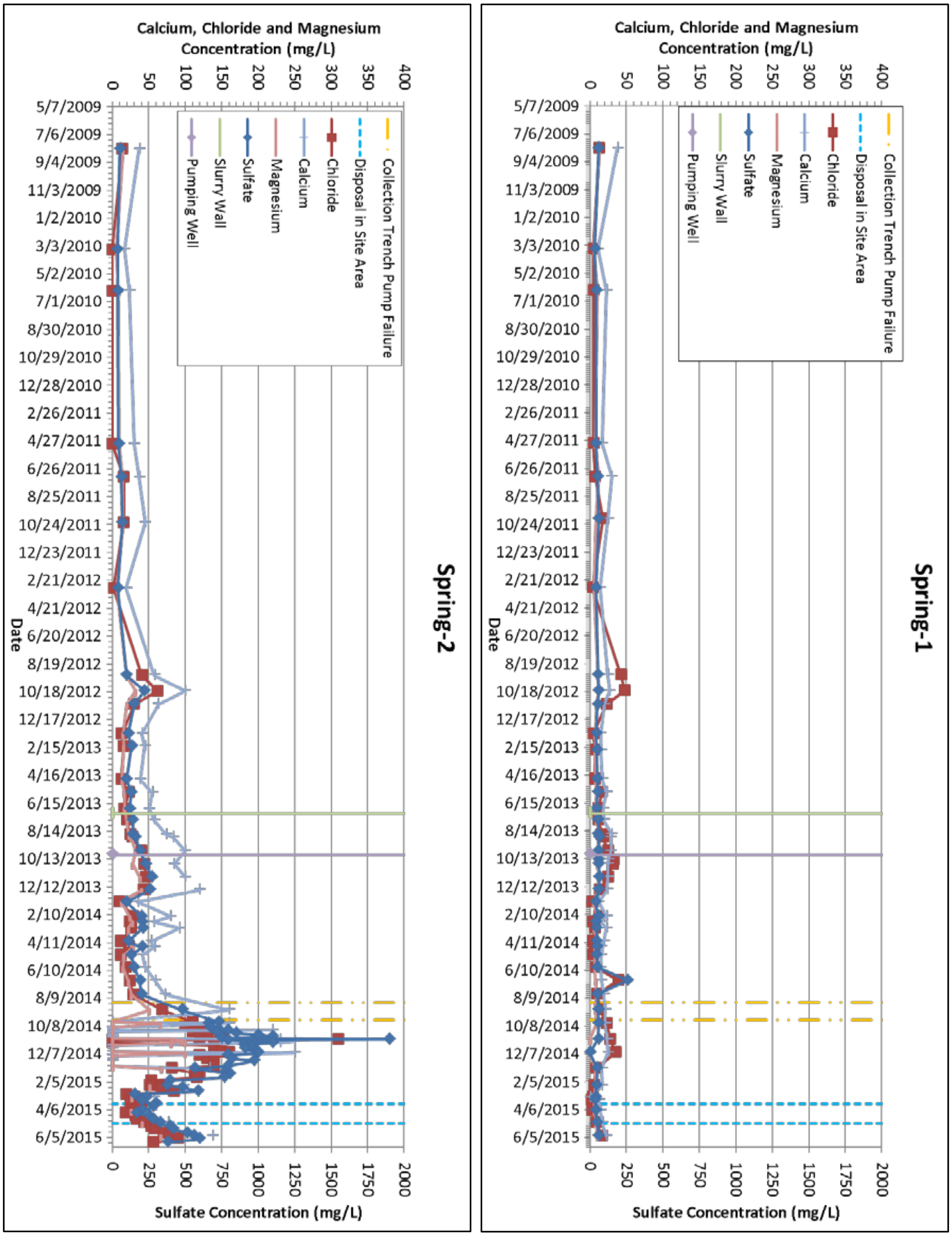

Figure 13. Water Quality at Spring-1 and Spring-2

Concentrations increase in Spring-2 after the pump failure in the collection trench August 2014.

It appears that when the pumping trench failed calcium, magnesium, chloride, and sulfate concentrations increased in Spring-2 even with the continuous operation of the groundwater pumping well. Groundwater pumping on the ridge has been continuous from October 2013 through the end of the research period in June 2015. Both piezometer PZ-103 and monitoring well MW-103A (installed next to the pumping well) had an approximate 0.5 m rise in groundwater elevation when the center pump in the pumping trench failed in August 2014 (Figure 14). In December 2014 groundwater levels rose 1.5 to 2.0 m. This can be attributed to more rain during this time period. The groundwater elevations returned to previous levels in February 2015. Groundwater elevations increased again in March 2015 (Figure 14).

The increase in groundwater elevation in March 2015 was caused by the resumption of solid waste disposal in the study area. Disposal continued until May 2015 and groundwater levels returned to the 336 m to 337 m amsl range. This shows that during disposal water levels in front of the pumping well increased to the 337.5 m amsl range with a maximum level measurement of 339 m amsl on April 10, 2015. Concentrations of chloride, magnesium and sulfate in Spring-2 increased and maxed out on June 8, 2015. Sulfate levels went from 206 mg/L to 598 mg/L, magnesium levels increased from 25.8 mg/L to 67 mg/L, calcium levels increased from 53.2 mg/L to 138 mg/L, and chloride levels increased from 18.3 mg/L to 90.1 mg/L. At the June 15, 2015 sampling event concentrations decreased in sulfate (382 mg/L) and chloride (55.8 mg/L) (Figure 13).

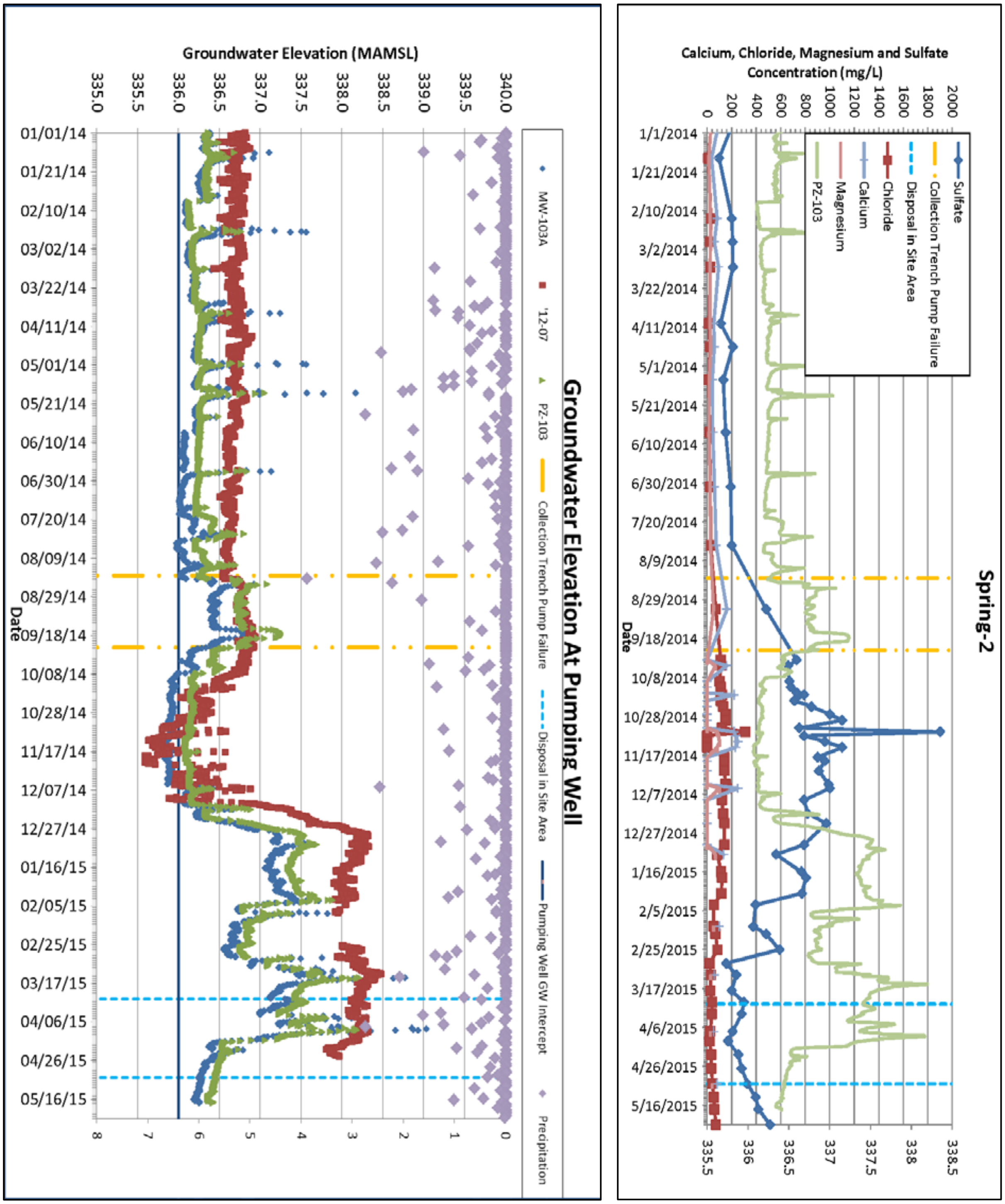

Figure 14. Spring-2 Water Quality Compared to Groundwater Elevations

Groundwater Elevations in the landfill and at the Pumping well compared to daily precipitation, and the water chemistry at Spring-2.

4.0 DISCUSSION OF AQUIFER PROPERTIES AND WATER QUALITY

The transmissivity value from the pumping test in the solid waste was on the same order of magnitude as the average of the high end slug test values (10^{-4}). It is not unusual for slug tests to estimate lower hydraulic conductivity values than pumping tests, because the pumping test reflects a larger volume of material and a greater number of natural discontinuities. Based on pumping tests conducting in the landfill the solid waste material has an in-situ effective hydraulic conductivity of 9.7×10^{-4} cm/sec.

The bulk of the rock mass, excluding the fractured bedrock, in the ridge exhibits a relatively low hydraulic conductivity, with a median hydraulic conductivity of 10^{-6} cm/sec. Permeability decreases with depth due increased overburden pressure and decreased weathering, and stress relief. The higher permeabilities are related to fracture traces and coal beds. The fractured bedrock exhibited a hydraulic conductivity in the 10^{-5} cm/sec range. These measurements indicate that the fracture traces likely transmit groundwater through the ridge at a much greater rate than the bulk rock mass.

The saddle in the ridge alone is an indication that groundwater might preferentially flow through this area. The saddle would indicate that the rock below it was weaker (e.g., fractured) which caused preferential weathering and resulted in the saddle. Secondary permeability due to jointing and stress-release fracturing accounts for most of the porosity and permeability in the Appalachian Plateau creating drainage nets (Seaber et al, 1988). When the rock mass above the saddle was removed, this accentuated the process as the compression on the rock was further reduced, likely causing additional fracturing. This fracturing is a potential preferential pathway for the contaminated groundwater flow along the ridge, further complicating the hydrogeology.

Under the conditions on our site, our results indicate the majority of contaminated groundwater flows through the fractured bedrock. This has been determined based on several observations:

1. When the pumping trench (which is set in fractured bedrock) failed, the concentrations of calcium, magnesium, chloride and sulfate increased in Spring-2 (Figure 10 and 13).

Chloride and sulfate concentrations exceeded the PADEP chapter 93 Water Quality Standards (Standards) of 250 mg/l.

2. While the pumping trench was operating at 1/3 capacity, and the pumping well (which is set in the coal seams and sandstone) did not prevent the concentrations of calcium, magnesium, chloride and sulfate from increasing in Spring-2. This indicates that while the coal seams have a high hydraulic conductivity they do not seem to transport the bulk of the contaminated groundwater flow through the ridge.
3. The slurry wall does not seem to prevent contaminated groundwater flow through the fractured bedrock. Ultimately, it was installed to slow down flow through the fractured rock, however, our data do not allow assessment of how effective this slowing is.

A rock unit having the highest hydraulic conductivity does not necessarily mean it will be the preferential flow pathway. In addition to the observations above, Spring-1 is located in a similar arrangement with the coal to Spring-2, but further from the saddle. Limited water quality effects at Spring-1 throughout the sampling period are consistent with primary contaminated groundwater transmission through the fractured rock, particularly in the saddle. This flow through the fractured zone may arise for several reasons. While the hydraulic conductivity of the coal (~10^{-3} cm/sec) is higher than the fractured bedrock (~10^{-5} cm/sec) but the compression levels of the coals seams are higher given their relative depth, and the coal seams are thin, particularly relative to the fractured rock. Based on the depth of the fractured rock versus the coal seam (12 m thick for the fractured rock on the ridge and 71 cm thick for the coal seam), the relative thickness of the aquifer materials, and the potential for a concentrated zone of fracturing in the saddle, it seems reasonable that the majority of groundwater flow could occur through the fractured rock.

Using the failure of the pumping trench in August to October 2014 as an unintended experiment, the effectiveness of the pumping well can be examined. Because the slurry wall does not remove groundwater flow through the ridge, the pumping well was the primary mechanism to limit contaminated groundwater flow through the ridge to Spring-2. The concentrations in the spring water during this time period indicate that the pumping well did not control the flow of contaminated groundwater through the ridge (Figure 13). Using the hydraulic conductivity of 10^{-5} cm/sec and assuming a porosity of 0.1 (for fractured rock), a pore water velocity of 0.1 meters per day was calculated. Based on this, it was determined that when the pumping trench failed it would take contaminated groundwater approximately 2,580 days to travel to Spring-2. The pumping trench failed on August 18, 2014 (Figure 13) and concentrations of calcium, chloride, magnesium, and sulfate all increased at the next sampling event on September 3, 2014. The pumping trench resumed operation on September 24, 2014. Concentrations continued to increase until November 5, 2014 (42 days after pumping resumed) before starting to decrease. This rapid change in spring water chemistry suggests that the primary flow path through the ridge is through macropores and fractures in the rock. Pumping tests of the fractured bedrock were not conducted and this fast flow could have been missed by the slug testing.

To determine if Spring-1 was impacted by the contaminated groundwater and ensure that the coal seams are not the preferential flow pathway for contaminated groundwater flow, water quality from October 16, 2012 was examined. Comparison of water quality between Spring-1 and Spring-2 from October 16, 2012 reveals specific differences in contaminant concentrations. If the source of water at Spring-1 and Spring-2 were the same, they should have similar relative concentrations of analytes. However, Spring-1 concentrations of chloride, sodium, magnesium, calcium, and sulfate on October 16, 2012 were similar to historic concentrations with lower concentrations of alkalinity (Table 2). Spring-2 has a higher concentration of calcium and sulfate relative to the magnesium, sodium, chloride and alkalinity concentrations (Table 2). When comparing water quality at Spring-1 and Spring-2 to landfill water (Figure 15), Spring-2's radial plot shape is closer to the shape of the landfill water radial plot than to Spring-1's radial plot, particularly in the concentrations of calcium and sulfate. This indicates that in addition to contrasts in concentration magnitude, the source of water constituents are likely distinct. This comparison is evidence that the coal seams are not the preferential flow path for the contaminated groundwater. Further, the similarity between Spring-2 and the landfill water radial plot shapes suggests that water quality at Spring-2 is be affected by the landfill. To further show that Spring-1 is not impacted by the landfill the radial plots from 10/16/12 and 11/5/14 are compared (Figure 15 and 16). The plot shapes for Spring-1 are similar in shape and magnitude. When comparing the radial plots for Spring-2 from 10/16/12 and 11/5/14 (Figures 15 and 16) there is a large increase in sulfate concentrations because of the increased flow from the landfill. The calcium sulfate concentration magnitude at Spring-2 on 11/5/14 is similar to the landfill water (Figure 16).

Another way to analyze the differences in contaminant concentrations in Spring-1, Spring-2, and the landfill is examining associations between contaminants. Figure 17 shows the association between sulfate and alkalinity during the research period at Spring-1, Spring-2, and the landfill water. The association at Spring-1 stays relatively consistent throughout the research period. Apart from some outliers, the landfill water shows a relatively consistent sulfate to alkalinity association throughout the research period. The association for Spring-2 samples through August 1, 2014 show similar sulfate to alkalinity associations as the Spring-1 data. After August 1, 2014 the sulfate to alkalinity associations start migrating toward associations found in the landfill water. This evolution in water chemistry suggests that 1) the water feeding Spring-1 receives relatively minimally contributions from the solid waste landfill when compared to Spring-2.

The calculated travel time of impacted water in the landfill to Spring-1 is the same as Spring-2. Using the calculation discussed above for travel time to Spring-2, it was determined that it would also take impacted water 2,580 day. This indicates that Spring-1 is not tied to the landfill by fractures like it appears to be the case at Spring-2.

Examining the water quality at Spring-2 over time allows evaluation of the effectiveness of the pumping trench. Specifically, using water quality data around the time of the pumping trench failure can help with this. Prior to the pump failure, while solid waste disposal was not occurring near the ridge area, the collection trench appears to prevent sufficient contaminant flow through the saddle in the ridge, as water chemistry remains under permitted concentrations during this period. Concentrations of chloride and sulfate exceeded the Standards of 250 mg/l at Spring-2 on November 15, 2014 before dropping below the standards again even though the pumping trench resumed operation on September 24, 2014. On March 25, 2015, near the end of the research period, disposal resumed near the ridge while the pumping trench was in operation. Concentrations of calcium, magnesium, chloride, and sulfate started to increase again (Figure 13). The water quality data before March 25, 2015 shows that the collection trench helps reduce contaminant flow through the ridge when disposal is not occurring near the research area.

Due to the location of the slurry wall it seems to be of limited effectiveness. The slurry wall was installed down gradient of the pumping trench so even if the slurry wall slows down groundwater flow through the fractured rock the pumping trench will not necessarily remove the contaminated groundwater. The pumping well is installed in the sandstone and coal seams so it will not remove the contaminated groundwater from the fractured rock that the slurry wall is slowing down.

The ultimate goal of this system was minimizing the flow of contaminated groundwater to Spring-2 and keep contamination levels downstream below PADEP approved levels. Based on the Standards the maximum allowable concentrations for chloride and sulfate in surface water is 250 mg/L. Chloride levels in Spring-2 only exceeded the Standards of 250 mg/L on November 15, 2014 and continued to be below the Standard through June 2015. Prior to additional disposal of material in the Site area starting in March 2015, sulfate levels were reduced to below 250 mg/L in Spring-2. After disposal in the Site area was resumed, the sulfate levels increased to concentrations over 250 mg/l. Disposal was ceased in the Site area in May 2015. Sulfate levels reached a maximum concentration of 598 mg/l on June 8, 2015 then decreased to 382 mg/l on June 15, 2015. If the water quality downstream of the site exceed the PADEP SWQS fines will be issued, and if the concentrations exceed for an extended period of time the discharge permit could be revoked. If this happens the operator of the landfill will no longer be able to dispose of waste in the research area.

It is assumed that when the landfill is closed and the waste is capped, the pumping trench effectiveness will increase and eventually no longer be necessary. Eventually (model estimates are 3-5 years) the landfill will be dewatered to levels where groundwater elevations are below the collection trench, and the pumps will be turned off. When the water levels in the landfill drop below the fractured bedrock water quality at Spring-2 is expected to eventually return to background conditions.

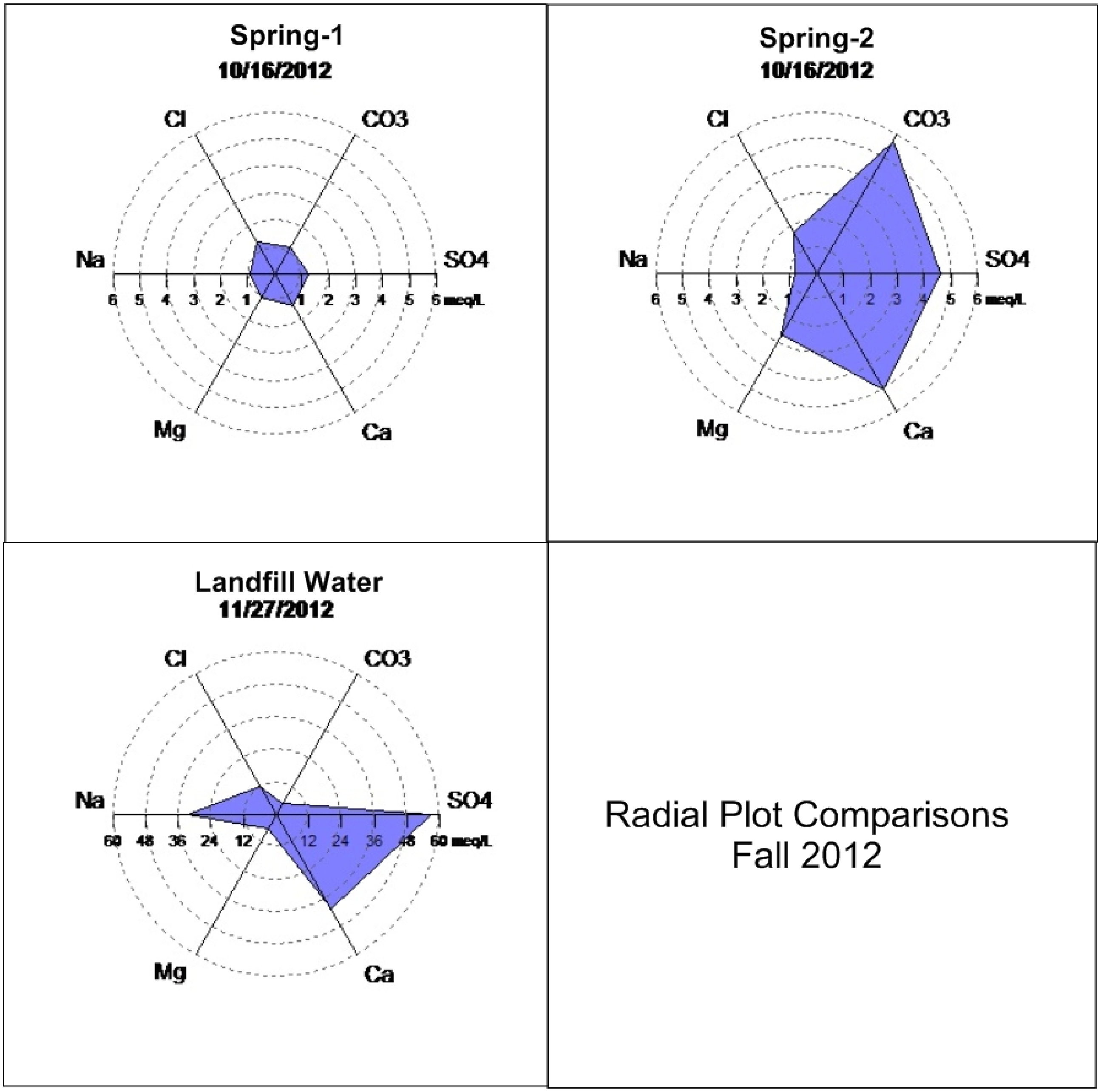

Figure 15. Radial Plots of Water Quality-Fall 2012

Radial plots of water quality at Spring-1, Spring-2 on 10/16/12 and the landfill water on 11/27/12.

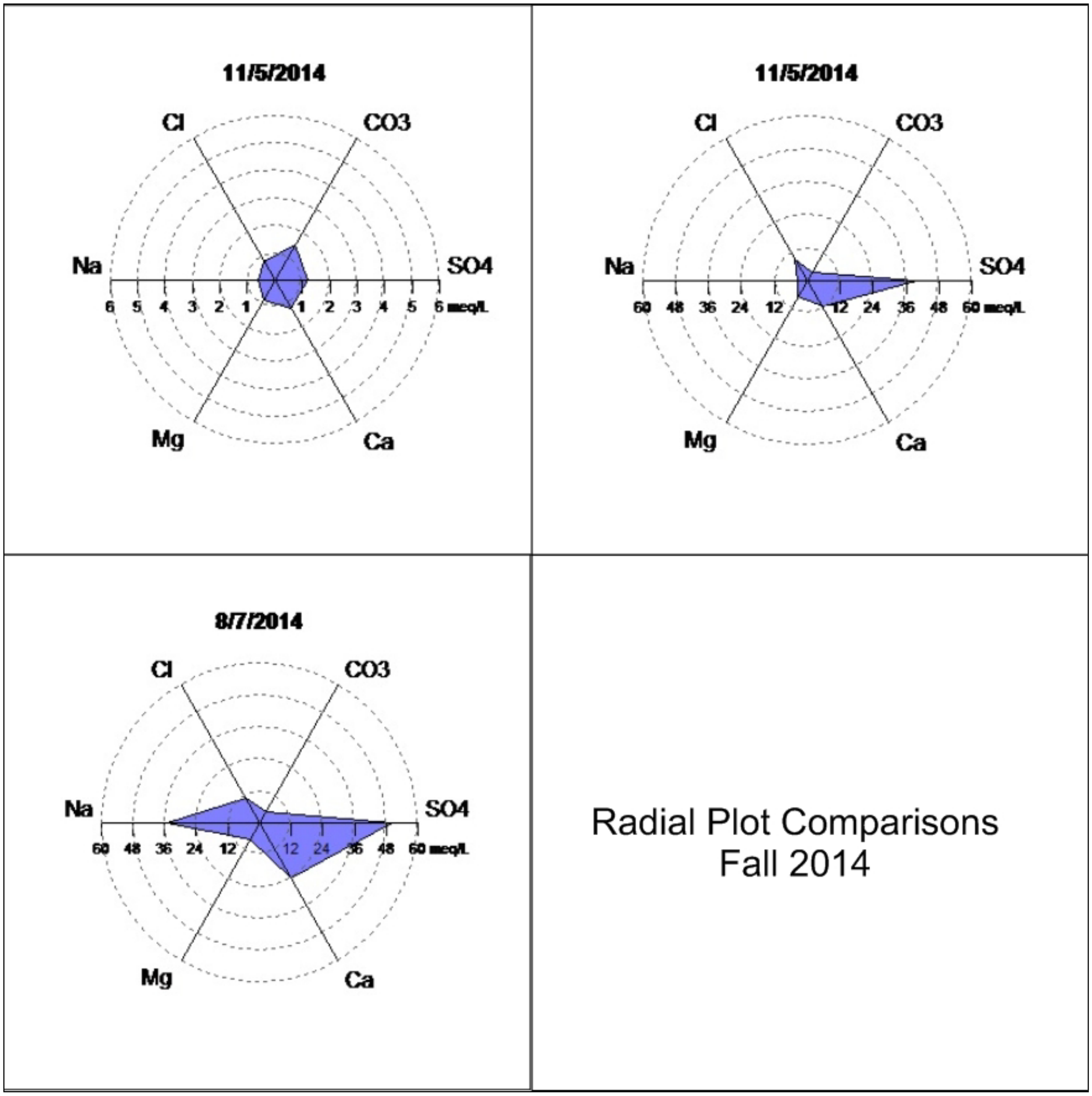

Figure 16. Radial Plots of Water Quality-Fall 2014

Radial Plots of Spring-1, Spring-2 and the landfill after the pump failed in the collection trench.

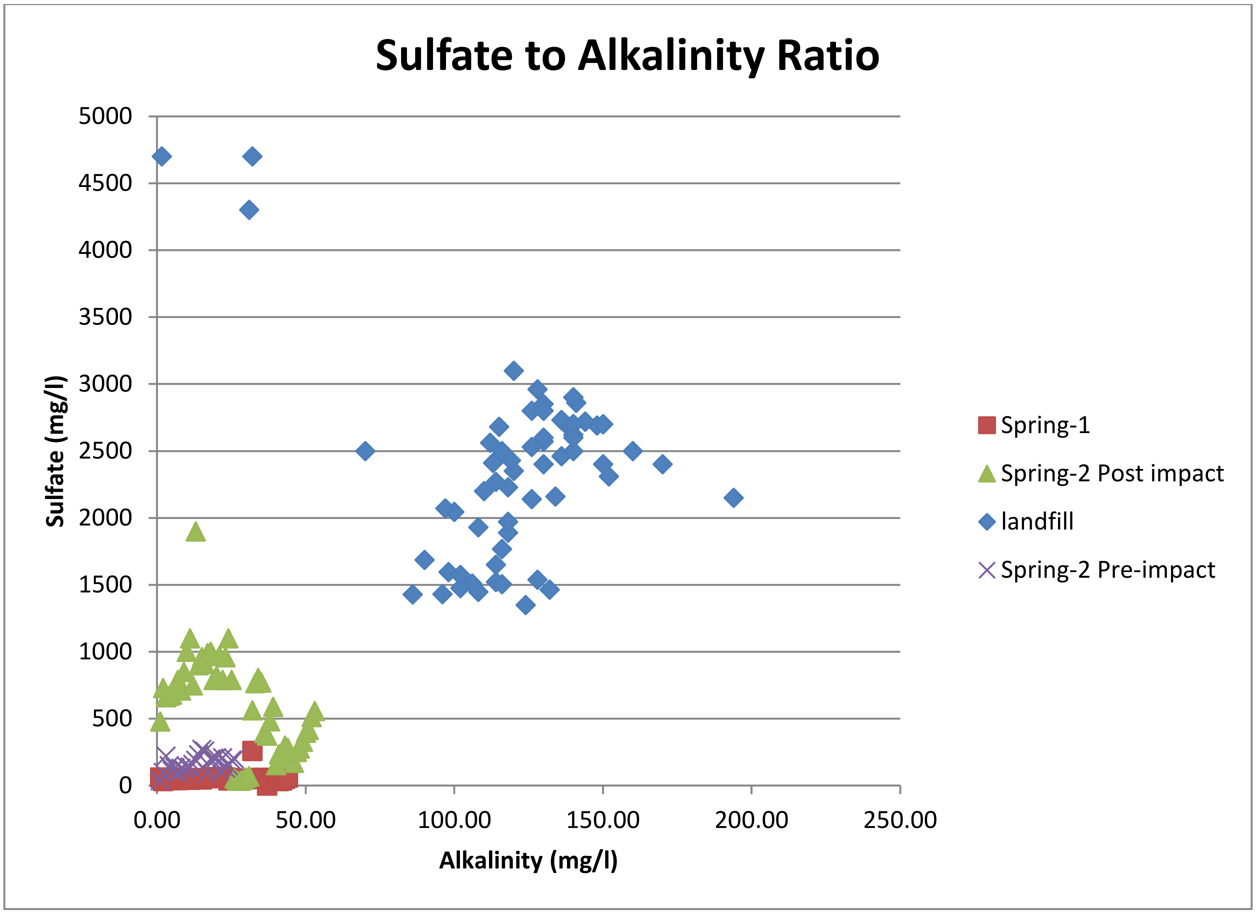

Figure 17. Sulfate to Alkalinity Comparison

Alkalinity to Sulfate association at Spring-1, Spring-2 pre-impact, Spring-2 post impact, and the landfill during the research period.

5.0 CONCLUSIONS

This research suggests that a system of groundwater control devices is not necessarily effectively preventing contaminated groundwater flow from a legacy landfill. The majority of contaminated groundwater flow appears to move through the fractured rock zones, contrary to designer expectations. This reality makes the collection trench the most effective control system. The preliminary evaluation before the groundwater control system was installed underestimated the flow through the fractured system and overestimated the flow through the coal seams. The differences between design and function diminished effectiveness in groundwater control.

Regardless of shortcomings in function, this site remains a challenge to manage. Topographic constraints in the site area prevent installation of potentially more optimal configurations (e.g., Bayer, 2006.) Installation of multiple control devices in this sort of complex hydrogeologic setting remains the best way to address these challenges. This measurement of system effectiveness reveals that models can guide design, but heterogeneity and unconformities are fundamentally important to successful groundwater control.

This research was conducted to determine if the three groundwater control systems were effective working in conjunction to control the flow of impacted groundwater from the landfill. Follow-up work may be conducted to examine the geochemical effects of the coal seams on the impacted groundwater. The coal seams could be acting as filters that are reducing concentrations of the impacted water as it flows through the coal seams. Additionally, this research was conducted over 3 years. Based on the calculated flows through the fractured rock Spring-1 could become impacted by the landfill in the future which will be observed from continued sampling.

APPENDIX A

WATER QUALITY DATA

Table A-1 (Page 1 of 4)
Spring-1

	Spring-1	Spring-1	Spring-1	Spring-1	Spring-1	Spring-1	Spring-1	Spring-1	Spring-1	Spring-1	Spring-1
Date Sampled:	8/6/2009	3/11/2010	6/9/2010	5/4/2011	7/14/2011	10/13/2011	3/9/2012	9/13/2012	10/16/2012	11/15/2012	1/17/2013
Field Parameters											
Flow (gpm)									2	3	25
pH (S.U.)	7.37	6.31	6.5		7.5	7.63	7.44	7.54	6.95	6.93	6.81
ORP (mV)	92	137	184		22	46.1	139	28.9	89.6	39	41.7
Dissolved Oxygen (mg/l)								7.84	5.6		10.12
Conductivity (umhos/cm)	313.8	135.6	187.9		269	332	155.9	339	314	290.6	152
Temperature (C)	16.5	4.2	14.3		19.43	16.95	6.2	21.89	12.78	6.6	6.54
Dissolved Metals (mg/l)											
Aluminum											
Antimony											
Arsenic								<0.001	0.00099 J B		
Barium								0.068 B	0.066		
Beryllium											
Boron								0.079 B ^	0.036 B		
Cadmium								<0.001	<0.001		
Calcium								27 B	27		
Chromium								0.0005 J	0.00026 J		
Cobalt											
Copper								0.0011 J B	0.00066 J		
Cyanide									<0.01		
Iron								0.0071 J	0.015 J B		
Lead								0.000021 J B	0.000049 J		
Magnesium								12 B	12 B		
Manganese								0.11 B	0.1		
Mercury								<0.0002	<0.0002		
Molybdenum								0.0015 J B	0.00029 J B		
Nickel											
Potassium								2.6 B	2.2 B		
Selenium								<0.005	0.0022 J B		
Silver								<0.001	<0.001		
Sodium								20 B	22 B		
Thallium								0.00015 J B	<0.001		
Vanadium											
Zinc								0.0066 B	0.0049 J		
Total Metals (mg/l)											
Aluminum											
Antimony											
Arsenic	0.0042	<0.0025	0.0058	<0.0025	<0.0025	<0.0025	0.0002 J	0.0012 B	0.0015 B	0.00016 J	<0.001
Barium								0.065	0.066		
Beryllium											
Boron	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.021	0.036 B	0.035 B	0.026 B	0.033 B
Cadmium								<0.001	<0.001		
Calcium	38	11	23	17	30	25	14	25	27	20	15
Chromium								0.00024 J	0.00023 J		
Cobalt											
Copper								0.0009 J	0.00055 J		
Cyanide									<0.01		
Iron	8.2	0.75	14	0.47	0.64	0.13	0.29 B	0.048 J	0.09 B	0.072	0.23 B
Lead								0.000052 J B	0.000023 J		
Magnesium	13	5.9	10	7.3	12	8.9	6.1	11	12	9	7.1
Manganese	0.59	0.55	0.54	0.031	0.19	0.032	0.02	0.11	0.17	0.03	0.032 B
Mercury	<0.0008	<0.0008	<0.0008	<0.0008	<0.0008	<0.0008	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002
Molybdenum								0.0011 J B	<0.005		
Nickel											
Potassium	3.4	1.8	4.2	1.5	3.5	2.1	1 B	2.4	2.2 B	1.3	1.1 B
Selenium								0.0041 J B	0.0044 J B		
Silver								<0.001	<0.001		
Sodium	5.3	2.9	2.6	4.8	9.4	6.9	4 B	19	21 B	15 B	5.3 B
Thallium								0.000093 J	<0.001		
Vanadium											
Zinc								0.0083	0.0027 J		
General Chemistry (mg/l unless otherwise noted)											
Ammonia	0.15	<0.050	<0.05	0.096	0.078	0.069	0.22 B	0.25 B	0.098 J B		
Total Alkalinity	73	6.8	37	13	72	30	14 B	36 B	33 B	43 B	22 B
Bicarbonate Alkalinity as CaCO3	73	6.8	37	13	71	30	14 B	36 B	33 B	35 B	22 B
Chemical Oxygen Demand	56	<20	69	<20	<20	34	<10	12	43		
Chloride	13	5	5	5	7.2	18	4.1	43	48	23	4.8
Fluoride	<1	<1.0	<1	<1.0	<1.0	<1.0	0.28 B	0.087	0.15		
Laboratory pH (S.U.)	7.26	6.86	7.17	7.22	7.76	7.46	6.54 HF	7.08 HF	7.15 HF		
Nitrate as N	0.11	2.3	0.5	0.29	0.48	0.6	2.4 B	<0.05	<0.05		
Nitrate Nitrite Nitrogen								0.022 J			
Specific Conductance (umhos/cm)	310	<5.0	180	160	260	270	160	340	350	280	170
Sulfate	61	35	43	42	53	61	42	55	59	53	43
TDS	100	80	110	110	160	190	110	190	210	170	95
Total Hardness											
Total Organic Carbon	1	1.2	3.8	1.8	4.1	2.4	1.1	2.1	1.8		
Turbidity (NTU)	510	2.8	15	8.1	4.1	4.0	5.7	0.39 J	0.46 J	0.66 J	2.6

Notes:
< - Analyte was not detected above the indicated Laboratory Reporting Limit.
J - The analyte was positively identified but the value is estimated as it is below the Laboratory Reporting Limit but above the Method Detection Limit
B - Compound was found in the blank and sample.

Table A-1 (Page 2 of 4)
Spring-1

	Spring-1	Spring-1	Spring-1	Spring-1	Spring-1	Spring-1	Spring-1	Spring-1	Spring-1	Spring-1	Spring-1
Date Sampled:	2/21/2013	4/25/2013	5/23/2013	6/27/2013	7/22/2013	8/21/2013	8/28/2013	9/26/2013	10/15/2013	10/24/2013	11/21/2013
Field Parameters											
Flow (gpm)	13	15	1.5	10	6	1		<0.5	0.5	<0.5	
pH (S.U.)	7.92	7.41	7.88	7.05	7.44	7.58	7.46	7.37	6.39	7.85	7.89
ORP (mV)	209	192	157	114	115	79	29	-76.4	169	53	
Dissolved Oxygen (mg/l)											
Conductivity (umhos/cm)	210	176	253.3	228.3	255	267.9	268.1	291	307	313.5	399.9
Temperature (C)	2.1	11.2	17.6	18.3	21.5	18.9	21.2	18.6	12.9	8.8	8.9
Dissolved Metals (mg/l)											
Aluminum	<0.02	<0.02			<0.02				<0.02		
Antimony	<0.03	<0.03			<0.03				<0.03		
Arsenic	<0.005	<0.005			<0.005				<0.005		
Barium	0.0314	0.0367			0.0428				0.0565		
Beryllium	<0.005	<0.005			<0.005				<0.005		
Boron	<0.2	<0.2			<0.2				<0.2		
Cadmium	<0.0025	<0.0025			<0.0025				<0.0025		
Calcium	15.6	17.2			18.9				25.4		
Chromium	<0.01	<0.01			<0.01				<0.01		
Cobalt	<0.005	<0.005			<0.005				<0.005		
Copper	0.0103	<0.01			<0.01				<0.01		
Cyanide					<0.01				<0.01		
Iron	<0.05	<0.05			<0.05				<0.05		
Lead	<0.005	<0.005			<0.005				<0.005		
Magnesium	7.51	7.63			9.17				11.2		
Manganese	0.0177	0.0264			0.0504				0.15		
Mercury	<0.0002	<0.0002			<0.0002				<0.0002		
Molybdenum	<0.005	<0.005			<0.005				<0.005		
Nickel	<0.02	<0.02			<0.02				<0.02		
Potassium	1.03	1.1			1.35				2.21		
Selenium	<0.005	<0.005			<0.005				<0.005		
Silver	<0.005	<0.005			<0.005				<0.005		
Sodium	6.98	6.12			9.5				13.9		
Thallium	<0.0025	<0.0025			<0.0025				<0.0025		
Vanadium	<0.005	<0.005			<0.005				<0.005		
Zinc	<0.02	<0.02			<0.02				<0.02		
Total Metals (mg/l)											
Aluminum	0.0724	0.0571			<0.02				<0.02		
Antimony	<0.03	<0.03			<0.03				<0.03		
Arsenic	<0.005	<0.005			<0.005		0.0008 J	0.00058 J	<0.005	0.00038 J	<0.001
Barium	0.0323	0.0377			0.0437				0.0585		
Beryllium	<0.005	<0.005			<0.005				<0.005		
Boron	<0.2	<0.2			<0.2		0.05	0.057	<0.2	0.034 B	0.03 B
Cadmium	<0.0025	<0.0025			<0.0025				<0.0025		
Calcium	15.3	17.3	23	18	19.2	30	29	29	25.8	25	25
Chromium	<0.01	<0.01			<0.01				<0.01		
Cobalt	<0.005	<0.005			<0.005				<0.005		
Copper	<0.01	<0.01			<0.01				<0.01		
Cyanide	<0.01	<0.01			<0.01				<0.01		
Iron	0.182	0.149			<0.05		0.11 B	0.073 B	0.0927	0.081 B	0.075
Lead	<0.005	<0.005			<0.005				<0.005		
Magnesium	7.49	7.65	9.9	7.5	9.27	13	12	10	11.4	11	12
Manganese	0.0269	0.0335			0.0521		0.021	0.057 B	0.186	0.045 B	0.04 B
Mercury	<0.0002	<0.0002			<0.0002				<0.0002		
Molybdenum	<0.005	<0.005			<0.005				<0.005		
Nickel	<0.02	<0.02			<0.02				<0.02		
Potassium	1.02	1.07			1.36		2.7 B	2.9 B	2.25	1.9	1.7
Selenium	<0.005	<0.005			<0.005				<0.005		
Silver	<0.005	<0.005			<0.005				<0.005		
Sodium	7.08	5.93			9.59		15	19 ^	14.1	15 B	16 B
Thallium	<0.0025	<0.0025			<0.0025				<0.0025		
Vanadium	<0.001	<0.001			<0.001				<0.001		
Zinc	<0.02	<0.02			<0.02				<0.02		
General Chemistry (mg/l unless otherwise noted)											
Ammonia	<0.2	<0.2			<0.2				<0.2		
Total Alkalinity	23	21.5			31.5		40 B	50	38.8	38 B	37 B
Bicarbonate Alkalinity as CaCO3	23	21.5			31.5		40 B	50	38.8	38 B	37 B
Chemical Oxygen Demand	<20	<20			<20				<20		
Chloride	7.82	7.04	16	12	11.8	16	18	25	32.7	32	25
Fluoride	<0.1	<0.1			<0.1				<0.1		
Laboratory pH (S.U.)	6.68	6.63			7.03				6.44		
Nitrate as N	1.25	1.22			0.527				<0.022		
Nitrate Nitrite Nitrogen											
Specific Conductance (umhos/cm)	198	198			233				321		
Sulfate	48.3	49.7	53	47	55.8	55	63	60	59.6	59	65
TDS	104	156	150	120	184	140	140	150	196	170	160
Total Hardness											
Total Organic Carbon	<0.5	<1			<1				1.38		
Turbidity (NTU)	3.3	2.9			<1		4.3	3.1	<1	3.2	2.4

Notes:
< - Analyte was not detected above the indicated Laboratory Reporting Limit.
J - The analyte was positively identified but the value is estimated as it is below the Laboratory Reporting Limit but above the Method Detection Limit
B - Compound was found in the blank and sample.

Table A-1 (Page 3 of 4)
Spring-1

	Spring-1	Spring-1	Spring-1	Spring-1	Spring-1	Spring-1	Spring-1	Spring-1	Spring-1	Spring-1	Spring-1
Date Sampled:	12/19/2013	1/14/2014	2/14/2014	2/26/2014	3/11/2014	4/9/2014	5/8/2014	4/21/2014	6/4/2014	7/2/2014	8/1/2014
Field Parameters											
Flow (gpm)	5	20	1.5	10	8	15	7	20	1	4	4
pH (S.U.)	7.27	7.29	6.78	7.91	7.66	6.45	7.26	6.68	7.05	7.5	7.31
ORP (mV)	88	-12.6	141	124	89	135.7	142	161	73.6	81	121.6
Dissolved Oxygen (mg/l)						7.4			0.98		
Conductivity (umhos/cm)	234.1	152	229.7	143	172.4	140	178.1	186	226	203.6	234
Temperature (C)	6.2	6.28	3.5	6	9.4	9.37	18.5	10.8	19.1	20.2	21.32
Dissolved Metals (mg/l)											
Aluminum				<0.02				<0.02			0.0064 J B
Antimony				<0.03				<0.03			<0.002
Arsenic				<0.005				<0.005			0.00067 J
Barium				0.0324				0.0326			0.038
Beryllium				<0.005				<0.005			<0.001
Boron				<0.2				<0.2			0.034
Cadmium				<0.0025				<0.0025			<0.001
Calcium				14.4				15.7			18 B
Chromium				<0.01				<0.01			0.00032 J
Cobalt				<0.005				0.0466			0.000054 J
Copper				<0.01				<0.01			0.00053 J
Cyanide				<0.01				<0.01			<0.01
Iron				<0.05				0.103			0.01 J
Lead				<0.005				<0.005			0.000089 J B
Magnesium				6.5				7.39			8.5
Manganese				0.015				0.0339			0.022
Mercury				<0.0002				<0.0002			<0.0002
Molybdenum				<0.005				<0.005			0.0012 J
Nickel				<0.02				0.0263			0.00031 J B
Potassium				1.06				0.978			1.5
Selenium				<0.005				<0.005			<0.005
Silver				<0.005				<0.005			<0.001
Sodium				4.69				5.81			11 B
Thallium				<0.0025				<0.0025			0.000025 J
Vanadium				<0.005				<0.005			<0.001
Zinc				<0.02				<0.02			0.0068 B
Total Metals (mg/l)											
Aluminum				0.0901				0.0413			0.1 B
Antimony				<0.03				<0.03			<0.002
Arsenic	0.00026 J	<0.001	0.00038 J	<0.005	0.00064 J	0.00021 J	0.00016 J	<0.005	0.00026 J	<0.001	<0.001
Barium				0.0339				0.0334			0.042
Beryllium				<0.005				<0.005			<0.001
Boron	0.032	0.021	0.026	<0.2	0.027 B	0.033	0.024	<0.2	0.028 B	0.032	0.035
Cadmium				<0.0025				<0.0025			<0.001
Calcium	24	12	23	14.7	23	19	16	15.7	15	16	19
Chromium				<0.01				<0.01			0.00048 J
Cobalt				<0.005				0.0439			0.00014 J
Copper				<0.01				<0.01			0.00041 J
Cyanide				<0.01				<0.01			<0.01
Iron	0.19	0.29	0.27 B	0.116	0.67	0.54 B	0.46	0.152	0.78	0.58	0.19
Lead				<0.005				<0.005			0.00028 J B
Magnesium	11	5.2	9.4	6.56	6.3	9.7	7.6	7.47	6.9	7.8	9
Manganese	0.042 B	0.035 B	0.033	0.0198	0.059 B	0.048 B	0.049	0.037	0.068	0.075	0.031
Mercury	<0.0002			<0.0002				<0.0002			<0.0002
Molybdenum				<0.005				<0.005			0.00068 J
Nickel				<0.02				0.025			0.00049 J B
Potassium	1.5	1	1.2 B	1.08	1.7	1.4 B	1.1 B	1	1.3	1.3	1.6
Selenium				<0.005				<0.005			0.0012 J B
Silver				<0.005				<0.005			<0.001
Sodium	12 B	3.8 B	12	4.8	6.7	5.6 B	5.7 B	5.76	6.5	7.1	11 B
Thallium				<0.0025				<0.0025			<0.001
Vanadium				<0.001				<0.001			0.00025 J
Zinc				<0.02				<0.02			0.0049 J B
General Chemistry (mg/l unless otherwise noted)											
Ammonia				<0.2				<0.2			0.13
Total Alkalinity	24 B	15 B	18 B	15.4	18 B	15 B	23 B	21.8	18 B	28 B	34 B
Bicarbonate Alkalinity as CaCO3	24	15 B	18 B	15.4	18 B	15 B	23 B	21.8	18 B	28 B	34 B
Chemical Oxygen Demand				30.3				<20			6 J
Chloride	14	3.5	13	4.3	7.1	3.9	4.1	5.94	8.4	39	10
Fluoride				<0.1				<0.1			0.036 J
Laboratory pH (S.U.)				6.86				6.69			7.46 HF
Nitrate as N				2.23				1.65			0.62
Nitrate Nitrite Nitrogen											
Specific Conductance (umhos/cm)				164.2				217			240
Sulfate	61	39	57	41.4	47	46	44	48.2	51	260	51
TDS	130	94	130	96	83	110	110	112	79	130	130
Total Hardness											
Total Organic Carbon				<1				<1			1.3
Turbidity (NTU)	1.5	7.8	2.5	3.3	19	7.8	7.2	2.3	3.7	14	11

Notes:
< - Analyte was not detected above the indicated Laboratory Reporting Limit.
J - The analyte was positively identified but the value is estimated as it is below the Laboratory Reporting Limit but above the Method Detection Limit
B - Compound was found in the blank and sample.

Table A-1 (Page 4 of 4)
Spring-1

	Spring-1	Spring-1	Spring-1	Spring-1	Spring-1	Spring-1	Spring-1	Spring-1	Spring-1	Spring-1	Spring-1
Date Sampled:	9/3/2014	10/2/2014	11/5/2014	12/4/2014	1/7/2015	2/13/2015	3/10/2015	3/16/2015	4/8/2015	5/5/2015	6/1/2015
Field Parameters											
Flow (gpm)	1.5	<0.5	<0.5	1	1.5	2	5	10	10	6	1.5
pH (S.U.)	7.75	7.75	7.99	7.49	6.5	7.87	7.5	6.3	6.67	7.15	6.94
ORP (mV)	41	15	65	63	232.6	73.1	-102.2	163	79.7	31.6	83.1
Dissolved Oxygen (mg/l)											
Conductivity (umhos/cm)	257.3	291.6	314.1	321	196	252	175	153.4	152	179	242
Temperature (C)	23.4	19.4	10.6	10.55	5.68	5.46	6.89	9.8	15.04	16.71	14.85
Dissolved Metals (mg/l)											
Aluminum		0.0081 J			0.0069 J			0.0156 J	0.0089 J		
Antimony		<0.002			<0.000175			<0.000175	<0.000175		
Arsenic		0.00034 J			<0.00015			<0.00015	0.000617 J		
Barium		0.043			0.0334			0.0349	0.0353		
Beryllium		<0.001			<0.00022			<0.00022	<0.00022		
Boron		0.034			0.0239 J			0.0412 J	0.142 J		
Cadmium		<0.001			<0.000175			<0.000175	<0.000175		
Calcium		22			16.7			13.1	14.7		
Chromium		0.00076 J			0.0004 J			<0.0004	0.0009 J		
Cobalt		0.00011 J			<0.0007			<0.0007	<0.0007		
Copper		0.00071 J			<0.0012			<0.0012	<0.0012		
Cyanide		<0.01			<0.01			<0.01	<0.01		
Iron		0.018 J			0.0082 J			0.0152 J	0.0181 J		
Lead		<0.001			<0.00052			<0.00052	<0.00052		
Magnesium		9.8			8.03			6.08	6.37		
Manganese		0.051			0.0394			0.005 J	0.0276		
Mercury		<0.0002			<0.00004			0.00008 J	<0.00004		
Molybdenum		<0.005			<0.001			<0.001	0.0015 J		
Nickel		0.00084 J			<0.0018			<0.0018	<0.0018		
Potassium		2.2			1.07			1.76	1.08		
Selenium		<0.005			0.000779 J			<0.000535	<0.000535		
Silver		<0.001			<0.0012			<0.0012	<0.0012		
Sodium		12			8.6			4.16	4.44		
Thallium		<0.001			<0.000175			<0.000175	<0.000175		
Vanadium		0.00057 J			<0.0006			<0.0006	<0.0006		
Zinc		0.0056 B			0.0171 J			0.0213	0.0062 J		
Total Metals (mg/l)											
Aluminum		0.097			0.115			0.123	0.212		
Antimony		0.000088 J B			<0.000175			<0.000175	<0.000175		
Arsenic	0.00067 J	0.00041 J	0.0015	0.00026 J	0.000183 J	<0.00015	0.0012 J	0.000222 J	0.0004 J	0.000294 J	0.000362 J
Barium		0.044			0.0341			0.0352	0.0393		
Beryllium		<0.001			<0.00022			<0.00022	<0.00022		
Boron	0.036	0.036	0.029	0.027	0.0306 J	0.0185 J	0.0482 J	0.0425 J	0.16 J	0.0628 J	0.187 J
Cadmium		<0.001			<0.000175			<0.000175	<0.000175		
Calcium	21	21	24	25	16.1	16.8	14.7 B	12.7	14.3	17.1	22.1
Chromium		0.00046 J			0.0004 J			<0.0004	0.0006 J		
Cobalt		0.00016 J			<0.0007			<0.0007	<0.0007		
Copper		0.00057 J			<0.0012			<0.0012	<0.0012		
Cyanide		<0.01			<0.01			<0.01	<0.01		
Iron	0.12 B	0.16	3.2	0.049 J	0.254	0.496	3.55	0.157	0.395	0.282	0.106
Lead		0.00021 J			<0.00052			<0.00052	0.000532 J		
Magnesium	7.8	9.9	10	9.5	7.81	7.72	6.89	5.93	6.51	8.18	10.5
Manganese	0.033	0.045	0.25 B	0.12	0.0601	0.0912	0.372	0.0125	0.0508	0.0587	0.141
Mercury		<0.0002			<0.00004			0.0001 J	<0.00004		
Molybdenum		0.00035 J B			0.001 J			0.0023 J	0.001 J		
Nickel		0.0008 J			<0.0018			<0.0018	<0.0018		
Potassium	1.9	2.1	2.9	1.6	1.09	1.06	1.31	1.69	1.14	1.13	1.5
Selenium		<0.005			<0.000535			<0.000535	<0.000535		
Silver		<0.001			<0.0012			<0.0012	<0.0012		
Sodium	11 B	11	14	18	8.23	7.06	5.31	3.85	4.4	7.54	13.2 B
Thallium		<0.001			<0.000175			<0.000175	<0.000175		
Vanadium		0.00044 J			<0.0006			<0.0006	<0.0006		
Zinc		0.005			0.0176 J			0.0136 J	0.0085 J		
General Chemistry (mg/l unless otherwise noted)											
Ammonia		<0.1			<0.06			<0.06	<0.06		
Total Alkalinity	46 B	54 B	45 B	44 B	23.6	20	16.2	10.4	15.8	24.6	34.3
Bicarbonate Alkalinity as CaCO3	46 B	54 B	45 B	44 B	23.6	20	16.2	10.4	15.8	24.6	34.3
Chemical Oxygen Demand		<10			3.574 J			3.574 J	3.59 J		
Chloride	14	23	28	35	8.36	5.94	4.52	2.78	3.36	8.56	16.9
Fluoride		0.064 J B			<0.025			<0.025	0.047 J		
Laboratory pH (S.U.)		7.26 HF			7.87			6.55	6.96		
Nitrate as N		0.12			1.81			4.23	2.19		
Nitrate Nitrite Nitrogen											
Specific Conductance (umhos/cm)		290			210.8			155.7	168.7		
Sulfate	57	59	57	74	50.3	44.8	39.1	35.4	39.7	51.2	60.1
TDS	130	170	180	190	132	112	88	96	112	124	180
Total Hardness											
Total Organic Carbon		2.5			0.767 J			1.08	1.09		
Turbidity (NTU)	2.7	4.4	20	0.58 J	3.97	10.1	23.9	4.17	6.43	6.54	2.28

Notes:
< - Analyte was not detected above the indicated Laboratory Reporting Limit.
J - The analyte was positively identified but the value is estimated as it is belo
B - Compound was found in the blank and sample.

Table A-2 (Page 1 of 8)
Spring-2

	Spring-2	Spring-2	Spring-2	Spring-2	Spring-2	Spring-2	Spring-2	Spring-2	Spring-2	Spring-2	Spring-2
Date Sampled:	8/6/2009	3/11/2010	6/9/2010	5/4/2011	7/14/2011	10/20/2011	3/9/2012	9/13/2012	10/16/2012	11/14/2012	1/17/2013
Field Parameters											
Flow (gpm)									1	2	6
pH (S.U.)	7.42	6.43	6.74		7.69	6.93	7.56	7.12	6.72	6.59	6.99
ORP (mV)	47	99	167		19.8	-4.9	158	62.4	53.5	73.3	42
Dissolved Oxygen (mg/l)								8.12	3.23	5.25	9.72
Conductivity (umhos/cm)	317.2	154.8	173.3		321	265	164.8	565	752	422	324
Temperature (C)	17.6	3.5	16.1		18.41	10.52	6.5	18.47	12.65	9.94	6.9
Dissolved Metals (mg/l)											
Aluminum											
Antimony											
Arsenic								0.001	0.0014 B		
Barium								0.12 B	0.13		
Beryllium											
Boron								0.13 B ^	0.058 B		
Cadmium								<0.001	<0.001		
Calcium								53 B	100		
Chromium								0.00056 J	0.00054 J		
Cobalt											
Copper								0.00085 J B	0.00072 J		
Cyanide									<0.01		
Iron								0.17	0.34 B		
Lead								0.000021 J B	<0.001		
Magnesium								18 B	32 B		
Manganese								0.73 B	0.3		
Mercury								<0.0002	<0.0002		
Molybdenum								0.0035 J B	0.00028 J B		
Nickel											
Potassium								2.8 B	2.5 B		
Selenium								0.00093 J	0.0034 J B		
Silver								0.000049 J	<0.001		
Sodium								10 B	19 B		
Thallium								0.00025 J B	<0.001		
Vanadium											
Zinc								0.0045 J B	0.01		
Total Metals (mg/l)											
Aluminum											
Antimony											
Arsenic	0.015	<0.0025	0.0049	<0.0025	<0.0025	<0.0025	0.00031 J	0.0059 B	0.0019 B	0.00022 J	<0.001
Barium								0.27	0.14		
Beryllium											
Boron	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.046	0.054 B	0.064 B	0.038 B	0.057 B
Cadmium								0.00033 J	<0.001		
Calcium	37	17	24	30	37	45	19	58	100	63	41
Chromium								0.0099	0.0008 J		
Cobalt											
Copper								0.011	0.00099 J		
Cyanide									<0.01		
Iron	39	<0.1	12	0.45	0.5	0.57	0.53 B	22	0.83 B	0.11	0.17 B
Lead								0.014 B	0.00043 J		
Magnesium	15	6	8.7	9.6	14	15	6.7	20	32	20	15
Manganese	3	<0.005	0.33	0.054	0.06	0.31	0.015	2.1	0.36	0.098	0.028 B
Mercury	<0.0008	<0.0008	<0.0008	<0.0008	<0.0008	<0.0008	<0.0002	0.000061 J	<0.0002	<0.0002	<0.0002
Molybdenum								0.0025 J B	0.00018 J B		
Nickel											
Potassium	5.8	1.1	4.5	1.7	3.1	2.1	1.2 B	3.3	2.5 B	1.6	1.3 B
Selenium								0.0022 J B	0.0054 B		
Silver								<0.001	<0.001		
Sodium	5.3	2.2	2.3	5.5	18	7.1	2.6 B	9.2	19 B	9.9 B	8.1 B
Thallium								0.00031 J	<0.001		
Vanadium											
Zinc								0.051	0.01		
General Chemistry (mg/l unless otherwise noted)											
Ammonia	0.11	<0.05	<0.05	0.06	0.071	0.078	0.24 B	0.27 B	0.089 J B		
Total Alkalinity	76	21	39	34	96	80	32 B	76 B	170 B	150 B	51 B
Bicarbonate Alkalinity as CaCO3	75	21	39	33	95	79	32 B	76 B	170 B	100 B	51 B
Chemical Oxygen Demand	51	<20	71	23	<20	28	7.9 J	20	48		
Chloride	14	0	0	0	16	16	2.1	41	62	30	13
Fluoride	<1	<1.0	<1	<1	<1	<1	0.35 B	0.064	0.31		
Laboratory pH (S.U.)	7.66	6.85	7.41	7.74	7.79	7.46	6.8 HF	7.05 HF	6.95 HF		
Nitrate as N	0.36	1.8	0.63	1.3	0.3	0.59	1.4 B	0.16	0.12		
Nitrate Nitrite Nitrogen								0.2			
Specific Conductance (umhos/cm)	300	150	180	190	360	330	170	480	660	560	350
Sulfate	54	36	38	43	62	70	38	98	220	150	110
TDS	200	96	130	130	230	220	120	330	490	290	210
Total Hardness											
Total Organic Carbon	2.4	1.8	5.9	1.9	2.3	1.8	1.8	60	2.2		
Turbidity (NTU)	140	2	34	15	0.53	3.8	4.3	470	7.9	2.3	5.3

Notes:
< - Analyte was not detected above the indicated Laboratory Reporting Limit.
J - The analyte was positively identified but the value is estimated as it is below the Laboratory Reporting Limit but above the Method Detection Limit
B - Compound was found in the blank and sample.

Table A-2 (Page 2 of 8)
Spring-2

	Spring-2	Spring-2	Spring-2	Spring-2	Spring-2	Spring-2	Spring-2	Spring-2	Spring-2	Spring-2	Spring-2
Date Sampled:	2/12/2013	4/25/2013	5/23/2013	6/27/2013	7/22/2013	8/21/2013	8/28/2013	9/26/2013	10/24/2013	11/21/2013	10/10/2013
Field Parameters											
Flow (gpm)	11	2	<0.5	10	3	1		<0.5	<0.5		0
pH (S.U.)	9.08	6.86	6.84	6.38	6.91	6.53	7.11	7.34	7.81	7.7	
ORP (mV)	139	202	173	123	91.8	124	104	-80.2	80		
Dissolved Oxygen (mg/l)											
Conductivity (umhos/cm)	404	732	468.7	458.3	507	567.1	564.1	677	735.8	749.1	
Temperature (C)	4.9	9.8	15.3	17.6	21.1	18	20.9	16.5	9.9	9.1	
Dissolved Metals (mg/l)											
Aluminum	<0.02	<0.02			<0.02						
Antimony	<0.03	<0.03			<0.03						
Arsenic	<0.005	<0.005			<0.005						
Barium	0.0539	0.0545			0.0826						
Beryllium	<0.005	<0.005			<0.005						
Boron	<0.2	<0.2			<0.2						
Cadmium	<0.0025	<0.0025			<0.0025						
Calcium	44.1	38.6			58.9						
Chromium	<0.01	<0.01			<0.01						
Cobalt	<0.005	<0.005			<0.005						
Copper	<0.01	<0.01			<0.01						
Cyanide					<0.01						
Iron	<0.05	<0.05			<0.05						
Lead	<0.005	<0.005			<0.005						
Magnesium	15.5	13.2			20.4						
Manganese	0.0279	0.0315			0.221						
Mercury	<0.0002	<0.0002			<0.0002						
Molybdenum	<0.005	<0.005			<0.005						
Nickel	<0.02	<0.02			<0.02						
Potassium	1.43	1.22			1.78						
Selenium	<0.005	<0.005			<0.005						
Silver	<0.005	<0.005			<0.005						
Sodium	9.42	8.01			13.3						
Thallium	<0.0025	<0.0025			<0.0025						
Vanadium	<0.005	<0.005			<0.005						
Zinc	<0.02	<0.02			<0.02						
Total Metals (mg/l)											
Aluminum	0.183	0.12			0.757						
Antimony	<0.03	<0.03			<0.03						
Arsenic	<0.005	<0.005			<0.005		0.00047 J	0.00052 J	0.00057 J	0.00064 J	
Barium	0.0553	0.0557			0.0921						
Beryllium	<0.005	<0.005			<0.005						
Boron	<0.2	<0.2			<0.2		0.074	0.067	0.054 B	0.049 B	
Cadmium	<0.0025	<0.0025			<0.0025						
Calcium	44.5	38.6	55	51	57.9	74	84	100	85	100	
Chromium	<0.01	<0.01			<0.01						
Cobalt	<0.005	<0.005			<0.005						
Copper	<0.01	<0.01			<0.01						
Cyanide	<0.01	<0.01			<0.01						
Iron	0.237	0.182			1.22		0.18 B	0.16 B	0.35 B	0.82	
Lead	<0.005	<0.005			<0.005						
Magnesium	15.7	13.3	17	17	20.1	23	26	32	28	38	
Manganese	0.0372	0.0388			0.296		0.33	0.21 B	0.35 B	0.49 B	
Mercury	<0.0002	<0.0002			<0.0002						
Molybdenum	<0.005	<0.005			<0.005						
Nickel	<0.02	<0.02			<0.02						
Potassium	1.59	1.27			1.91		3.1 B	2.4 B	2.2	2.3	
Selenium	<0.005	<0.005			<0.005						
Silver	<0.005	<0.005			<0.005						
Sodium	10.4	8.11			13.5		17	20 ^	15 B	18 B	
Thallium	<0.0025	<0.0025			<0.0025						
Vanadium	<0.001	<0.001			0.0016						
Zinc	<0.02	<0.02			<0.02						
General Chemistry (mg/l unless otherwise noted)											
Ammonia	<0.2	<0.2			<0.2						
Total Alkalinity	47.2	45.2			72.9		86 B	92	94 B	85 B	
Bicarbonate Alkalinity as CaCO3	47.2	45.2			72.9		86 B	92	94 B	85 B	
Chemical Oxygen Demand	<20	<20			32.1						
Chloride	15.9	12.7	23	17	20.3	25	28	40	44	46	
Fluoride	0.168	0.118			0.141						
Laboratory pH (S.U.)	6.61	6.11			6.63						
Nitrate as N	1.11	0.377			0.117						
Nitrate Nitrite Nitrogen											
Specific Conductance (umhos/cm)	406	350			511						
Sulfate	134	97.6	130	120	141	140	160	190	230	270	
TDS	276	240	240	280	348	310	290	370	520	470	
Total Hardness											
Total Organic Carbon	1.14	1.2			1.2						
Turbidity (NTU)	8	6			35		14	8.6	12	12	

Notes:

< - Analyte was not detected above the indicated Laboratory Reporting Limit.

J - The analyte was positively identified but the value is estimated as it is below the Laboratory Reporting Limit but above the Method Detection Limit

B - Compound was found in the blank and sample.

	Spring-2	Spring-2	Spring-2	Spring-2	Spring-2	Spring-2	Spring-2	Spring-2	Spring-2	Spring-2	Spring-2
Date Sampled:	12/19/2013	1/14/2014	2/14/2014	2/26/2014	3/11/2014	4/9/2014	4/21/2014	5/8/2014	6/4/2014	7/2/2014	8/1/2014
Field Parameters											
Flow (gpm)	2	20	1.5		2	10	5	7	1	2.5	2.5
pH (S.U.)	7.3	7.89	6.81	7.45	7.54	7.16	6.56	7.42	7.41	7.48	7.45
ORP (mV)	111	-57.3	157	74.3	75	70.7	57.3	178	5	60	61
Dissolved Oxygen (mg/l)						7.18			1.79		
Conductivity (umhos/cm)	779.5	338	579.3	589	567.1	383	595	418.6	449	551.4	664
Temperature (C)	5.9	5.56	3.9	3.8	7.2	12.16	12.6	17.7	17.59	19.1	18.49
Dissolved Metals (mg/l)											
Aluminum				<0.02			<0.02				0.0043 J B
Antimony				<0.03			<0.03				<0.002
Arsenic				<0.005			<0.005				0.00088 J
Barium				0.0562			0.0469				0.08
Beryllium				<0.005			<0.005				<0.001
Boron				<0.2			<0.2				0.083
Cadmium				<0.0025			<0.0025				<0.001
Calcium				57			57.6				76 B
Chromium				<0.01			<0.01				0.00033 J
Cobalt				<0.005			0.0441				0.00012 J
Copper				<0.01			<0.01				0.00078 J
Cyanide				<0.01			<0.01				<0.01
Iron				<0.05			0.0923				0.015 J
Lead				<0.005			<0.005				<0.001
Magnesium				27.7			28.7				28
Manganese				<0.01			<0.01				0.11
Mercury				<0.0002			<0.0002				<0.0002
Molybdenum				<0.005			<0.005				0.00033 J
Nickel				<0.02			0.0261				0.00085 J B
Potassium				1.77			1.55				1.9
Selenium				<0.005			<0.005				0.00025 J B
Silver				<0.005			<0.005				<0.001
Sodium				22.6			26				22 B
Thallium				<0.0025			<0.0025				<0.001
Vanadium				<0.005			<0.005				<0.001
Zinc				<0.02			<0.02				0.0092 B
Total Metals (mg/l)											
Aluminum				0.103			0.335				0.58 B
Antimony				<0.03			<0.03				<0.002
Arsenic	0.0007 J	<0.001	0.00039 J	<0.005	0.00089 J	0.00028 J	<0.005	0.00017 J	0.00037 J	0.00056 J B	0.00059 J
Barium				0.0581			0.0505				0.083
Beryllium				<0.005			<0.005				0.000084 J
Boron	0.062 ^	0.05	0.05	<0.2	0.063 B	0.087	<0.2	0.061	0.063 B	0.077	0.077
Cadmium				<0.0025			<0.0025				<0.001
Calcium	120	35	80	57.2	92	53	58	42	45	59	72
Chromium				<0.01			<0.01				0.0011 J
Cobalt				<0.005			0.0471				0.00047 J
Copper				<0.01			<0.01				0.001 J
Cyanide				<0.01			<0.01				0.002 J
Iron	0.68	0.16	0.23 B	0.132	0.51	0.62 B	0.632	0.52	1.4	1.7	0.88
Lead				<0.005			<0.005				0.00076 J B
Magnesium	40	13	24	27.6	22	22	28.7	16	15	22	26
Manganese	0.41 B	0.034 B	0.16	<0.01	0.086 B	0.054 B	0.0306	0.066	0.15	0.17	0.14
Mercury	<0.0002			<0.0002			<0.0002				<0.0002
Molybdenum				<0.005			<0.005				0.00029 J
Nickel				<0.02			0.0283				0.0012 B
Potassium	2.4	1.3	1.6 B	1.86	2	1.9 B	1.6	1.4 B	1.6	1.9	1.9
Selenium				<0.005			<0.005				<0.005
Silver				<0.005			<0.005				<0.001
Sodium	23 B	9 B	17	22.5	17	17 B	26	13 B	12	16	20 B
Thallium				<0.0025			<0.0025				<0.001
Vanadium				<0.001			<0.001				0.0014
Zinc				<0.02			<0.02				0.0092 B
General Chemistry (mg/l unless otherwise noted)											
Ammonia				<0.2			<0.2				<0.1
Total Alkalinity	61 B	42 B	56 B	46.9	48 B	42 B	61.3	55 B	54 B	69 B	77 B
Bicarbonate Alkalinity as CaCO3	61	42 B	56 B	46.9	48 B	42 B	61.3	55 B	54 B	69 B	77 B
Chemical Oxygen Demand				<20			<20				<10
Chloride	43	10	29	23.7	26	12	23.1	12	18	24	29
Fluoride				0.126			0.103				0.094
Laboratory pH (S.U.)				6.73			6.45				7.58 HF
Nitrate as N				2.02			1.36				0.31
Nitrate Nitrite Nitrogen											
Specific Conductance (umhos/cm)				581.1			667				690
Sulfate	260	97	200	207	210	110	208	130	150	190	200
TDS	470	220	360	384	360	210	416	280	230	360	420
Total Hardness											
Total Organic Carbon				1.06			1.11				1.7
Turbidity (NTU)	11	19	8.2	3.8	19	4.8	13.7	23	3.3	21	31

Notes:
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B - Compound was found in the blank and sample.

Spring-2

	Spring-2	Spring-2	Spring-2	Spring-2	Spring-2	Spring-2	Spring-2	Spring-2	Spring-2	Spring-2	Spring-2
Date Sampled:	9/3/2014	9/29/2014	10/2/2014	10/10/2014	10/13/2014	10/16/2014	10/17/2014	10/20/2014	10/23/2014	10/27/2014	10/30/2014
Field Parameters											
Flow (gpm)	1	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
pH (S.U.)	8.2	7.64	8.22	8.38	8.19	8.11	7.14	8.04	8	6.85	7.29
ORP (mV)	43	86	47	68	86	26	81	133	34	74	72
Dissolved Oxygen (mg/l)											
Conductivity (umhos/cm)	1251	1616	1623	1631	1664	1682	1909	1759	2075	2108	2124
Temperature (C)	22	19.7	19	14.1	17.1	15.8	18.4	14.5	17.1	13	11.8
Dissolved Metals (mg/l)											
Aluminum			0.0065 J				0.0087 J B				
Antimony			<0.002				<0.002				
Arsenic			0.0016				0.0022				
Barium			0.11				0.11				
Beryllium			<0.001				<0.001				
Boron			0.17				0.23				
Cadmium			0.000093 J				<0.001				
Calcium			200				230				
Chromium			0.0012 J				0.0016 J				
Cobalt			0.00025 J				0.00071 B				
Copper			0.0014 J				0.0037				
Cyanide			<0.01				<0.01				
Iron			0.032 J				0.015 J				
Lead			<0.001				<0.001				
Magnesium			77				95 B				
Manganese			0.027				1.4 B				
Mercury			<0.0002				<0.0002				
Molybdenum			<0.005				0.0016 J				
Nickel			0.00084 J				0.002				
Potassium			3.3				3.8				
Selenium			0.00095 J B				0.00022 J				
Silver			<0.001				<0.001				
Sodium			66				95 B				
Thallium			<0.001				<0.001				
Vanadium			0.0013				0.0006 J				
Zinc			0.005 B				0.0068				
Total Metals (mg/l)											
Aluminum			0.051				0.28 B				
Antimony			0.00014 J B				<0.002				
Arsenic	0.0032		0.00058 J				0.0017				
Barium			0.1				0.11				
Beryllium			<0.001				<0.001				
Boron	0.16		0.16				0.24				
Cadmium			<0.001				0.00014 J				
Calcium	160		160				220				
Chromium			0.00063 J				0.0036				
Cobalt			0.00026 J				0.001 B				
Copper			0.0011 J				0.004				
Cyanide			<0.01				<0.01				
Iron	0.045 J B		0.11				0.71				
Lead			0.0001 J				0.0014				
Magnesium	51		66				89 B				
Manganese	0.046		0.039				0.94 B				
Mercury			<0.0002				<0.0002				
Molybdenum			0.0016 J B				0.0022 J				
Nickel			0.00068 J				0.0034				
Potassium	3		2.8				4.2				
Selenium			0.00035 J				0.00054 J				
Silver			<0.001				<0.001				
Sodium	49 B		56				93 B				
Thallium			<0.001				0.00011 J				
Vanadium			0.00085 J				0.011				
Zinc			0.0038 J				0.016				
General Chemistry (mg/l unless otherwise noted)											
Ammonia			<0.1				<0.1				
Total Alkalinity	120 B		110 B				160 B				
Bicarbonate Alkalinity as CaCO3	120 B		110 B				160 B				
Chemical Oxygen Demand			6.1 J				<10				
Chloride	69	110	110	100	110	110	120	110	130	150	150
Fluoride			0.14 B				0.19				
Laboratory pH (S.U.)			7.8 HF				6.93 HF				
Nitrate as N			0.25				0.29				
Nitrate Nitrite Nitrogen											
Specific Conductance (umhos/cm)			1600				1900				
Sulfate	480	730	660	670	680	730	790	710	850	1000	1100
TDS	940		1200				1400				
Total Hardness											
Total Organic Carbon			2.2				2.5				
Turbidity (NTU)	1.1		1.2				12				

Notes:
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B - Compound was found in the blank and sample.

Table A-2 (Page 5 of 8)
Spring-2

	Spring-2	Spring-2	Spring-2	Spring-2	Spring-2	Spring-2	Spring-2	Spring-2	Spring-2	Spring-2	Spring-2
Date Sampled:	11/3/2014	11/5/2014	11/7/2014	11/10/2014	11/13/2014	11/18/2014	11/20/2014	11/25/2014	12/2/2014	12/4/2014	12/10/2014
Field Parameters											
Flow (gpm)	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5		<0.5	<0.5
pH (S.U.)	8.16	7.95	7.29	7.13	7.36	7.21	7.34	6.94	7.11	7.07	8.25
ORP (mV)	109	47	124	80	87	131	140	120	134	124.7	-54
Dissolved Oxygen (mg/l)											
Conductivity (umhos/cm)	1875	1896	2015	2107	2183	2030	2148	2121	2273	2094	1904
Temperature (C)	8.4	10.9	9.3	13.6	9.4	6.4	6.3	10	8.4	9.66	6.8
Dissolved Metals (mg/l)											
Aluminum											
Antimony											
Arsenic											
Barium											
Beryllium											
Boron											
Cadmium											
Calcium											
Chromium											
Cobalt											
Copper											
Cyanide											
Iron			0.083	0.062	0.024 J						
Lead											
Magnesium											
Manganese											
Mercury											
Molybdenum											
Nickel											
Potassium											
Selenium											
Silver											
Sodium											
Thallium											
Vanadium											
Zinc											
Total Metals (mg/l)											
Aluminum			0.37 B	0.29 B	0.013 J						
Antimony			0.000055 J	<0.002	<0.002						
Arsenic		0.0013	0.0026	0.0024	0.0019					0.002	
Barium			0.075	0.079	0.067						
Beryllium			<0.001	<0.001	<0.001						
Boron		0.14	0.21 B	0.22 B	0.18					0.23	
Cadmium			<0.001	<0.001	0.00014 J						
Calcium		220	230	250	230					250	
Chromium			0.0011 J	0.00089 J	0.003						
Cobalt			0.00065	0.0007	0.00041 J						
Copper			0.0014 J	0.0012 J	0.0017 J						
Cyanide											
Iron		0.04 J	0.71	0.63	0.04 J					0.11	
Lead			0.00069 J	0.00058 J	0.000094 J						
Magnesium		82	95	100	81					100	
Manganese		0.019 B	0.47 B	0.78 B	0.61					0.39	
Mercury			<0.0002	<0.0002	<0.0002						
Molybdenum			0.0013 J	0.0012 J	0.001 J B						
Nickel			0.0017	0.0016	0.0021						
Potassium		3.1								3	
Selenium			0.0012 J	0.00088 J	<0.005						
Silver			<0.001	<0.001	<0.001						
Sodium		76								110	
Thallium			0.000019 J	0.000016 J	0.000015 J						
Vanadium											
Zinc			0.019 B	0.014 B	0.011						
General Chemistry (mg/l unless otherwise noted)											
Ammonia			0.1	0.089 J	0.092 J						
Total Alkalinity		110 B								150 B	
Bicarbonate Alkalinity as CaCO3		110 B								150 B	
Chemical Oxygen Demand			72	57	7.4 J						
Chloride	120	310				140	140	140	150	160	120
Fluoride			0.3 B	0.15	0.15						
Laboratory pH (S.U.)			6.92 HF	7.11 HF	6.93 HF						
Nitrate as N											
Nitrate Nitrite Nitrogen			0.45 B	0.29 B	0.24 B						
Specific Conductance (umhos/cm)											
Sulfate	750	1900	790	960	1100	900	960	910	990	1000	790
TDS		1500	1300	1500	1600					1800	
Total Hardness			970	1100	910						
Total Organic Carbon			2.6	1.6	1.5						
Turbidity (NTU)		1.3	30 H	8.1	0.5 J					0.34 J	

Notes:
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Table A-2 (Page 6 of 8)
Spring-2

	Spring-2	Spring-2	Spring-2	Spring-2	Spring-2	Spring-2	Spring-2	Spring-2	Spring-2	Spring-2	Spring-2
Date Sampled:	12/17/2014	12/22/2014	1/2/2015	1/7/2015	1/16/2015	1/19/2015	1/27/2015	2/2/2015	2/13/2015	2/17/2015	2/25/2015
Field Parameters											
Flow (gpm)	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	1	<0.5	1	<0.5
pH (S.U.)	7.28	7.46	7.17	6.77	7.45	7.45	6.98	7.15	6.91	6.9	7.28
ORP (mV)	124.6	148	168	140	-23	120	299	212	311.2	177	159
Dissolved Oxygen (mg/l)											
Conductivity (umhos/cm)	2240	2087	1992	1481	1932	1970	1886	1115	1227	1254	1530
Temperature (C)	6.71	9.8	7.5	5.14	6.1	5.4	5.8	5.1	4.91	5.2	4
Dissolved Metals (mg/l)											
Aluminum				0.0199 J							
Antimony				<0.000175							
Arsenic				<0.00015							
Barium				0.0451							
Beryllium				<0.00022							
Boron				0.249							
Cadmium				<0.000175							
Calcium				136							
Chromium				<0.0004							
Cobalt				<0.0007							
Copper				<0.0012							
Cyanide				<0.01							
Iron				<0.0015							
Lead				<0.00052							
Magnesium				68.4							
Manganese				0.0181							
Mercury				<0.00004							
Molybdenum				0.0036 J							
Nickel				<0.0018							
Potassium				2.45							
Selenium				<0.000535							
Silver				<0.0012							
Sodium				88.9							
Thallium				<0.000175							
Vanadium				<0.0006							
Zinc				0.04							
Total Metals (mg/l)											
Aluminum				0.14							
Antimony				<0.000175							
Arsenic				<0.0003					0.000317 J		
Barium				0.0461							
Beryllium				<0.00022							
Boron				0.253					0.193 J		
Cadmium				<0.000175							
Calcium				134					97.8		
Chromium				<0.0004							
Cobalt				<0.0007							
Copper				<0.0012							
Cyanide				<0.01							
Iron				0.211					0.103		
Lead				<0.00104							
Magnesium				67.8					51.2		
Manganese				0.0297					0.0092 J		
Mercury				<0.00004							
Molybdenum				0.0037 J							
Nickel				<0.0018							
Potassium				2.49					2.1		
Selenium				0.0029 J							
Silver				<0.0012							
Sodium				88.4					66.9		
Thallium				<0.00035							
Vanadium				<0.0006							
Zinc				0.0396							
General Chemistry (mg/l unless otherwise noted)											
Ammonia				<0.06							
Total Alkalinity				98.5					66		
Bicarbonate Alkalinity as CaCO3				98.5					66		
Chemical Oxygen Demand				<3							
Chloride	130	140	140	82.1	113	120	116	53.7	51.5	67.6	84.4
Fluoride				0.071 J							
Laboratory pH (S.U.)				7.67							
Nitrate as N				1.11							
Nitrate Nitrite Nitrogen											
Specific Conductance (umhos/cm)				1473							
Sulfate	820	970	790	563	767	805	771	394	375	481	589
TDS				1080					720		
Total Hardness											
Total Organic Carbon				1.27							
Turbidity (NTU)				3.09					1.82		

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Table A-2 (Page 7 of 8)
Spring-2

	Spring-2	Spring-2	Spring-2	Spring-2	Spring-2	Spring-2	Spring-2	Spring-2	Spring-2	Spring-2	Spring-2
Date Sampled:	3/4/2015	3/10/2015	3/18/2015	3/24/2015	3/30/2015	4/8/2015	4/13/2015	4/20/2015	4/27/2015	5/5/2015	5/12/2015
Field Parameters											
Flow (gpm)	2	1	2	<0.5	<0.5	1	<0.5	<0.5	1	<0.5	<0.5
pH (S.U.)	7.06	7.21	7.32	6.7	6.5	7.31	6.33	7.14	6.94	7.05	7.68
ORP (mV)	165	-102.4	31	30	113	-45.2	80	13.5	35.5	78.6	16
Dissolved Oxygen (mg/l)											
Conductivity (umhos/cm)	542.5	656	583.1	876.4	826.4	611	506.9	668	677	814	1040
Temperature (C)	5.4	7.94	6.1	2.4	6.3	11.27	12	14.12	12.6	14.11	16.1
Dissolved Metals (mg/l)											
Aluminum						0.0142 J					
Antimony						<0.000175					
Arsenic						<0.00015					
Barium						0.0423					
Beryllium						<0.00022					
Boron						0.542					
Cadmium						<0.000175					
Calcium						52.7					
Chromium						0.0012 J					
Cobalt						0.0007 J					
Copper						<0.0012					
Cyanide						<0.01					
Iron						0.0114 J					
Lead						<0.00052					
Magnesium						25.4					
Manganese						0.0033 J					
Mercury						<0.00004					
Molybdenum						<0.001					
Nickel						<0.0018					
Potassium						1.83					
Selenium						<0.000535					
Silver						<0.0012					
Sodium						34.2					
Thallium						<0.000175					
Vanadium						<0.0006					
Zinc						0.0248					
Total Metals (mg/l)											
Aluminum						0.117					
Antimony						<0.000175					
Arsenic		0.00031 J				0.000187 J				0.000196 J	
Barium						0.0439					
Beryllium						<0.00022					
Boron		0.142 J				0.606				0.231	
Cadmium						<0.000175					
Calcium		56.8				53.2				77.3	
Chromium						0.0004 J					
Cobalt						<0.0007					
Copper						<0.0012					
Cyanide						<0.01					
Iron		0.322				0.119				0.0693	
Lead						<0.00052					
Magnesium		26.6				25.8				40.9	
Manganese		0.0136				0.0077 J				0.0139	
Mercury						<0.00004					
Molybdenum						<0.001					
Nickel						<0.0018					
Potassium		1.91				1.98				1.89	
Selenium						<0.000535					
Silver						<0.0012					
Sodium		37.9				34.7				52.5	
Thallium						<0.000175					
Vanadium						<0.0006					
Zinc						0.0273					
General Chemistry (mg/l unless otherwise noted)											
Ammonia						<0.06					
Total Alkalinity		50				49.2				74.8	
Bicarbonate Alkalinity as CaCO3		50				49.2				74.8	
Chemical Oxygen Demand						9.639 J					
Chloride	19.2	30.7	25.2	40.2	37.8	24.6	18.3	31.8	33.1	43.6	53.3
Fluoride						0.132					
Laboratory pH (S.U.)						6.67					
Nitrate as N						1.61					
Nitrate Nitrite Nitrogen											
Specific Conductance (umhos/cm)						623.8					
Sulfate	155	236	199	299	281	206	170	253	279	328	395
TDS		440				452				908	
Total Hardness											
Total Organic Carbon						1.54					
Turbidity (NTU)		7.71				3.32				1.75	

Notes:
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B - Compound was found in the blank and sample.

Table A-2 (Page 8 of 8)
Spring-2

	Spring-2	Spring-2	Spring-2	Spring-2	Spring-2
Date Sampled:	5/18/2015	5/26/2015	6/1/2015	6/8/2015	6/15/2015
Field Parameters					
Flow (gpm)	<0.5	<0.5	<0.5	<0.5	<0.5
pH (S.U.)	7.35	7.15	7.16	7.36	6.88
ORP (mV)	105	102	15.8	166	186
Dissolved Oxygen (mg/l)					
Conductivity (umhos/cm)	1126	1282	1256	1505	1066
Temperature (C)	14.9	15.7	11.96	17	14.1
Dissolved Metals (mg/l)					
Aluminum					
Antimony					
Arsenic					
Barium					
Beryllium					
Boron					
Cadmium					
Calcium					
Chromium					
Cobalt					
Copper					
Cyanide					
Iron					
Lead					
Magnesium					
Manganese					
Mercury					
Molybdenum					
Nickel					
Potassium					
Selenium					
Silver					
Sodium					
Thallium					
Vanadium					
Zinc					
Total Metals (mg/l)					
Aluminum					
Antimony					
Arsenic			0.0012		
Barium					
Beryllium					
Boron			0.327		
Cadmium					
Calcium			138		
Chromium					
Cobalt					
Copper					
Cyanide					
Iron			1.24		
Lead					
Magnesium			67		
Manganese			0.0818		
Mercury					
Molybdenum					
Nickel					
Potassium			2.66		
Selenium					
Silver					
Sodium			80.7 B		
Thallium					
Vanadium					
Zinc					
General Chemistry (mg/l unless otherwise noted)					
Ammonia					
Total Alkalinity			104		
Bicarbonate Alkalinity as CaCO3			104		
Chemical Oxygen Demand					
Chloride	57.9	70.4	79.2	90.1	55.8
Fluoride					
Laboratory pH (S.U.)					
Nitrate as N					
Nitrate Nitrite Nitrogen					
Specific Conductance (umhos/cm)					
Sulfate	418	513	559	598	382
TDS			1080		
Total Hardness					
Total Organic Carbon					
Turbidity (NTU)			31.9		

Notes:
< - Analyte was not detected above the indicated Laboratory Reporting Limit.
J - The analyte was positively identified but the value is estimated as it is below the Laboratory Reporting Limit but above the Method Detection Limit
B - Compound was found in the blank and sample.

APPENDIX B

BORING LOGS

WELL NUMBER 12-10

CLIENT Confidential
PROJECT NAME Solid Waste Landfill
PROJECT NUMBER
PROJECT LOCATION Western Pennsylvania
DATE STARTED 8/13/12 **COMPLETED** 8/16/12
GROUND ELEVATION **BACKFILL** PVC Well
DRILLING CONTRACTOR
WATER LEVELS:
DRILLING METHOD Auger/
BEFORE CORING ---
SS
▼ **AT END OF DRILLING** 10.4 ft
NOTES
AFTER DRILLING ---

DEPTH (m)	SAMPLE TYPE NUMBER	RECOVERY %	BLOW COUNTS (N VALUE)	GRAPHIC LOG	MATERIAL DESCRIPTION
0	SS 1	100	1		Brown silty CLAY, moist to moist+, very soft, **(TOPSOIL)**
					Dark gray SILT, trace sparkley substance, and fine sand, moist+ to wet, very soft, **(SOLID WASTE)**
					Dark gray to black SILT, moist+ to wet, very soft, **(SOLID WASTE)**
1.5	ST 1	100			
3					▼
4.5					
6	SS 2	100	1-1		
7.6					

WELL DIAGRAM

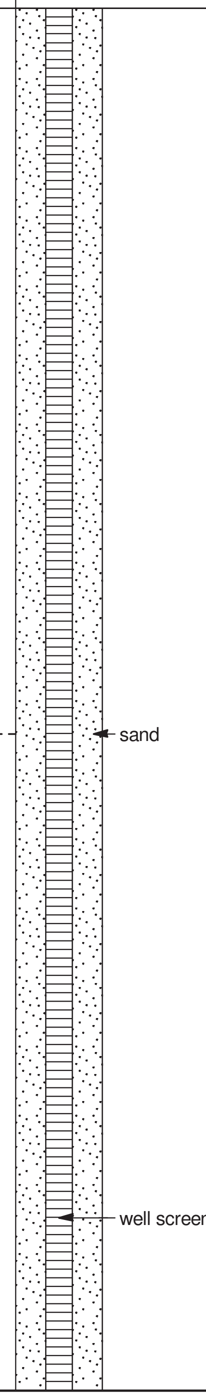
(Continued Next Page)

Figure B-1: 12-10 Boring Log

CLIENT Confidential
PROJECT NAME Solid Waste Landfill
PROJECT NUMBER
PROJECT LOCATION Western Pennsylvania

DEPTH (m)	SAMPLE TYPE NUMBER	RECOVERY %	BLOW COUNTS (N VALUE)	GRAPHIC LOG	MATERIAL DESCRIPTION
7.6					Dark gray to black SILT, moist+ to wet, very soft, **(SOLID WASTE)** *(continued)*
9.1					
10.7					
12.2	SS 3	100	3-1		Dark gray to black SILT, trace fine sand, moist to moist+, very soft, **(SOLID WASTE)**
13.7	ST 2	0			
18.3	ST 3	100			

WELL DIAGRAM



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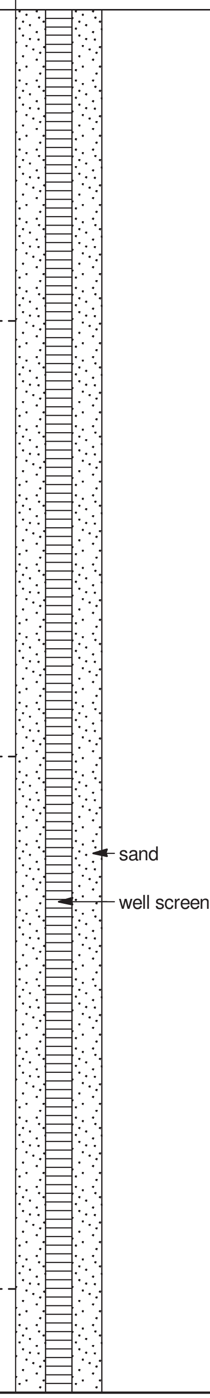
WELL NUMBER 12-10

CLIENT Confidential **PROJECT NAME** Solid Waste Landfill

PROJECT NUMBER **PROJECT LOCATION** Western Pennsylvania

DEPTH (m)	SAMPLE TYPE NUMBER	RECOVERY %	BLOW COUNTS (N VALUE)	GRAPHIC LOG	MATERIAL DESCRIPTION
					Dark gray to black SILT, trace fine sand, moist to moist+, very soft, **(SOLID WASTE)** *(continued)*
16.7					
18.3					Dark gray SILT, trace fine sand, moist+, soft, **(SOLID WASTE)**
	SS 4	100	6-4-3-5 (7)		
19.8					
					Dark gray SILT, trace fine sand, moist+, very soft to medium stiff, **(SOLID WASTE)**
21.3					
22.8					
24.4					Gray to dark gray SILT, trace fine sand, moist to moist+, very stiff, **(SOLID WASTE)**
	SS 5	100	7-6-25-47 (31)		

WELL DIAGRAM



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WELL NUMBER 12-10

CLIENT Confidential

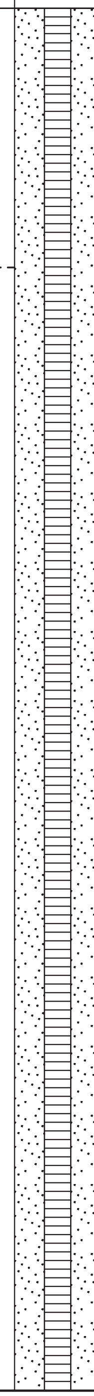
PROJECT NUMBER

PROJECT NAME Solid Waste Landfill

PROJECT LOCATION Western Pennsylvania

DEPTH (m)	SAMPLE TYPE NUMBER	RECOVERY %	BLOW COUNTS (N VALUE)	GRAPHIC LOG	MATERIAL DESCRIPTION
					Gray to dark gray SILT, trace fine sand, moist to moist+, very stiff, **(SOLID WASTE)** *(continued)*
25.9					
					Dark gray and black SILT, trace fine sand, and silt granulars, moist to moist+, medium stiff to stiff, **(SOLID WASTE)**
27.4	ST 4	100			
28.9					
30.5	SS 6	100	3-2-4-5 (6)		
32					
33.5					

WELL DIAGRAM



GENERAL BH / TP / WELL 921-22X.8001_12-10.GPJ 101-986 SLDA.GPJ 3/15/15

(Continued Next Page)

CLIENT Confidential

PROJECT NAME Solid Waste Landfill

PROJECT NUMBER

PROJECT LOCATION Western Pennsylvania

DEPTH (m)	SAMPLE TYPE NUMBER	RECOVERY %	BLOW COUNTS (N VALUE)	GRAPHIC LOG	MATERIAL DESCRIPTION	WELL DIAGRAM
35					Dark gray and black SILT, trace fine sand, and silt granulars, moist to moist+, medium stiff to stiff, **(SOLID WASTE)** *(continued)*	
36.5	SS 7	100	6-6-6-8 (12)			
					Brown silty CLAY, trace fine sand, moist to moist+, **(RESIDUAL SOIL)**	
					Bottom of boring at 37.2 meters	

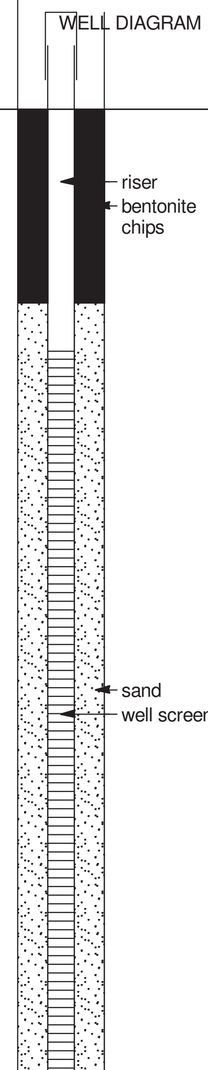
GENERAL BH / TP / WELL 921-22X.8001_12-10.GPJ 101-986 SLDA.GPJ 3/15/15

WELL NUMBER 12-10A

CLIENT Confidential
PROJECT NAME Solid Waste Landfill
PROJECT NUMBER
PROJECT LOCATION Western Pennsylvania
DATE STARTED 8/20/12 **COMPLETED** 8/20/12
GROUND ELEVATION **BACKFILL** PVC Well
DRILLING CONTRACTOR
WATER LEVELS:
DRILLING METHOD Auger/
BEFORE CORING ---
SS
AT END OF DRILLING ---
NOTES
AFTER DRILLING ---

DEPTH (m)	SAMPLE TYPE NUMBER	GRAPHIC LOG	MATERIAL DESCRIPTION
0			See Log 12-10 for details., **(SOLID WASTE)**
1.5			
3			
4.5			
6			Bottom of boring at 6 meters

WELL DIAGRAM



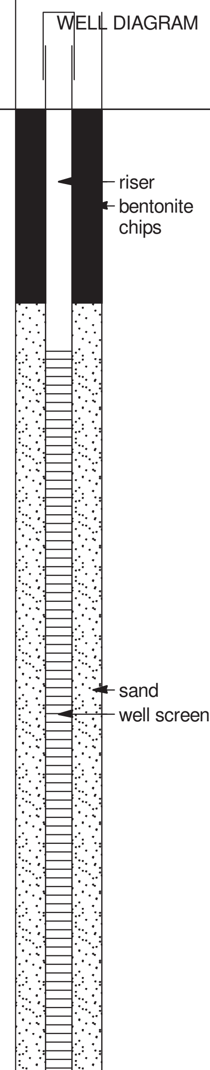
GENERAL BH / TP / WELL 921-22X.8001_12-10.GPJ 101-986 SLDA.GPJ 3/15/15

Figure B-2: 12-10A Boring Log

WELL NUMBER 12-10B

CLIENT Confidential	**PROJECT NAME** Solid Waste Landfill
PROJECT NUMBER	**PROJECT LOCATION** Western Pennsylvania
DATE STARTED 8/21/12 **COMPLETED** 8/22/12	**GROUND ELEVATION** **BACKFILL** PVC Well
DRILLING CONTRACTOR	**WATER LEVELS:**
DRILLING METHOD Auger/	**BEFORE CORING** ---
SS	**AT END OF DRILLING** ---
NOTES	**AFTER DRILLING** ---

DEPTH (m)	SAMPLE TYPE NUMBER	GRAPHIC LOG	MATERIAL DESCRIPTION	WELL DIAGRAM
0			See Log 12-10 for details, **(SOLID WASTE)**	
1.5				
3				
4.5				
6			Bottom of boring at 6 meters	



GENERAL BH / TP / WELL 921-22X.8001_12-10.GPJ 101-986 SLDA.GPJ 3/15/15

Figure B-3: 12-10B Boring Log

WELL NUMBER MW-101

CLIENT Confidential
PROJECT NAME Solid Waste Landfill
PROJECT NUMBER
PROJECT LOCATION Western Pennsylvania
DATE STARTED 9/12/12 **COMPLETED** 9/13/12
GROUND ELEVATION **BACKFILL** 0.05 PVC Well
DRILLING CONTRACTOR
WATER LEVELS:
DRILLING METHOD Hollow Stem Auger & HQ Core
BEFORE CORING 37.0 ft
AT END OF DRILLING ---
NOTES
AFTER DRILLING ---

DEPTH (m)	SAMPLE TYPE NUMBER	RECOVERY % (RQD)	BLOW COUNTS (N VALUE)	REMARKS	U.S.C.S.	MATERIAL DESCRIPTION
0						Brown SILT, and silty clay, with organics, moist, soft, **(TOPSOIL)**
	SS 1	70	4-6-6-8 (12)		ML	Light brown SILT, and weathered rock fragments, trace organics, moist, medium stiff, **(RESIDUAL SOIL)**
					CL-ML	Reddish brown silty CLAY, some mottling, and rock fragments, moist to moist-, stiff, (shale), **(RESIDUAL SOIL)**
	SS 2	90	4-6-7-9 (13)		CL-ML	Gray silty CLAY, trace mottling, moist, stiff, **(RESIDUAL SOIL)**
1.5						
	SS 3	100	4-50/0.5			Light brown and dark gray weathered ROCK FRAGMENTS, some fine sand, and clay, moist- to dry, hard, (shale and sandstone), **(WEATHERED ROCK)**
	SS 4	100	8-50/0.5			
3						
	SS 5	100	21-50/0.3			
4.5						
	SS 6	67	24-50/0.4			
	RC 1	100 (19)				Dark gray SILTSTONE, moderately weathered, broken, hard, Fe staining throughout, multiple horizontal fractures, diagonal fracture
6						

WELL DIAGRAM

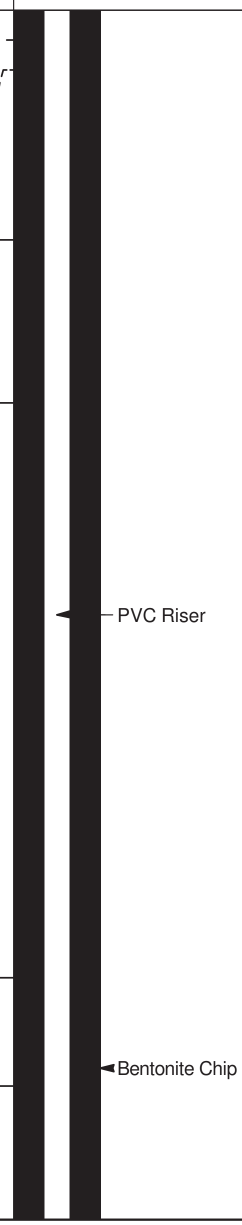


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Figure B-4: MW-101 Boring Log

CLIENT Confidential **PROJECT NAME** Solid Waste Landfill

PROJECT NUMBER **PROJECT LOCATION** Western Pennsylvania

DEPTH (m)	SAMPLE TYPE NUMBER	RECOVERY % (RQD)	BLOW COUNTS (N VALUE)	REMARKS	U.S.C.S.	GRAPHIC LOG	MATERIAL DESCRIPTION
6 – 7.5 – 9 – 10.6	RC 2	98 (13)		water in fractures			Dark gray SILTY CLAYSTONE, moderately weathered, broken, hard to medium hard, Fe staining within fractures, multiple horizontal fractures, diagonal fractures , highly weathered *(continued)*
	RC 3	98 (17)		clay surrounding core			
							Gray CLAYSTONE, moderately weathered, broken, hard, trace of silt (concentration decreasing with ∇ depth)
12	RC	100		clay surrounding			Dark gray SILTSTONE, highly weathered to moderately weathered, very broken to broken, hard to medium hard, little to no Fe staining, trace of fine-grained sand

WELL DIAGRAM

GENERAL BH / TP / WELL BORING LOGS.GPJ 101-986 SLDA.GPJ 3/15/15

(Continued Next Page)

WELL NUMBER MW-101

CLIENT Confidential

PROJECT NAME Solid Waste Landfill

PROJECT NUMBER

PROJECT LOCATION Western Pennsylvania

DEPTH (m)	SAMPLE TYPE NUMBER	RECOVERY % (RQD)	BLOW COUNTS (N VALUE)	REMARKS	U.S.C.S.	GRAPHIC LOG	MATERIAL DESCRIPTION	WELL DIAGRAM
13.7	4	(0)		core			Dark gray SILTSTONE, highly weathered to moderately weathered, very broken to broken, hard to medium hard, little to no Fe staining, trace of fine-grained sand *(continued)*	Screen
							Bottom of boring at 14.5 meters.	

WELL NUMBER MW-102B

CLIENT Confidential | **PROJECT NAME** Solid Waste Landfill
PROJECT NUMBER | **PROJECT LOCATION** Western Pennsylvania
DATE STARTED 11/23/12 **COMPLETED** 11/27/12 | **GROUND ELEVATION** **BACKFILL** 0.05 PVC Well
DRILLING CONTRACTOR | **WATER LEVELS:**
DRILLING METHOD Air | **BEFORE CORING** ---
Rotary | **AT END OF DRILLING** ---
NOTES | **AFTER DRILLING** ---

DEPTH (m)	SAMPLE TYPE NUMBER	GRAPHIC LOG	MATERIAL DESCRIPTION	WELL DIAGRAM
0			Black to red to brown silty CLAY, some decomposed rock fragments, and organics, moist, **(TOPSOIL)**	
			Brown and orange silty CLAY, some decomposed shale, moist-, **(RESIDUAL SOIL)**	
1.5				
3			Brown SHALE, moderately weathered, medium hard to soft	
4.5				
			Brown and gray CLAYSTONE, medium hard to soft	
6				

(Continued Next Page)

Figure B-5: MW-102B Boring Log

CLIENT Confidential | **PROJECT NAME** Solid Waste Landfill

PROJECT NUMBER | **PROJECT LOCATION** Western Pennsylvania

DEPTH (m)	SAMPLE TYPE NUMBER	GRAPHIC LOG	MATERIAL DESCRIPTION	WELL DIAGRAM
6			Brown and gray CLAYSTONE, medium hard to soft *(continued)*	
7.6				
9.1			Gray SANDSTONE, medium hard to hard	
10.7				
12.1				

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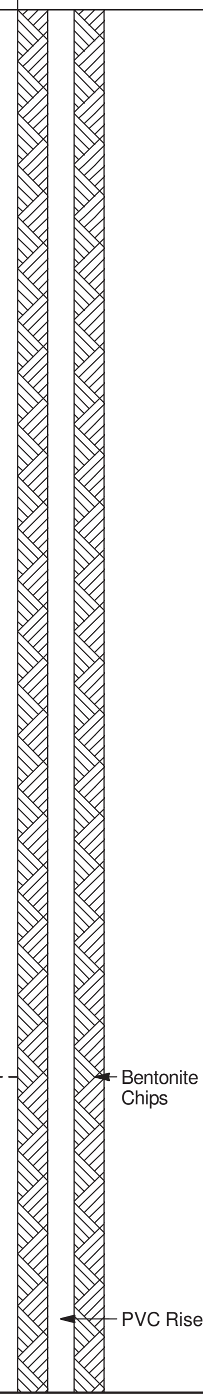
GENERAL BH / TP / WELL BORING LOGS.GPJ 101-986 SLDA.GPJ 3/15/15

CLIENT Confidential **PROJECT NAME** Solid Waste Landfill

PROJECT NUMBER **PROJECT LOCATION** Western Pennsylvania

DEPTH (m)	SAMPLE TYPE NUMBER	GRAPHIC LOG	MATERIAL DESCRIPTION
			Gray SANDSTONE, medium hard to hard *(continued)*
13.7			
15.2			
16.7			
18.2			
			Dark gray and black SILTSTONE, medium hard to hard
19.8			

WELL DIAGRAM



GENERAL BH / TP / WELL BORING LOGS.GPJ 101-986 SLDA.GPJ 3/15/15

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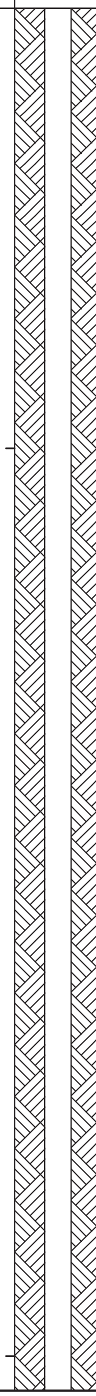
CLIENT Confidential **PROJECT NAME** Solid Waste Landfill
PROJECT NUMBER **PROJECT LOCATION** Western Pennsylvania

DEPTH (m)	SAMPLE TYPE NUMBER	GRAPHIC LOG	MATERIAL DESCRIPTION	WELL DIAGRAM
			Dark gray and black SILTSTONE, medium hard to hard *(continued)*	
21.3				
			Dark gray SANDY SILTSTONE, medium hard to hard	
22.8				
24.3				
25.9				
			Gray SILTSTONE, hard	



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CLIENT Confidential **PROJECT NAME** Solid Waste Landfill
PROJECT NUMBER **PROJECT LOCATION** Western Pennsylvania

DEPTH (m)	SAMPLE TYPE NUMBER	GRAPHIC LOG	MATERIAL DESCRIPTION	WELL DIAGRAM
			Gray SILTSTONE, hard *(continued)*	
27.4				
28.9				
30.4				
105				
33.5				

GENERAL BH / TP / WELL BORING LOGS.GPJ 101-986 SLDA.GPJ 3/15/15

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CLIENT Confidential **PROJECT NAME** Solid Waste Landfill
PROJECT NUMBER **PROJECT LOCATION** Western Pennsylvania

DEPTH (m)	SAMPLE TYPE NUMBER	GRAPHIC LOG	MATERIAL DESCRIPTION	WELL DIAGRAM
			Gray SILTSTONE, hard *(continued)*	
35				
36.5				
38.1				Hydrated Bentonite Seal
39.6				Clean Sand
			Black COAL, soft, shale interbedded	Screen
			Gray SILTSTONE, medium hard	

GENERAL BH / TP / WELL BORING LOGS.GPJ 101-986 SLDA.GPJ 3/15/15

(Continued Next Page)

WELL NUMBER MW-102B

CLIENT Confidential

PROJECT NAME Solid Waste Landfill

PROJECT NUMBER

PROJECT LOCATION Western Pennsylvania

DEPTH (m)	SAMPLE TYPE NUMBER	GRAPHIC LOG	MATERIAL DESCRIPTION	WELL DIAGRAM
41.1			Bottom of boring at 41.1 meters	

GENERAL BH / TP / WELL BORING LOGS.GPJ 101-986 SLDA.GPJ 3/15/15

WELL NUMBER MW-103A

CLIENT Confidential
PROJECT NAME Solid Waste Landfill
PROJECT NUMBER
PROJECT LOCATION Western Pennsylvania
DATE STARTED 9/10/12 **COMPLETED** 9/11/12
GROUND ELEVATION **BACKFILL** 0.05 PVC Well
DRILLING CONTRACTOR
WATER LEVELS:
DRILLING METHOD Air Rotary
BEFORE CORING 33.0 ft
AT END OF DRILLING 25.1 ft
NOTES
AFTER DRILLING ---

DEPTH (m)	SAMPLE TYPE NUMBER	U.S.C.S.	GRAPHIC LOG	MATERIAL DESCRIPTION	WELL DIAGRAM
0		CL-ML		Light brown and tan silty CLAY, and weathered rock fragments, moist to moist-, (shale and siltstone), **(RESIDUAL SOIL)**	
1.5					
3					Bentonite Chip
4.5				Gray and brown CLAYSTONE	
6					PVC Riser

GENERAL BH / TP / WELL BORING LOGS.GPJ 101-986 SLDA.GPJ 3/15/15

(Continued Next Page)

Figure B-6: MW-103A Boring Log

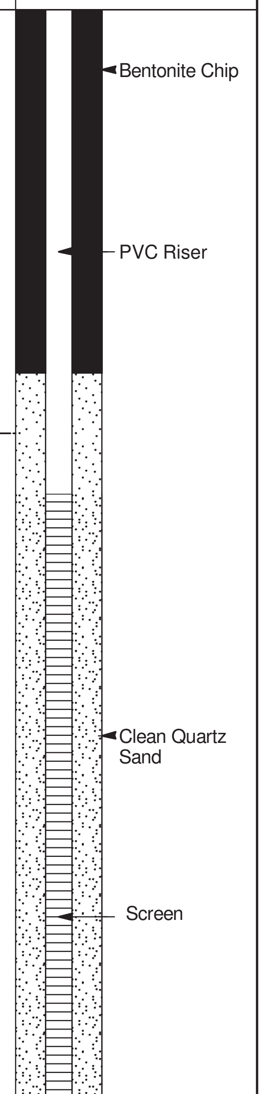
WELL NUMBER MW-103A

CLIENT Confidential | **PROJECT NAME** Solid Waste Landfill

PROJECT NUMBER | **PROJECT LOCATION** Western Pennsylvania

DEPTH (m)	SAMPLE TYPE NUMBER	U.S.C.S.	GRAPHIC LOG	MATERIAL DESCRIPTION
6				Gray and brown CLAYSTONE *(continued)*
7.6				
				Gray CLAYSTONE AND SANDSTONE, interbedded
9.1				
10.7				
				Bottom of boring at 11.6 meters

WELL DIAGRAM



CLIENT Confidential		**PROJECT NAME** Solid Waste Landfill	
PROJECT NUMBER		**PROJECT LOCATION** Western Pennsylvania	
DATE STARTED 9/6/12	**COMPLETED** 9/10/12	**GROUND ELEVATION**	**BACKFILL** 0.05 PVC Well
DRILLING CONTRACTOR		**WATER LEVELS:**	
DRILLING METHOD Air Rotary		▽ **BEFORE CORING** 25.0 ft	
CEC REP	**CHECKED BY**	▼ **AT END OF DRILLING** 58.3 ft	
NOTES		**AFTER DRILLING** ---	

DEPTH (m)	SAMPLE TYPE NUMBER	U.S.C.S.	GRAPHIC LOG	MATERIAL DESCRIPTION	WELL DIAGRAM
0		CL-ML		Light brown and tan silty CLAY, and weathered rock fragments, moist to moist-, (shale and siltstone), **(RESIDUAL SOIL)**	
1.5					Bentonite Chip
3					
4.5				Gray and brown CLAYSTONE	PVC Riser
6					

GENERAL BH / TP / WELL BORING LOGS.GPJ 101-986 SLDA.GPJ 3/15/15

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Figure B-7: MW-103B Boring Log

WELL NUMBER MW-103B

CLIENT Confidential

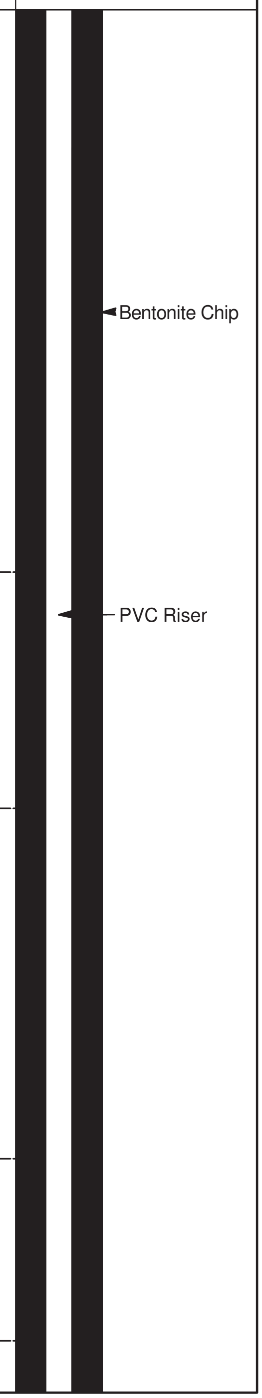
PROJECT NAME Solid Waste Landfill

PROJECT NUMBER

PROJECT LOCATION Western Pennsylvania

DEPTH (m)	SAMPLE TYPE NUMBER	U.S.C.S.	GRAPHIC LOG	MATERIAL DESCRIPTION
6				Gray and brown CLAYSTONE *(continued)*
7.6				▽
				Gray CLAYSTONE AND SANDSTONE, interbedded
9.1				
				Light gray SANDSTONE
10.7				
				Gray CLAYSTONE AND SANDSTONE
12.1				
				Dark gray and brown CLAYSTONE

WELL DIAGRAM



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GENERAL BH / TP / WELL BORING LOGS.GPJ 101-986 SLDA.GPJ 3/15/15

CLIENT Confidential

PROJECT NAME Solid Waste Landfill

PROJECT NUMBER

PROJECT LOCATION Western Pennsylvania

DEPTH (m)	SAMPLE TYPE NUMBER	U.S.C.S.	GRAPHIC LOG	MATERIAL DESCRIPTION	WELL DIAGRAM
				Dark gray and brown CLAYSTONE *(continued)*	
13.7					
15.2					
16.7				▼	
18.2				Brown and gray CLAYSTONE AND SANDSTONE	
				Very dark gray to black SHALE	PVC Riser
19.8				Dark gray SILTSTONE	

(Continued Next Page)

CLIENT Confidential **PROJECT NAME** Solid Waste Landfill

PROJECT NUMBER **PROJECT LOCATION** Western Pennsylvania

DEPTH (m)	SAMPLE TYPE NUMBER	U.S.C.S.	GRAPHIC LOG	MATERIAL DESCRIPTION	WELL DIAGRAM
				Dark gray SILTSTONE *(continued)*	
				Gray CLAYSTONE AND SANDSTONE	
				Gray SANDSTONE	
21.3					Bentonite Chip
22.8					
24.3					
25.9					PVC Riser

(Continued Next Page)

CLIENT Confidential
PROJECT NAME Solid Waste Landfill
PROJECT NUMBER
PROJECT LOCATION Western Pennsylvania

DEPTH (m)	SAMPLE TYPE NUMBER	U.S.C.S.	GRAPHIC LOG	MATERIAL DESCRIPTION	WELL DIAGRAM
				Gray SANDSTONE *(continued)*	
27.4				Gray SILTSTONE, some fine-grained sandstone	
28.9					
30.5					Bentonite Chip
				Gray SHALE AND SANDSTONE	
32					
33.5					

(Continued Next Page)

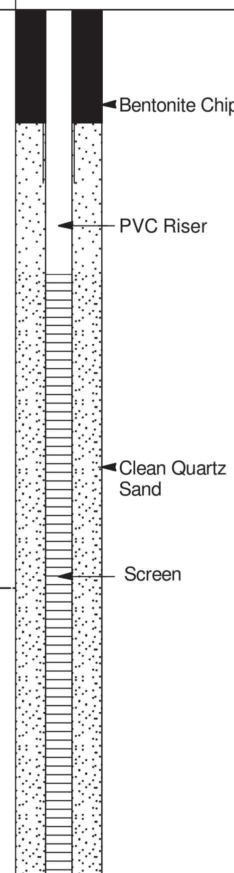
WELL NUMBER MW-103B

CLIENT Confidential | **PROJECT NAME** Solid Waste Landfill

PROJECT NUMBER | **PROJECT LOCATION** Western Pennsylvania

DEPTH (m)	SAMPLE TYPE NUMBER	U.S.C.S.	GRAPHIC LOG	MATERIAL DESCRIPTION
				Gray SHALE AND SANDSTONE *(continued)*
35				
36.5				
				Black COAL, interbedded with shale
38.1				
				Bottom of boring at 38.3 meters

WELL DIAGRAM



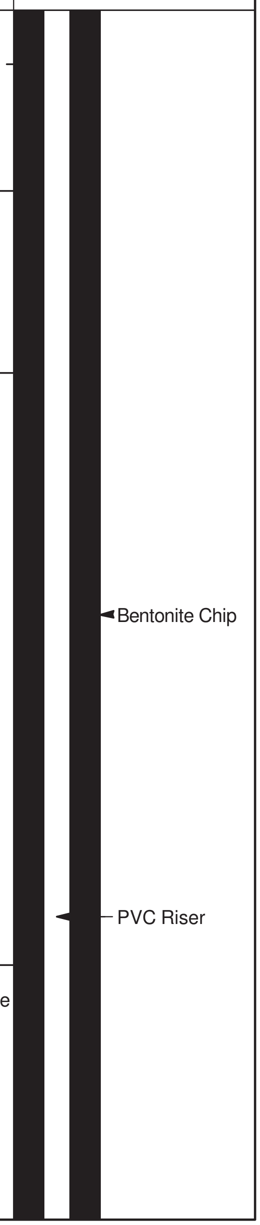
GENERAL BH / TP / WELL BORING LOGS.GPJ 101-986 SLDA.GPJ 3/15/15

WELL NUMBER MW-103C

CLIENT Confidential
PROJECT NAME Solid Waste Landfill
PROJECT NUMBER
PROJECT LOCATION Western Pennsylvania
DATE STARTED 9/4/12 **COMPLETED** 9/6/12
GROUND ELEVATION **BACKFILL** 0.05 PVC Well
DRILLING CONTRACTOR
WATER LEVELS:
DRILLING METHOD Hollow Stem Auger & HQ Core
▽ **BEFORE CORING** 28.0 ft
AT END OF DRILLING ---
NOTES
AFTER DRILLING ---

DEPTH (m)	SAMPLE TYPE NUMBER	RECOVERY % (RQD)	BLOW COUNTS (N VALUE)	REMARKS	U.S.C.S.	MATERIAL DESCRIPTION
0	SS 1	85	2-8-11-17 (19)			Brown, tan, and reddish-brown silty CLAY, some weathered rock fragments, moist to moist-, medium stiff, **(RESIDUAL SOIL)**
					CL-ML	Orange and gray silty CLAY, trace weathered rock fragments, and mottling, moist-, very stiff, **(RESIDUAL SOIL)**
	SS 2	85	7-17-50/0.3		CL-ML	Reddish brown and tan SILT AND CLAY, some weathered rock fragments, moist- to dry, hard, (shale), **(RESIDUAL SOIL)**
1.5						
	SS 3	60	50/0.5			Tan and gray weathered ROCK FRAGMENTS, some silty clay, moist- to dry, hard, (shale), **(WEATHERED ROCK)**
3	SS 4	100	23-50/0.3			
	SS 5	100	25-50/0.5			
4.5	SS 6	133	15-50/0.1			
	RC 1	100 (0)		core is wet		Gray and brown CLAYSTONE, highly weathered, broken, medium hard to hard, micro laminated, trace of very fine-grained sand, multiple horizontal fractures, Fe staining, diagonal fracture
6						

WELL DIAGRAM



GENERAL BH / TP / WELL BORING LOGS.GPJ 101-986 SLDA.GPJ 3/15/15

(Continued Next Page)

Figure B-8: MW-103C Boring Log

CLIENT Confidential
PROJECT NUMBER
PROJECT NAME Solid Waste Landfill
PROJECT LOCATION Western Pennsylvania

DEPTH (m)	SAMPLE TYPE NUMBER	RECOVERY % (RQD)	BLOW COUNTS (N VALUE)	REMARKS	U.S.C.S.	GRAPHIC LOG	MATERIAL DESCRIPTION	WELL DIAGRAM
6							Gray and brown CLAYSTONE, highly weathered, broken, medium hard to hard, micro laminated, trace of very fine-grained sand, multiple horizontal fractures, Fe staining a' *(continued)*	
	RC 2	70 (19)					Dark gray SANDSTONE, highly weathered, broken, medium hard to hard, micaceous, massive, very fined-grained and SHALE lenses, multiple horizontal fractures, Fe staining, diagonal fractures, vertical fracture	
7.6								Bentonite Chip
							∇	
							Gray CLAYSTONE, highly weathered, very broken, very soft	
9.1	RC 3	94 (28)					Gray SANDSTONE, moderately weathered, broken, hard, micaceous, massive, very fine-grained to fine-grained, trace of shale, multiple horizontal fractures, clay within about 25% of fractures, vertical fracture, Fe staining	2" PVC Riser
10.7							Gray SANDSTONE, moderately weathered, broken to moderately broken, hard, micaceous, fine-grained to medium-grained, <0.03" shale lenses, lenticular bedding, Fe staining and very broken with clay	
	RC 4	100 (62)		begin coring with water				
12.2								

(Continued Next Page)

WELL NUMBER MW-103C

CLIENT Confidential **PROJECT NAME** Solid Waste Landfill

PROJECT NUMBER **PROJECT LOCATION** Western Pennsylvania

DEPTH (m)	SAMPLE TYPE NUMBER	RECOVERY % (RQD)	BLOW COUNTS (N VALUE)	REMARKS	U.S.C.S.	GRAPHIC LOG	MATERIAL DESCRIPTION	WELL DIAGRAM
13.7	RC 5	100 (78)					Gray SANDSTONE, slightly weathered, moderately broken, hard, micaceous, fine-grained to medium-grained, 0.03"-3" shale lenses, lenticular bedding, Fe staining, some horizontal fractures, vertical fractures	
15.2								Bentonite Chip
16.7	RC 6	100 (87)					Dark gray CLAYSTONE, moderately weathered, moderately broken, hard, Fe staining and vertical fracture, highly weathered and very broken	
18.3								PVC Riser
							Very dark gray and black to dark gray CARBONACEOUS SHALE, slightly weathered, slightly broken, hard, micro laminated, some horizontal fractures, trace of fine-grained sandstone lenses, shells, highly weathered and broken	
19.8							Dark gray SILTSTONE, moderately weathered, broken, medium hard, trace of shells, diagonal fracture, highly weathered and broken	

(Continued Next Page)

CLIENT Confidential | **PROJECT NAME** Solid Waste Landfill

PROJECT NUMBER | **PROJECT LOCATION** Western Pennsylvania

DEPTH (m)	SAMPLE TYPE NUMBER	RECOVERY % (RQD)	BLOW COUNTS (N VALUE)	REMARKS	U.S.C.S.	GRAPHIC LOG	MATERIAL DESCRIPTION	WELL DIAGRAM
							Dark gray SILTSTONE, moderately weathered, broken, medium hard, trace of shells, diagonal fracture, highly weathered and broken *(continued)*	
							Black COAL, moderately weathered, broken, soft	
	RC 7	94 (81)					Gray SANDSTONE, slightly weathered, slightly broken, hard, micaceous, massive, very fine-grained, little to no Fe staining, diagonal fractures, some shale lenses and cross-bedding	
21.3								
							Gray SANDSTONE, slightly weathered, slightly broken, hard, micaceous, massive, fine-grained to medium-grained, some shale lenses and cross-bedding	
22.8	RC 8	100 (81)						
							Gray SHALE AND SANDSTONE, slightly weathered to fresh, slightly broken, medium hard, micaceous, thin bedded, fine-grained to medium-grained, interbedded, diagonal fracture , horizontal fracture	
24.3								
	RC 9	100 (96)					Gray CLAYSTONE, slightly weathered to fresh, slightly broken, hard to very hard, massive, silty with some fine-grained sandstone lenses, trace of pyrite, trace of crossbedding, diagonal fracture	
25.9								PVC Riser

(Continued Next Page)

CLIENT Confidential **PROJECT NAME** Solid Waste Landfill

PROJECT NUMBER **PROJECT LOCATION** Western Pennsylvania

DEPTH (m)	SAMPLE TYPE NUMBER	RECOVERY % (RQD)	BLOW COUNTS (N VALUE)	REMARKS	U.S.C.S.	GRAPHIC LOG	MATERIAL DESCRIPTION	WELL DIAGRAM
27.4							Gray CLAYSTONE, slightly weathered to fresh, slightly broken, hard to very hard, massive, silty with some fine-grained sandstone lenses, trace of pyrite, trace of crossbedding, diagonal fracture *(continued)*	
	RC 10	99 (99)						
28.9								
30.5								Bentonite Chip
	RC 11	100 (98)						
32								
33.5								Bentonite Chip
	RC 12	100 (96)						

(Continued Next Page)

CLIENT Confidential

PROJECT NUMBER

PROJECT NAME Solid Waste Landfill

PROJECT LOCATION Western Pennsylvania

DEPTH (m)	SAMPLE TYPE NUMBER	RECOVERY % (RQD)	BLOW COUNTS (N VALUE)	REMARKS	U.S.C.S.	GRAPHIC LOG	MATERIAL DESCRIPTION	WELL DIAGRAM
							Very dark gray to black CLAYSTONE, slightly weathered to fresh, slightly broken to broken, medium hard to hard, shells, lenticular bedding and medium-grained sandstone lenses *(continued)*	
35	RC 13	100 (91)						PVC Riser
36.5							Black COAL, moderately weathered, broken, medium hard to soft, shale interbedded	
	RC 14	95 (61)					Gray CLAYSTONE, moderately weathered to slightly weathered, broken to slightly broken, medium hard, massive, trace of silt	
38.1								
39.6								Clean Quartz Sand
							Gray CLAYSTONE, slightly weathered, broken, hard, massive, some limestone or calcite fragments, diagonal fracture, trace of fine-grained sandstone lenses	Screen
	RC 15	99 (99)						

(Continued Next Page)

WELL NUMBER MW-103C

CLIENT Confidential

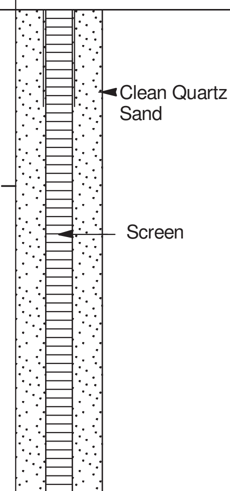
PROJECT NAME Solid Waste Landfill

PROJECT NUMBER

PROJECT LOCATION Western Pennsylvania

DEPTH (m)	SAMPLE TYPE NUMBER	RECOVERY % (RQD)	BLOW COUNTS (N VALUE)	REMARKS	U.S.C.S.	GRAPHIC LOG	MATERIAL DESCRIPTION
41.1							Gray CLAYSTONE, slightly weathered, broken, hard, massive, some limestone or calcite fragments, diagonal fracture, trace of fine-grained sandstone lenses *(continued)*
							Gray SILTSTONE, slightly weathered, slightly broken, hard to very hard, massive, some limestone or calcite fragments/veins, diagonal fracture
42.6	RC 16	100 (95)					
							Bottom of boring at 43.3 meters

WELL DIAGRAM



GENERAL BH / TP / WELL BORING LOGS.GPJ 101-986 SLDA.GPJ 3/15/15

WELL NUMBER MW-105

CLIENT Confidential
PROJECT NAME Solid Waste Landfill
PROJECT NUMBER
PROJECT LOCATION Western Pennsylvania
DATE STARTED 9/20/12 **COMPLETED** 9/20/12
GROUND ELEVATION **BACKFILL** 0.05PVC Well
DRILLING CONTRACTOR
WATER LEVELS:
DRILLING METHOD Hollow Stem Auger & HQ Core
∇ **BEFORE CORING** 23.0 ft
AT END OF DRILLING ---
NOTES
AFTER DRILLING ---

DEPTH (m)	SAMPLE TYPE NUMBER	RECOVERY % (RQD)	BLOW COUNTS (N VALUE)	REMARKS	U.S.C.S.	MATERIAL DESCRIPTION	WELL DIAGRAM
0						Brown clayey SILT, some organics, moist, very soft, **(TOPSOIL)**	
	SS 1	85	2-2-4-5 (6)		CL-ML	Brown clayey SILT, trace fine sand, and rock fragments, moist, medium stiff, **(RESIDUAL SOIL)**	
1.5	SS 2	65	1-1-6-11 (7)		CL-ML	Brown CLAY AND SILT, trace rock fragments, moist-, medium stiff, (shale), **(RESIDUAL SOIL)**	Bentonite Chip
	SS 3	75	2-5-9-16 (14)		ML	Brown, gray, and black sandy SILT, some rock fragments, moist to moist-, stiff, (shale and siltstone), **(RESIDUAL SOIL)**	
3	SS 4	100	15-50/0.4		CL-ML	Gray, light brown, and orange sandy SILTSTONE, some silty clay, moist-, very stiff, **(WEATHERED ROCK)**	
	SS 5	100	32-50/0.2				PVC Riser
4.5	SS 6	100	11-50/0.4			Gray weathered SAND AND ROCK FRAGMENTS, moist, very stiff, (siltstone), **(WEATHERED ROCK)**	
	RC	100		water in fractures		Gray to dark gray CLAYSTONE, highly weathered, broken, soft, some fine-grained sand, multiple horizontal fractures, Fe staining in fractures, diagonal fracture	
6						Dark gray SILTSTONE, moderately weathered, broken, medium hard, trace of fine-grained sand, multiple horizontal fractures, Fe staining and diagonal fracture	

GENERAL BH / TP / WELL BORING LOGS.GPJ 101-986 SLDA.GPJ 3/15/15

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Figure B-9: MW-105 Boring Log

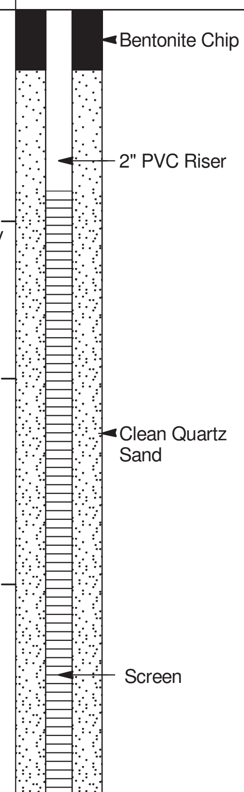
WELL NUMBER MW-105

CLIENT Confidential **PROJECT NAME** Solid Waste Landfill

PROJECT NUMBER **PROJECT LOCATION** Western Pennsylvania

DEPTH (m)	SAMPLE TYPE NUMBER	RECOVERY % (RQD)	BLOW COUNTS (N VALUE)	REMARKS	U.S.C.S.	GRAPHIC LOG	MATERIAL DESCRIPTION
6	1	(11)					Dark gray SILTSTONE, moderately weathered, broken, medium hard, trace of fine-grained sand, multiple horizontal fractures, Fe staining and diagonal fracture *(continued)* ∇
							Gray SILTSTONE, moderately weathered to slightly weathered, broken, medium hard, fine-grained sand, very broken with Fe staining
7.6							Dark gray SANDSTONE, moderately weathered to slightly weathered, broken, hard, micaceous, massive, very fine-grained to fine-grained
9.1	RC 2	100 (53)		clay surrounding core			Dark gray and gray SANDSTONE, slightly weathered, moderately broken, hard, micro laminated, fine-grained with shale lenses, Fe staining
							Bottom of boring at 10 meters

WELL DIAGRAM



WELL NUMBER MW-105B

CLIENT Confidential
PROJECT NAME Solid Waste Landfill
PROJECT NUMBER
PROJECT LOCATION Western Pennsylvania
DATE STARTED 11/29/12 **COMPLETED** 11/30/12
GROUND ELEVATION **BACKFILL** 0.05 PVC Well
DRILLING CONTRACTOR
WATER LEVELS:
DRILLING METHOD Air
Rotary
BEFORE CORING ---
AT END OF DRILLING ---
NOTES
AFTER DRILLING ---

DEPTH (m)	SAMPLE TYPE NUMBER	GRAPHIC LOG	MATERIAL DESCRIPTION	WELL DIAGRAM
0			Brown to orangish yellow silty CLAY, some decomposed shale, and organics, moist+, **(TOPSOIL)**	
			Brown and orange silty CLAY, some decomposed shale, moist, **(RESIDUAL SOIL)**	
1.5				
3				
			Dark brown silty CLAY, moist, **(RESIDUAL SOIL)**	
			Dark gray decomposed claystone, moist-, **(RESIDUAL SOIL)**	
			Gray SANDSTONE, slightly weathered, medium hard to hard	
4.5				
6				

(Continued Next Page)

Figure B-10: MW-105B Boring Log

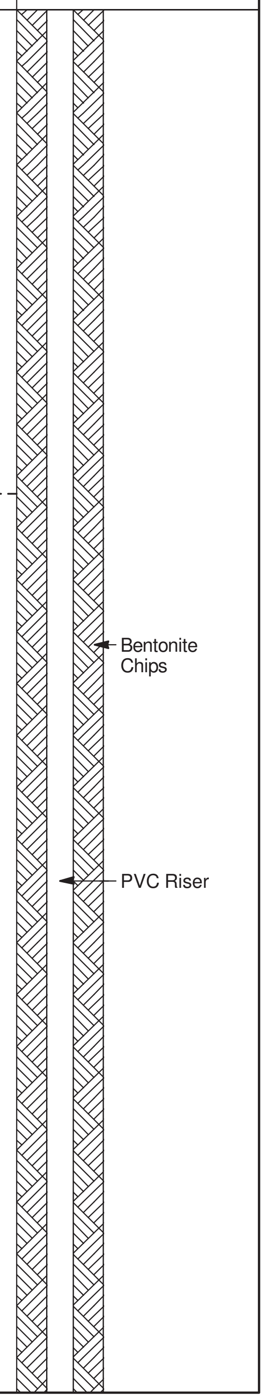
CLIENT Confidential

PROJECT NUMBER

PROJECT NAME Solid Waste Landfill

PROJECT LOCATION Western Pennsylvania

DEPTH (m)	SAMPLE TYPE NUMBER	GRAPHIC LOG	MATERIAL DESCRIPTION	WELL DIAGRAM
6			Gray SANDSTONE, slightly weathered, medium hard to hard *(continued)*	
7.6				
			Gray SILTSTONE, hard to very hard	
9.1				
10.6				
12.2				



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GENERAL BH / TP / WELL BORING LOGS.GPJ 101-986 SLDA.GPJ 3/15/15

WELL NUMBER MW-105B

CLIENT Confidential
PROJECT NAME Solid Waste Landfill
PROJECT NUMBER
PROJECT LOCATION Western Pennsylvania

DEPTH (m)	SAMPLE TYPE NUMBER	GRAPHIC LOG	MATERIAL DESCRIPTION	WELL DIAGRAM
			Gray SILTSTONE, hard to very hard *(continued)*	
13.7				
15.2				
16.7				
18.3				
				Hydrated Bentonite Seal
19.8				

(Continued Next Page)

WELL NUMBER MW-105B

CLIENT Confidential

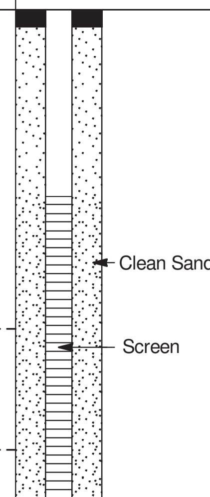
PROJECT NAME Solid Waste Landfill

PROJECT NUMBER

PROJECT LOCATION Western Pennsylvania

DEPTH (m)	SAMPLE TYPE NUMBER	GRAPHIC LOG	MATERIAL DESCRIPTION
			Gray SILTSTONE, hard to very hard *(continued)*
21.3			
			Black COAL, medium hard to soft, shale interbedded
			Gray SILTSTONE, hard
			Bottom of boring at 22.5 meters

WELL DIAGRAM



WELL NUMBER MW-107A

CLIENT Confidential
PROJECT NAME Solid Waste Landfill
PROJECT NUMBER
PROJECT LOCATION Western Pennsylvania
DATE STARTED 8/30/12 **COMPLETED** 8/31/12
GROUND ELEVATION **BACKFILL** 0.05 PVC Well
DRILLING CONTRACTOR
WATER LEVELS:
DRILLING METHOD Air Rotary
▽ **BEFORE CORING** 34.0 ft
AT END OF DRILLING ---
NOTES
AFTER DRILLING ---

DEPTH (m)	SAMPLE TYPE NUMBER	U.S.C.S.	GRAPHIC LOG	MATERIAL DESCRIPTION
0				Light brown silty CLAY, some organics, moist, **(TOPSOIL)**
		ML		Brown clayey SILT, trace weathered rock fragments, moist-, **(RESIDUAL SOIL)**
1.5				
3				
4.5				Dark brown and gray CLAYSTONE
6				

WELL DIAGRAM

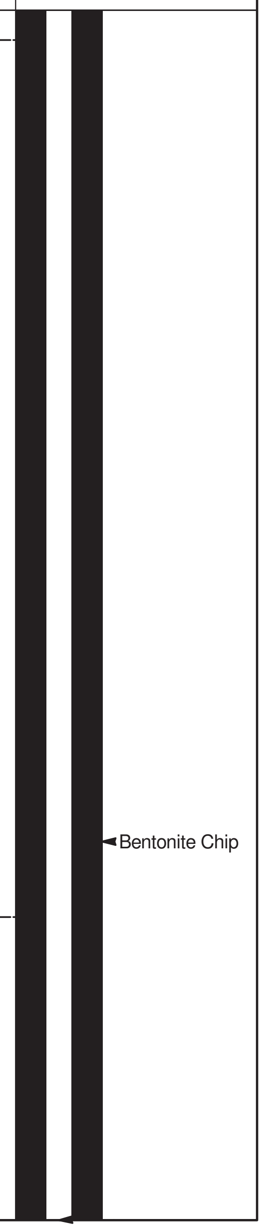


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Figure B-11: MW-107A Boring Log

WELL NUMBER MW-107A

CLIENT Confidential

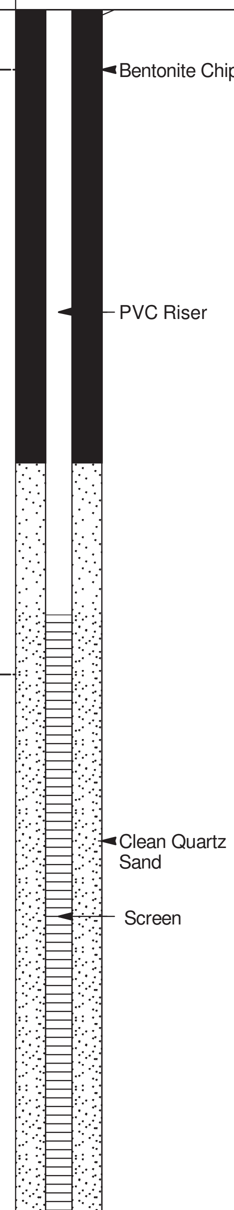
PROJECT NAME Solid Waste Landfill

PROJECT NUMBER

PROJECT LOCATION Western Pennsylvania

DEPTH (m)	SAMPLE TYPE NUMBER	U.S.C.S.	GRAPHIC LOG	MATERIAL DESCRIPTION
6				Dark brown and gray CLAYSTONE *(continued)*
				Gray SANDSTONE WITH CLAY SEAMS
7.6				
9.1				
				Gray CLAYSTONE
				∇
10.7				
12.2				
				Bottom of boring at 12.2 meters

WELL DIAGRAM



WELL NUMBER MW-107B

CLIENT Confidential

PROJECT NAME Solid Waste Landfill

PROJECT NUMBER

PROJECT LOCATION Western Pennsylvania

DATE STARTED 8/28/12 **COMPLETED** 8/30/12

GROUND ELEVATION **BACKFILL** 0.05PVC Well

DRILLING CONTRACTOR

WATER LEVELS:

DRILLING METHOD Air

▽ **BEFORE CORING** 31.5 ft

Rotary

AT END OF DRILLING ---

NOTES

AFTER DRILLING ---

DEPTH (m)	SAMPLE TYPE NUMBER	U.S.C.S.	GRAPHIC LOG	MATERIAL DESCRIPTION	WELL DIAGRAM
0				Light brown silty CLAY, some organics, moist, **(TOPSOIL)**	
		ML		Brown clayey SILT, trace weathered rock fragments, moist-, **(RESIDUAL SOIL)**	
1.5		CL-ML		Brown clayey SILT, moist, (shale), **(RESIDUAL SOIL)**	Bentonite Chip
3					PVC Riser
4.5				Gray-brown clayey SILT, moist, (weathered shale), **(RESIDUAL SOIL)**	
				Dark brown and gray CLAYSTONE	
6					

GENERAL BH / TP / WELL BORING LOGS.GPJ 101-986 SLDA.GPJ 3/15/15

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Figure B-12: MW-107B Boring Log

WELL NUMBER MW-107B

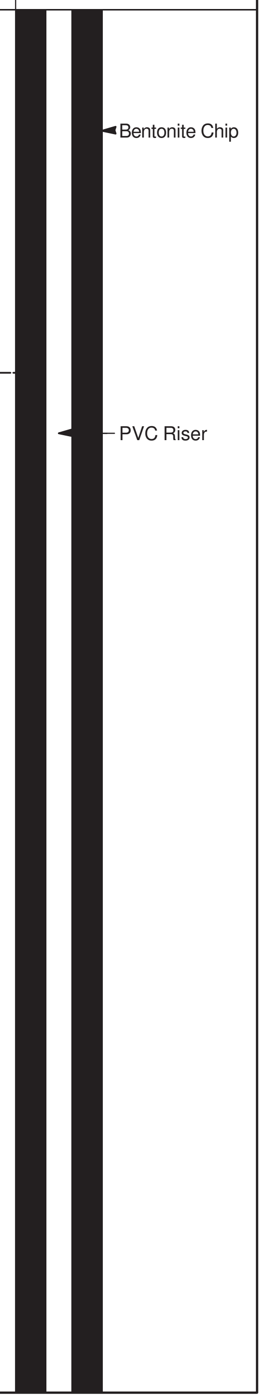
CLIENT Confidential

PROJECT NAME Solid Waste Landfill

PROJECT NUMBER

PROJECT LOCATION Western Pennsylvania

DEPTH (m)	SAMPLE TYPE NUMBER	U.S.C.S.	GRAPHIC LOG	MATERIAL DESCRIPTION	WELL DIAGRAM
6				Dark brown and gray CLAYSTONE *(continued)*	
7.6					
				Gray SANDSTONE WITH CLAY SEAMS	
9.1					
				∇	
10.7					
12.2					



GENERAL BH / TP / WELL BORING LOGS.GPJ 101-986 SLDA.GPJ 3/15/15

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CLIENT Confidential

PROJECT NAME Solid Waste Landfill

PROJECT NUMBER

PROJECT LOCATION Western Pennsylvania

DEPTH (m)	SAMPLE TYPE NUMBER	U.S.C.S.	GRAPHIC LOG	MATERIAL DESCRIPTION	WELL DIAGRAM
				Gray SANDSTONE WITH CLAY SEAMS *(continued)*	
13.7					
15.2					
16.7					
					Bentonite Chip
18.3				Gray CLAYSTONE	
19.8					PVC Riser

(Continued Next Page)

CLIENT Confidential

PROJECT NAME Solid Waste Landfill

PROJECT NUMBER

PROJECT LOCATION Western Pennsylvania

DEPTH (m)	SAMPLE TYPE NUMBER	U.S.C.S.	GRAPHIC LOG	MATERIAL DESCRIPTION	WELL DIAGRAM
				Gray CLAYSTONE *(continued)*	
				Dark gray SANDY CLAYSTONE	
21.3				Gray SANDSTONE	
22.8					
				Dark gray SANDY CLAYSTONE	
24.4					
25.9					

GENERAL BH / TP / WELL BORING LOGS.GPJ 101-986 SLDA.GPJ 3/15/15

(Continued Next Page)

WELL NUMBER MW-107B

CLIENT Confidential | **PROJECT NAME** Solid Waste Landfill

PROJECT NUMBER | **PROJECT LOCATION** Western Pennsylvania

DEPTH (m)	SAMPLE TYPE NUMBER	U.S.C.S.	GRAPHIC LOG	MATERIAL DESCRIPTION	WELL DIAGRAM
				Dark gray SANDY CLAYSTONE *(continued)*	
27.4					
28.9					PVC Riser
				Gray CLAYSTONE, some sandstone lenses	
30.5					Bentonite Chip
32					
33.5					

GENERAL BH / TP / WELL BORING LOGS.GPJ 101-986 SLDA.GPJ 3/15/15

(Continued Next Page)

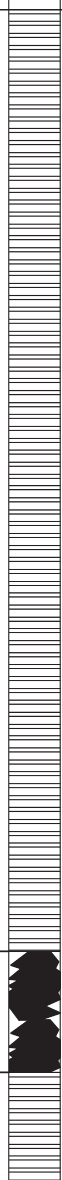
CLIENT Confidential

PROJECT NAME Solid Waste Landfill

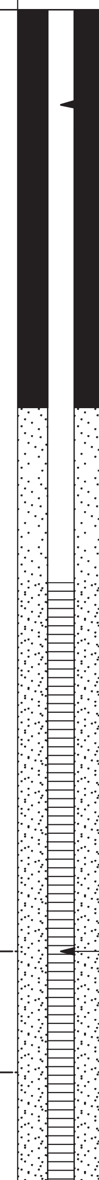
PROJECT NUMBER

PROJECT LOCATION Western Pennsylvania

DEPTH (m)	SAMPLE TYPE NUMBER	U.S.C.S.	GRAPHIC LOG	MATERIAL DESCRIPTION
				Gray CLAYSTONE, some sandstone lenses *(continued)*
35				
36.5				
38.1				
				Black COAL
				Gray CLAYSTONE
39.6				
				Bottom of boring at 39.9 meters



WELL DIAGRAM



CLIENT Confidential
PROJECT NAME Solid Waste Landfill
PROJECT NUMBER
PROJECT LOCATION Western Pennsylvania
DATE STARTED 8/22/12 **COMPLETED** 8/28/12
GROUND ELEVATION **BACKFILL** 0.05 PVC Well
DRILLING CONTRACTOR
WATER LEVELS:
DRILLING METHOD Hollow Stem Auger & HQ Core
BEFORE CORING 26.8 ft
AT END OF DRILLING ---
NOTES
AFTER DRILLING ---

DEPTH (m)	SAMPLE TYPE NUMBER	RECOVERY % (RQD)	BLOW COUNTS (N VALUE)	REMARKS	U.S.C.S.	MATERIAL DESCRIPTION
0	SS 1	55	5-13-15-17 (28)		ML	Dark brown silty CLAY, some organics, moist, **(TOPSOIL)** Light brown clayey SILT, trace shale fragments, moist- to dry, very stiff, **(RESIDUAL SOIL)**
	SS 2	70	2-3-7-9 (10)		CL-ML	Brown clayey SILT, some weathered rock fragments, trace fine sand, moist- to moist, hard, (shale), **(RESIDUAL SOIL)**
1.5	SS 3	100	3-7-9-16 (16)			
3	SS 4	100	2-10-20-31 (30)		CL-ML	Brown and orange clayey SILT, and weathered rock fragments, trace very fine sand, moist, hard, (shale), **(RESIDUAL SOIL)**
	SS 5	100	11-50/0.4		CL-ML	Reddish brown and gray clayey SILT, and weathered rock fragments, moist, hard, (shale), **(RESIDUAL SOIL)**
4.5	SS 6	100	29-50/0.2			Brown ROCK FRAGMENTS, moist- to dry, hard, (weathered shale), **(WEATHERED ROCK)**
	RC 1	100 (6)				Red-brown and gray SHALEY SANDSTONE, completely weathered, very broken, medium hard, micaceous, Fe staining throughout run Dark gray CLAYSTONE, highly weathered, broken, hard, multiple horizontal fractures, Fe staining some shale
6						

WELL DIAGRAM

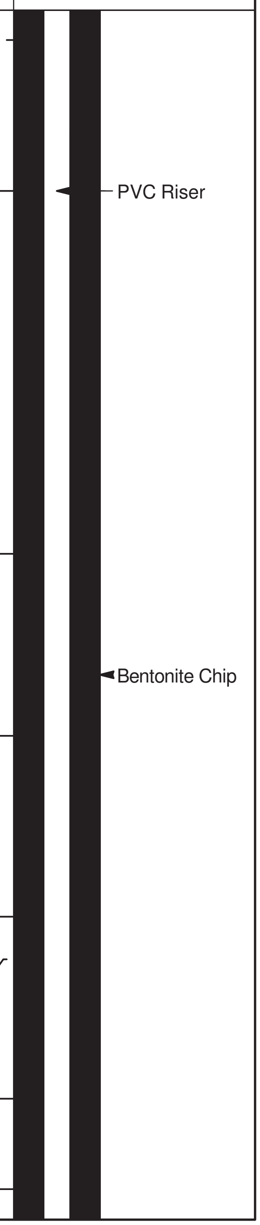


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Figure B-13: MW-107C Boring Log

CLIENT Confidential **PROJECT NAME** Solid Waste Landfill
PROJECT NUMBER **PROJECT LOCATION** Western Pennsylvania

DEPTH (m)	SAMPLE TYPE NUMBER	RECOVERY % (RQD)	BLOW COUNTS (N VALUE)	REMARKS	U.S.C.S.	GRAPHIC LOG	MATERIAL DESCRIPTION	WELL DIAGRAM
6							Gray SANDSTONE, slightly weathered, broken, very hard, micaceous, very fine-grained with trace of thin shale lenses, a few horizontal fractures *(continued)*	
							Dark gray CLAYSTONE, moderately weathered, broken, hard, very broken, diagonal fracture, Fe staining	
							Brown and gray SANDSTONE, highly weathered, broken, medium hard, thinly laminated, very fine-grained with shale lenses	
7.6								Bentonite Chip
	RC 2	92 (4)					Gray SANDSTONE, moderately weathered to slightly weathered, broken to moderately broken, hard, siliceous, thinly laminated, fine-grained, multiple horizontal fractures, diagonal fracture, black shale, some Fe staining	
9.1							Gray SANDSTONE, slightly weathered, moderately broken, hard to very hard, massive, fine-grained with shale lenses, Fe staining in fractures , small diagonal fracture, some horizontal fractures	PVC Riser
	RC 3	87 (56)						
							Gray SANDSTONE, moderately weathered, broken, hard, fine to medium-grained with shale lenses, multiple horizontal fractures	
10.7								
	RC 4	100 (68)					Gray SANDSTONE, slightly weathered, slightly broken, hard, massive, medium to coarse-grained with thin, dark gray impurities, very little Fe staining, clay in fractures	
12.2								
							Dark gray CLAYSTONE, slightly weathered, moderately broken, medium hard, thin bedded, Fe staining and diagonal	

(Continued Next Page)

CLIENT Confidential **PROJECT NAME** Solid Waste Landfill

PROJECT NUMBER **PROJECT LOCATION** Western Pennsylvania

DEPTH (m)	SAMPLE TYPE NUMBER	RECOVERY % (RQD)	BLOW COUNTS (N VALUE)	REMARKS	U.S.C.S.	GRAPHIC LOG	MATERIAL DESCRIPTION	WELL DIAGRAM
	RC 5	99 (71)		begin coring with water			Black and dark gray SHALE, slightly weathered, moderately broken, hard, thinly laminated, multiple horizontal fractures, Fe staining, vertical fracture , very fine-grained to fine-grained sandstone interbedded, lenticular bedding throughout *(continued)*	
13.7								
							Black and dark gray CLAYSTONE, slightly weathered, slightly broken to moderately broken, very hard, massive, interbedded with very thin layers of very fine-grained to fine-grained sandstone	
15.2	RC 6	98 (86)						
16.7	RC 7	98 (78)						
							Dark gray CLAYSTONE, slightly weathered, slightly broken, hard, micro laminated, diagonal fractures, trace of pyrite and fine-grained sand	
18.3								
	RC 8	100 (73)						
19.8								

(Continued Next Page)

CLIENT Confidential **PROJECT NAME** Solid Waste Landfill
PROJECT NUMBER **PROJECT LOCATION** Western Pennsylvania

DEPTH (m)	SAMPLE TYPE NUMBER	RECOVERY % (RQD)	BLOW COUNTS (N VALUE)	REMARKS	U.S.C.S.	GRAPHIC LOG	MATERIAL DESCRIPTION	WELL DIAGRAM
							Black CARBONACEOUS SHALE, slightly weathered, slightly broken, hard, massive, diagonal fracture	Bentonite Chip
21.3	RC 9	100 (79)					Gray SANDSTONE, slightly weathered, slightly broken, hard, cross-bedded, fine-grained with shale lenses	PVC Riser
22.8							Dark gray CLAYSTONE, slightly weathered, moderately broken, medium hard, zones of cross-bedding and fine-grained sand	
24.4	RC 10	100 (86)						
25.9								

(Continued Next Page)

CLIENT Confidential **PROJECT NAME** Solid Waste Landfill

PROJECT NUMBER **PROJECT LOCATION** Western Pennsylvania

DEPTH (m)	SAMPLE TYPE NUMBER	RECOVERY % (RQD)	BLOW COUNTS (N VALUE)	REMARKS	U.S.C.S.	GRAPHIC LOG	MATERIAL DESCRIPTION	WELL DIAGRAM
27.4							Dark gray CLAYSTONE, slightly weathered, slightly broken, medium hard to hard, fine-grained to medium-grained sandstone lenses, diagonal fracture, vertical fracture *(continued)*	
	RC 11	94 (94)						
28.9								
30.5	RC 12	100 (100)						Bentonite Chip
32								
	RC 13	102 (95)						
33.5								PVC Riser

(Continued Next Page)

CLIENT Confidential
PROJECT NAME Solid Waste Landfill
PROJECT NUMBER
PROJECT LOCATION Western Pennsylvania

DEPTH (m)	SAMPLE TYPE NUMBER	RECOVERY % (RQD)	BLOW COUNTS (N VALUE)	REMARKS	U.S.C.S.	GRAPHIC LOG	MATERIAL DESCRIPTION	WELL DIAGRAM
							Dark gray CLAYSTONE, slightly weathered, slightly broken, medium hard to hard, fine-grained to medium-grained sandstone lenses, diagonal fracture, vertical fracture *(continued)*	
35	RC 14	100 (100)						Bentonite Chip
36.5							Very dark gray CLAYSTONE, slightly weathered to moderately weathered, moderately broken, hard, some concretions, Fe staining, vertical fracture and very broken, shells and fossils , trace of shale , fine-grained sand lenses	
38.1	RC 15	100 (63)					Black COAL, slightly weathered, moderately broken, soft, shale interbedded	
							Gray CLAYSTONE, moderately weathered, broken, soft, massive, diagonal fracture, trace of calcite in matrix, limestone rip-up clast	
39.6	RC 16	88 (22)						

GENERAL BH / TP / WELL BORING LOGS.GPJ 101-986 SLDA.GPJ 3/15/15

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CLIENT Confidential

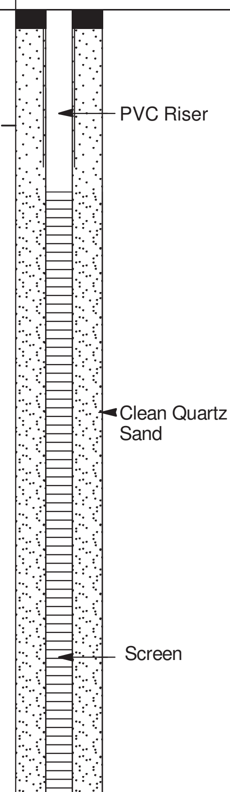
PROJECT NUMBER

PROJECT NAME Solid Waste Landfill

PROJECT LOCATION Western Pennsylvania

DEPTH (m)	SAMPLE TYPE NUMBER	RECOVERY % (RQD)	BLOW COUNTS (N VALUE)	REMARKS	U.S.C.S.	GRAPHIC LOG	MATERIAL DESCRIPTION
41.1							
	RC 17	100 (95)					Gray SILTSTONE, slightly weathered, moderately broken, medium hard, massive, trace of pyrite and limestone fragments, medium-grained to fine-grained sandstone lenses, diag. fractures
42.6							
44.2	RC 18	100 (94)					
							Bottom of boring at 44.9 meters

WELL DIAGRAM



WELL NUMBER MW-113

CLIENT Confidential
PROJECT NAME Solid Waste Landfill
PROJECT NUMBER
PROJECT LOCATION Western Pennsylvania
DATE STARTED 9/17/12 **COMPLETED** 9/18/12
GROUND ELEVATION **BACKFILL** 0.05 PVC Well
DRILLING CONTRACTOR
WATER LEVELS:
DRILLING METHOD Hollow Stem Auger & NQ Core
BEFORE CORING ---
AT END OF DRILLING 22.5 ft
NOTES
AFTER DRILLING ---

DEPTH (m)	SAMPLE TYPE NUMBER	RECOVERY % (RQD)	BLOW COUNTS (N VALUE)	MATERIAL DESCRIPTION	WELL DIAGRAM
0				Brown SILT, dry, **(RESIDUAL SOIL)**	
	SS 1	80	3-3-4 (7)	Light brown SILT, dry, **(RESIDUAL SOIL)**	
	SS 2	100	7-14-21 (35)	Tan sandy SILT, dry, **(RESIDUAL SOIL)**	
1.5					
	SS 3	100	10-18-22 (40)	Brown and gray SILT, and clay, some shale fragments, moist-, **(RESIDUAL SOIL)**	
	SS 4	100	15-17-28 (45)	Brown sandy SILT, with sandstone fragments, moist-, **(RESIDUAL SOIL)**	
3					Bentonite Chip
					PVC Riser
	SS 5	87	10-17-21 (38)		
4.5					
	SS 6	100	7-19-24 (43)		
	SS 7	100	44-50/0.3	Brown SANDY SHALE, moderately weathered, very broken, iron staining in fractures	
6					

GENERAL BH / TP / WELL BORING LOGS.GPJ 101-986 SLDA.GPJ 3/15/15

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Figure B-14: MW-113 Boring Log

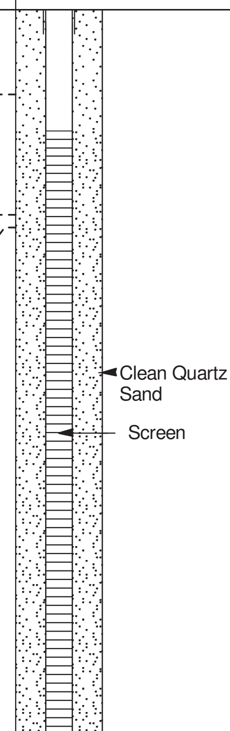
WELL NUMBER MW-113

CLIENT Confidential **PROJECT NAME** Solid Waste Landfill

PROJECT NUMBER **PROJECT LOCATION** Western Pennsylvania

DEPTH (m)	SAMPLE TYPE NUMBER	RECOVERY % (RQD)	BLOW COUNTS (N VALUE)	GRAPHIC LOG	MATERIAL DESCRIPTION
6	NQ	100 (0)			Brown SANDY SHALE, moderately weathered, very broken, iron staining in fractures *(continued)*
					Gray SHALE, very broken, clay in fractures
					Gray SHALE AND CLAY, very broken
					Gray SANDY SHALE, moderately broken
7.6	NQ	100 (29)			
9.1					
					Bottom of boring at 9.75 meters

WELL DIAGRAM



WELL NUMBER MW-114A

CLIENT Confidential
PROJECT NAME Solid Waste Landfill
PROJECT NUMBER
PROJECT LOCATION Western Pennsylvania
DATE STARTED 8/31/12 **COMPLETED** 8/31/12
GROUND ELEVATION **BACKFILL** 0.05 PVC Well
DRILLING CONTRACTOR
WATER LEVELS:
DRILLING METHOD Air Rotary
BEFORE CORING ---
AT END OF DRILLING 39.3 ft
NOTES
AFTER DRILLING ---

DEPTH (m)	SAMPLE TYPE NUMBER	GRAPHIC LOG	MATERIAL DESCRIPTION	WELL DIAGRAM
0			Brown SILT, and clay, trace sandstone fragments, moist, **(RESIDUAL SOIL)**	
1.5				
			Yellowish tan sandy CLAY, moist, **(RESIDUAL SOIL)**	
			Orangish brown SILT, and clay, moist, **(RESIDUAL SOIL)**	
3				
			Brown CLAY, moist-, **(RESIDUAL SOIL)**	
4.5			Tan CLAY, dry, **(RESIDUAL SOIL)**	
			Grayish brown CLAY, dry, **(RESIDUAL SOIL)**	
6				

GENERAL BH / TP / WELL BORING LOGS.GPJ 101-986 SLDA.GPJ 3/15/15

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Figure B-15: MW-114A Boring Log

CLIENT Confidential

PROJECT NAME Solid Waste Landfill

PROJECT NUMBER

PROJECT LOCATION Western Pennsylvania

DEPTH (m)	SAMPLE TYPE NUMBER	GRAPHIC LOG	MATERIAL DESCRIPTION	WELL DIAGRAM
6			Grayish brown CLAY, dry, **(RESIDUAL SOIL)** *(continued)*	PVC Riser Bentonite Chip
			Dark brown CLAY, and shale fragments, dry, **(RESIDUAL SOIL)**	
			Gray SHALE, moderately weathered, slightly broken	
			Brown and gray SANDSTONE, moderately weathered, very broken	
			Gray SANDSTONE, fresh, moderately broken	
7.6				
9.1				
			Brown SANDSTONE, highly weathered	
10.7			Gray SANDSTONE, fresh, moderately broken	
			▼	
12.2			Brown SANDSTONE, slightly weathered, moderately broken	
			Gray SANDSTONE, fresh, moderately broken	

GENERAL BH / TP / WELL BORING LOGS.GPJ 101-986 SLDA.GPJ 3/15/15

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WELL NUMBER MW-114A

CLIENT Confidential

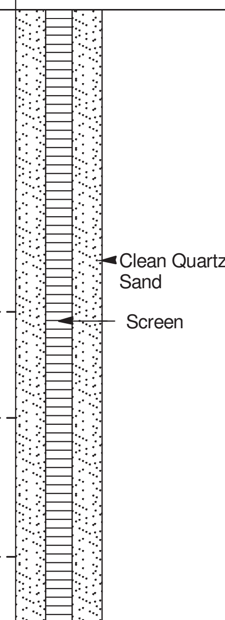
PROJECT NAME Solid Waste Landfill

PROJECT NUMBER

PROJECT LOCATION Western Pennsylvania

DEPTH (m)	SAMPLE TYPE NUMBER	GRAPHIC LOG	MATERIAL DESCRIPTION
			Gray SANDSTONE, fresh, moderately broken *(continued)*
13.7			
			Brown SANDSTONE, moderately weathered, moderately broken
15.2			Gray SANDSTONE, slightly broken
			Gray SANDY SHALE, fresh, slightly broken
			Bottom of boring at 16.15 meters

WELL DIAGRAM



WELL NUMBER MW-114B

CLIENT Confidential	**PROJECT NAME** Solid Waste Landfill
PROJECT NUMBER	**PROJECT LOCATION** Western Pennsylvania
DATE STARTED 8/27/12 **COMPLETED** 8/30/12	**GROUND ELEVATION** **BACKFILL** 0.05 PVC Well
DRILLING CONTRACTOR	**WATER LEVELS:**
DRILLING METHOD Hollow Stem Auger & NQ Core	**BEFORE CORING** ---
	AT END OF DRILLING 32.9 ft
NOTES	**AFTER DRILLING** ---

DEPTH (m)	SAMPLE TYPE NUMBER	RECOVERY % (RQD)	BLOW COUNTS (N VALUE)	GRAPHIC LOG	MATERIAL DESCRIPTION	WELL DIAGRAM
0	SS 1	60	1-1-1 (2)		Brown SILT, and clay, trace sandstone fragments, moist, **(RESIDUAL SOIL)**	
	SS 2	40	2-3-2 (5)			
1.5						
	SS 3	87	1-7-6 (13)		Yellowish tan sandy CLAY, moist, **(RESIDUAL SOIL)**	
3	SS 4	100	1-4-4 (8)		Orangish brown SILT, and clay, moist, **(RESIDUAL SOIL)**	
	SS 5	100	1-2-5 (7)		Brown CLAY, moist-, **(RESIDUAL SOIL)**	
4.5	SS 6	100	2-4-8 (12)		Tan CLAY, dry, **(RESIDUAL SOIL)**	
6	SS 7	67	10-13-10 (23)		Grayish brown CLAY, dry, **(RESIDUAL SOIL)**	

GENERAL BH / TP / WELL BORING LOGS.GPJ 101-986 SLDA.GPJ 3/15/15

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Figure B-16: MW-114B Boring Log

WELL NUMBER MW-114B

CLIENT Confidential | **PROJECT NAME** Solid Waste Landfill

PROJECT NUMBER | **PROJECT LOCATION** Western Pennsylvania

DEPTH (m)	SAMPLE TYPE NUMBER	RECOVERY % (RQD)	BLOW COUNTS (N VALUE)	GRAPHIC LOG	MATERIAL DESCRIPTION	WELL DIAGRAM
6					Grayish brown CLAY, dry, **(RESIDUAL SOIL)** *(continued)*	
	SS 8	100	50/0.2		Dark brown CLAY, and shale fragments, dry, **(RESIDUAL SOIL)**	
					Gray SHALE, moderately weathered, slightly broken, some iron staining in fractures	
					Brown and gray SANDSTONE, moderately weathered, very broken	
	NQ	89 (30)			Gray SANDSTONE, fresh, moderately broken, iron staining in fractures clay in fracture	
7.6						
9.1	NQ	86 (26)				
					Brown SANDSTONE, highly weathered, clay in fractures	
10.7					Gray SANDSTONE, fresh, moderately broken	
12.2					Brown SANDSTONE, slightly weathered, moderately broken	
	NQ	94 (57)			Gray SANDSTONE, fresh, moderately broken, black shale laminations in fractures	

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GENERAL BH / TP / WELL BORING LOGS.GPJ 101-986 SLDA.GPJ 3/15/15

CLIENT Confidential **PROJECT NAME** Solid Waste Landfill

PROJECT NUMBER **PROJECT LOCATION** Western Pennsylvania

DEPTH (m)	SAMPLE TYPE NUMBER	RECOVERY % (RQD)	BLOW COUNTS (N VALUE)	GRAPHIC LOG	MATERIAL DESCRIPTION
					Gray SANDSTONE, fresh, moderately broken, black shale laminations in fractures *(continued)*
13.7					
					Brown SANDSTONE, moderately weathered, moderately broken
15.2					Gray SANDSTONE, slightly broken
	NQ	80 (40)			Gray SANDY SHALE, fresh, slightly broken, iron staining
16.7					
18.3					
	NQ	100 (84)			
19.8					

WELL DIAGRAM

(Continued Next Page)

GENERAL BH / TP / WELL BORING LOGS.GPJ 101-986 SLDA.GPJ 3/15/15

CLIENT Confidential **PROJECT NAME** Solid Waste Landfill

PROJECT NUMBER **PROJECT LOCATION** Western Pennsylvania

DEPTH (m)	SAMPLE TYPE NUMBER	RECOVERY % (RQD)	BLOW COUNTS (N VALUE)	GRAPHIC LOG	MATERIAL DESCRIPTION	WELL DIAGRAM
					Gray SANDY SHALE, fresh, slightly broken, iron staining *(continued)*	
21.3						
	NQ	97				
22.8					Gray SANDSTONE, moderately broken, iron staining	
24.4						
	NQ	98 (68)			Gray SANDY SHALE, fresh, slightly broken, sand veins	
25.9						

GENERAL BH / TP / WELL BORING LOGS.GPJ 101-986 SLDA.GPJ 3/15/15

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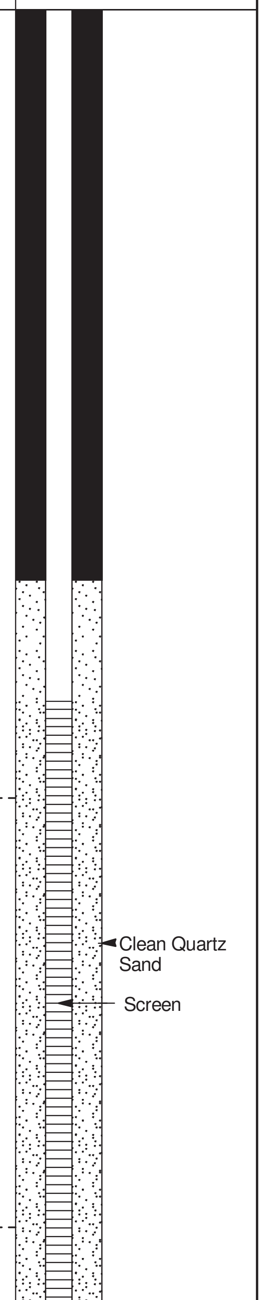
WELL NUMBER MW-114B

CLIENT Confidential
PROJECT NAME Solid Waste Landfill
PROJECT NUMBER
PROJECT LOCATION Western Pennsylvania

DEPTH (m)	SAMPLE TYPE NUMBER	RECOVERY % (RQD)	BLOW COUNTS (N VALUE)	GRAPHIC LOG	MATERIAL DESCRIPTION
					Gray SANDY SHALE, fresh, slightly broken, sand veins *(continued)*
27.4					
	NQ	100 (98)			
28.9					
30.5					
					Gray FINE SANDSTONE, fresh
	NQ	100 (93)			
32					
					Dark gray SHALE, fresh, soft shale in fractures
33.5					

WELL DIAGRAM



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PROJECT NAME Solid Waste Landfill

PROJECT NUMBER

PROJECT LOCATION Western Pennsylvania

DEPTH (m)	SAMPLE TYPE NUMBER	RECOVERY % (RQD)	BLOW COUNTS (N VALUE)	GRAPHIC LOG	MATERIAL DESCRIPTION	WELL DIAGRAM
	NQ	103 (90)			Black CARBONACEOUS SHALE, fresh, slightly broken	
35						
					Dark gray SHALE	
36.5						
	NQ	68 (54)				
38.1						
					Bottom of boring at 38.8 meters	

WELL NUMBER MW-116B

CLIENT Confidential	**PROJECT NAME** Solid Waste Landfill
PROJECT NUMBER	**PROJECT LOCATION** Western Pennsylvania
DATE STARTED 11/21/12 **COMPLETED** 11/21/12	**GROUND ELEVATION** **BACKFILL** 0.05 PVC Well
DRILLING CONTRACTOR	**WATER LEVELS:**
DRILLING METHOD Air	**BEFORE CORING** ---
Rotary	**AT END OF DRILLING** 52.2 ft
NOTES	**AFTER DRILLING** ---

DEPTH (m)	SAMPLE TYPE NUMBER	U.S.C.S.	GRAPHIC LOG	MATERIAL DESCRIPTION	WELL DIAGRAM
0				Light brown and tan silty CLAY, and weathered rock fragments, moist to moist-, (shale and siltstone), **(RESIDUAL SOIL)**	
1.5		CL-ML			
3				Gray and brown CLAYSTONE	
4.5					
6					

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Figure B-17: MW-116B Boring Log

WELL NUMBER MW-116B

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PROJECT NUMBER

PROJECT NAME Solid Waste Landfill

PROJECT LOCATION Western Pennsylvania

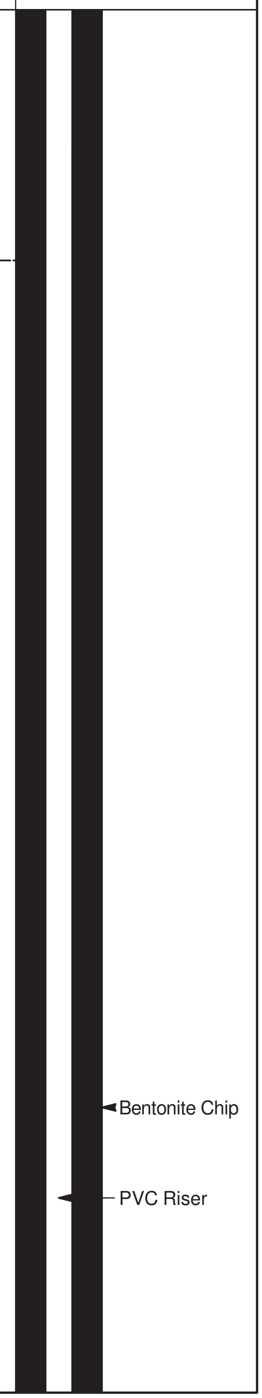
DEPTH (m)	SAMPLE TYPE NUMBER	U.S.C.S.	GRAPHIC LOG	MATERIAL DESCRIPTION	WELL DIAGRAM
6				Brown SANDSTONE	
7.6				Gray SHALE AND SANDSTONE, interbedded	
9.1					
				Brown SANDSTONE	
10.7				Gray SANDSTONE	
12.2					

(Continued Next Page)

CLIENT Confidential | **PROJECT NAME** Solid Waste Landfill

PROJECT NUMBER | **PROJECT LOCATION** Western Pennsylvania

DEPTH (m)	SAMPLE TYPE NUMBER	U.S.C.S.	GRAPHIC LOG	MATERIAL DESCRIPTION	WELL DIAGRAM
				Gray SANDSTONE *(continued)*	
13.7					
				Gray SHALE	
15.2					
				▼	
16.7					
18.3					
19.8					



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GENERAL BH / TP / WELL BORING LOGS.GPJ 101-986 SLDA.GPJ 3/15/15

CLIENT Confidential | **PROJECT NAME** Solid Waste Landfill
PROJECT NUMBER | **PROJECT LOCATION** Western Pennsylvania

DEPTH (m)	SAMPLE TYPE NUMBER	U.S.C.S.	GRAPHIC LOG	MATERIAL DESCRIPTION	WELL DIAGRAM
				Gray SHALE *(continued)*	
21.3					
22.8				Gray SHALE AND SANDSTONE, interbedded	
24.4				Black COAL	
				Gray SHALE AND SANDSTONE, interbedded	
				Gray SANDSTONE	
25.9					

GENERAL BH / TP / WELL BORING LOGS.GPJ 101-986 SLDA.GPJ 3/15/15

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CLIENT Confidential **PROJECT NAME** Solid Waste Landfill
PROJECT NUMBER **PROJECT LOCATION** Western Pennsylvania

DEPTH (m)	SAMPLE TYPE NUMBER	U.S.C.S.	GRAPHIC LOG	MATERIAL DESCRIPTION	WELL DIAGRAM
				Gray SANDSTONE *(continued)*	
27.4					
				Gray SHALE	
28.9					
30.5					
32					
33.5					

GENERAL BH / TP / WELL BORING LOGS.GPJ 101-986 SLDA.GPJ 3/15/15

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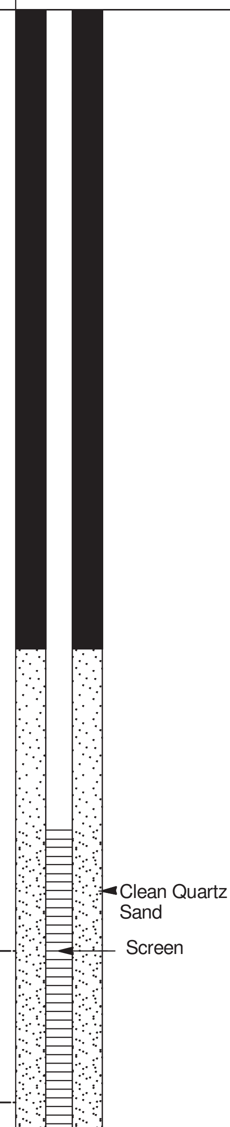
WELL NUMBER MW-116B

CLIENT Confidential | **PROJECT NAME** Solid Waste Landfill

PROJECT NUMBER | **PROJECT LOCATION** Western Pennsylvania

DEPTH (m)	SAMPLE TYPE NUMBER	U.S.C.S.	GRAPHIC LOG	MATERIAL DESCRIPTION
				Gray SHALE *(continued)*
35				
36.5				
38.1				
				Black COAL
				Gray SHALE
39.6				Bottom of boring at 39.6 meters

WELL DIAGRAM

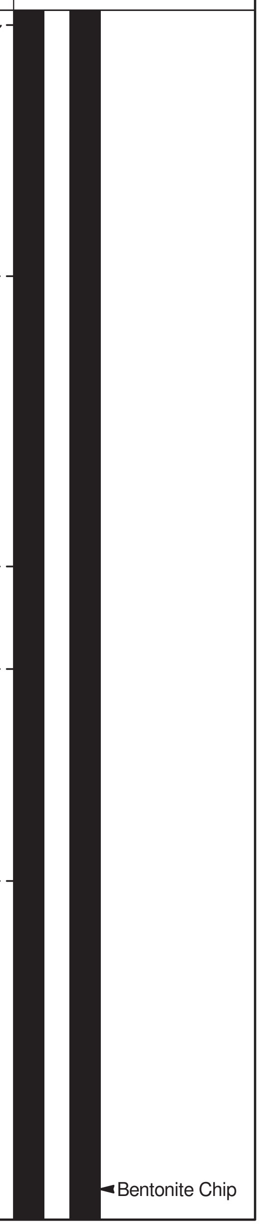


WELL NUMBER OW-112B

CLIENT Confidential		**PROJECT NAME** Solid Waste Landfill	
PROJECT NUMBER		**PROJECT LOCATION** Western Pennsylvania	
DATE STARTED 9/4/12	**COMPLETED** 9/5/12	**GROUND ELEVATION**	**BACKFILL** PVC Well
DRILLING CONTRACTOR		**WATER LEVELS:**	
DRILLING METHOD NQ		**BEFORE CORING** ---	
Core		**AT END OF DRILLING** 27.2 ft	
NOTES		**AFTER DRILLING** ---	

DEPTH (m)	SAMPLE TYPE NUMBER	RECOVERY % (RQD)	BLOW COUNTS (N VALUE)	GRAPHIC LOG	MATERIAL DESCRIPTION
0	SS 1	60	2-4-7 (11)		Brownish gray FINE SAND, dry, **(RESIDUAL SOIL)** Tan FINE SAND, and silt, dry, **(RESIDUAL SOIL)**
	SS 2	100	32-50-50/0.4		
1.5					Grayish brown SHALE, highly weathered, very broken
	SS 3	100	23-50/0.3		
	SS 4	100	50/0.2		Dark brown SHALE, highly weathered, very broken
3	NQ	100 (0)			
					Brownish gray SHALE, highly weathered, very broken
4.5					Dark gray SHALE, highly weathered, very broken
	NQ	100 (0)			
6					

WELL DIAGRAM



GENERAL BH / TP / WELL BORING LOGS.GPJ 101-986 SLDA.GPJ 3/15/15

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Figure B-18: 0W-112B Boring Log

WELL NUMBER OW-112B

CLIENT Confidential

PROJECT NAME Solid Waste Landfill

PROJECT NUMBER

PROJECT LOCATION Western Pennsylvania

DEPTH (m)	SAMPLE TYPE NUMBER	RECOVERY % (RQD)	BLOW COUNTS (N VALUE)	GRAPHIC LOG	MATERIAL DESCRIPTION
6					Dark gray SHALE, highly weathered, very broken *(continued)*
7.6	NQ	44 (10)			▼
9.1					
10.7	NQ	80 (16)			Black CARBONACEOUS SHALE, moderately weathered, very broken
12.2					Dark gray SHALE, highly weathered, moderately broken, clay in fractures

WELL DIAGRAM

GENERAL BH / TP / WELL BORING LOGS.GPJ 101-986 SLDA.GPJ 3/15/15

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CLIENT Confidential

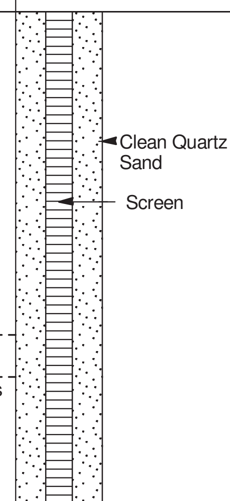
PROJECT NAME Solid Waste Landfill

PROJECT NUMBER

PROJECT LOCATION Western Pennsylvania

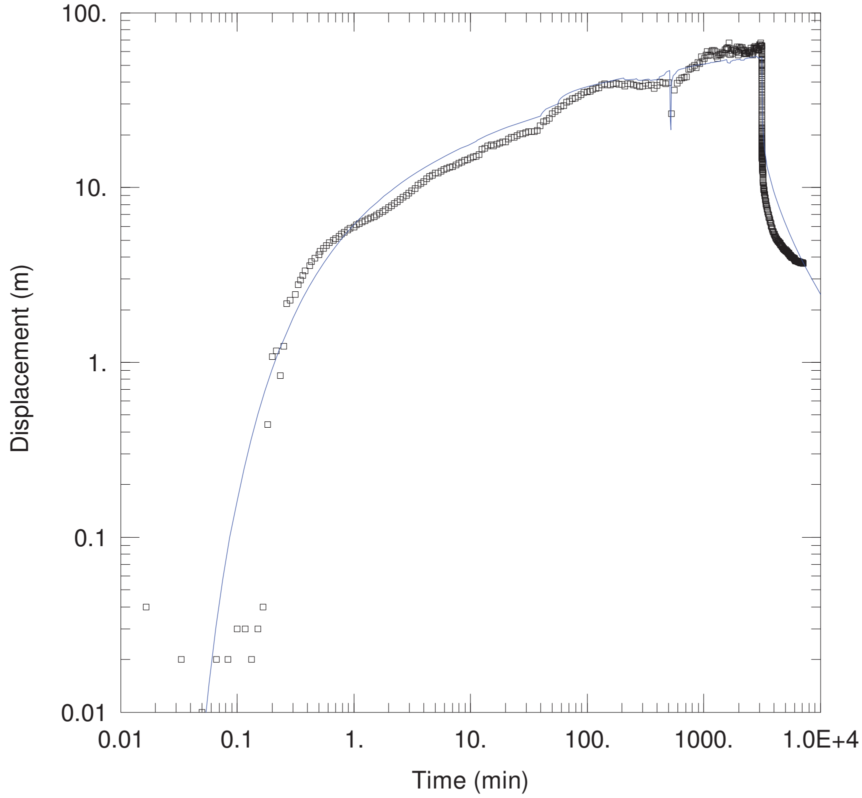
DEPTH (ft)	SAMPLE TYPE NUMBER	RECOVERY % (RQD)	BLOW COUNTS (N VALUE)	GRAPHIC LOG	MATERIAL DESCRIPTION
					Dark gray SHALE, highly weathered, moderately broken, clay in fractures *(continued)*
13.7					
					Black COAL, very broken
					Gray SANDSTONE, moderately weathered, very broken, iron staining in fractures
15.2					
					Bottom of boring at 15.5 meters

WELL DIAGRAM



APPENDIX C

SLUG TEST AND PUMPING TEST RESULTS



WELL TEST ANALYSIS

Data Set: P:\...\12-10_allData.aqt
Date: 03/07/15 Time: 09:38:21

PROJECT INFORMATION

Test Well: 12-10 Test
Date: 10/3/12

AQUIFER DATA

Saturated Thickness: 34.6 m

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
12-10	0	0

Observation Wells

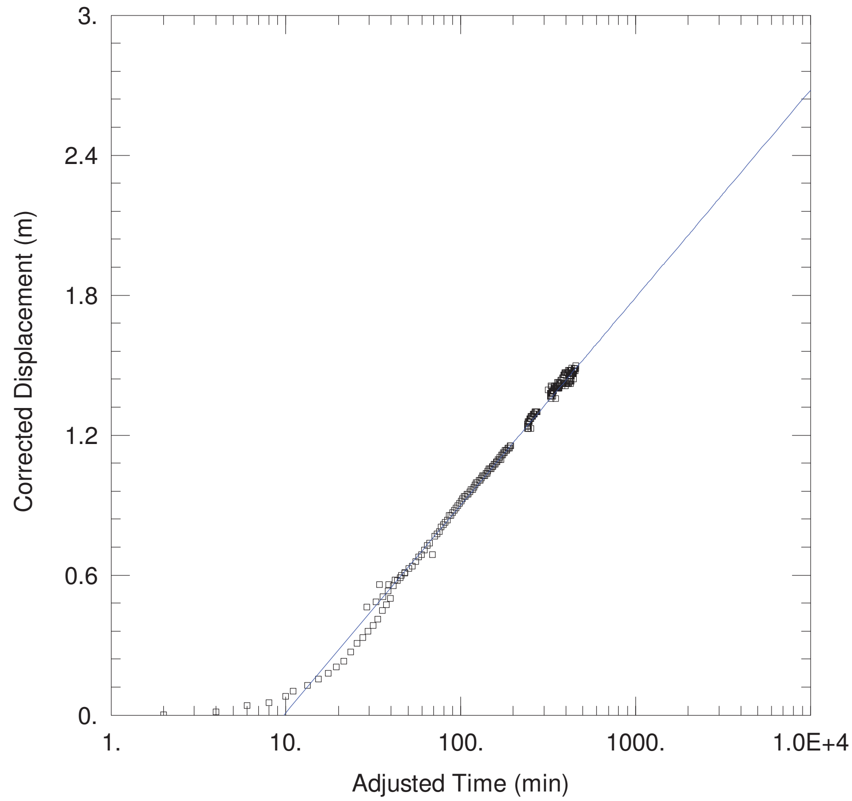
Well Name	X (m)	Y (m)
▫ 12-10	0	0

SOLUTION

Aquifer Model: Unconfined Solution Method: Neuman

T = 0.1884 cm^2/sec S = 0.1052
Sy = 0.1 ß = 0.001

Figure C-1: 12-10 Pumping Test



WELL TEST ANALYSIS

Data Set: P:\...\12-10A_single_noRec_FINAL_111212.aqt
Date: 03/07/15 Time: 09:37:27

PROJECT INFORMATION

Test Well: 12-10A
Test Date: 10/3/12

AQUIFER DATA

Saturated Thickness: 34.6 m Anisotropy Ratio (Kz/Kr): 1.166E+4

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
12-10	0	0

Observation Wells

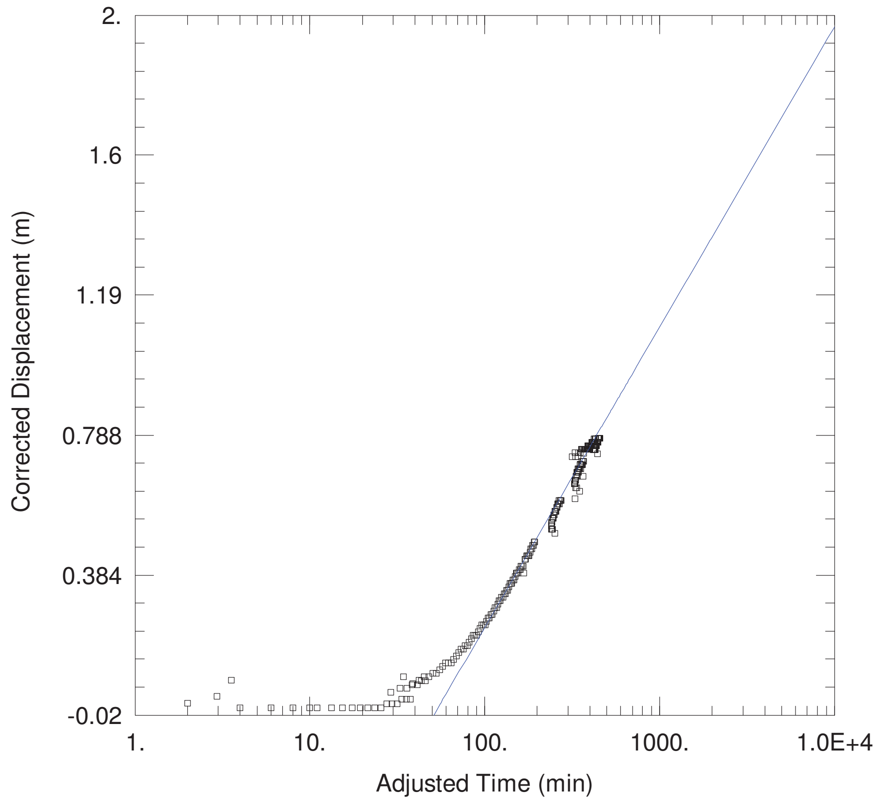
Well Name	X (m)	Y (m)
□ 12-10A	0	3.9

SOLUTION

Aquifer Model: Unconfined Solution Method: Cooper-Jacob

T = 3.284 cm^2/sec S = 0.02827

Figure C-2: 12-10A Pumping Test



WELL TEST ANALYSIS

Data Set: P:\...\12-10B_single_noRec_FINAL_111212.aqt
Date: 03/07/15 Time: 09:37:09

PROJECT INFORMATION

Test Well: 12-10B
Test Date: 10/3/12

AQUIFER DATA

Saturated Thickness: 34.6 m Anisotropy Ratio (Kz/Kr): 1.87

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
12-10	0	0

Observation Wells

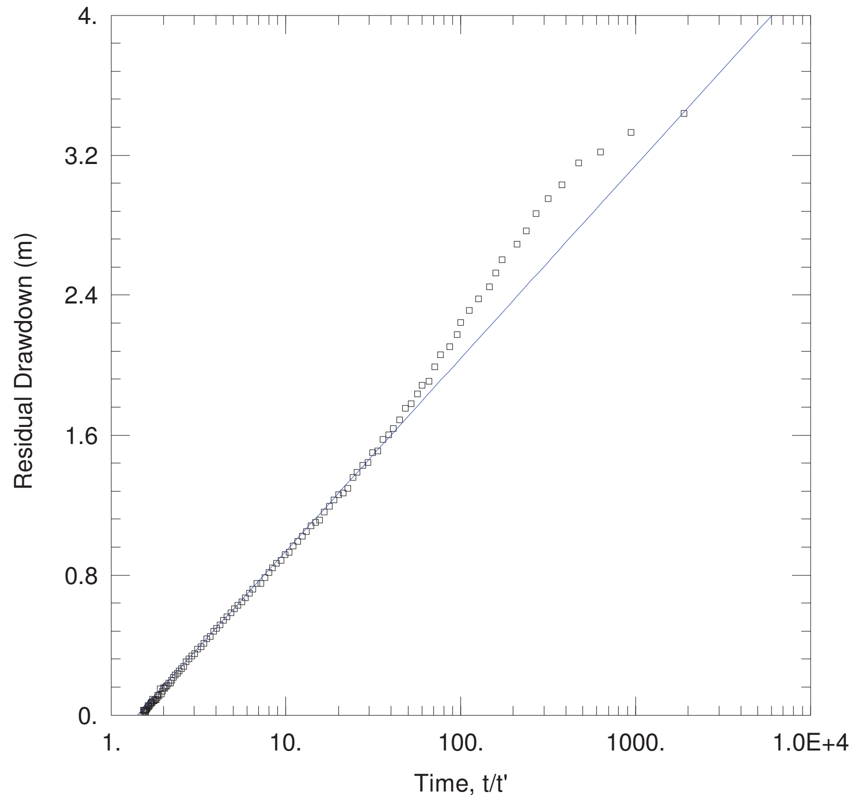
Well Name	X (m)	Y (m)
▫ 12-10B	0	8

SOLUTION

Aquifer Model: Unconfined Solution Method: Cooper-Jacob

T = 3.368 cm^2/sec S = 0.03814

Figure C-3: 12-10B Pumping Test



WELL TEST ANALYSIS

Data Set: P:\...\MW-103B.aqt
Date: 03/07/15 Time: 09:39:35

PROJECT INFORMATION

Test Well: MW-103B
Test Date: 11/2/12

AQUIFER DATA

Saturated Thickness: 1.5 m Anisotropy Ratio (Kz/Kr): 1.

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
MW-103B	0	0

Observation Wells

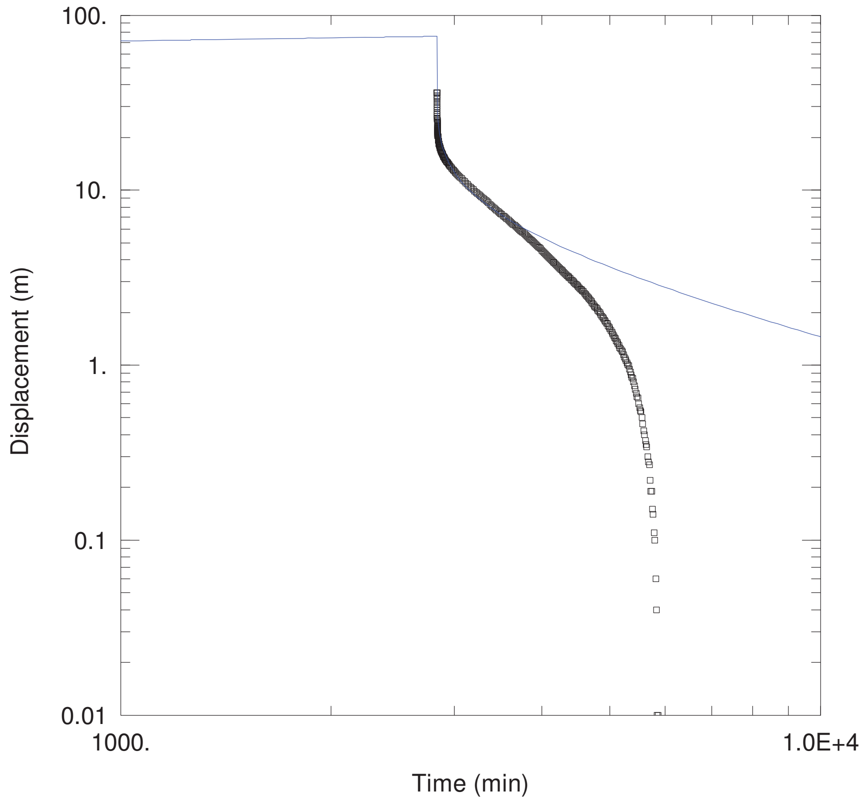
Well Name	X (m)	Y (m)
▫ MW-103B	0	0

SOLUTION

Aquifer Model: Confined Solution Method: Theis (Recovery)

T = 0.5749 cm^2/sec S/S' = 1.413

Figure C-4: MW-103B Pumping Test



WELL TEST ANALYSIS

Data Set: P:\...\MW-103B.aqt
Date: 03/07/15 Time: 09:44:54

PROJECT INFORMATION

Test Well: MW-103B
Test Date: 12/5/12

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
MW-103B	0	0

Observation Wells

Well Name	X (m)	Y (m)
□ MW-103B	0	0

SOLUTION

Aquifer Model: Confined

Solution Method: Theis

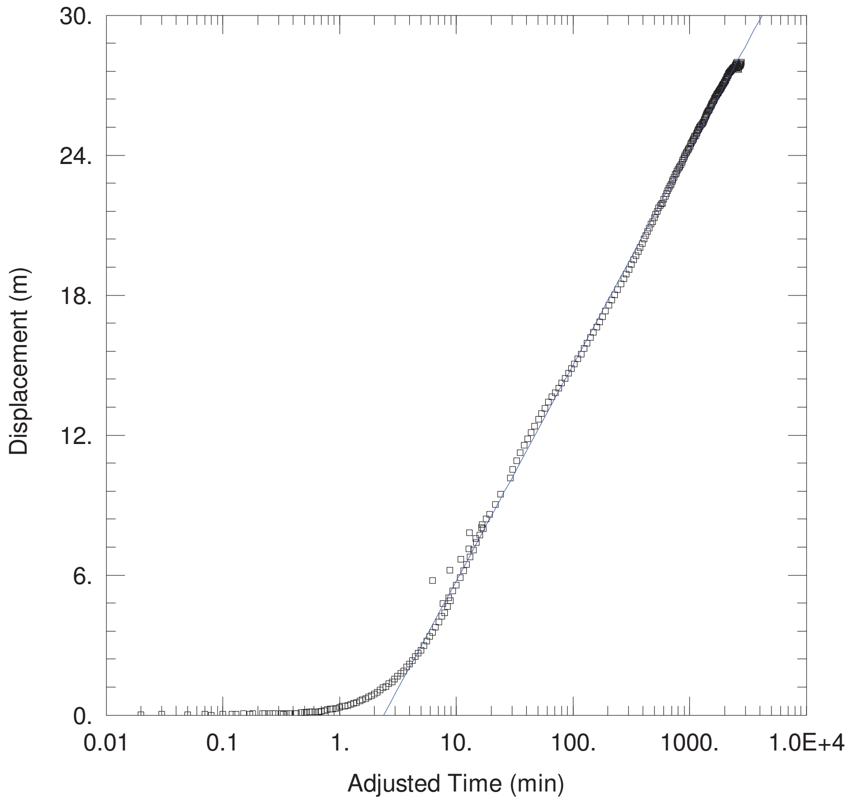
T = 0.2829 cm^2/sec

Kz/Kr = 1.

S = 3.06E-5

b = 1.5 m

Figure C-5: MW-103B Slug Test



WELL TEST ANALYSIS

Data Set: P:\...\MW-102B.aqt
Date: 03/07/15 Time: 09:41:08

PROJECT INFORMATION

Test Well: MW-103B
Test Date: 12/5/12

AQUIFER DATA

Saturated Thickness: 1.5 m Anisotropy Ratio (Kz/Kr): 1.

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
MW-103B	0	0

Observation Wells

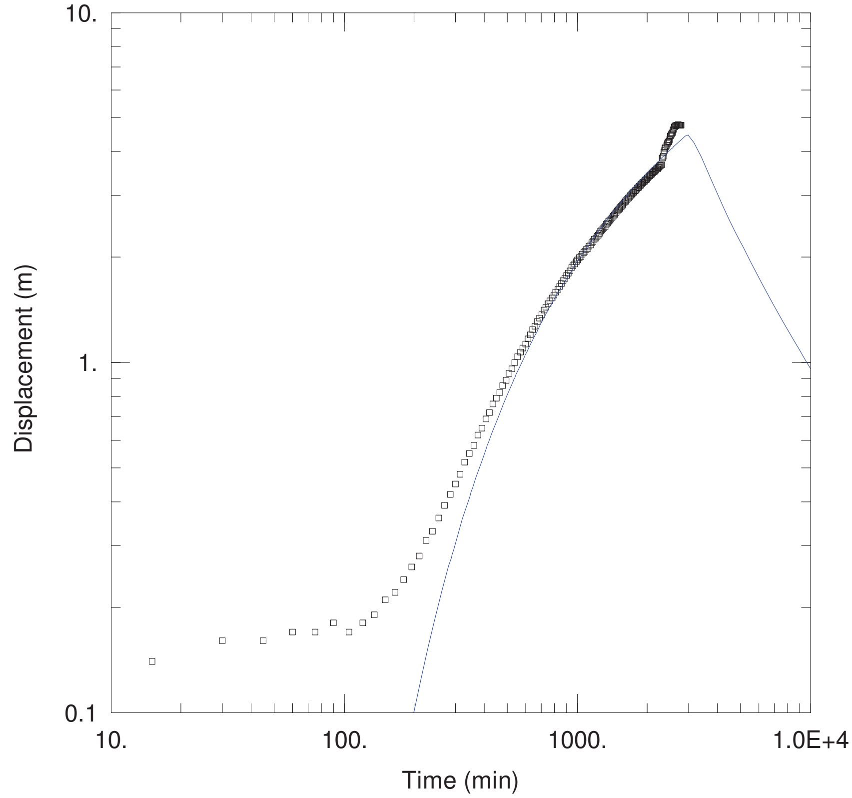
Well Name	X (m)	Y (m)
□ MW-102B	--9.05	50.1

SOLUTION

Aquifer Model: Confined Solution Method: Cooper-Jacob

T = 0.3074 cm^2/sec S = 3.821E-6

Figure C-6: MW-102B Pumping Test



WELL TEST ANALYSIS

Data Set: P:\...\MW-105B.aqt
Date: 03/07/15 Time: 09:42:14

PROJECT INFORMATION

Test Well: MW-103B
Test Date: 12/5/12

AQUIFER DATA

Saturated Thickness: 1.5 m Anisotropy Ratio (Kz/Kr): 1.

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
MW-103B	0	0

Observation Wells

Well Name	X (m)	Y (m)
□ MW-105B	122.6	61.5

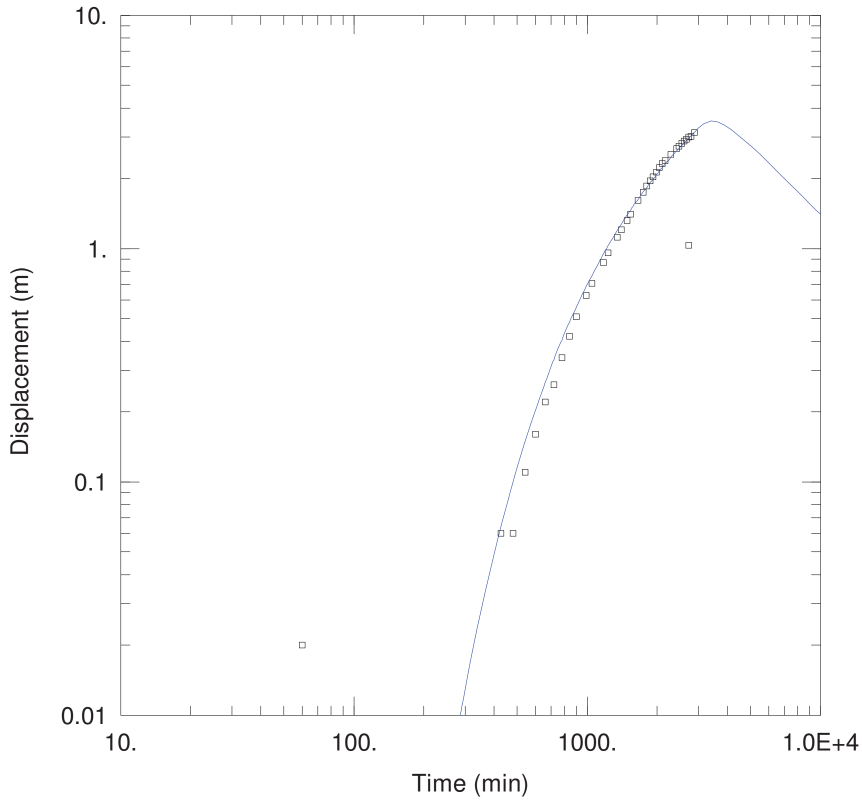
SOLUTION

Aquifer Model: Confined Solution Method: Theis (Step Test)

T = 0.4061 cm^2/sec
S = 0.0002265
Sw = 0.
C =
P = 2.

Step Test Model: Jacob-Rorabaugh
Time (t) = 1.min
s(t) =
W.E. = 100.% (Q from last step)

Figure C-7: MW-105B Pumping Test



WELL TEST ANALYSIS

Data Set: P:\...\MW-107B.aqt
Date: 03/07/15 Time: 09:42:58

PROJECT INFORMATION

Test Well: MW-103B
Test Date: 12/5/12

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
MW-103B	0	0

Observation Wells

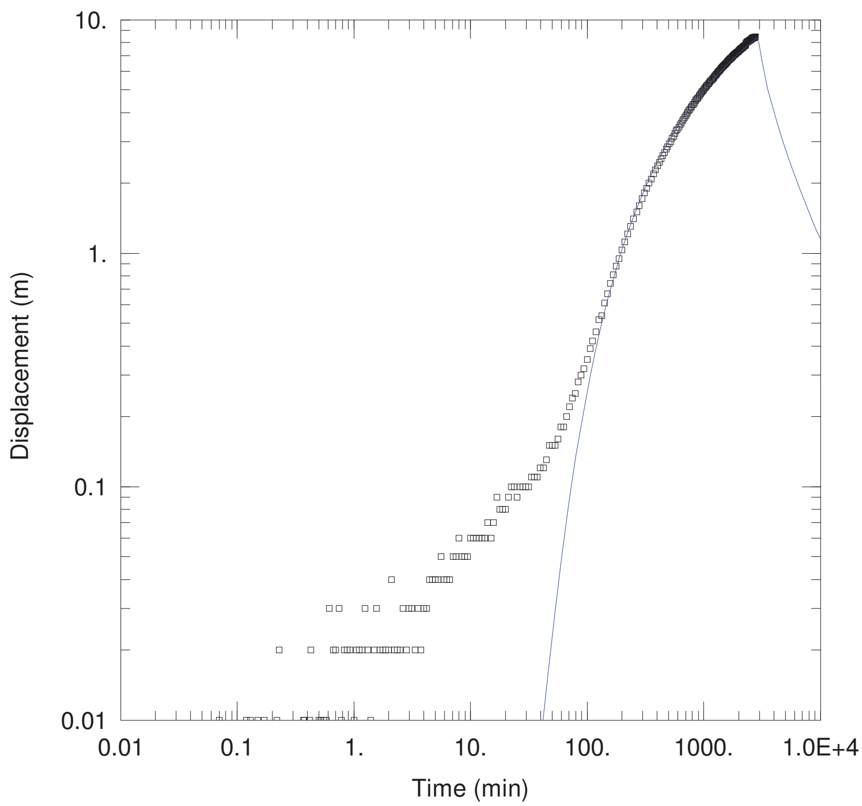
Well Name	X (m)	Y (m)
□ MW-107B	181	-517

SOLUTION

Aquifer Model: Confined
Solution Method: Theis

T = 0.2528 cm^2/sec
S = 2.535E-5
Kz/Kr = 1.
b = 1.5 m

Figure C-8: MW-107B Slug Test



WELL TEST ANALYSIS

Data Set: P:\...\MW-116B.aqt
Date: 03/07/15 | Time: 09:43:22

PROJECT INFORMATION

Test Well: MW-103B
Test Date: 12/5/12

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
MW-103B	0	0

Observation Wells

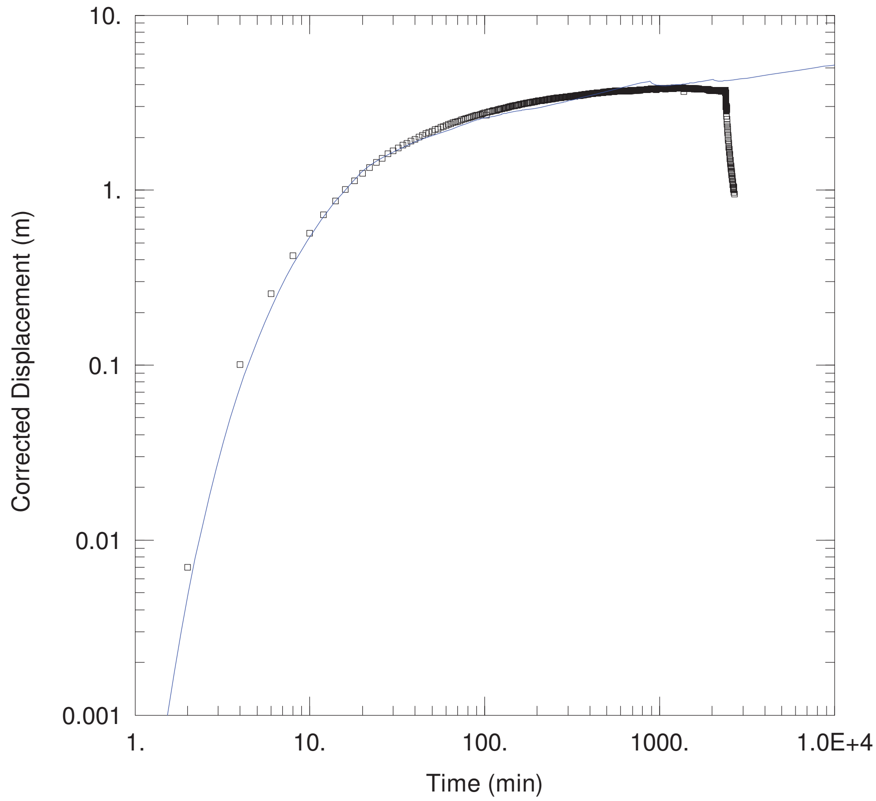
Well Name	X (m)	Y (m)
□ MW-116B	103.4	-60.12

SOLUTION

Aquifer Model: Confined
Solution Method: Theis

T = 0.3502 cm^2/sec
S = 9.337E-5
Kz/Kr = 1.
b = 1.5 m

Figure C-9: MW-116B Slug Test



WELL TEST ANALYSIS

Data Set: P:\...\OW-112B.aqt
Date: 03/07/15 Time: 09:46:43

PROJECT INFORMATION

Test Well: MW-112
Test Date: 10/8/12

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
MW-112	0	0

Observation Wells

Well Name	X (m)	Y (m)
□ OW-112B	27	0

SOLUTION

Aquifer Model: Unconfined

Solution Method: Theis

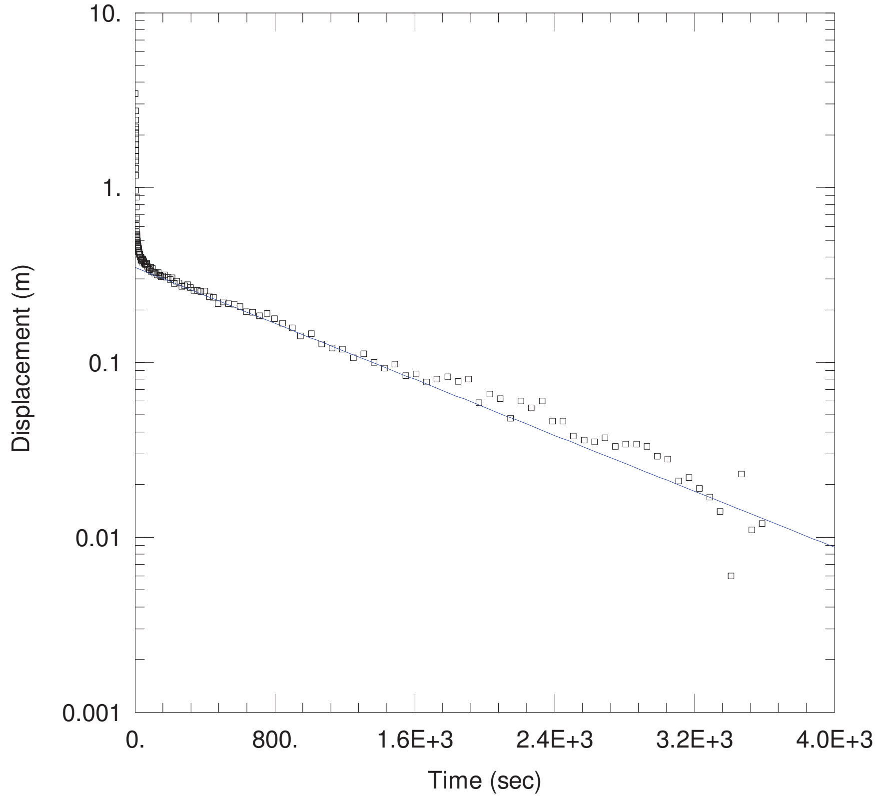
T = 0.2884 cm^2/sec

S = 8.449E-5

Kz/Kr = 1.

b = 19.6 m

Figure C-10: OW-112B Slug Test



WELL TEST ANALYSIS

Data Set: P:\...\12-10A Slug test.aqt
Date: 03/07/15 Time: 09:23:19

PROJECT INFORMATION

Well: 12-10A Test
Date: 11/26/12

AQUIFER DATA

Saturated Thickness: 35.3 m Anisotropy Ratio (Kz/Kr): 1.

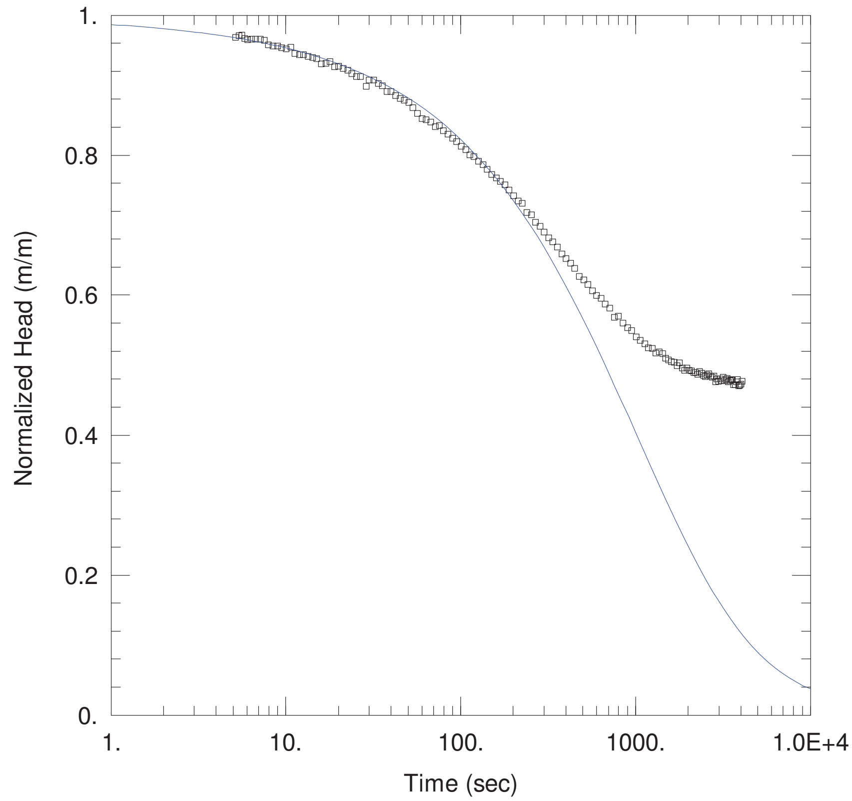
WELL DATA (12-10A)

Initial Displacement: 1.05 m
Total Well Penetration Depth: 4.2 m
Casing Radius: 0.025 m
Static Water Column Height: 4.2 m
Screen Length: 4.2 m
Well Radius: 0.05 m
Gravel Pack Porosity: 0.35

SOLUTION

Aquifer Model: Unconfined Solution Method: Bouwer-Rice
K = 4.032E-5 cm/sec y0 = 0.1064 m

Figure C-11: 12-10A Slug Test



WELL TEST ANALYSIS

Data Set: P:\...\P-1(50) Slug Test_dbtRevision.aqt
Date: 03/07/15 Time: 09:21:54

PROJECT INFORMATION

Test Well: PZ-1(50)
Test Date: 11/26/12

AQUIFER DATA

Saturated Thickness: 66.7 m Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (P-1(50))

Initial Displacement: 1.14 m
Total Well Penetration Depth: 14.m
Casing Radius: 0.025 m

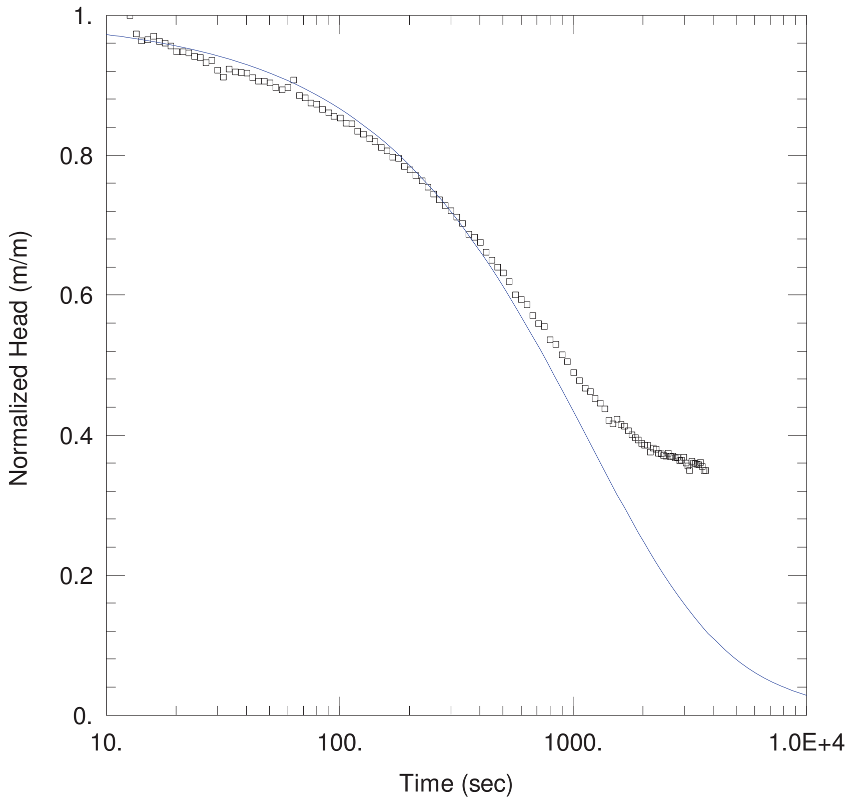
Static Water Column Height: 16 m
Screen Length: 3. m
Well Radius: 0.05m
Gravel Pack Porosity: 0.

SOLUTION

Aquifer Model: Confined Solution Method: Cooper-Bredehoeft-Papadopulos

T = 0.005129 cm^2/sec S = 0.007049

Figure C-12: P-1(50) Pumping Test



WELL TEST ANALYSIS

Data Set: P:\...\P-1(150) Slug Test_dbt revision.aqt
Date: 03/07/15 Time: 09:22:33

PROJECT INFORMATION

Test Well: P-1(150)
Test Date: 11/26/12

AQUIFER DATA

Saturated Thickness: 64 m Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (P-1(150))

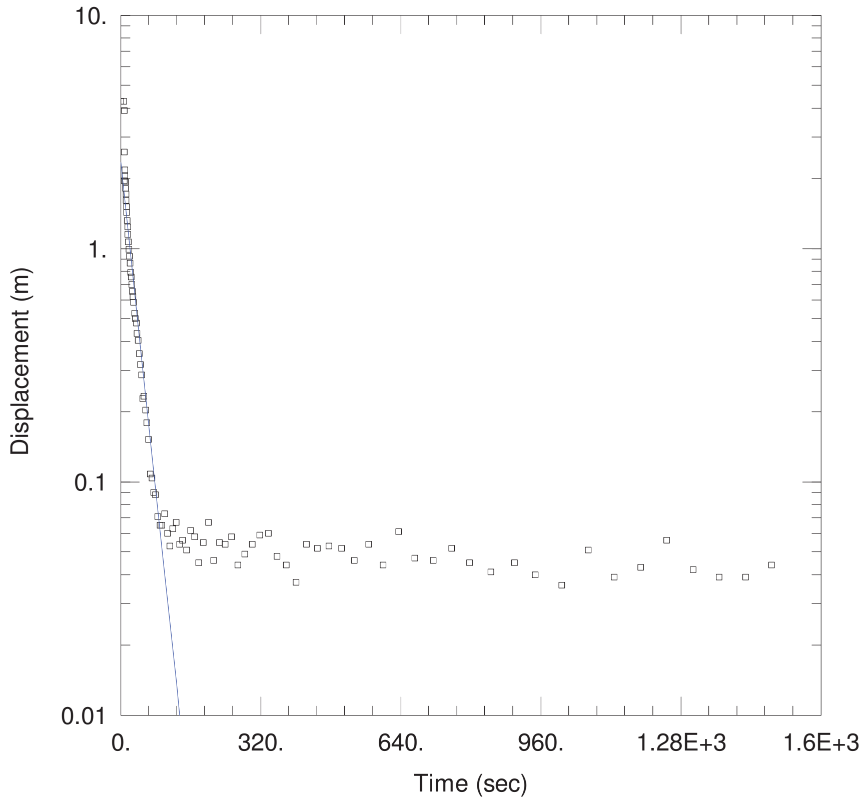
Initial Displacement: 0.7 m
Total Well Penetration Depth: 42.6 m
Casing Radius: 0.025 m
Static Water Column Height: 42.7m
Screen Length: 3. m
Well Radius: 0.25m
Gravel Pack Porosity: 0.

SOLUTION

Aquifer Model: Confined Solution Method: Cooper-Bredehoeft-Papadopulos

T = 0.007057 cm^2/sec S = 0.001

Figure C-13: P-1(150) Pumping Test



WELL TEST ANALYSIS

Data Set: P:\...\P-1(220) Slug Test.aqt
Date: 03/07/15 | Time: 09:22:59

PROJECT INFORMATION

Test Well: P-1(220)
Test Date: 11/26/12

AQUIFER DATA

Saturated Thickness: 65 m | Anisotropy Ratio (Kz/Kr): 1.

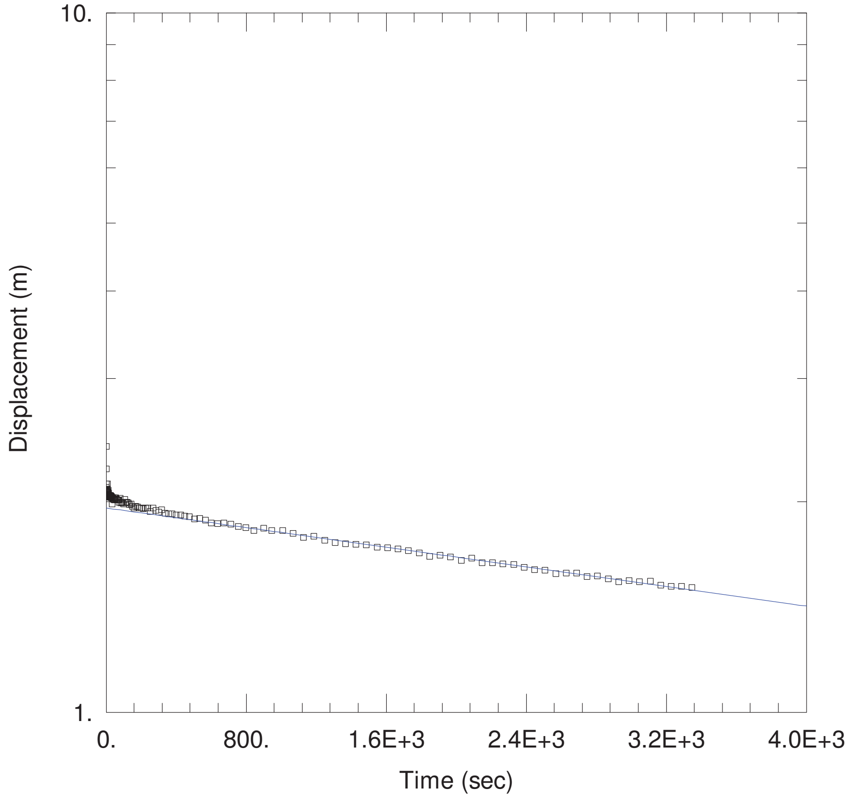
WELL DATA (P-1(220))

Initial Displacement: 1.3 m | Static Water Column Height: 58.8m
Total Well Penetration Depth: 58.8m | Screen Length: 3. m
Casing Radius: 0.025 m | Well Radius: 0.05m
Gravel Pack Porosity: 0.

SOLUTION

Aquifer Model: Unconfined | Solution Method: Bouwer-Rice
K = 0.001431 cm/sec | y0 = 0.71 m

Figure C-14: P-1(220) Slug Test



WELL TEST ANALYSIS

Data Set: P:\...\MW-101.aqt
Date: 03/07/15 | Time: 09:15:04

PROJECT INFORMATION

Test Well: MW-101
Test Date: 10/23/12

AQUIFER DATA

Saturated Thickness: 3.6 m | Anisotropy Ratio (Kz/Kr): 1.

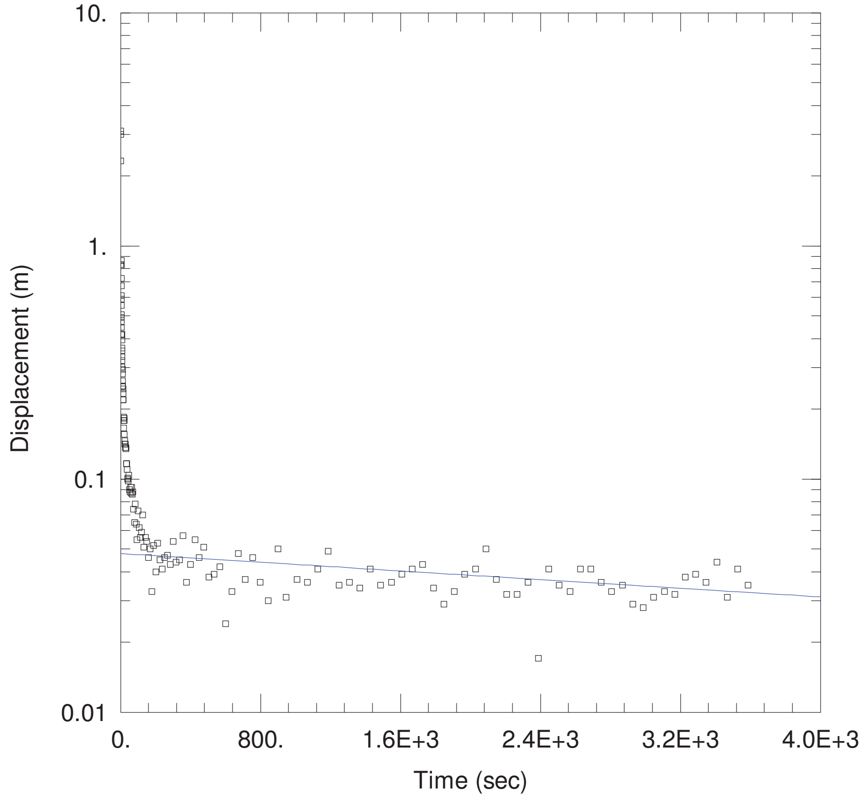
WELL DATA (MW-101)

Initial Displacement: 0.73 m
Total Well Penetration Depth: 3.6 m
Casing Radius: 0.025 m
Static Water Column Height: 3.6m
Screen Length: 3.0m
Well Radius: 0.05m
Gravel Pack Porosity: 0.

SOLUTION

Aquifer Model: Unconfined | Solution Method: Bouwer-Rice
K = 2.391E-6 cm/sec | y0 = 0.6 m

Figure C-15: MW-101 Slug Test



WELL TEST ANALYSIS

Data Set: P:\...\MW-103a.aqt
Date: 03/07/15 Time: 09:16:18

PROJECT INFORMATION

Test Well: MW-103a
Test Date: 10/16/12

AQUIFER DATA

Saturated Thickness: 8.8 m
Anisotropy Ratio (Kz/Kr): 1.

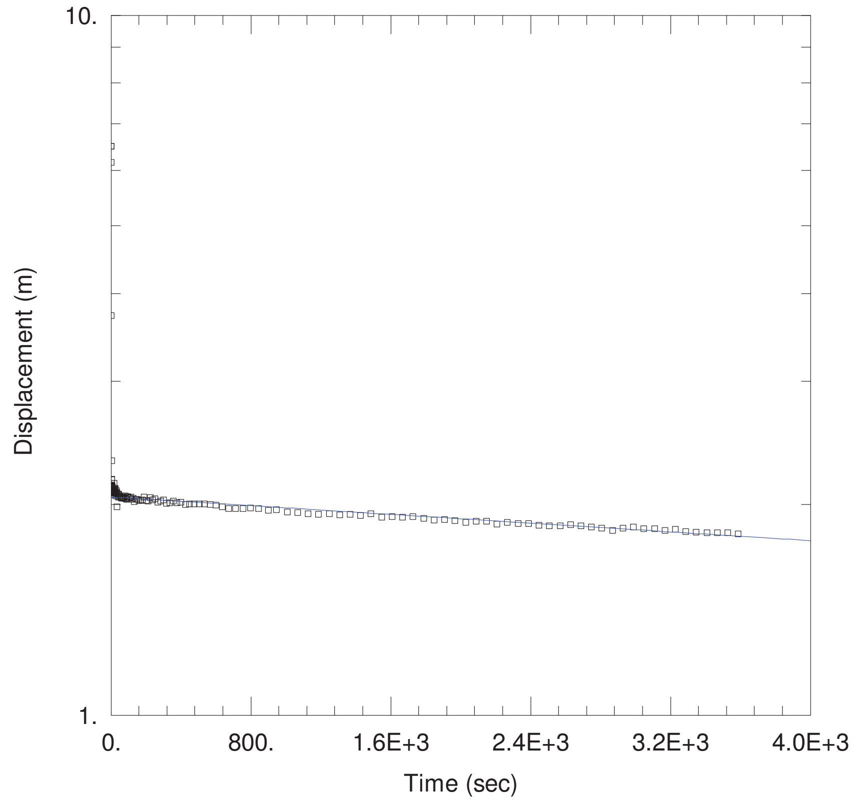
WELL DATA (MW-103a)

Initial Displacement: 0.9 m
Total Well Penetration Depth: 3.1 m
Casing Radius: 0.025 m
Static Water Column Height: 3.2 m
Screen Length: 3.0m
Well Radius: 0.05m
Gravel Pack Porosity: 0.

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice
K = 2.662E-6 cm/sec
y0 = 0.015 m

Figure C-16: MW-103a Slug Test



WELL TEST ANALYSIS

Data Set: P:\...\MW-103c.aqt
Date: 03/07/15 Time: 09:16:57

PROJECT INFORMATION

Test Well: MW-103c
Test Date: 10/16/12

AQUIFER DATA

Saturated Thickness: 1.5 m Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (MW-103c)

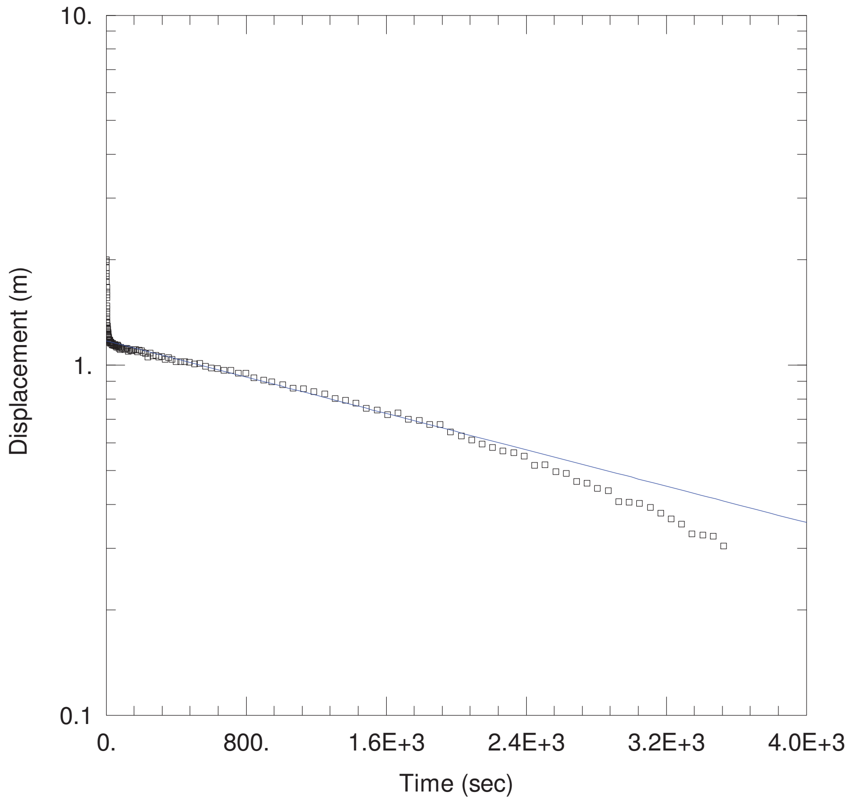
Initial Displacement: 2.0 m
Total Well Penetration Depth: 1.5 m
Casing Radius: 0.025 m
Static Water Column Height: 5.8 m
Screen Length: 1.5m
Well Radius: 0.05m
Gravel Pack Porosity: 0.

SOLUTION

Aquifer Model: Confined Solution Method: Bouwer-Rice

K = 1.655E-6 cm/sec y0 = 0.62 m

Figure C-17: MW-103c Slug Test



WELL TEST ANALYSIS

Data Set: P:\...\MW-105.aqt
Date: 03/07/15 Time: 09:17:15

PROJECT INFORMATION

Test Well: MW-105
Test Date: 10/22/12

AQUIFER DATA

Saturated Thickness: 2.´ m Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (MW-105)

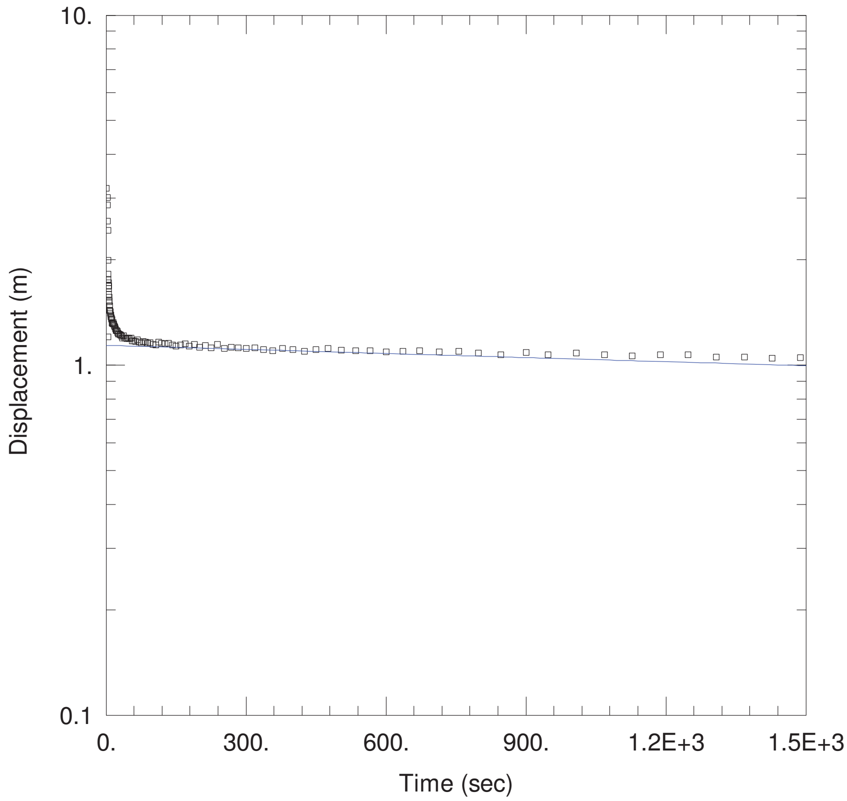
Initial Displacement: 0.6 m
Total Well Penetration Depth: 1.5 m
Casing Radius: 0.025 m

Static Water Column Height: 2.4 m
Screen Length: 1.5 m
Well Radius: 0.05 m
Gravel Pack Porosity: 0.

SOLUTION

Aquifer Model: Unconfined Solution Method: Bouwer-Rice
K = 1.239E-5 cm/sec y0 = 0.36 m

Figure C-18: MW-105 Slug Test



WELL TEST ANALYSIS

Data Set: P:\...\MW-107a.aqt
Date: 03/07/15
Time: 09:17:58

PROJECT INFORMATION

Test Well: MW-107a
Test Date: 10/22/12

AQUIFER DATA

Saturated Thickness: 18 m
Anisotropy Ratio (Kz/Kr): 1.

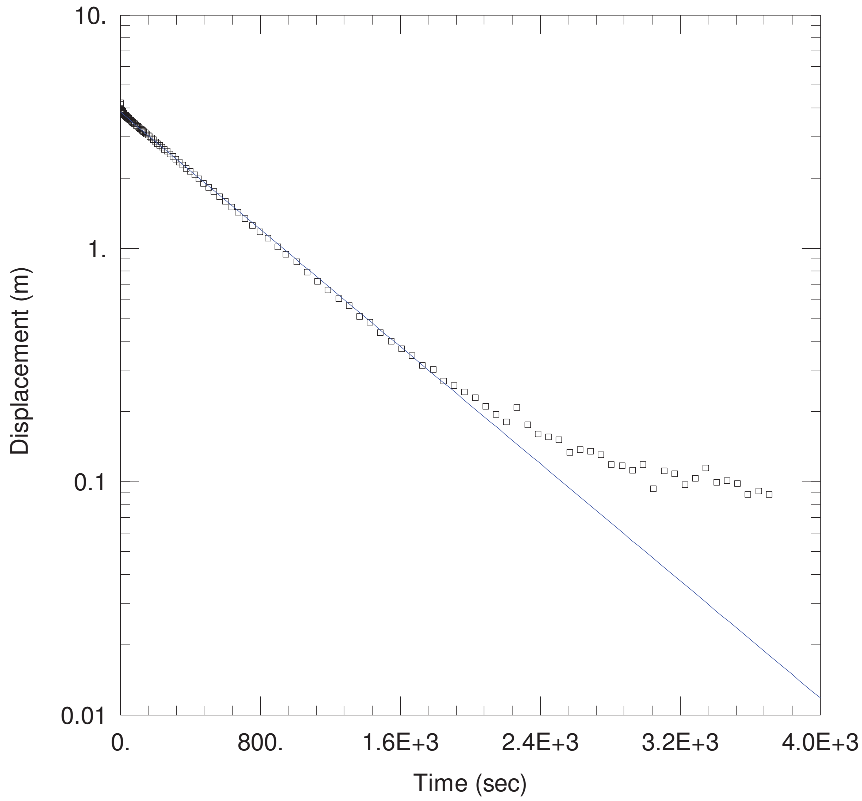
WELL DATA (MW-107a)

Initial Displacement: 1.0 m
Total Well Penetration Depth: 3 m
Casing Radius: 0.025 m
Static Water Column Height: 3. m
Screen Length: 3. m
Well Radius: 0.05m
Gravel Pack Porosity: 0.

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice
K = 2.166E-6 cm/sec
y0 = 0.35 m

Figure C-19: MW-107a Slug Test



WELL TEST ANALYSIS

Data Set: P:\...\MW-107b.aqt
Date: 03/07/15 Time: 09:18:16

PROJECT INFORMATION

Test Well: MW-107b
Test Date: 10/22/12

AQUIFER DATA

Saturated Thickness: 1. m Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (MW-107b)

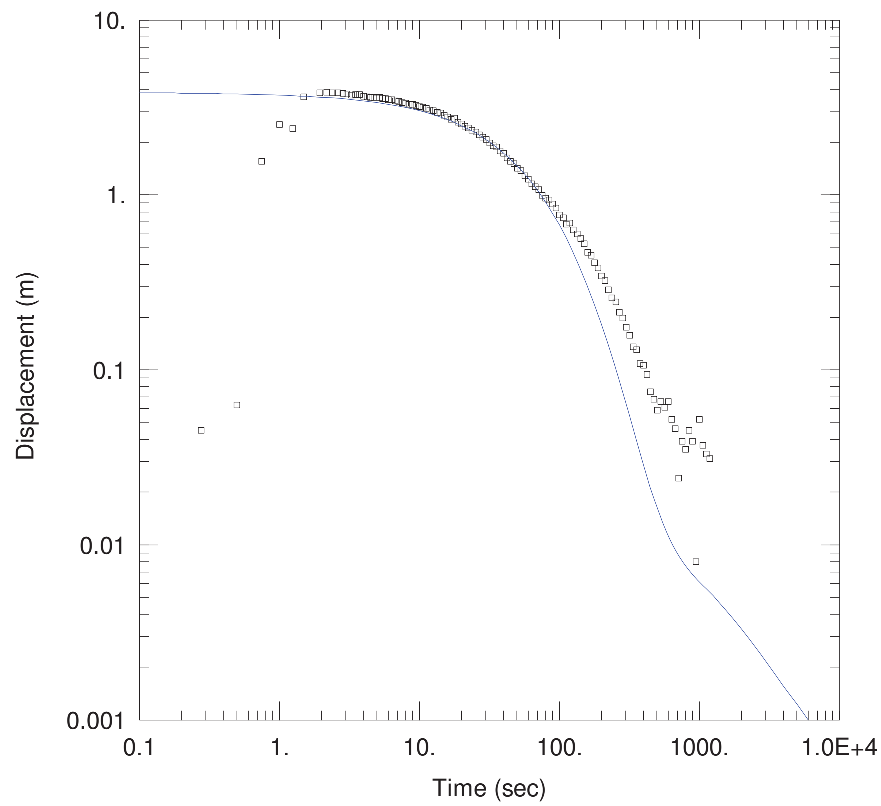
Initial Displacement: 1.3 m
Total Well Penetration Depth: 1. m
Casing Radius: 0.025 m
Static Water Column Height: 22. m
Screen Length: 1. m
Well Radius: 0.05 m

SOLUTION

Aquifer Model: Confined Solution Method: Bouwer-Rice

K = 9.294E-5 cm/sec y0 = 1.17 m

Figure C-20: MW-107b Slug Test



WELL TEST ANALYSIS

Data Set: P:\...\MW-107c.aqt
Date: 03/07/15 Time: 09:18:42

PROJECT INFORMATION

Test Well: MW-107c
Test Date: 10/22/12

AQUIFER DATA

Saturated Thickness: 11. m

WELL DATA (MW-107c)

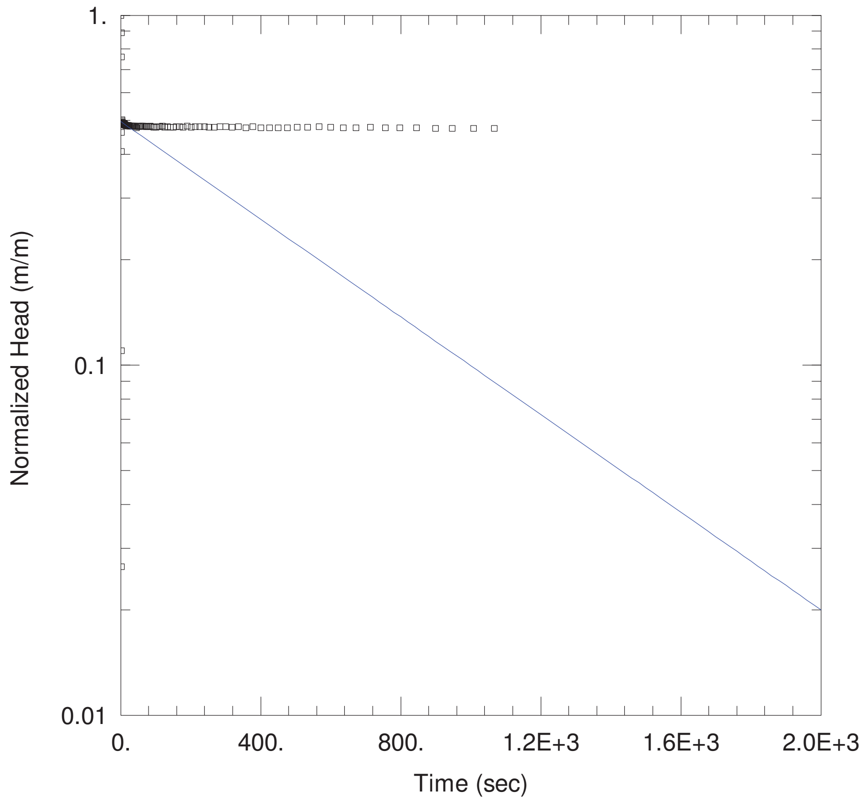
Initial Displacement: 1.2 m
Total Well Penetration Depth: 35.4 m
Casing Radius: 0.025 m
Static Water Column Height: 36 m
Screen Length: 3. m
Well Radius: 0.05m

SOLUTION

Aquifer Model: Confined
Solution Method: KGS Model

Kr = 0.000851 cm/sec
Kz/Kr = 1.
Ss = 0.008 ft

Figure C-21: MW-107c Slug Test



WELL TEST ANALYSIS

Data Set: P:\...\MW-110.aqt
Date: 03/07/15 | Time: 09:19:48

PROJECT INFORMATION

Test Well: MW-110
Test Date: 10/23/12

AQUIFER DATA

Saturated Thickness: 7.6 m | Anisotropy Ratio (Kz/Kr): 1.

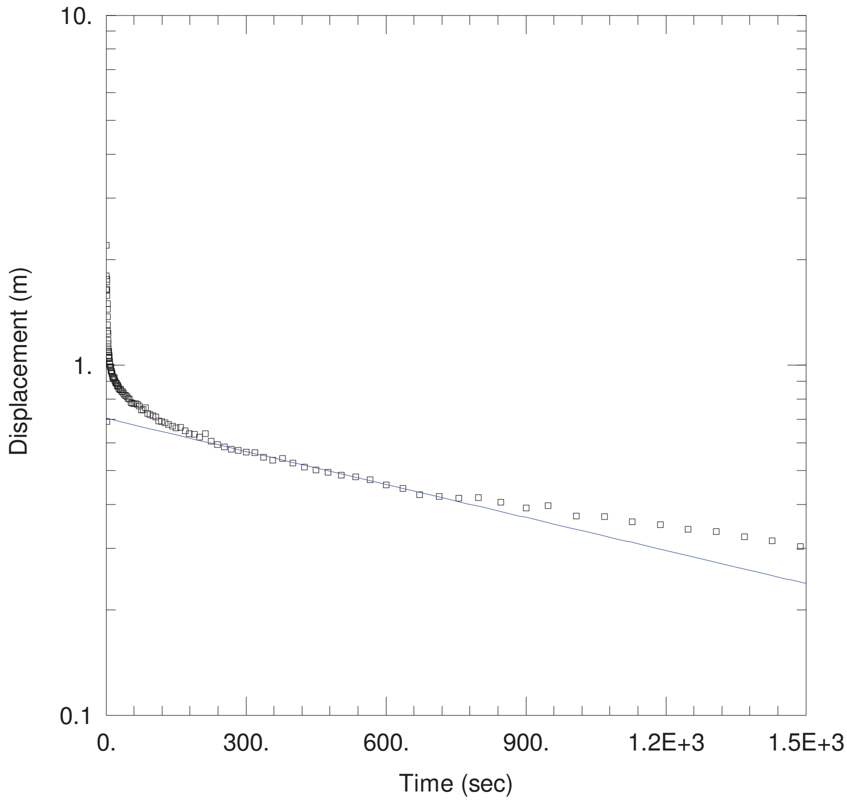
WELL DATA (MW-110)

Initial Displacement: 2.4 m | Static Water Column Height: 37. m
Total Well Penetration Depth: 18 m | Screen Length: 3 m
Casing Radius: 0.025 m | Well Radius: 0.05m

SOLUTION

Aquifer Model: Unconfined | Solution Method: Bouwer-Rice
K = 2.022E-6 ft/sec | y0 = 1.211 m

Figure C-22: MW-110 Slug Test



WELL TEST ANALYSIS

Data Set: P:\...\MW-111.aqt
Date: 03/07/15 Time: 09:20:13

PROJECT INFORMATION

Test Well: MW-111
Test Date: 10/16/12

AQUIFER DATA

Saturated Thickness: 20 m Anisotropy Ratio (Kz/Kr): 1.

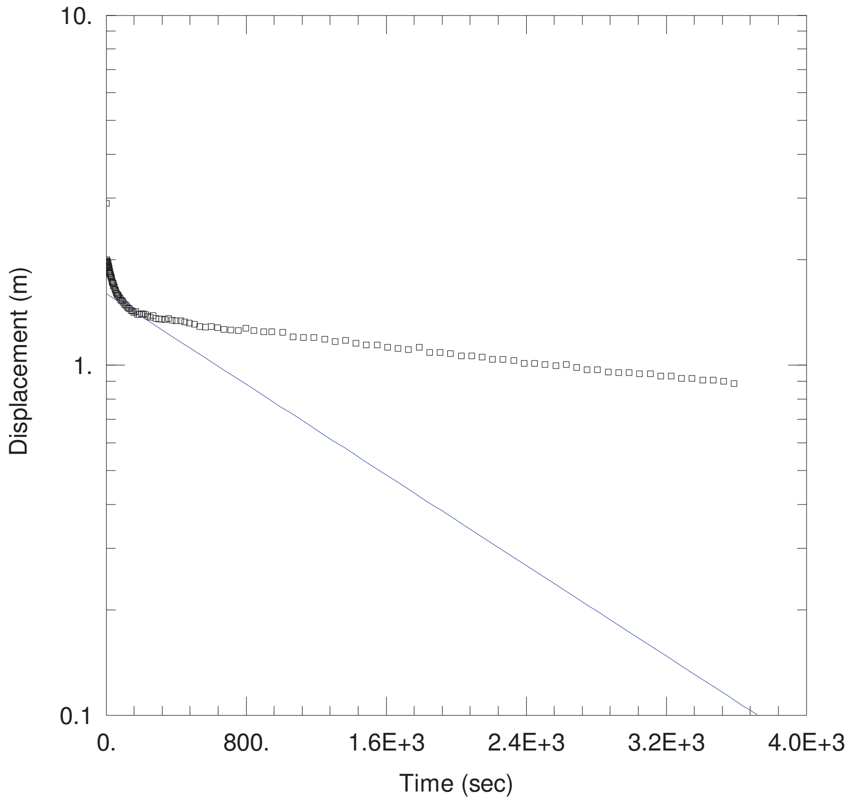
WELL DATA (MW-111)

Initial Displacement: 0.5 m
Total Well Penetration Depth: 2.4 m
Casing Radius: 0.025 m
Static Water Column Height: 2.4 m
Screen Length: 2.4 m
Well Radius: 0.05 m
Gravel Pack Porosity: 0.

SOLUTION

Aquifer Model: Unconfined Solution Method: Bouwer-Rice
K = 2.023E-5 cm/sec y0 = 0.214 m

Figure C-23: MW-111 Slug Test



WELL TEST ANALYSIS

Data Set: P:\...\MW-113.aqt
Date: 03/07/15 Time: 09:20:31

PROJECT INFORMATION

Test Well: MW-113
Test Date: 10/23/12

AQUIFER DATA

Saturated Thickness: 3.6 m Anisotropy Ratio (Kz/Kr): 1.

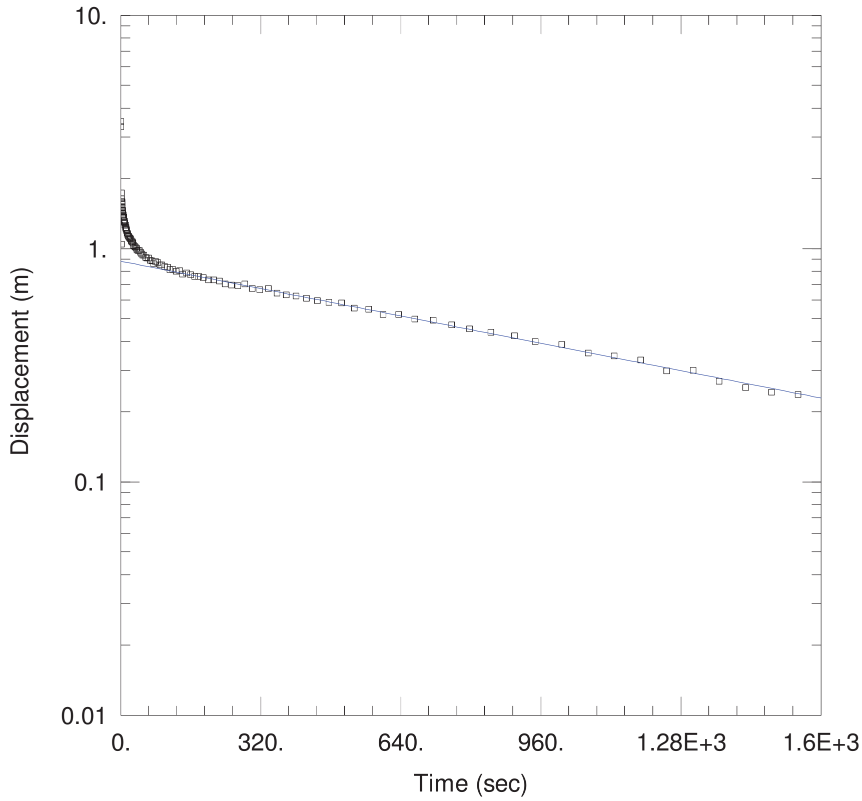
WELL DATA (MW-113)

Initial Displacement: 0.88 m Static Water Column Height: 4.2m
Total Well Penetration Depth: 3.6 m Screen Length: 3. m
Casing Radius: 0.025 m Well Radius: 0.05m
Gravel Pack Porosity: 0.

SOLUTION

Aquifer Model: Unconfined Solution Method: Bouwer-Rice
K = 2.204E-5 cm/sec y0 = 0.48 m

Figure C-24: MW-113 Slug Test



WELL TEST ANALYSIS

Data Set: P:\...\MW-114A.aqt
Date: 03/07/15 Time: 09:20:54

PROJECT INFORMATION

Test Well: MW-114A
Test Date: 10/23/12

AQUIFER DATA

Saturated Thickness: 4.5 m
Anisotropy Ratio (Kz/Kr): 1.

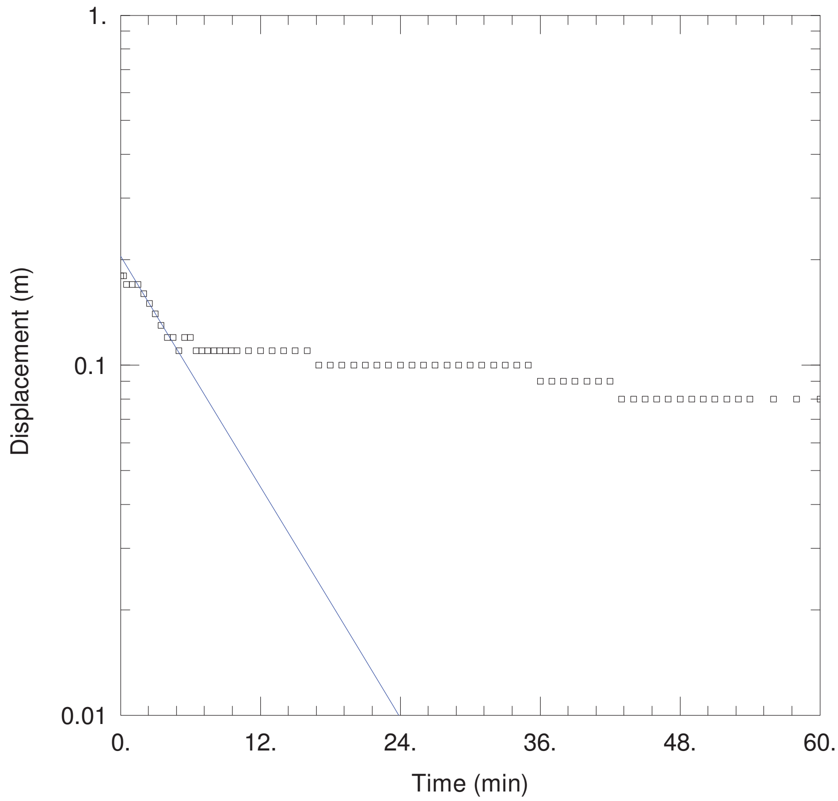
WELL DATA (MW-114A)

Initial Displacement: 1.1 m
Total Well Penetration Depth: 3.6 m
Casing Radius: 0.025 m
Static Water Column Height: 3.6m
Screen Length: 3 m
Well Radius: 0.05m
Gravel Pack Porosity: 0.

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice
K = 2.257E-5 cm/sec
y0 = 0.2688 m

Figure C-25: MW-114A Slug Test



WELL TEST ANALYSIS

Data Set: P:\...\MW-114B.aqt
Date: 03/07/15
Time: 09:21:11

PROJECT INFORMATION

Test Well: MW-114B
Test Date: 10/23/12

AQUIFER DATA

Saturated Thickness: 0.6 m
Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (MW-114B)

Initial Displacement: 0.05 m
Static Water Column Height: 0.22m
Total Well Penetration Depth: 34 m
Screen Length: 3. m
Casing Radius: 0.025 m
Well Radius: 0.05m

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice
K = 0.0003364 cm/sec
y0 = 0.062 m

Figure C-26: MW-114B Slug Test

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