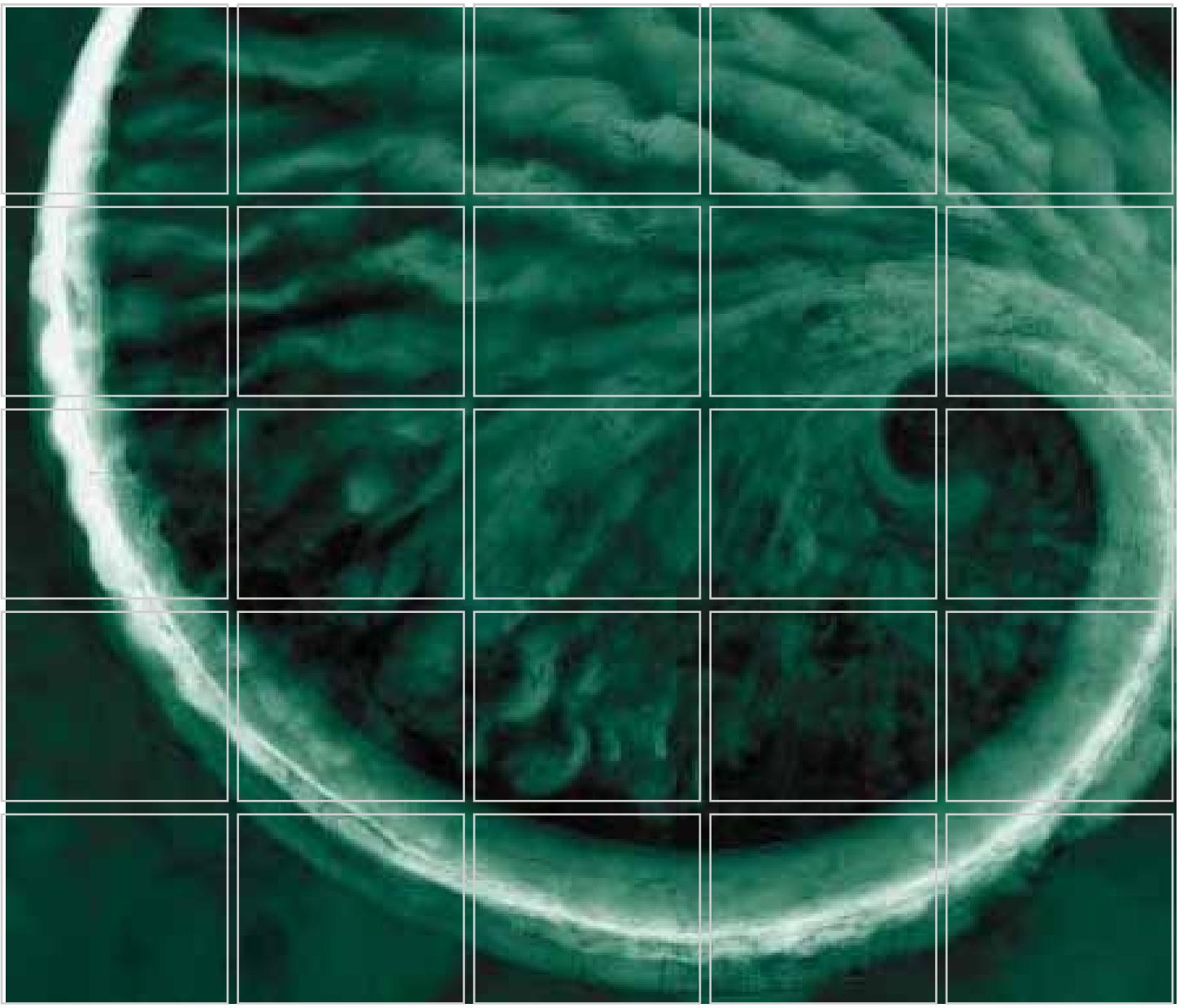

Preliminary Design Report - Groundwater Source Control Measure

Arkema, Inc. Facility
Portland, Oregon

Prepared for:
Legacy Site Services, LLC

May 2010

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Preliminary Design Report – Groundwater Source Control Measure, *Arkema, Inc Facility, Portland, Oregon*

May 2010

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LIST OF ACRONYMS

Arkema	Arkema, Inc.
BMP	Best management practices
City	The city of Portland
Consent Order	Order on Consent DEQ No. LQVC-NWR-08-04
COPC	Constituent of Potential Concern
DDT	Dichloro diphenyl trichloroethane
DSM	Deep soil mixing
DTW	Depth to water
ERM	ERM-West, Inc.
FBR	Fluidized bed reactor
FFS	Draft Focused Feasibility Study, Groundwater Source Control Interim Remedial Measure (ERM 2008)
FS	Feasibility study
Ft bgs	Feet below ground surface
Gpm	Gallons per minute
GWBW	Ground water barrier wall
GWET	Groundwater extraction and treatment
GW SCM	Groundwater source control measure
HFCS	High fructose corn syrup
JSCS	Joint source control strategy
LPGAC	Liquid-phase granular activated carbon
LSS	Legacy Site Services, LLC
Mg/L	Milligrams per Liter
NaOH	Sodium hydroxide
NPDES	National Pollutant Discharge Elimination System
NTCRA	Non time critical removal action
OAR	Oregon Administrative Rule

ODEQ	Oregon Department of Environmental Quality
PBR	Packed bed reactor
PDR	Preliminary design report
QA/QC	Quality assurance/quality control
RAO	Remedial action objectives
RI	Remedial Investigation
RW	Recovery well
SCM	Source control measure
Site	The former Arkema Portland plant
SU	Standard units
SW SCM	Storm water source control measure
USEPA	Unites states environmental protection agency
Work Plan	Draft Groundwater Source Control Measure Design and Implementation Work Plan (ERM 2009b)

1.0 INTRODUCTION

On behalf of Legacy Site Services, LLC (LSS), agent for Arkema, Inc. (Arkema), ERM-West Inc. (ERM) has prepared this Preliminary Design Report (PDR) for the former Arkema Portland Plant (the site) located at 6400 NW Front Avenue in Portland, Oregon (Figure 1-1). This PDR has been prepared pursuant to the Order on Consent requiring source control measures and a feasibility study (FS) issued by the Oregon Department of Environmental Quality (ODEQ), signed 31 October 2008 (DEQ No. LQVC-NWR-08-04) (Consent Order).

The purpose of this PDR is to present the preliminary design basis for the implementation of groundwater source control measures (GW SCMs). This PDR has been prepared in accordance with the *Scoping Technical Memorandum, Groundwater Source Control Interim Remedial Measure*, (ERM 2006); *Summary of Remedial Technology Alternatives Memorandum, Groundwater Source Control Interim Remedial Measure Focused Feasibility Study* (ERM 2008a); *Draft Focused Feasibility Study, Groundwater Source Control Interim Remedial Measure* (FFS) (ERM 2008b); *Draft Groundwater Source Control Measure Design and Implementation Work Plan* (Work Plan) (ERM 2009b); and associated comments and approvals received from the ODEQ and United States Environmental Protection Agency (USEPA).

The following subsections provide a brief description of the site history and background (additional detail is presented in the FFS (ERM 2008b), the GW SCM selection and design process to date, the objectives of this PDR, and the organization for the remainder of the report .

1.1 BACKGROUND

1.1.1 Site History

Inorganic chemicals were manufactured at the site from 1941 until 2001, when the facility was closed and chemical manufacturing was discontinued. For most of the site's history, chemical activities involved electrolytic decomposition of brine solutions to manufacture inorganic chemicals, including sodium chlorate, chlorine, sodium hydroxide, hydrogen, and hydrochloric acid. Other chemical manufacturing processes during the site's operational history included the production of

dichloro diphenyl trichloroethane (DDT) from 1947 to 1954, and ammonium perchlorate from 1958 to 1962 (ERM 2005).

Decommissioning and removal of the manufacturing infrastructure were completed in early 2005. The only remaining original structures are the office building located at the site entrance on Front Street, and several concrete floor slabs left in place as environmental caps (Figure 1-2). Arkema maintains leases from the Oregon Department of State Lands for the docks in the Willamette River, which are not currently in use.

Arkema (formerly known as ATOFINA Chemicals, Inc., Elf Atochem North America, Inc., and the Pennwalt Corporation) has conducted investigations and performed a number of interim remedial measures (also referred to as SCMs) in the upland portion of the site since 1994. These historical investigations and SCMs were conducted under the ODEQ Voluntary Cleanup Program. Results of the historical investigations were presented in the *Upland Remedial Investigation Report Lots 3 & 4 and Tract A – Revision 1* (RI), which was submitted to ODEQ in December 2005 (ERM 2005). Results of the SCMs implemented between 2000 and 2006 have been presented to the ODEQ and were summarized in the FFS (ERM 2008b).

A groundwater source control evaluation was submitted to the ODEQ in 2007 (Integral 2007) and an addendum submitted in 2008 (Integral 2008). The source control screening evaluation concluded that implementation of a GW SCM would prevent additional contaminant flux to the Willamette River, as required by the Joint Source Control Strategy (JSCS)[1]. In May 2008, LSS submitted the FFS in support of the GW SCM at the site (ERM 2008b). The FFS provided a remedial alternatives evaluation and selected the preferred alternative for the GW SCM (additional details regarding the FFS are presented in Section 1.1.2 below). On 23 February 2009, ODEQ approved the general approach for the GW SCM. This approach includes installation of a groundwater barrier wall (GWBW) and a groundwater extraction and treatment (GWET) system, with treated water being discharged to the Willamette River.

Arkema and ODEQ entered into the Consent Order for the upland portion of the site on 31 October 2008. The upland Consent Order requires

1 *The Portland Harbor Joint Source Control Strategy* prepared by the Oregon Department of Environmental Quality and the United States Environmental Protection Agency (ODEQ 2005) is a framework for making upland source control decisions at the Portland Harbor Superfund Site.

submittal of various documents in support of upland SCMs (groundwater, storm water, and erodible soil) and the site-wide upland FS. The current phase of work has been implemented under the 2009 Work Plan (ERM 2009b), a document required by the Consent Order.

Following this PDR, the next submittal to the ODEQ required under the Work Plan is the Pre-Final Design package. The Pre-Final Design will include specific design details of the GWBW and GWET system, draft versions of planning documents, and local and state agency permit review documents. The Pre-Final Design package will form the basis for the preparation of vendor and contractor bid documents.

1.1.2 Groundwater Source Control Measure Development

The JSCS is a guidance document that was developed by ODEQ and USEPA to identify, evaluate, and control potential sources of contamination that may impact the Willamette River in a manner that is consistent with the objective and schedule for the Portland Harbor Superfund Site RI/FS (ODEQ 2005). The goal of the JSCS is to achieve timely upland source control to prevent the risk of significant recontamination after the Portland Harbor cleanup is completed. The JSCS recommends that upland source control be substantially completed to the greatest extent practicable before or during any early removal actions, as well as non time-critical removal actions (NTCRAs), in order to reduce the potential for recontamination of river sediment.

Several innovative in situ interim remedial measures were implemented at the site between September 2000 and April 2006. Despite the success of those interim remedial measures, LSS did not believe an in situ remedial approach would be capable of meeting the source control objectives, many of which are not yet defined, in the USEPA-envisioned timeframe for the sediment NTCRA currently being planned at the Arkema site. Because of the NTCRA schedule, LSS has been required to pursue an alternative strategy of physical and hydraulic containment to achieve groundwater source control.

Following discussions with the ODEQ in September 2006, the draft Scoping Technical Memorandum (ERM 2006) was prepared to identify and outline the general concepts necessary to complete a GW SCM. ODEQ provided comments on this memorandum in January 2007, which were addressed in a letter submitted by LSS in March 2007.

LSS subsequently commenced preparation of the FFS in April 2007 to evaluate the alternatives for a GW SCM to achieve the following remedial action objectives (RAOs):

- Establish hydraulic control of groundwater constituents of potential concern (COPCs) at the site, and maintain an inward groundwater gradient toward the upland portion of the site, away from the Willamette River;
- Reduce the potential for recontamination of river sediments via the groundwater pathway following the Arkema NTCRA;
- Allow upland SCMs to proceed on an independent schedule from the NTCRA without impeding or compromising that work; and
- Implement a remedy, which to the extent practicable, will complement, and be compatible with potential final upland remedies for the site.

The GW SCM evaluated in the FFS (ERM 2008b) consisted of the following primary components:

1. A containment barrier wall to physically separate the affected upland portions and in-water portions of the site;
2. Hydraulic control (groundwater extraction and treatment) to prevent groundwater containing unacceptable concentrations of COPCs from moving around, over, or under the containment barrier wall; and
3. Management of treated groundwater from the ex situ treatment system with treated effluent discharged to the Willamette River under a National Pollutant Discharge Elimination System (NPDES) Permit.

As requested by ODEQ, LSS submitted the *Summary of Remedial Technology Alternatives Memorandum Groundwater Source Control Interim Remedial Measure Focused Feasibility Study* (ERM 2008a) in January 2008. This document provided a technology screening and summarized the range of remedial alternatives (i.e., proposed barrier wall alignments, treatment system options, and discharge options) being evaluated as part of the FFS (ERM 2008b).

Supporting studies and evaluations, including groundwater modeling, GWBW geotechnical engineering analysis, slurry materials testing, and groundwater treatability study, were completed between 20006 and 2008. Following the completion of this supporting work and the technology screening, a detailed evaluation and comparative analysis of the various

remedial action alternatives was performed and presented in the FFS (ERM 2008b) submitted to ODEQ in May 2008.

ODEQ conditionally approved the FFS (ERM 2008b) and provided comments on the proposed GW SCM in a letter dated 29 July 2008. On 12 September 2008, LSS submitted responses to ODEQ comments on the FFS.

In a memorandum dated 20 February 2009, ODEQ recommended alternatives for the primary components of the GW SCM.

A proposed layout of the recommended GW SCM is presented in Figure 1-2. The final GWBW alignment will be determined during the Pre-Final Design phase. A conceptual cross section of the GW SCM is presented in Figure 1-3.

The recommended barrier wall component of the GW SCM required construction of a GWBW along the top of the river bank extending to the top of the basalt using conventional slurry wall technology. The recommended GWET system for the GW SCM consisted of the following major components:

- Twenty-two groundwater recovery wells screened in the Shallow and Intermediate Zones;
- Chemical precipitation reactor with aeration and pH adjustment via sodium hydroxide;
- Solids handling system (i.e., clarifier with polymer feed, sludge holding tank, filter press, and associated equipment);
- A pH adjustment tank;
- Optional post-clarification solids filter, if required;
- Fluidized bed reactor (FBR) with solids filter for biomass handling, with the option of utilizing either the packed bed reactor or EHC®/sand reactor; and
- Two liquid-phase granular activated carbon (LPGAC) vessels in series.

The recommended treated water discharge option consisted of discharge to the Willamette River.

The lateral and vertical extent of the GW SCM was primarily determined by the extent of four major COPCs in groundwater: hexavalent chromium, perchlorate, chlorobenzene, and DDT and associated breakdown products

DDD and DDE, (collectively DDx). The historical interim remedial measures have focused on remediating one or more of these four COPCs. Historical data indicates that the primary on-site sources of these compounds are limited to areas on Lots 3 and 4 (ERM 2005, ERM 2010a). The most recent groundwater monitoring results (August 2009) from across the entire site were compared to the proposed GWBW alignment. The results of the comparison are shown in Figures A-1 through A-12 in Appendix A and confirm that the primary extent of COPCs on Lots 3 and 4 was contained by the GW SCM.

The GW SCM described in this PDR focuses on Lot 4 and a portion of Lot 3. Once an approved groundwater source control evaluation for the former Rhone Poulenc site is available, ODEQ and LSS will evaluate the need for Rhone Poulenc to perform additional GW SCMs along Lots 1, 2 and the remainder of Lot 3.

ODEQ published a public notice on 9 March 2009 seeking public comments on the recommended remedial alternative. A public meeting was held on 14 April 2009 to present the GW SCM. The public comment period closed on 21 April 2009 and the ODEQ issued a response to public comments in a letter dated 21 May 2009. The GW SCM Work Plan (ERM 2009b) was prepared following the FFS, as required by the Consent Order. The *Pre-Design Investigation Report* (presented in Appendix B) and this Preliminary Design Report are the subsequent deliverables required by the Work Plan.

1.2 OBJECTIVES

The objectives of this PDR are as follows:

- Present the potential constraints on, and basis for, design and implementation of the GW SCM; and
- Present an updated schedule for design and implementation of the GW SCM.

1.3 REPORT ORGANIZATION

The remainder of this report is organized as follows:

- Section 2.0 presents the remedy summary, existing conditions, design basis, and required permitting for the GWBW;

- Section 3.0 presents the remedy summary, design basis, discussion of individual components, and required permitting for the GWET System;
- Section 4.0 presents the conceptual performance monitoring during operation of the GW SCM;
- Section 5.0 presents the proposed schedule for design, permitting, and implementation of the GW SCM; and
- Section 6.0 lists the references cited in this PDR.

2.0 GROUNDWATER BARRIER WALL

A summary of the GWBW and its design basis, components, and permitting requirements are presented in this section.

2.1 REMEDY SUMMARY

The recommended barrier wall component for the GW SCM was the construction of a conventional slurry wall as follows:

- Bentonite slurry wall installed using conventional slurry backfill construction technology;
- Wall located along the river side high bank route (top of the river bank with necessary setback); and
- Wall constructed to a depth of approximately 50 to 85 vertical feet below ground surface (ft bgs), to the top of the basalt.

A proposed layout of the recommended riverside barrier wall is presented in Figure 1-2.

2.2 EXISTING CONDITIONS

Site conditions that could potentially affect construction of the GWBW primarily include subsurface debris present within the fill material, utilities, and site stratigraphy. Figure 2-1 depicts the current site features, surface topography, existing utilities, and anticipated debris locations within the vicinity of the GWBW.

2.2.1 Subsurface Debris and Utilities

Subsurface debris and obstructions have been identified during prior site investigation activities (i.e., monitoring well installation and borehole drilling). Historical knowledge by site personnel familiar with former facility operations also suggests that large debris (e.g. concrete foundations) is likely present within the fill material. For design purposes, the debris is classified into two types, including (1) incidental, soft debris (e.g. wood, brick, other small obstructions), and (2) construction/large debris (e.g. concrete) that has resulted in boring refusal. Large debris

could potentially interfere with GWBW installation and must be removed to facilitate GWBW construction. A subsurface debris investigation is currently under way in accordance with the ODEQ-approved *Subsurface Debris Investigation Work Plan* (ERM 2010b). The purpose of the subsurface debris investigation is to characterize and delineate the debris. On 26 and 27 April 2010, two test trenches were excavated (a total of approximately 250 feet of trenching) within the areas where large debris had previously been encountered. Visual observations were recorded and two soil samples were collected and submitted for geotechnical analysis. Additionally, several pieces of large concrete debris were removed and staged for eventual off-site disposal. The detailed results of the subsurface debris investigation will be presented in a separate technical memorandum, following receipt of geotechnical testing data.

As depicted in Figure 2-1, numerous (approximately 12 to 15) subsurface and overhead utilities are present in the vicinity of the proposed GWBW. Many of these utilities are associated with former facility operations and are no longer in use. Those abandoned utilities crossing, or in the vicinity of, the proposed GWBW alignment, including unused process lines, storm sewer drains, and water lines, will be cut, capped or plugged (isolated) prior to or during the first phases of installation of the GWBW.

The only active utilities in the vicinity of the GWBW are the overhead power line and subsurface storm sewer drains. The overhead power line extends to the west and north from Dock 1 (Figure 2-1). The overhead power line will be temporarily re-routed in the area around Dock 1 to facilitate installation of the GWBW.

The active storm sewer drains currently discharge through Outfalls 1, 2, 3, and 4 (Figure 2-1). A Storm Water SCM (SW SCM) and Memorandum of Agreement and Order is currently being negotiated at the site with details/controls as presented in the *Draft Storm Water Source Control Measure Design and Implementation Work Plan* (Integral 2009). As part of the SW SCM, in general the surface water runoff near the GWBW will be routed by swales away from the riverbank to a centralized treatment system and discharged through Outfall 4. The location of the storm water treatment system is not yet finalized. The existing storm sewer lines discharging to Outfalls 1, 2, and 3 will be abandoned in place, allowing these lines to be cut and isolated where they intersect the GWBW.

2.2.2 *Site Soils*

A detailed description of site soils has been presented in the RI (ERM 2005), and is discussed in the *Pre-Design Investigation Report* (Appendix B). In general, site soils consist primarily of sand with some silts and clays. Geologic cross-sections depicting the site lithology are presented as Figures 2-2 and 2-3. The lithology along the proposed GWBW alignment is comprised of fill materials consisting of silt and fine-sand sized particles with debris present from the surface to between 20 and 25 ft bgs, with native fine to coarse sands to approximately 45 ft bgs. These native sands comprise the upper water bearing zones (Shallow and Intermediate Zones). The Shallow and Intermediate Zones are separated by a thin silt layer (Shallow-Intermediate Silt) that occurs at approximately 35 ft bgs. Impacts from COPCs on Lot 4 are predominantly associated with the Shallow and Intermediate Zones. As per the FFS (ERM 2008b), the GW SCM is focused on hydraulic containment of the Shallow and Intermediate Zone within this area.

Below the Intermediate Zone is a silt layer to approximately 60 ft bgs, and a fine silty sand layer present to approximately 85 ft bgs, collectively referred to as the Deep Zone. Basalt bedrock (Fractured Basalt Zone) is encountered approximately 47 ft bgs at the northern end of the GWBW alignment and approximately 85 ft bgs at the southern end.

As discussed below in Section 2.3, the non-cohesive nature of the native soils will be considered within a GWBW and clearance trench stability analyses. Further, the coarse-grained fill and native soils will be considered within the construction and slurry mixing activities to ensure stable conditions and proper GWBW installation.

2.3 *DESIGN BASIS*

This section presents the design basis and assumptions for the major GWBW design components.

2.3.1 *Construction Technique*

Construction of a GWBW at the site poses various technical challenges, including sandy (i.e., non-cohesive) soil, subsurface debris, underground utilities, proximity to the Willamette River, and as well as the total planned depth of the wall. Conventional slurry trenching technology was used as a conservative assumption for the purposes of evaluating

remedial alternatives in the FFS (ERM 2008a). However, a variety of GWBW construction techniques exist, some of them better suited for certain site conditions and constraints.

To identify the most effective GWBW construction technique for the site, the advantages and disadvantages of several applicable techniques were evaluated as part of the Preliminary Design. The alternative GWBW construction techniques considered included the following:

- Conventional slurry wall construction;
- Deep soil mixing (DSM); and
- Jet grouting.

Each of these techniques are capable of achieving the design requirements, which include: 1) low permeability (i.e., 10^{-5} to 10^{-6} cm/s), and 2) a minimum thickness of 3 feet. The advantages and disadvantages of each technique are summarized below.

2.3.1.1 *Conventional Slurry Wall Construction*

Conventional slurry wall construction consists of excavating a trench to the design depth (i.e., to the top of basalt). A bentonite slurry fill is used to hold the trench open during excavation. The excavated soil is mixed ex-situ with bentonite and water to create a soil-bentonite backfill mixture. As the trench excavation progresses, the backfill mixture is placed back into the trench, creating the barrier wall. The sequential excavation, backfill mixing, and placement process continues for the entire length of the wall. For the purposes of this design, conventional slurry wall construction refers to the use of a hydraulic excavator with long-stick attachment (as opposed to the crane-mounted clam shell method of slurry wall construction). Advantages of conventional slurry wall construction include the following:

- Traditional method for barrier wall construction;
- Established quality assurance/quality control (QA/QC) activities;
- Ability to visually observe slurry and backfill mixes; and
- Relatively lower cost than alternative approaches.

Disadvantages of conventional slurry wall construction include the following:

- Requires relatively large working area;

- Wall depth required at the site is near the maximum practicable depth possible using conventional methods (i.e., hydraulic excavator);
- Success of installation is largely dependent on the constructor, including the mechanics and methodology of backfill placement (e.g. the slope of the soil-bentonite backfill);
- Large subsurface obstructions must be removed; and
- Involves intensive QA/QC processes, including observation and testing of trench excavation, slurry fill to keep trench open, ex-situ mixing of low permeability backfill, and placement of low permeability backfill.

2.3.1.2 *Deep Soil Mixing*

DSM consists of constructing a series of overlapping columns of mixed soil and bentonite. The columns are installed by advancing a series of hollow stem augers to the design depth. As the augers are advanced, slurry is pumped through the hollow stem and injected into the soil. The flights of the auger mix the slurry and soil in situ, creating the barrier wall. Advantages of DSM include the following:

- In situ mixing reduces the number of construction steps and QA/QC protocols;
- Requires relatively small working area; and
- Capable of installation at greater depths than those attainable with conventional slurry wall construction.

Disadvantages of DSM include the following:

- In situ mixing cannot be visually observed;
- Large obstructions must be removed; and
- More expensive than conventional slurry wall construction.

2.3.1.3 *Jet Grouting*

Jet grouting consists of injecting the bentonite slurry at extremely high velocities and pressure. The high pressure jet of bentonite slurry breaks up the soil structure completely, mixing the soil and slurry to form the barrier wall. Advantages of jet grouting include the following:

- In situ mixing reduces the number of construction steps and QA/QC protocols;

- Ability to work in small areas, including in, around, and underneath structures; and
- Capable of installation at greater depths than those attainable with conventional slurry wall construction.

Disadvantages of jet grouting include the following:

- In situ application cannot be visually observed;
- Technique is sensitive to changes in soil, requiring assessment of the proper pressures for different soil types; and
- Significantly more expensive than conventional slurry wall construction.

2.3.1.4 *Summary and Recommendations*

One of the primary advantages of DSM and jet grouting include the ability to operate in relatively small areas and in close proximity to structures. These advantages are of limited value at the site since adequate space is available upgradient of the riverbank. Soil strength can also be enhanced with these techniques, but this is not a significant concern at the site. When the value of these advantages is reduced, DSM and jet grouting become less attractive due to their higher cost. Although DSM and jet grouting are capable of installation at greater depths, conventional slurry trenching techniques are capable of achieving the maximum design depth.

Based on the evaluation of the advantages and disadvantages with respect to site conditions, LSS believes that the conventional slurry wall technique is the most suitable construction method. Therefore, this will be the presumptive barrier wall construction technique as the design progresses. However, the installation of the GWBW will be contracted through a performance-based specification, including a minimum thickness of 3 feet and maximum permeability in the range of 10^{-5} to 10^{-6} cm/s. Consequently, the design and bid specifications will be prepared to allow conventional slurry wall construction or alternative construction techniques, so long as the objectives of the GWBW are met.

2.3.2 *Backfill Mix Design*

The maximum potential effectiveness of the GWBW (i.e., lowest hydraulic conductivity) is determined by the selection and proportioning of components that make up the slurry wall backfill. Typical slurry wall backfills consist of excavated soil mixed with clay (bentonite or

attapulgite), and may also include cementitious materials (e.g. Portland cement, slag cement). The selection and proportioning of the clay component of the slurry backfill mixture must take into account specific site conditions, as certain groundwater constituents can have a negative effect on the long-term effectiveness of the barrier wall due to chemical and physical interactions. The degree to which a backfill mix is able to withstand degradation by site conditions is referred to as "compatibility."

Notable conditions of the site that could potentially affect the compatibility of the backfill mix are the presence of monochlorobenzene that is present in thin layers as a dense non-aqueous phase liquid in the former Acid Plant area, and elevated levels of chlorides in the former Chlorate Plant area (Figure 1-2). Dense non-aqueous phase liquids in general, are known to reduce the water absorption of hydrated clay materials, causing desiccation cracking, and thereby increasing the hydraulic conductivity. This has also been shown to occur in mixtures of soil and clay. The addition of a cementitious material may limit the increase of hydraulic conductivity, as could the use of attapulgite clay.

Bentonite clays are known to be potentially incompatible with saline environments. Therefore, the high level of chlorides at the site is a concern. Typically, attapulgite clay is used in saline environments. There are bentonite products available which are marketed as saline-resistant and chemical resistant.

Given the potential compatibility concerns, a slurry material testing program was conducted as part of the FFS (ERM 2008b). This testing program was designed to determine the feasibility of several approaches to constructing a GWBW. The testing program was carried out using site-specific materials, including groundwater and soil, to simulate actual and "worst case" conditions the GWBW will experience. The results from the slurry materials testing program are summarized in Table 2-1 and indicate that both bentonite and attapulgite are likely to be suitable slurry backfill clay additives without the addition of a cementitious component. Groundwater and soil collected from the areas with the highest chloride concentrations, and a DNAPL sample, were discretely tested in order to evaluate slurry backfill mixture performance in the worst cases. The results were favorable (i.e., hydraulic conductivity less than 1×10^{-7} cm/s) for all combinations of site soil and clay backfill mixes and site groundwater permeants tested.

The GWBW contractor will be responsible for selecting a specific backfill mix, or selecting a proprietary blend. The contractor will be required to

test the proposed backfill mix in a laboratory (bench scale), then in the field (pilot scale). Bench scale testing will include long-term compatibility testing in which certain quantities of permeant (e.g. two pore volumes) are passed through the mix in order to simulate long-term use of the wall. The backfill mix selected by the contractor will need to meet the maximum requirement for hydraulic conductivity in situ, as discussed in the section below.

2.3.3 *Quality Assurance/Quality Control Activities*

The ability to ensure a successful slurry wall installation through engineering design is limited as the slurry wall construction is largely dependent on available contractor methods and expertise. However, this element of uncertainty can be managed through the implementation of a rigorous QA/QC program. QA/QC activities are performed for each stage of slurry wall construction, from pre-construction through post-construction, to ensure the finished product will meet the intent of the design. The Construction Quality Assurance Plan, part of the Pre-Final Design package, will detail the specific elements of the QA/QC program. Some of the QA/QC activities that will be considered for incorporation into the Construction Quality Assurance Plan are presented in Table 2-2.

2.3.4 *Clearance Trench*

As described in Section 2.2.1, subsurface debris and obstructions have been encountered during historical drilling activities at the site. Additionally, site personnel familiar with former facility operations indicate that large debris, including concrete foundations, were disposed of on site. Locations where debris is believed to be present along the GWBW alignment are depicted in Figure 2-4. Large subsurface debris can adversely affect slurry wall construction either through refusal or potential creation of large voids resulting in sudden loss of stabilizing slurry. As a result, large debris along the proposed GWBW alignment must be removed by performing clearance trenching prior to slurry wall construction. At a minimum, the clearance trenching is anticipated to extend from GWBW station 5+30 to 11+70, the locations where hard debris and/or refusal were encountered (see Figure 2-4). The clearance trench will be excavated to the bottom of the fill material, approximately 20 to 25 ft bgs. As discussed in Section 2.2.1, approximately 50 percent of this clearance trench has already been completed as part of the subsurface debris investigation.

Based on the initial results of the subsurface debris investigation, the fill material is anticipated to support clearance trench side slopes of between 0 horizontal to 1 vertical (0:1) (i.e., vertical side slopes) to 1:1. The length, depth, and width of the proposed clearance trench will be confirmed upon completion of the subsurface debris investigation.

Large debris (i.e., debris with dimensions greater than the thickness of the GWBW) will be removed and disposed off site, and the remaining material will be returned to the excavation as backfill. Clean structural fill will be imported, as necessary, to return the excavation to existing grade. The backfilled material will be sufficiently compacted (i.e., bucket compaction) to ensure stability during GWBW installation.

Utility conduits intersecting the GWBW will require capping or plugging (isolation) to prevent sudden loss of slurry, and potential trench instability during wall construction. Limited additional excavation and trenching in specific utility locations will be required prior to GWBW installation. As discussed in Section 2.2.1, the abandonment of the active subsurface utilities with respect to the existing stormwater outfalls will be coordinated with the implementation of the proposed SW SCM.

An electric utility substation consisting of a 10 foot by 10 foot concrete slab and utility rack is located approximately 30 feet north of the proposed GWBW alignment in the vicinity of GWBW station 9+00 (see Figure 2-4). The clearance trench will not be excavated between GWBW stations 8+70 and 9+30 to avoid disturbance of the substation facility. It is noted that large debris is not expected to be present in this area. Alternatively, if clearance trenching suggests that debris may be present in this area, the substation could be supported (e.g. underpinning) or temporarily removed to facilitate trenching.

2.3.5 *Wall Alignment*

Ideally, the GWBW would be constructed as close to the top of the riverbank as possible and to the extent achievable, minimize the mass remaining between the GWBW and the Willamette River (i.e., the "stranded wedge"). However, other factors must be considered, including worker safety, stability of the riverbank, and wall constructability, when locating the GWBW.

Preliminary slope stability analyses were performed using existing geotechnical data to determine the minimum GWBW setback both with, and without, a clearance trench (Appendix C). The results of the slope

stability analyses indicate that the GWBW setback is driven by the clearance trench. Based on slope stability, practical implementation, and safety, the minimum setback with no clearance trench is 30 feet. The GWBW setback is 50 feet within the areas potentially requiring a clearance trench. The GWBW alignment presented in Figure 2-4 includes an approximate 50 foot setback from the top of the riverbank along much of the length of the wall. This set back was calculated on limited site specific data. However, based the observations and initial findings of the subsurface debris investigation the GWBW may be located closer to the riverbank. The wall alignment will be confirmed following completion of the subsurface debris investigation.

In order to construct the GWBW, sufficient space must be available for backfill mixing operations and equipment maneuvering. For conventional side-mix slurry wall construction, approximately 1 foot of lateral space for every 1 foot of wall depth is required on at least one side of the GWBW. This results in a lateral space requirement of between 50 and 85 feet on the upland side of the GWBW alignment. Additionally, for conventional slurry wall construction, sharp angles or bends in the wall alignment (i.e., greater than 15 degrees) require pulling out of the trench, repositioning the excavator, and constructing a lead-in trench to connect to the previously completed wall segment. With a typical slope of 1:1, lead-in trenches can require significant space on deep wall sections. An alternative is to construct sweeping bends with radii ranging from 100 to 150 feet where space is available, thus permitting continuous trenching. This latter method was assumed for the proposed GWBW alignment at the site. The preliminary GWBW alignment is presented in plan view in Figure 2-4. A geologic profile along the GWBW alignment is presented in Figure 2-5.

2.3.6 Erosion/Sediment Control and Construction Storm Water Management

Local permits pertaining to erosion and sediment control are not required for this project, as discussed below in Section 2.4; however, the substantive requirements must be met. Applicable erosion and sediment control measures, as per the city of Portland (the "City") Erosion and Sediment Control Manual, include construction sequencing, "development activity controls," and best management practices (BMPs). The applicable measures will be detailed in an Erosion, Sediment, and Pollution Control Plan and are summarized in this section.

Interim storm water management controls will be constructed as part of the site wide SW SCM, as identified in the *Draft Stormwater Source Control*

Measure Design & Implementation Work Plan (Integral 2009). Storm water management under this plan includes site grading, focused capping, and construction of a network of filter rock swales. Storm water will be conveyed to an impermeable detention basin, then to a filtration treatment system before being discharged via Outfall 4 to the Willamette River. The SW SCM will be completed in coordination with the construction of the GWBW. It is anticipated that the controls associated with the SW SCM will be in place prior to construction of the GWBW, and will, therefore, supplement the erosion and sediment control and construction storm water management BMPs.

Construction of the GWBW will be sequenced to reduce the active area (i.e., by segments or continuous trenching and backfill). Reducing the amount of disturbed area at a given time will reduce the potential to produce sediment-laden runoff. The construction of the GWBW is also currently scheduled to occur in the driest time of the year, between May and September.

Development activity controls are non-BMPs which limit the potential for adverse effects to storm water during construction. The project will include a contractor staging area, as discussed below, which will limit the potential for adverse effects due to equipment storage, refueling and maintenance, and materials storage.

Erosion and sediment control BMPs are required if the potential for erosion and sedimentation cannot be eliminated by the use of construction sequencing and development activity controls alone. The BMPs (as per the City Erosion and Sediment Control Manual) best suited to control erosion and sediment at the site include temporary sediment control (silt) fence and storm drain inlet protection. The placement of BMPs will be determined upon final GWBW design, but the approximate BMP locations are presented in Figure 2-6. Generally, silt fence will be placed between the proposed GWBW, near the top of bank, and the Willamette River. A wire-reinforced silt fence will be considered to ensure durability.

Finally, where erosion occurs and sediment-laden runoff is produced, the runoff will be directed through a network of filter rock swales to an impermeable detention basin and a filtration treatment system before being discharged to the Willamette River. This storm water management system is part of the proposed SW SCM at the site.

2.3.7 *Utilities*

As noted in Section 2.2 and depicted in Figure 2-4, several utilities intersect the proposed GWBW alignment, including process lines, storm sewer, and water. Many of these utilities are associated with former facility operations and are no longer in use. These utilities will be identified, cut, and isolated as a component of the GWBW installation. The overhead electric line extending to the west from Dock 1 will be temporarily rerouted to facilitate GWBW installation.

2.3.8 *Staging Area*

Space will be provided at the site for use by the contractor to stage equipment and materials necessary for GWBW construction. At the contractor's preference, the staging area may be a centrally located, stationary staging area or a mobile staging area that moves with the GWBW construction operation. However, it is anticipated that any staging area will be located on the upland side of the GWBW. A potential staging area location is depicted in Figure 2-4.

2.4 *PERMITTING*

This section discusses the permits required for the construction of the GWBW component of the GW SCM.

2.4.1 *State*

The project is being conducted under Oregon State Cleanup Rules through the Consent Order with the ODEQ as the lead agency. As this is a cleanup project, state permit requirements must be met, but the permits are not required. However, based on discussions with the ODEQ, a NPDES General Construction Storm Water Permit (1200-C) will be obtained for discharge of storm water during construction of the GW SCM in order to minimize the ODEQ review schedule. The 1200-C permit is required for projects that have an anticipated disturbed area greater than one acre. Projects with a disturbed area greater than five acres require public review of the permit application. The area anticipated to be disturbed during the implementation of the GW SCM is approximately 4 acres.

A NPDES Individual Permit will be required for the discharge of both storm water after construction, and treated effluent from the GWET

system. The conditions and requirements of the NDPES Individual Permit are currently under negotiation between LSS and ODEQ.

2.4.2 *Local*

The project is being conducted under Oregon State Cleanup Rules through the Consent Order, with the ODEQ as the lead agency. It is currently understood, as per preliminary discussions with City personnel, that development permit approvals will not be required because the project will fall under the City "exempt" process; however, the substantive requirements of relevant permits must be met. The exempt process has been established as a means of providing City input to an ODEQ-managed cleanup project that is being conducted under the permit waiver process. The exempt process consists of a 1 month review by the city of Portland Bureau of Development Services and Bureau of Environmental Services for compliance with applicable City codes and regulations, including greenway overlay zoning requirements. This review will be performed for a fixed fee, and does not include a public comment period. A letter of determination will be issued by the City which may contain additional requirements. Additional requirements may be negotiated with City review personnel; however, there is no formal appeal process.

3.0 GROUNDWATER EXTRACTION AND TREATMENT SYSTEM

A summary of the GWET system and its design bases, components, and permitting requirements are presented in this section of the report.

3.1 REMEDY SUMMARY

The recommended GWET system consists of the following components:

- A total of 22 recovery wells, including 13 screened in the Shallow Zone and 9 screened in the Intermediate Zone, each equipped with a pump;
- Precipitation reactor with aeration and pH adjustment via sodium hydroxide to remove iron and other metals potentially present at concentrations exceeding their discharge limits in groundwater;
- Solids handling system (i.e., clarifier with polymer feed, sludge holding tank, filter press, and associated equipment) to dewater and prepare precipitated solids for off-site transportation and disposal;
- A pH adjustment tank to neutralize the groundwater pH prior to anaerobic biological treatment;
- FBR to anaerobically biodegrade perchlorate, chlorate, and potentially biodegradable organics present in groundwater, with the option of utilizing either a packed bed reactor (PBR) or EHC®/sand reactor in the event they are determined to be more cost effective than a FBR;
- Post-FBR sand filter to remove biomass potentially carried over into the FBR effluent;
- Two LPGAC units in series to remove volatile organic compounds (i.e., chlorobenzene) and pesticides (i.e., DDT) from groundwater; and
- Discharge to the Willamette River through existing Outfall 4.

The preliminary basis for designing, and descriptions of the above components, are presented in Sections 3.2 and 3.3 below. Permitting requirements for the GWET system are summarized in Section 3.4.

3.2 DESIGN BASIS

Technical information and data that will serve as a basis of the preliminary design and development of specifications for the GWET system components are presented in this section.

3.2.1 Pumping Rate and Recovery Wells

The average predicted groundwater pumping rate to achieve the GW SCM RAOs is approximately 109 gallons per minute (gpm) as presented in the *Pre-Design Investigation Report* (ERM 2010), included as Appendix B. This average predicted pumping rate will be spread across 22 recovery wells with each being pumped at a rate between 3 and 6 gpm, as summarized on Table 3-1.

For design purposes, the total groundwater extraction rate is assumed to vary from 54 gpm (-50percent) to 142 gpm (+30percent) to account for modeling uncertainties, potential seasonal fluctuations (i.e., higher flow rates may be required in the winter when there are higher precipitation amounts, and lower flow rates in the summer when rainfall amounts are lower) and provide operational flexibility. Depending on location, season, and operating conditions, the individual recovery wells are anticipated to be pumped at rates between 2 gpm and 9 gpm. Thirteen of the recovery wells will be screened within the shallow aquifer (down to a depth of approximately 35 ft bgs) and nine will be screened within the intermediate aquifer (down to a depth of approximately 45 ft bgs). The recovery wells will need to be completed below grade within an accessible vault rated for heavy truck traffic to reduce their impact to a potential future site-wide remedy and/or redevelopment of the site.

A three-dimensional, numerical groundwater flow model was developed for the site to predict the required groundwater pumping rate and recovery well layout required to achieve the GW SCM RAOs. The design of the groundwater model and methods that were used to calibrate the model to observed groundwater conditions at the facility are described in the *Draft Groundwater Modeling Report, Arkema Inc., Facility, Portland, Oregon* (ERM 2007).

Groundwater pumping tests were completed at the site in 2009 to provide supplemental hydraulic conductivity data for refining the groundwater flow model. The pumping test procedures and data are presented in the *Pre-Design Investigation Report* (ERM 2010), included as Appendix B to this

report. The groundwater model has been updated based on the results of the aquifer pump testing and revised GWBW layout.

The updated groundwater model was used to determine the number and distribution of recovery wells required to achieve hydraulic containment of the Shallow and Intermediate Zones, as well as the predicted groundwater pumping rate to achieve the GW SCM RAOs. The area that requires hydraulic containment to achieve the RAOs (i.e., the "target capture zone") for hexavalent chromium, perchlorate, chlorobenzene, and DDT was determined from the spatial distribution of these compounds in groundwater (Appendix A).

The efficiencies of the recovery wells that will be installed for the full scale GWET system will likely to be similar to the recovery wells installed under the aquifer testing program (Appendix B). For this reason, the maximum flow rate from individual recovery wells was set at 6 gpm for the purposes of groundwater modeling and designing the recovery well network. Recovery well locations were then manually adjusted until particle tracking in the Shallow, Intermediate, and top portion of the Deep Zone indicated that hydraulic containment of the target capture zone was achieved. The locations of the target capture zone, recovery wells, and anticipated flow paths within the Shallow, Intermediate, as well as the Deep Zones are shown in Figures 3-1, 3-2, and 3-3 respectively. The actual capture zone of the GW SCM will be larger than the target capture zone.

The actual groundwater pumping rate required to achieve the GW SCM RAOs may vary throughout the year based on seasonal water levels, precipitation, operational monitoring, and performance monitoring results. As indicated, the installed pumping capacity of individual recovery wells will range from approximately 2 gpm to 9 gpm to account for potential flow rate uncertainties. Operational monitoring will consist of continuous measurement of groundwater levels in recovery wells behind the GWBW and observation wells located on the riverside of the GWBW. These measurements will be used to control the extraction well pumps in order to maintain an inward hydraulic gradient across the GWBW.

Performance monitoring will consist of manual groundwater elevation measurements and contouring to verify that hydraulic containment of the COPCs on the upgradient side of the GWBW is being maintained. As discussed in Section 5.0, the GW SCM performance monitoring program will include an evaluation of actual capture zones. The groundwater flow model may be used as a tool for assisting with this evaluation.

3.2.2 *Constituents of Potential Concern and Influent Concentrations*

Constituents present in groundwater, and water quality parameters that may affect the design of the GWET System, are presented in Table 3-2. The following data sources were used to estimate expected influent concentrations to the GWET system:

- Analytical results from the most recent groundwater samples collected from monitoring wells during the site-wide sampling events in April 2007 and August 2009;
- Analytical results from samples collected during pumping tests in 2009; and
- Analytical results from groundwater samples used for the groundwater treatability study in 2007.

While actual influent concentrations will likely vary, the influent groundwater concentrations presented in Table 3-2 are conservative estimates. Based on actual observations of many GW extraction and treatment systems, actual influent concentrations will decrease over time. However, sporadic increases in concentrations could occur in the short term due to areas of groundwater containing constituents at higher concentrations being pulled toward the recovery wells and/or more groundwater being pumped from areas with COPCs at higher concentrations. The conservative estimates of influent concentrations provide some additional level of assurance that the GWET system will be able to effectively treat the groundwater if higher constituent concentrations are encountered.

Effluent quality objectives for the treated groundwater were developed by comparing the estimate influent concentrations to potential removal estimates and effluent concentrations, based on typical treatment system performance (provided by vendors). The effluent quality objectives that will be used for GWET system design are summarized on Table 3-3.

3.2.3 *Discharge Location and Limits*

Treated groundwater will be discharged, along with treated site-wide storm water, to the Willamette River through existing Outfall 4. Figure 3-4 is a preliminary plan view of the GWET system layout that shows the location of Outfall 4. The parameters that will be used to design the GWET system are summarized in table 3-4. The COPCs in groundwater that will be included on the NPDES permit for discharge of treated effluent and

their respective limits are currently being discussed between LSS and ODEQ. Actual discharge limits will not be known until the final NPDES discharge permit is received. NPDES permitting of the treated groundwater discharge is discussed in Section 3.4.1.

3.2.4 *Groundwater Treatability Study*

A bench-scale groundwater treatability study was conducted between April 2007 and February 2008 to evaluate the potential effectiveness of various treatment technologies. The technologies evaluated, sampling and testing protocols, results, and conclusions of the treatability study are presented in the *Treatment of Groundwater from the Arkema Facility in Portland, Oregon: Bench-Scale Treatability Study Report* (Adventus 2008).

Results of the treatability study were used as a basis for the groundwater treatment system design, and are summarized as follows:

- Chemical precipitation consisting of aeration with sodium hydroxide (NaOH) to adjust the pH to 8.0 standard units (SU) followed by the addition of an anionic polymer and polishing filtration (25-micron) was able to effectively reduce the concentration of iron to less than its treatability discharge criteria of 0.3 milligrams per liter (mg/L). Based on these results, iron co-chemical precipitation was selected as the initial treatment step of the groundwater treatment system. Iron was the only metal of interest present at measurable concentrations in the groundwater samples collected for treatability testing, and testing efforts evaluated removal of iron. However, iron co-precipitation is expected to be effective for treatment of a number of metals, including hexavalent chromium, detected in historical groundwater samples. Although polishing filtration was required to achieve the treatability discharge criteria for iron during the bench-scale treatability study, filtration is not expected to be required for the full-scale treatment system. Specifically, the bench-scale testing relied upon manual decanting of the treated effluent from jar testing, while the full-scale system will include an engineered clarifier system for removal of fine solids. The design of the GWET system will also allow for addition of a post-clarifier solids filter in the event that such a filter is required to achieve effluent quality objectives.
- Titration tests indicated that the volume of NaOH required to achieve a pH of 8.0 SU ranged from $3x10^{-5}$ gallons (NaOH, 20 percent weight by volume) to $5x10^{-4}$ gallons (NaOH, 40 percent weight by volume) per gallon of groundwater. The dosage required depended on the age of the groundwater sample. Lower volumes of NaOH were required to

achieve the target pH during the initial stages of the treatability study, suggesting that NaOH feed rates for the GWET system will be on the low end of this observed range.

- The polymer dosage that effectively coagulated the precipitated solids and enhanced their settlement in the clarifier was $2x10^{-4}$ gallons (CSC Technology 4816P, 0.1 percent) per gallon of groundwater.
- Iron co-precipitation using a supplemental iron source was initially planned to be evaluated during the treatability study as a means to remove iron and other metals present at concentrations above their potential effluent quality objectives. However, sufficient iron was present in the treatability study sample so that an additional source of iron was not needed for the co-precipitation process. Additionally, no conclusions could be drawn for other metals, as they were present at relatively low concentrations in the treatability study. The concentration of iron present in groundwater pumped from the recovery wells appears to be lower in samples collected from monitoring wells compared to iron in the treatability study sample. Pending recommendations from the equipment vendor selected to provide the metals precipitation system, a supplemental iron source is assumed to be required for the GWET system to provide high enough iron concentrations for sufficient iron co-precipitation to achieve applicable effluent quality objectives of other metals. As such, the GWET system design will provide the ability to add ferrous sulfate (or another source of iron) to the chemical precipitation reactor and include space for the supporting feed tank, feed pump, and corresponding controls.
- As stated above, although necessary during the treatability study to achieve the treatability discharge objective for iron, post-clarifier filtering to prevent precipitated solids being carried over in the clarifier effluent may not be necessary based on expected performance of a full-scale chemical precipitation and clarifier system. However, the design will provide the ability and space to add a post-clarifier solids filter, if necessary.
- Both FBRs and PBRs were effective at reducing the concentrations of perchlorate and chlorate to below laboratory detection limits with a hydraulic residence time of approximately 3 hours. These treatments were effect at both low (i.e., 1,600 mg/L) and high (i.e., 8,000 mg/L) chloride concentrations. A single FBR with sand as a reactor media was effective at treating perchlorate and chlorate. LPGAC may be considered as an alternate reactor media based on documented performance of existing FBRs for similar groundwater treatment

applications. A single PBR filled with Adventus' proprietary biological treatment media, AQUAMEND®, was also effective at treating perchlorate and chlorate.

- High fructose corn syrup (HFCS) was used as the organic carbon source for the FBR and PBR during the treatability study. An estimated feed rate of 1.6×10^{-4} gallons of HFCS per gallon of groundwater was recommended for a full-scale treatment system based on the results of the treatability study (Adventus 2008). HFCS may not be used for the full-scale treatment system, as the biological treatment system manufacturer selected will be requested to recommend a cost-effective organic carbon source (e.g. acetic acid) and a feed rate.
- Ammonium phosphate was used as the nutrient source for the FBR and PBR during the treatability study, with target feed concentrations of 1 mg/L of phosphate-P and 10 mg/L ammonium-N. The biological treatment system manufacturer selected to provide the system will be requested to recommend a cost-effective nutrient source and a feed rate.

3.2.5 *Conveyance Piping*

Groundwater conveyance piping will be installed below ground to reduce the impact to the implementation of a potential future site-wide remedy and/or redevelopment of the site. Piping will be buried at a minimum depth of 2 ft bgs to protect against weather and heavy truck and equipment traffic that may be experienced during implementation of a potential future site-wide remedy and/or potential redevelopment activities. Cleanouts will need to be located along the piping run so that accumulated solids can be removed from the piping, if necessary. Cleanouts will be completed below ground in an accessible vault capable of withstanding heavy truck and equipment traffic.

3.2.6 *Treatment Equipment Building*

The groundwater treatment equipment is required to be located within a heated and insulated building for protection from weather, security reasons, and aesthetics. If necessary, the building will be fenced around its perimeter for security reasons.

The building floor where groundwater treatment equipment and chemical feed tanks are located will serve as a secondary containment area in case of a leak and/or to collect equipment wash/rinse water generated during equipment cleaning and maintenance. The floor will include collection

trenches and sump where leaking water and wash/rinse water will be collected and pumped into the treatment system. The building will also contain appropriate health and safety equipment, such as eye wash stations and spill response materials.

3.2.7 Utilities

Potable water, electricity, and compressed air will be required for the treatment equipment building. Sanitary sewer connection is not required, as a portable toilet facility, equipped with hand-washing capability, will be located adjacent to the building and available during construction. Restrooms in existing on-site buildings will be available for use by operation and maintenance personnel. Sanitary sewer connections can be added to the treatment equipment building in the future, if necessary.

Potable water and electrical lines to the building will be buried underground to reduce the impact to potential redevelopment of the site. Water piping should be buried at a minimum depth of 2 ft bgs to protect against weather and heavy truck and equipment traffic that may be experienced during implementation of a potential future site-wide remedy and/or redevelopment activities. Electrical power for the GWET will come from the existing electrical substation. Electrical lines from the substation to the recovery wells and treatment building will be inside conduit, buried at a depth of 2 ft bgs, as required by code.

3.3 REMEDY COMPONENTS

Figure 3-4 is a preliminary plan view site layout map of the GWET system showing the locations of recovery wells, conveyance piping, treatment equipment building, and discharge piping. Figure 3-5 is a preliminary process flow diagram of the GWET system depicting the treatment equipment arrangement and process flows. The following sections briefly describe the primary GWET system components.

3.3.1 Recovery Wells

The GWET system includes 13 shallow recovery wells (RWs) and 9 intermediate RWs. The RWs will be installed in the locations shown in Figures 3-4. Shallow RWs will be installed to the top of the shallow intermediate silt layer separating the Shallow and Intermediate Zone aquifers. The top of this layer occurs between the depths of approximately 32 and 35 ft bgs in the vicinity of the GWBW. Intermediate RWs will be

installed to a depth of approximately 45 ft bgs, which is the approximate bottom of the Intermediate Zone.

RWs will be installed in compliance with Oregon Administrative Rule (OAR) 690-200 *Well Construction Standards* and OAR-690-240 *Construction, Maintenance, Alteration, Conversion, and Abandonment of Monitoring Wells, Geotechnical Holes and Other Holes in Oregon*. Figures 3-6, 3-7, and 3-8 are schematics of typical Shallow and Intermediate RWs and summarize the construction details of each recovery well type. Shallow RWs will be installed as follows:

- Borings will be advanced using a mobile drilling rig equipped with 8-1/4-inch inner diameter hollow-stem augers. For the purpose of visual soil description and logging, the borings will be logged using split spoon samplers at 5-foot intervals to 25 ft bgs, then logged continuously until the Shallow-Intermediate Silt is encountered;
- Wells will be constructed of 4-inch diameter stainless steel well casing equipped with 5 to 10 feet of 0.02-inch slotted stainless steel, rod-based, wire-wrapped, and v-notched well screen; and
- Wells will be sealed with hydrated bentonite chips from the top of the sand filter pack to approximately 3 ft bgs, and then be completed below ground inside a vault.

Intermediate RWs outside of the Acid Plant area (i.e., south of Dock 1) will be installed as described above except that they will be installed to the top of the Deep Zone at a depth of approximately 45 ft bgs. Intermediate RWs within the Acid Plant area (i.e., north of Dock 1) will be installed with the objective of preventing potential carry down of COPCs from the Shallow Zone to the Intermediate Zone. These RWs will be installed as follows:

- Borings will be advanced using a mobile sonic drilling rig equipped with nominal 10-inch inner diameter casing, and will be logged continuously until the Shallow Intermediate Silt is encountered;
- The 10-inch conductor casing will be advanced to approximately 0.5 feet into the Shallow-Intermediate Silt and a bentonite plug installed;
- Nominal 8-inch casing will then be advanced through the conductor casing to the top of the Deep Zone;
- Wells will be constructed of 4-inch diameter stainless steel well casing equipped with 5 to 10 feet of 0.02-inch slotted stainless steel, rod-based, wire-wrapped, and v-notched well screen; and

- Wells will be sealed with hydrated bentonite chips from the top of the sand filter pack to approximately 3 ft bgs, and then be completed below ground inside a vault.

The 4-inch well diameter was selected based on the relatively low flow rate that will be pumped from the wells (i.e., up to 6 gpm) and this size being sufficient to fit most pumps and controls required to pump groundwater at the design flow rate. Stainless steel was selected as the material based on its durability (e.g. heavy truck/equipment traffic, and well cleaning and redevelopment) and generally good resistance to corrosion. However, the potential for corrosion of the stainless steel will need to be evaluated as part of the Pre-Final Design because of the relatively high chloride concentrations in groundwater at some areas of the site. An alternative material of construction would be Schedule 80 polyvinyl chloride casing and screen. The continuous wire-wrapped and v-notched well screen improves well performance through a larger percent of open space and reduces the potential for fine solids to get lodged in, and clog the well screen.

The RWs will be completed below ground inside lockable well vaults flush with the ground surface to accommodate potential implementation of a future site-wide remedy and/or redevelopment of the site. The vault size and materials of construction will be evaluated and selected as part of the Pre-Final Design. Additional equipment that may be installed inside the vaults include pump discharge piping, valves, gauges, flow meter, pump controls/monitoring equipment, compressed air lines, and/or electrical power wires.

3.3.2 Groundwater Extraction Pumps

Each RW will be equipped with a submersible pump capable of pumping groundwater over a range of targeted flow rates, as determined by groundwater modeling. Depending on location, season, and operating conditions, the individual recovery wells are anticipated to be pumped at rates between 2 gpm and 9 gpm. The pumps will either be electric submersibles equipped with a standard fixed-speed or variable-speed motor, or will be pneumatic pumps. Pump control equipment needed at the wellhead will be installed inside the vault so that equipment is below ground surface.

Electric submersible pumps will require electric power to be run to each recovery well from a bank of pump controls (e.g. on-off switch, motor starters, controls, power disconnect with lockout capability) to be located

in the treatment equipment building. The electric submersible pumps would be controlled using a float switch or pressure transducer-type level sensor to maintain the drawdown required to achieve the hydraulic containment RAO. For fixed-speed electric motors, the pump would be operated in an on-off mode. A flow control valve would be used to control the groundwater flow rate to maintain the required drawdown. For variable-speed motors, the pumping rate is proportional to the pump motor speed, which would automatically adjust to maintain the required drawdown. These pumps are durable and capable of higher pumping heads than pneumatic pumps, but can be more expensive because of the controls needed to operate them.

Pneumatic pumps would be powered by an air compressor with a single compressed air header manifolded to the individual well pumps. Each pump would be equipped with a pressure regulator to control the pressure and corresponding pumping rate, and a pulse counter to estimate the flow rate. The pumps do not require separate level controls. The pumps can be set at a level corresponding to the desired drawdown level and will continue to pump groundwater from the well when the level is above the required drawdown level. These pumps are durable, easy to operate, and have simple controls. However, an air compressor is required and they have lower pumping head capabilities than electric submersible pumps.

Information needed to evaluate and select the desired groundwater extraction pump includes the following:

- Conveyance piping configuration (e.g. each well pump manifolded to a single header verses each well pump having a dedicated conveyance pipe to the groundwater treatment system) as necessary to estimate the required pumping head;
- Pumping head required to pump the groundwater from the recovery wells to the groundwater treatment system at rate of 6 gpm;
- Height of groundwater within the recovery well to ensure there is sufficient groundwater depth for the pump to be effective;
- Required drawdown to achieve the hydraulic containment RAO to ensure the pump can effectively achieve this drawdown and to select the required pump control method;
- Potential for seasonal fluctuation of the required drawdown to assess the need to adjust the level control/pump intake depth; and
- Cost considering capital, operation, and maintenance.

The above information will be evaluated and determined as part of the Pre-Final Design, as necessary, to specify the groundwater extraction pumps.

3.3.3 *Conveyance Piping*

Piping to convey groundwater from the recovery wells to the groundwater treatment equipment building will be run below ground at a depth of 2 ft bgs to reduce impact to implementation of a potential future site-wide remedy and/or potential redevelopment of the site, prevent freezing of groundwater in the pipe, and to protect the pipe from heavy truck and equipment traffic. The piping will be constructed of SDR-11 HDPE, based on ease of installation, reliability (e.g. low likelihood of pipe failure and leaks), and durability (e.g. resistance to damage; freezing will not damage).

The conveyance piping layout shown in Figure 3-4 assumes that the individual recovery wells will be manifolded to a single header pipe rather than each recovery well having a dedicated conveyance pipe run to a central location. Cleanouts will be located along the piping run so that accumulated solids can be removed from the piping, if necessary, and they will be completed below ground, inside an accessible vault. The single header system will be less expensive to install (one header pipe and fewer cleanouts) but will require more equipment (e.g. valves, gauges, flow meter, etc.) to be located at the individual RW well heads, and potentially result in higher operation and maintenance costs. The conveyance piping layout and required pipe sizes will be evaluated, based on cost and operational considerations, and specified as part of the Pre-Final Design.

3.3.4 *Chemical Precipitation*

Iron co-precipitation will be used to remove iron and other metals present in groundwater at concentrations exceeding the effluent quality objectives, future NPDES discharge limits, or that may affect the downstream anaerobic biological treatment process. Based on the treatability studies, chemical precipitation will consist of the following, as depicted in Figure 3-5:

- A precipitation reactor (vertical tank equipped with a mixer) where influent groundwater is equalized, mixed with sodium hydroxide to raise the pH to between 7.5 and 8.5 SU (pending vendor recommendations and actual performance), aerated using an air

injection blower to oxidize the iron and enhance its precipitation and the removal of other metals, and mixed with recycled sludge from the clarifier as necessary to enhance its performance;

- A sodium hydroxide feed tank and metering pump to feed sodium hydroxide to the chemical precipitation reactor;
- A parallel-plate type of clarifier equipped with a rapid mix tank where polymer is added to enhance floc formation and settling characteristics, a flocculator to further enhance floc formation, a settling chamber, and an overflow weir where the clarified effluent leaves the clarifier;
- A polymer storage tank, polymer blending unit, and polymer metering pump to feed the anionic polymer to the clarifier's rapid mix tank;
- A diaphragm pump to pump settled solids/sludge from the bottom of the clarifier to the sludge holding tank/thickener, and a small portion recycled back to the chemical precipitation reactor;
- A sludge holding tank/thickener with mixer to concentrate the solids, with the supernatant pumped to the chemical precipitation reactor;
- A diaphragm pump to pump sludge from the sludge holding tank/thickener to the filter press; and
- A filter press to dewater the sludge where the dewatered sludge is placed into a roll-off container for transportation and off-site disposal. The filtrate is pumped to the chemical precipitation reactor.

As discussed in Section 3.2.4, iron co-precipitation was initially considered as an enhancement to chemical precipitation to more effectively remove metals other than iron. However, sufficient iron was present in the treatability study sample such that an additional source of iron was not necessary to affect the iron co-precipitation process. Pending recommendations from the equipment vendor selected to provide the metals precipitation system, a supplemental iron source is assumed to be required for the GWET system to provide high enough iron concentrations for sufficient iron co-precipitation. As such, the design will include the addition of ferrous sulfate (or other source of iron) to the chemical precipitation reactor with supporting feed tank, feed pump, and corresponding controls.

While full-scale iron co-precipitation and clarification is anticipated, a post-solids filtration unit may be necessary to remove solids in the clarifier effluent and achieve removal of solids and trace metals. Solid particles of

metals remaining in the clarifier effluent could potentially be re-dissolved in the strong reducing conditions in the FBR and pass through the post-FBR solid filter. As such, the GWET system design will provide sufficient space for adding a post-clarifier filter unit, if necessary.

The iron co-precipitation equipment will be provided by a vendor as a packaged treatment system with corresponding controls. Multiple vendors will be provided with a set of performance specifications and related project data (e.g. influent concentrations, effluent quality objectives, flow rate information, preliminary mass balance information), and asked to provide a proposal for a packaged treatment system. The vendor will be responsible for treatment equipment design, fabrication, delivery, and operator training. The design and implementation schedule will be expedited by completing equipment bidding in parallel with the Pre-Final Design so that the selected treatment system can be incorporated directly into the Pre-Final Design.

Alternative processes will be considered and evaluated during the Pre-Final Design based on new information obtained and/or vendor recommendations during the bidding process. An example of a potential alternative includes pumping solids from the bottom of the clarifier to a solids filter with disposable or re-useable filters. This value engineering step will seek to identify a more cost-effective treatment process. If such a process is identified, it will be incorporated into the Pre-Final Design.

3.3.5 Neutralization Tank

Effluent from the clarifier will be discharged by gravity to a tank equipped with a mixer where an acid will be added to lower the groundwater pH to a more neutral level between approximately 7.0 and 7.5 SU. This pH level is optimal for the downstream anaerobic biological treatment process. An acid feed tank and chemical feed pump will be used to feed the acid to the neutralization tank. The preferred acid for neutralization (e.g., hydrochloric, phosphoric, sulfuric) will be selected as part of detailed design of the GWET system. A pump will be provided to pump effluent from the neutralization tank to the anaerobic FBR. The tank size, acid to be used, acid feed system, and related details will be evaluated and specified as part of the Pre-Final Design.

3.3.6 Anaerobic Biological Treatment

Based on the treatability study results, anaerobic biological treatment was shown to be effective at removing chlorate and perchlorate from site

groundwater. An FBR is the presumptive anaerobic biological treatment process planned for this design.

The FBR process consists of pumping groundwater up through a vertical column filled with a biological growth media, either sand or LPGAC, to fluidize the media. The groundwater volume being fed to the reactor is made up of influent groundwater and a large portion of recycle from the FBR effluent. Microorganisms grow on the media surface. The fluidization of the media increases the contact between the microorganisms and the constituents of concern (i.e., chlorate and perchlorate), thus enhancing the biodegradation of these constituents. A significant portion of the fluidization flow rate is FBR effluent recycle. This recycle increases the total hydraulic residence time in the reactor and improves the FBR treatment performance. An organic carbon source and nutrients are added to enhance the treatment performance. A biosolids separation device is included at the top of the reactor vessel to remove biosolids from the fluidized media, which increases the density of the media and enables it drop back into the reactor rather than be discharged out the top of the reactor.

The FBR for this application includes the following:

- A fluidization pump, to pump effluent from the neutralization tank and FBR recycle up through the column at a rate sufficient to fluidize the media;
- An organic carbon (e.g. acetic acid) feed tank and feed pump to provide the organic carbon needed by the microorganisms to grow and biodegrade the chlorate and perchlorate;
- A nutrient feed tank and feed pump to provide the phosphorus and nitrogen (e.g. ammonium phosphate, as per the treatability study [Adventus 2008]) needed by the microorganisms to optimally grow and biodegrade the chlorate and perchlorate; and
- An FBR filled with sand and/or LPGAC, to serve as the fluidization media, and equipped with a biosolids separation device, recycle discharge to divert some effluent back through the FBR, and effluent discharge.

The FBR and associated equipment will be provided by a vendor as a packaged treatment system with corresponding controls. Multiple vendors will be provided with a set of performance specifications and related project data (e.g. influent concentrations, effluent quality objectives, flow rate information, preliminary mass balance information),

and asked to provide a proposal to provide a packaged treatment system. The vendor will be responsible for treatment equipment design, fabrication, delivery, and operator training. The design and implementation schedule will be expedited by completing equipment bidding in parallel with the Pre-Final Design so that the selected treatment system can be incorporated directly into the Pre-Final Design.

Alternative processes will be considered and evaluated during the Pre-Final Design based on new information obtained and/or vendor recommendations during the bidding process. The treatability study results indicated that a PBR and EHC®/sand reactor were effective at removing chlorate and perchlorate from groundwater, and thus may be considered for this application. This value engineering step will seek to identify a more cost-effective treatment process. If one of these processes is determined to be more cost effective than a FBR, it will be incorporated into the Pre-Final Design.

3.3.7 Sand Filter

Effluent from the FBR will contain biosolids that need to be filtered to prevent plugging of the downstream LPGAC units and potential additional biological growth. A sand filter is currently planned for this application. The sand filter will require backwashing to remove the solids. The backwashed water will be discharged to the chemical precipitation reactor. The sand filter size and related details will be evaluated and specified as part of the Pre-Final Design.

Alternative filter types will be considered and evaluated during the Pre-Final Design based on new information obtained and/or vendor recommendations. An example that may potentially be effective is a backwashable cartridge filter. This value engineering step will seek to identify a more cost-effective treatment process. If another filter type is determined to be more cost effective than a sand filter, it will be incorporated into the Pre-Final Design.

3.3.8 Granular Activated Carbon Adsorption

Two LPGAC units in series will be used to remove volatile organic compounds and pesticides potentially still present in the effluent and to meet the effluent quality objectives. The LPGAC units may periodically need to be backwashed in the event of solids accumulation and/or biological growth, and the backwashed water will be discharged to the chemical precipitation reactor.

The LPGAC units and associated equipment will be bid out to one or more vendors. The vendors will be provided with a set of performance specifications and related project data (e.g. influent concentrations, effluent quality objectives, flow rate information, mass balance information). The vendor will be responsible for selecting the required units, providing the carbon, delivery, operator training, and providing periodic carbon change-out services. Additional redundant units may be required to facilitate continuous operation during carbon change-out. The design and implementation schedule will be expedited by completing equipment bidding in parallel with the Pre-Final Design so that the selected treatment system can be incorporated directly into the Pre-Final Design.

3.3.9 Treated Groundwater Holding Tank

A portion of the treated groundwater will be diverted to a storage tank, so it can be available for backwashing the sand filter and LPGAC units. When the tank is full, treated groundwater will continue to the existing Outfall 4 discharge location. The tank will be equipped with a pump to provide the volume required to backwash the sand filters and LPGAC units. The tank and pump sizes will be evaluated and specified in the Pre-Final Design.

3.3.10 Discharge

Treated groundwater will be discharged, along with site-wide storm water, to the Willamette River through existing Outfall 4. Figure 3-4 is a preliminary plan view layout of the GWET system that shows the location of Outfall 4. Piping used to convey treated groundwater to the outfall discharge line will be run below ground and constructed of SDR-11 HDPE, just as conveyance piping from the recovery wells. Cleanouts will not be required for the treated effluent since the source of potential line plugging (e.g. iron precipitation, various solids) have been removed by the treatment process. The outfall discharge piping is also located below ground, so the tie-in location will be located below ground. The pipe size and tie-in details will be evaluated and specified as part of the Pre-Final Design.

3.3.11 Treatment Equipment Building

The groundwater treatment equipment will be located within a heated and insulated building for weather protection, security reasons, and aesthetics. The building will be fenced around its perimeter for security.

The building floor where groundwater treatment equipment will be located will serve as a secondary containment in case of a leak and/or to collect equipment wash/rinse water generated during equipment cleaning and maintenance. The floor will include collection trenches and/or sump where leaking water and wash/rinse water will be collected and pumped into the chemical precipitation reactor. Segregated secondary containment areas will be considered as part of the Pre-Final Design to contain potential releases from the sodium hydroxide, polymer, phosphoric acid, acetic acid, and nutrient feed tanks and/or pumps, and will be incorporated into the design, if necessary.

The building and associated foundation/floor will be provided by a pre-fabricated building vendor and installed by a local contractor on behalf of the vendor. As such, one or more vendors will be provided with a set of building requirements and specifications, and asked to provide a proposal to provide and construct the building. The vendor will be responsible for building and foundation design, certification of design drawings by a State of Oregon-registered professional engineer, delivery of materials, and construction of the foundation and building. Bidding will be completed in parallel with the Pre-Final Design so that the selected treatment system can be incorporated into the Pre-Final Design to expedite the design and construction schedule.

3.4 PERMITTING

3.4.1 State

State of Oregon permits that are expected to be required for the construction and operation of the GWET system include the following:

- NPDES Individual Permit for discharging treated groundwater to the Willamette River (currently under discussion with ODEQ); and
- A Construction Storm Water General Permit (1200C), if required.

Based on discussions between the ODEQ and Federal agencies, no Federal permits will be required for this project. The Pre-Final Design package will be provided to other Federal agencies as determined necessary by ODEQ.

The initial steps in NPDES permitting of the treated groundwater discharge will be submission to ODEQ of the following forms completed by LSS:

- Application Form 1 - General Information, Consolidated Permits Program; and
- Application Form 2D - New Sources and New Dischargers: Application for Permit to Discharge Process Wastewater.

The NPDES application for the new source is required to be filed 180 days prior to discharge.

3.4.2 *Local*

As discussed in Section 2.4, preliminary discussions with City personnel indicated that since the project is being conducted under a Consent Order with ODEQ, the project can be implemented through the Exempt Process. Under this process, City development permit approvals are not required; however, the substantive requirements of the permits must be met. The optional City permits that are applicable to the construction of the GWET system and associated infrastructure include the following:

- Building Permit; and
- Electrical, plumbing, and mechanical permits.

Additional permits may be required following a land use review by the Portland Bureau of Development Services.

4.0 PERFORMANCE MONITORING

Achieving hydraulic containment of COPCs is a key RAO of the GW SCM. Performance monitoring to evaluate that this RAO is being achieved will consist of a network of pressure transducers continuously monitoring hydraulic heads in selected wells, and periodic depth to water (DTW) measurements. The transducer measurements will be used to control recovery well pumping rates. The periodic DTW measurements will be used evaluate the capture zone of the GW CM and to confirm and recalibrate the transducers as necessary. An overview of the performance monitoring program is presented in this section.

4.1 REAL-TIME MONITORING

The DTW will be measured in the monitoring wells located immediately behind, and on the river side of the GWBW, on a frequent basis (i.e. daily). These DTW measurements will be made with automated devices (i.e., transducers) and fed back to an on-site computer. They will be used to adjust the flow rates of the recovery well pumps, as necessary, to maintain an inward hydraulic gradient across the GWBW. These groundwater level measurements will be able to be monitored on a real-time basis via dial-in type connection.

The selected wells will be screened in the Shallow and Intermediate Zones and will correspond to the respective RW screened interval. The selection of specific monitoring wells to be used to control system operation will be based the final system layout. The monitoring wells and control mechanisms will be detailed in the Compliance Monitoring Plan, included as part of the Pre-Final Design.

4.2 CAPTURE ZONE ANALYSIS

The USEPA has published the guidance document *A Systematic Approach for Evaluation of Capture Zones at Pump and Treat Systems* (USEPA 2008) for the development of hydraulic containment performance monitoring programs. ODEQ has requested that this guidance be followed to develop the conceptual monitoring program discussed below.

The groundwater elevations in the Shallow and Intermediate Zones across the GW SCM area will be manually measured using a combination of existing and proposed new wells. A preliminary layout of the piezometer/well network and target capture zones is shown in Figure 4-1.

The DTW data will be used to verify transducer readings, calculate groundwater elevations, and develop groundwater elevation contour maps depicting the groundwater flow direction in the area of the GW SCM. The groundwater flow results will be used to evaluate the groundwater flow in each aquifer zone to determine whether hydraulic containment is being achieved by the GW SCM.

Groundwater modeling may be used as a tool, if necessary, to evaluate the groundwater elevation data, hydraulic containment, and potential changes to the groundwater extraction rates from individual extraction wells to optimize the GW SCM performance.

The area-wide DTW manual measurement frequency for capture zone analysis will be as follows:

- Year 1 – DTW measurements will be completed monthly to evaluate performance variability throughout the year and to make potential changes needed to optimize the GW SCM performance;
- Year 2 – DTW measurements will be conducted quarterly to evaluate and demonstrate consistent performance throughout the year; and
- Year 3 and beyond – DTW measurements will be conducted annually if the corresponding groundwater elevation contour maps from Years 1 and 2 demonstrate consistent performance in regards to achieving hydraulic containment of the COPCs.

LSS will request approval from ODEQ before modifying the monitoring frequency.

4.3 TREATMENT SYSTEM

Influent and effluent samples will be collected from the groundwater treatment system and analyzed to evaluate the system's performance at achieving the required discharge limits. The NPDES permit to be issued for discharging the treated groundwater to the Willamette River will specify the monitoring frequency and constituents/water quality parameters to be analyzed in the samples. Typical requirements consist of

monthly sample collection, analysis, and reporting. These requirements will be included in the Compliance Monitoring Plan.

Samples will be collected from the influent and effluent of the various treatment equipment units of the GWET system more frequently during start up of the system. The start up period is required to evaluate actual influent concentrations, establish a population of microorganisms capable of degrading chlorate and perchlorate, determine optimal recirculation flow rates, assess hydraulic containment, and adjust pumping rates to maintain containment. The start up process is anticipated to take approximately six months, and the performance of the individual treatment components and overall GWET system can be evaluated and optimized during this time.

Once the system is demonstrated to consistently achieve the required discharge limits, the sampling frequency to evaluate individual treatment system components will be changed to match those required in the NPDES permit (i.e., monthly).

5.0 SCHEDULE

Figure 5-1 provides an updated schedule for the design and construction of the GW SCM. This schedule is subject to modification as the design, procurement, installation, construction, and start-up of the GW SCM progresses. Updated schedules will be provided in subsequent design deliverables.

6.0 REFERENCES

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Figures

Project No. 0114849.01

Date: 05/05/10

Drawn By: R. Olson

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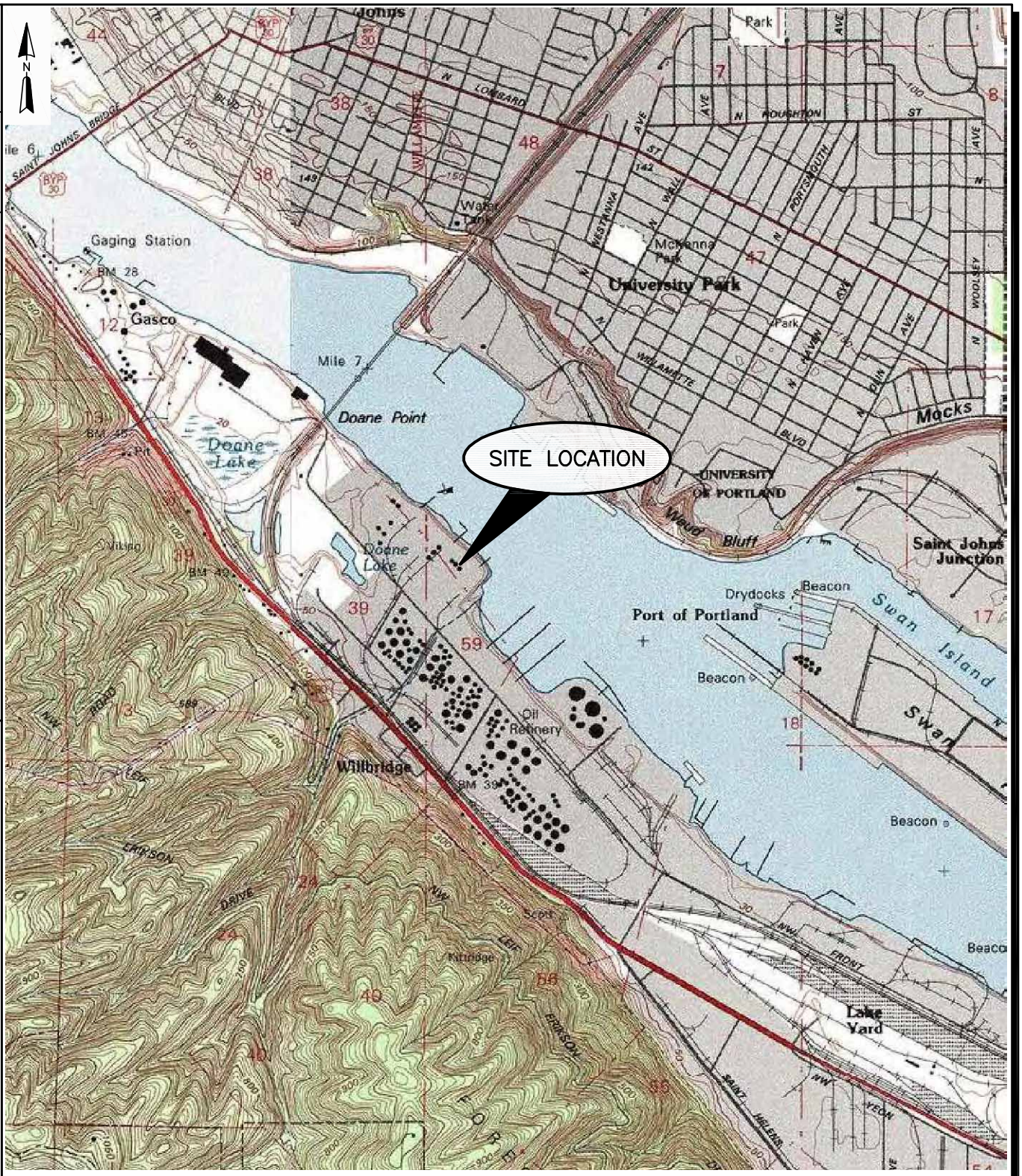


SCALE 1:24,000

1 1/2 0 1 MILE

1000 0 1000 2000 3000 4000 5000 6000 7000 FEET

1 .5 0 1 KILOMETER

Figure 1-1

Site Location

Preliminary Design Report

Groundwater Source Control Measure

Arkema, Inc.

Portland, Oregon

ERM *05/10*

References:
TOPO!® Software
U.S.G.S. 7.5 Minute Series (Topographic) Quadrangle,
Linnton, OR Version: 1990; Current: 1990
Portland, OR WA Version: 1990; Current: 1990

Project Number: 0093634.05

Date: 05/06/2010

Created By: mike.appel

F:\RM106\A\Arkema\0057055 Groundwater Modeling\ArcGis\Arkema Preliminaery Barrier Wall Design - Figure 1-2.mxd

Legend

- Shallow Zone Recovery Well
- Intermediate Zone Recovery Well
- Proposed Barrier Wall Alignment
- Target Capture
- Lot Boundaries
- Site Boundary

N

0 125 250 500 Feet

Data Sources: Aerial Photo: July 2005

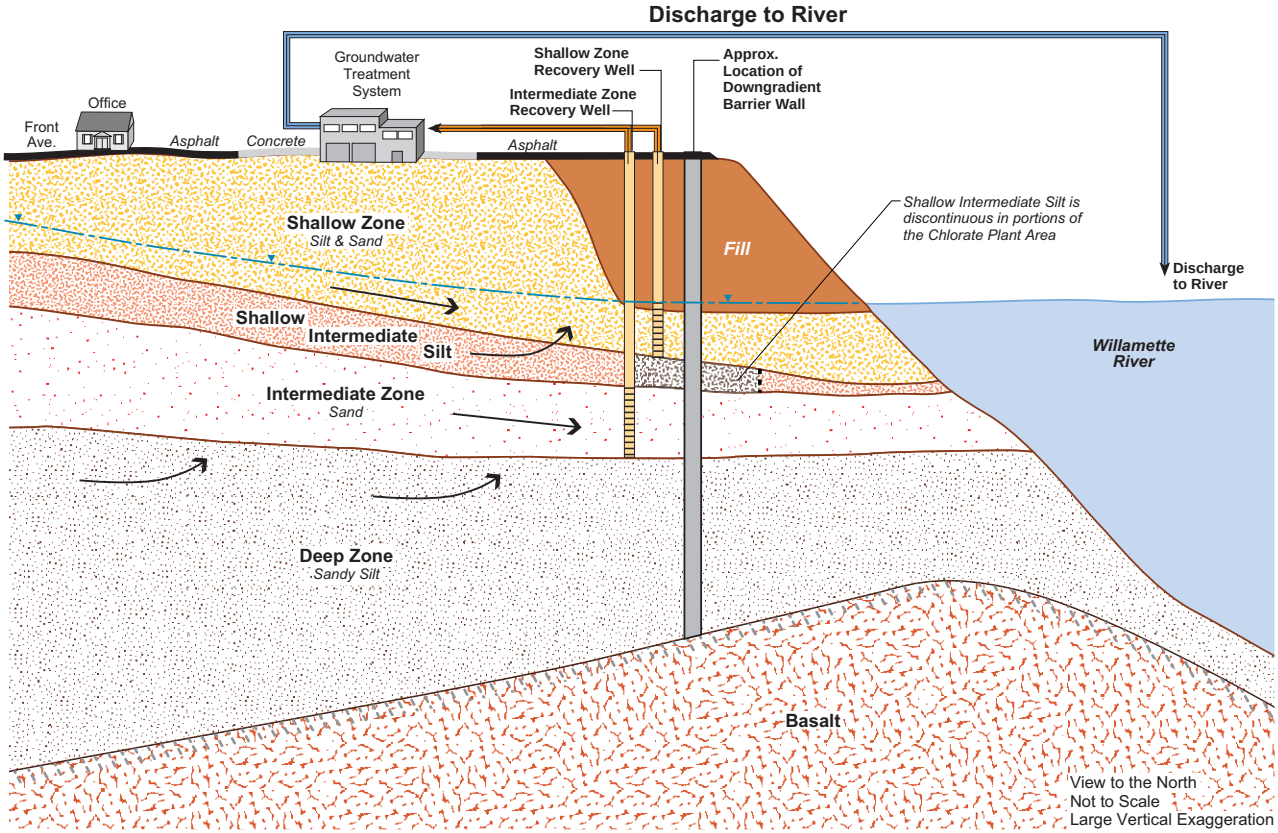
Figure 1-2
Site Layout
Preliminary Design Report
Groundwater Source Control Measure
Arkema, Inc.
Portland, Oregon

ERM 05/10

Project No. 114849

Date: 5-17-10

Drawn By: EJK

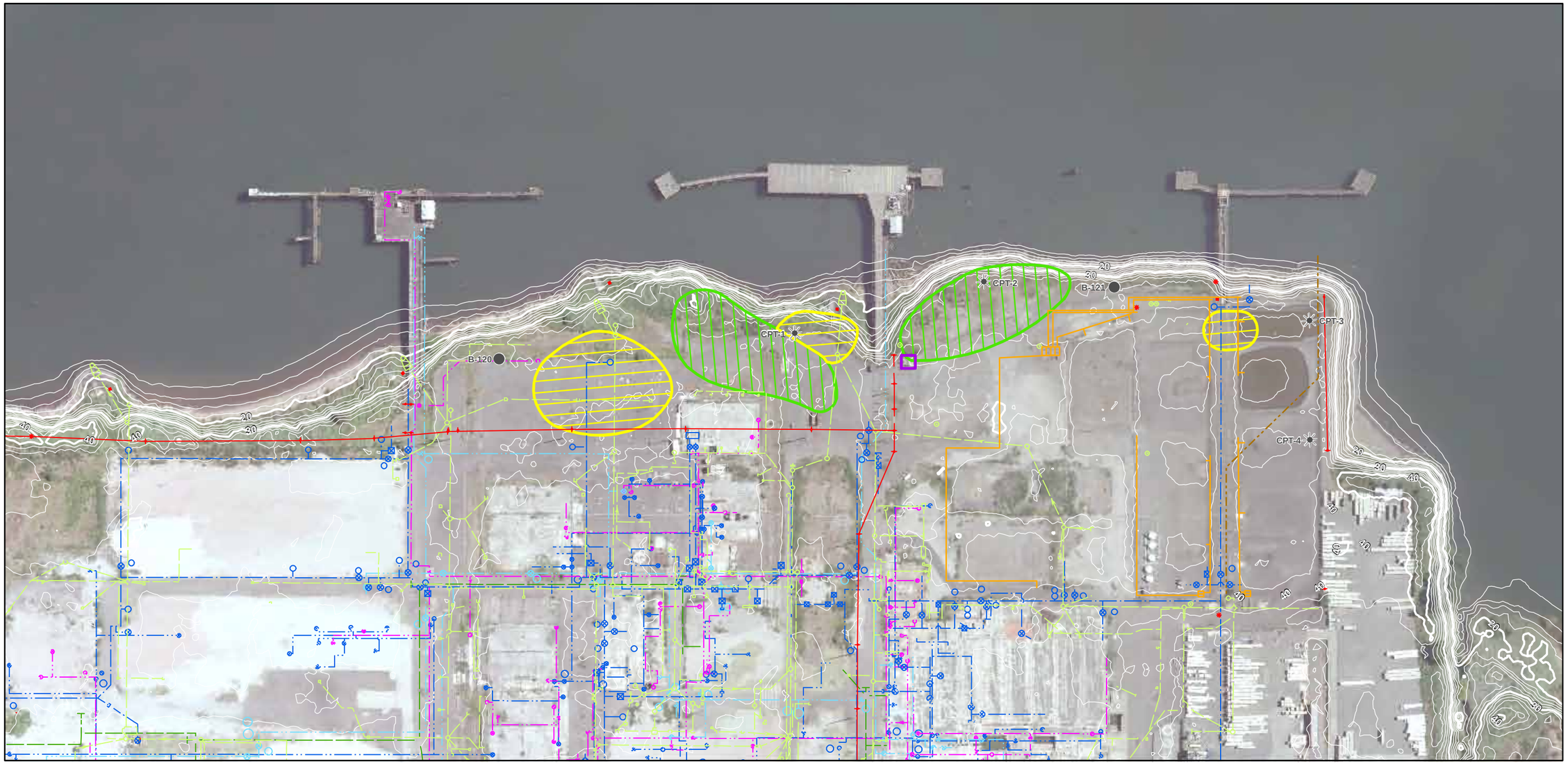


→ Conceptual Groundwater Flow Direction

Figure 1-3

Groundwater Source Control Measure Conceptual Design
Preliminary Design Report
Groundwater Source Control Measure
Arkema, Inc.
Portland, Oregon

ERM *FIG 1-3 5-17-10*



Legend

- Mud Rotary Boring
- CPT Boring Location
- Index Contour (10 ft Interval)
- Ground Surface Contour (2 ft interval)
- Parcel and Property Boundaries

Areas of Subsurface Debris

- Soft Debris
- Refusal/Concrete Debris

- Industrial Stormwater Drain
- Domestic Sewer
- City Water Line
- River Water Line
- Steam Line
- Domestic Water Line
- Electric Power Line (Overhead)
- Electrical Substation
- Brine Line
- 24" Abandoned Steel

N

0 150 300 Feet

Data Sources: Aerial Photo: City of Portland, June 2008
LiDAR Survey- i-TEN Associates, 2001.
Utility locations approximate, from Arkema facility maps.

Figure 2-1
Groundwater Barrier Wall Existing Conditions
Preliminary Design Report
Groundwater Source Control Measure
Arkema, Inc.
Portland, Oregon

ERM 04/10

File: \\rmdenfs02\dataRM\dataDEN\RM106\AArkema\0093634 Riverbank Soil Screening\GIS\TrenchDesign\Figure 2-1_Groundwater Barrier Wall Existing Conditions.mxd

Drawn By: Nicole Lopez

Date: 05/17/2010

Project: 0093634.05

Project No.

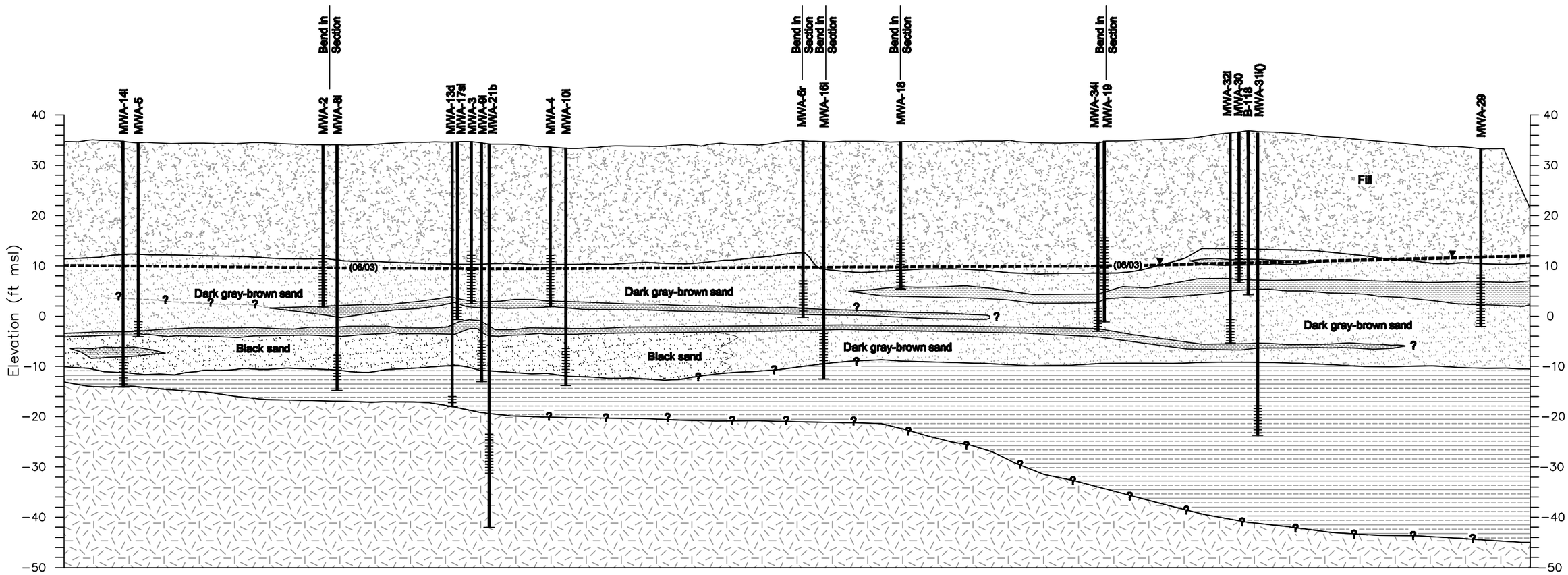
Date: 05/17/10

Drawn By: JE/MJA

CAD File: F:\Arkema\TrenchDesign\002042310-17.dwg

A (Plant North)

A' (Plant South)



LEGEND

- Fill
- Sand with varying amounts of silt
- Silt with varying amounts of fine sand
- Silt with some clay and fine sand
- Basalt

B-59 — Geoprobe® boring number

MWA-1 — Well number

Cased interval

Screen interval

Shallow-zone groundwater surface (approximate); June 2003

Inferred soil or geologic contact (queried where uncertain)

(Vertical Exaggeration = 5X)

VERTICAL SCALE IN FEET 1" = 20'

HORIZONTAL SCALE IN FEET 1" = 100'

Figure 2-2

Riverbank Cross Section A-A'

Preliminary Design Report

Groundwater Source Control Measure

Arkema Inc.

Portland, Oregon

ERM 05/10

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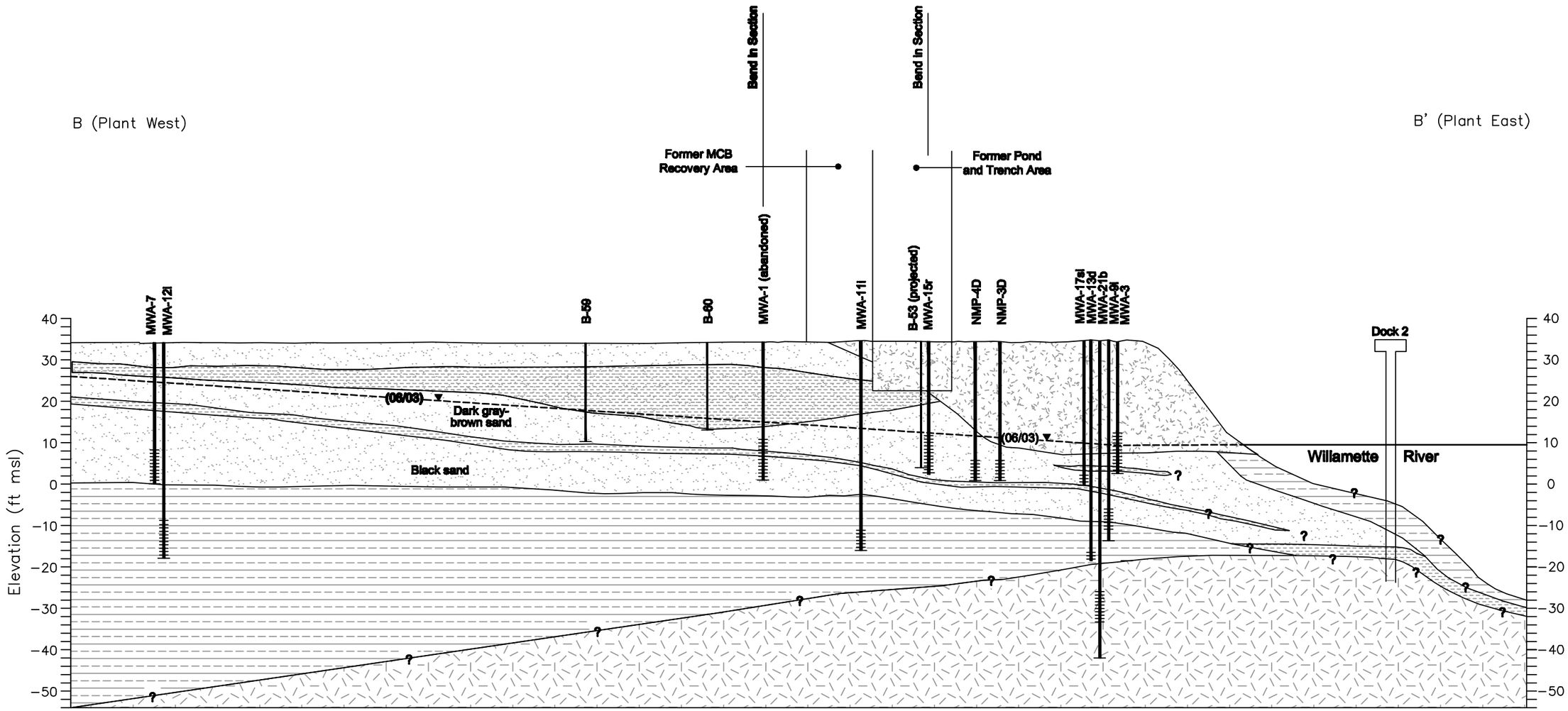
Drawn By: JE/MJA
Date: 05/17/10
Project No.



LEGEND

- Fill
- Sand with varying amounts of silt
- Silt with varying amounts of fine sand
- Silt with some clay and fine sand
- Basalt

B-59 — Geoprobe® boring number
MWA-1 — Well number
Cased interval
Screen interval
Shallow-zone groundwater surface (approximate); June 2003; Based on monitoring well data only
Inferred soil or geologic contact (queried where uncertain)

Stratigraphy Beneath River Provided by Exponent

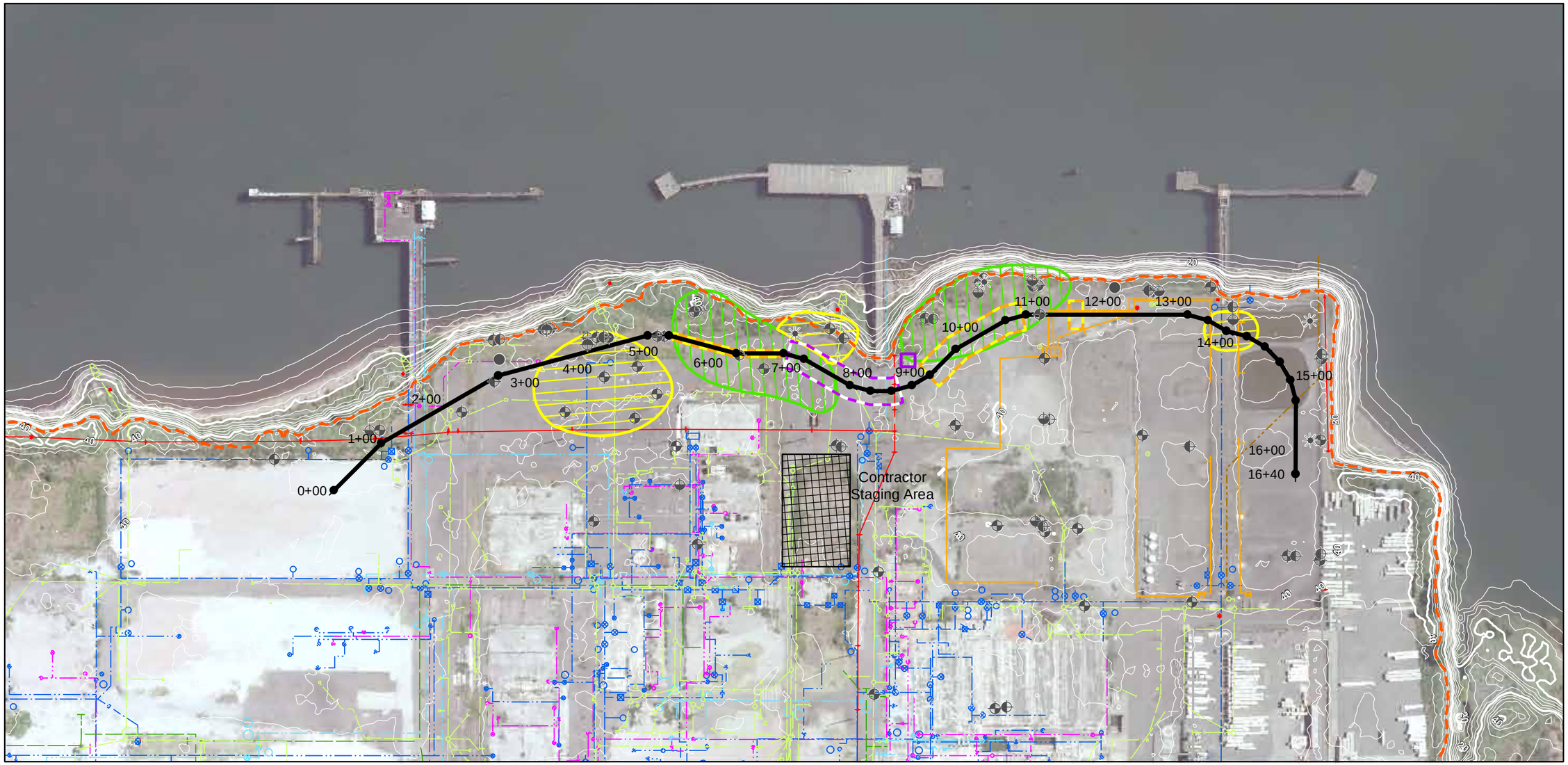
(Vertical Exaggeration = 4X)

0
APPROX. VERTICAL SCALE IN FEET 1" = 25'
25

0 100
APPROX. HORIZONTAL SCALE IN FEET 1" = 100'

Figure 2-3
Riverbank Cross Section B-B'
Preliminary Design Report
Groundwater Source Control Measure
Arkema Inc.
Portland, Oregon

HRM 05/10



Legend

Existing Monitoring Wells
- Shallow Zone
- Shallow-Intermediate Zone
- Intermediate Zone
- Deep Zone
- Gravel Zone
- Basalt Zone

- Mud Rotary Boring
- CPT Boring Location
- Proposed Barrier Wall Alignment
- Clearance Trench (Proposed)
- Clearance Trench (Previously Excavated)
- Index Contour (10 ft Interval)
- Ground Surface Contour (2 ft interval)
- Top of Bank (35 ft Contour or defined break in grade)

- Parcel and Property Boundaries
- Brine Line
- 24" Abandoned Steel

Areas of Subsurface Debris
- Soft Debris
- Refusal/Concrete Debris

- Industrial Stormwater Drain
- Domestic Sewer
- City Water Line
- River Water Line
- Steam Line
- Domestic Water Line
- Electric Power Line (Overhead)
- Electrical Substation

N

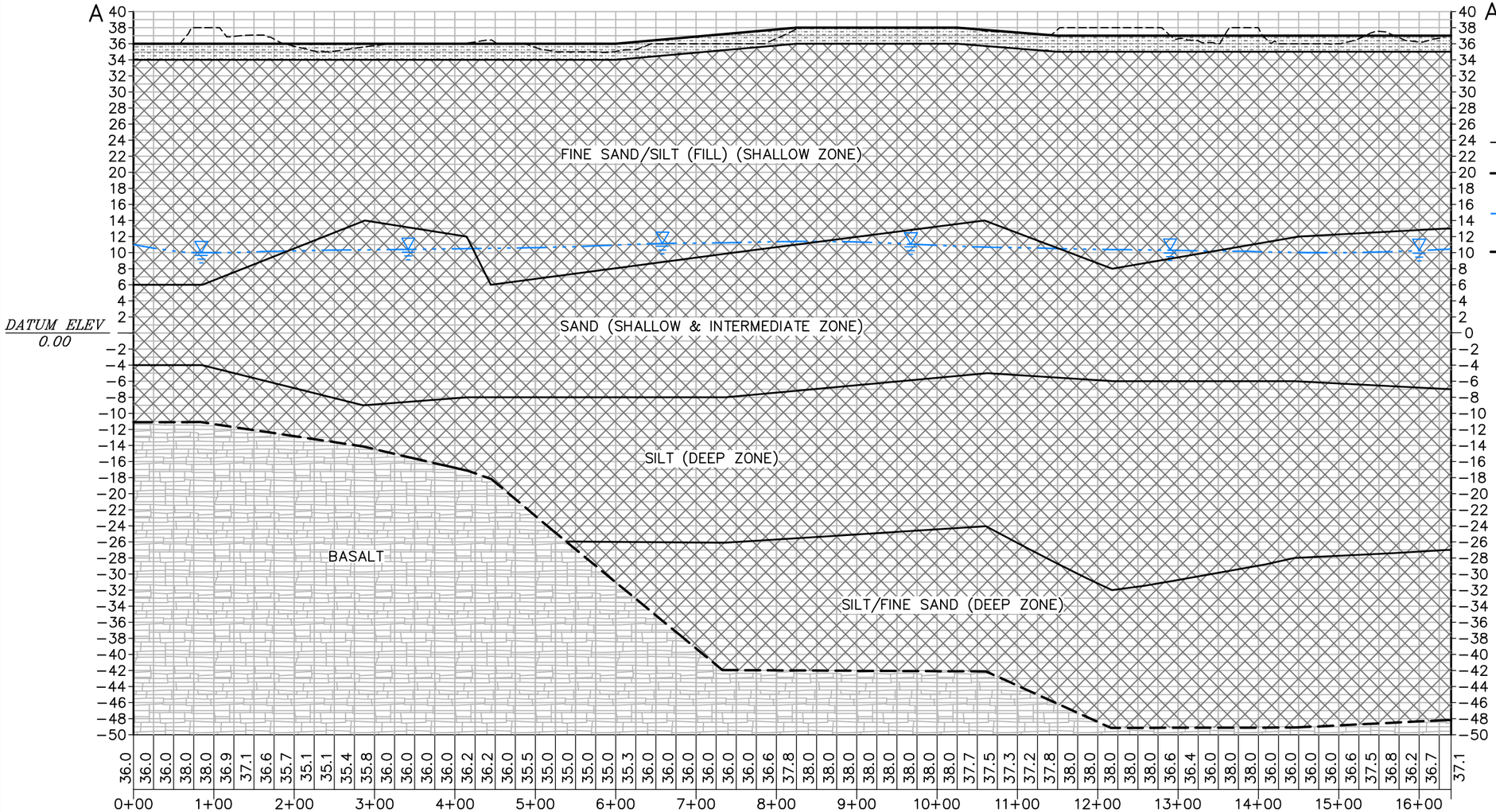
0 150 300 Feet

Data Sources: Aerial Photo: City of Portland, June 2008
LiDAR Survey- i-TEN Associates, 2001.
Utility locations approximate, from Arkema facility maps.

Figure 2-4
Proposed Barrier Wall Alignment
Preliminary Design Report
Groundwater Source Control Measure
Arkema, Inc.
Portland, Oregon

ERM 04/10

File: \\rmdentfs02\dataRM\dataDEN\RM106\A\Arkema\0093634 Riverbank Soil Screening\GIS\TrenchDesign\Figure 2-4 - Proposed Barrier Wall Alignment.mxd
Drawn By: mike.appel
Date: 05/17/2010
Project: 0093634.05



LEGEND

- EXISTING GRADE
- PROPOSED FINAL GRADE (APPROXIMATE)
- EXISTING GROUNDWATER ELEVATION
- TOP OF BASALT (BEDROCK)
- BARRIER WALL CAP (2' THICK TYP.)
- BARRIER WALL (TO BEDROCK)

NOTES:

1. THE HYDROGEOLOGIC ZONES ARE PAIRED WITH THEIR CORRESPONDING GEOLOGIC MATERIAL DESCRIPTION. THE INTERFACES DEPICT THE TRANSITION BETWEEN GEOLOGIC MATERIALS FOR THE PURPOSE OF BARRIER WALL CONSTRUCTION AND DO NOT NECESSARILY CORRESPOND TO THE TRANSITION BETWEEN HYDROGEOLOGIC ZONES.

0 15

0 150
SCALE (IN FEET)

0 150 300
SCALE (IN FEET)

FIGURE 2-5

GEOLOGIC PROFILE ALONG GROUNDWATER BARRIER WALL ALIGNMENT
PRELIMINARY DESIGN REPORT
GROUNDWATER SOURCE CONTROL MEASURE
ARKEMA INC.
PORTLAND, OREGON

ERM MAY 2010

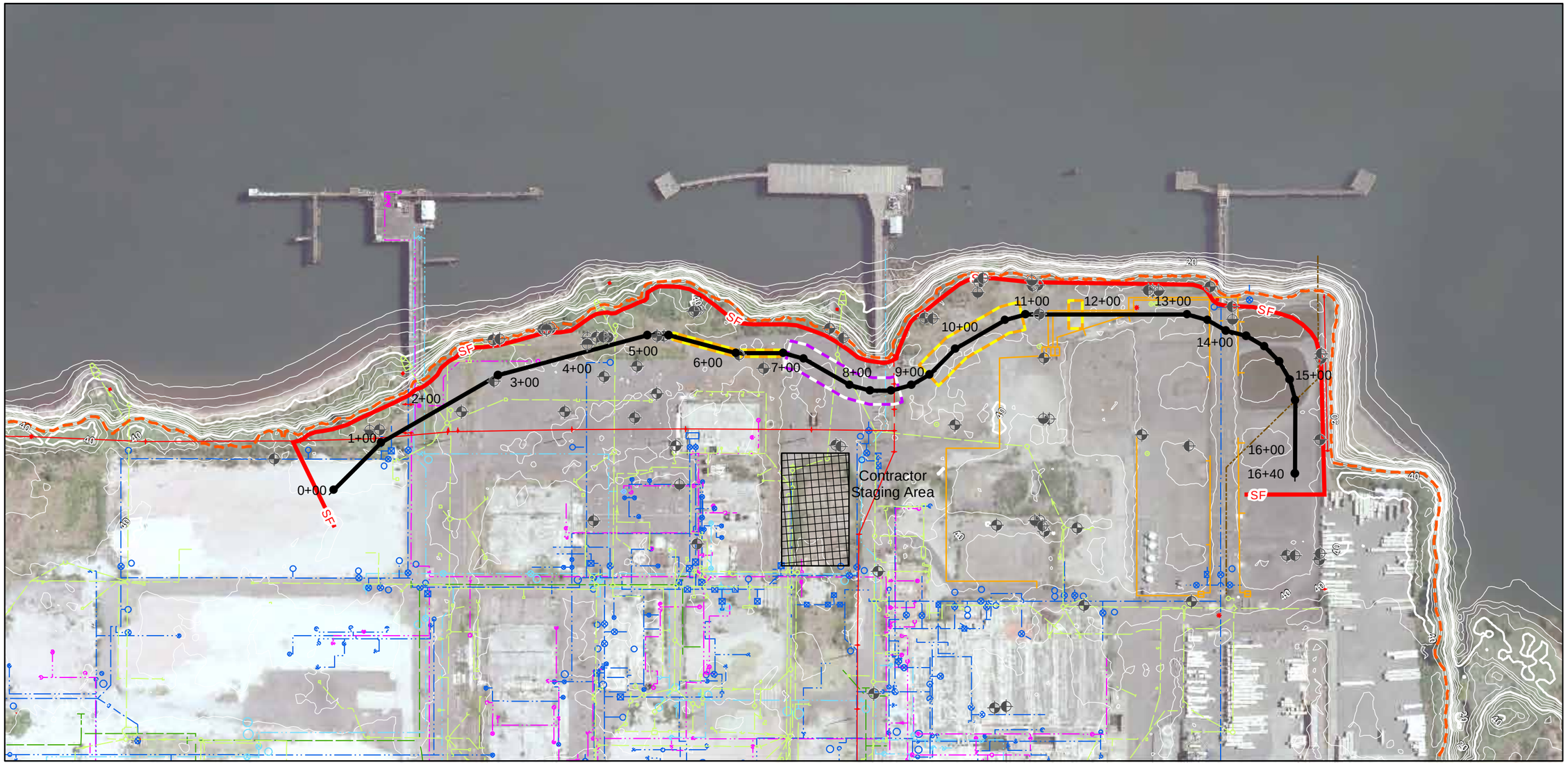
Project No. 0093638
Date: 05/03/10
Drawn By: RMK-HOL
CAD File: Cadd\ClntA-D\ARKEMA\0093638\0093638-01
R:\Cadd\ClntA-D\ARKEMA\0093638\0093638-01.DWG, SLURRY WALL P-P, 5/17/2010 4:24:39 PM, RMK - HOLLAND

Project: 0093634.05

Date: 05/17/2010

Drawn By: mike.appel

F:\RM106\A\Arkema\0057055 Groundwater Modeling\ArcGis\Arkema Performance Monitoring Well Network - Figure 3-9.mxd



Legend

- Proposed Barrier Wall Alignment
- Clearance Trench (Proposed)
- Clearance Trench (Previously Excavated)
- Index Contour (10 ft Interval)
- Ground Surface Contour (2 ft interval)
- Top of Bank (35 ft Contour or defined break in grade)
- SF Proposed Silt Fence
- Industrial Stormwater Drain
- Domestic Sewer
- City Water Line
- River Water Line
- Steam Line
- Domestic Water Line
- Electric Power Line (Overhead)
- Brine Lines
- 24" Abandoned Steel

Notes:

1. Barrier Wall construction will be sequenced to minimize the area of open excavation.

N

0 150 300 Feet

Data Sources: Aerial Photo: City of Portland, June 2008
LiDAR Survey- i-TEN Associates, 2001.
Utility locations approximate, from Arkema facility maps.

Figure 2-6
Erosion and Sediment Control Plan
Preliminary Design Report
Groundwater Source Control Measure
Arkema, Inc.
Portland, Oregon

ERM 05/10

Project: 0093634.05

Date: 05/18/2010

Drawn By: TFC

F:\RM1106\A\Arkema\0057055 Groundwater Modeling\ArcGis\Arkema Preliminary Barrier Wall Design - Figure 3-1.mxd

Legend

- Shallow Zone Groundwater Flow Path
- Shallow Zone Head Solution (ft NAVD88)
- Shallow Zone Recovery Well
- Intermediate Zone Recovery Well
- Proposed Barrier Wall Alignment
- Target Capture Zone

N

0 150 300 Feet

Data Sources: Aerial Photo: City of Portland, June 2008

Figure 3-1

Shallow Zone Groundwater Flow Path and Head Solution
Preliminary Design Report
Groundwater Source Control Measure
Arkema, Inc.
Portland, Oregon

ERM 05/10

Project: 0093634.05

Date: 05/17/2010

Drawn By: TKO

Arkema Preliminary Barrier Wall Design - Intermediate Zone

File: \\rmdenfs02\dataRM\dataDEN\RM1061\A\Arkema\0057055 Groundwater Modeling\ArcGis\Arkema P

Legend

- Intermediate Zone Groundwater Flow Path
- Intermediate Zone Head Solution (ft NAVD88)
- Proposed Barrier Wall Alignment
- Target Capture Zone
- Shallow Zone Withdrawal Well
- Intermediate Zone Withdrawal Well

N

0 150 300 Feet

Data Sources: Aerial Photo: City of Portland, June 2008

Figure 3-2

Intermediate Zone Groundwater Flow Path and Head Solution
Preliminary Design Report
Groundwater Source Control Measure
Arkema, Inc.
Portland, Oregon

ERM 05/10

Project: 0093634.05

Date: 05/17/2010

Drawn By: TFC

File: \\rmdenfs02\dataRM\dataDEN\RM1106\A\Arkema\0057055 Groundwater Modeling\ArcGis\Arkema Preliminary Barrier Wall Design - Deep Zone.mxd

Legend

- Deep Zone Groundwater Flow Path
- Deep Zone Head Solution (ft NAVD88)
- Proposed Barrier Wall Alignment
- Target Capture Zone
- Shallow Zone Withdrawal Well
- Intermediate Zone Withdrawal Well

N

0 150 300 Feet

Data Sources: Aerial Photo: City of Portland, June 2008

Figure 3-3

Deep Zone Groundwater Flow Path and Head Solution
Preliminary Design Report
Groundwater Source Control Measure
Arkema, Inc.
Portland, Oregon

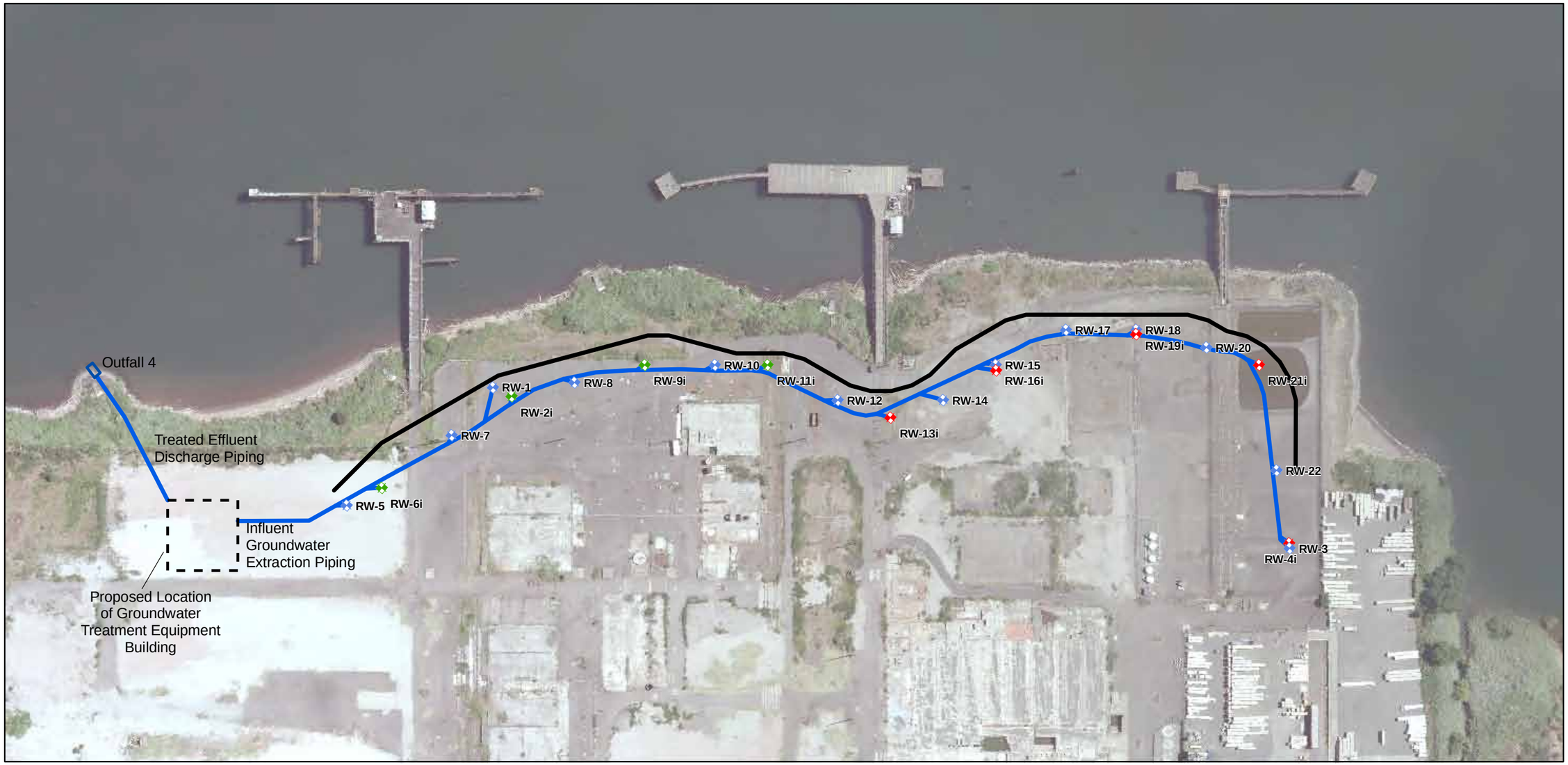
ERM 05/10

Project: 0093634.05

Date: 05/18/2010

Drawn By: TFC

F:\RM106\A\Arkema\0057055 Groundwater Modeling\ArcGis\Figure 3-4 Preliminary GWET System Layout.mxd



Legend

- Shallow Zone Recovery Well
- Intermediate Zone Recovery Well
- Intermediate Zone Recovery Well (installed with temporary conductor casing)
- Proposed Barrier Wall Alignment
- Underground Groundwater Conveyance Piping

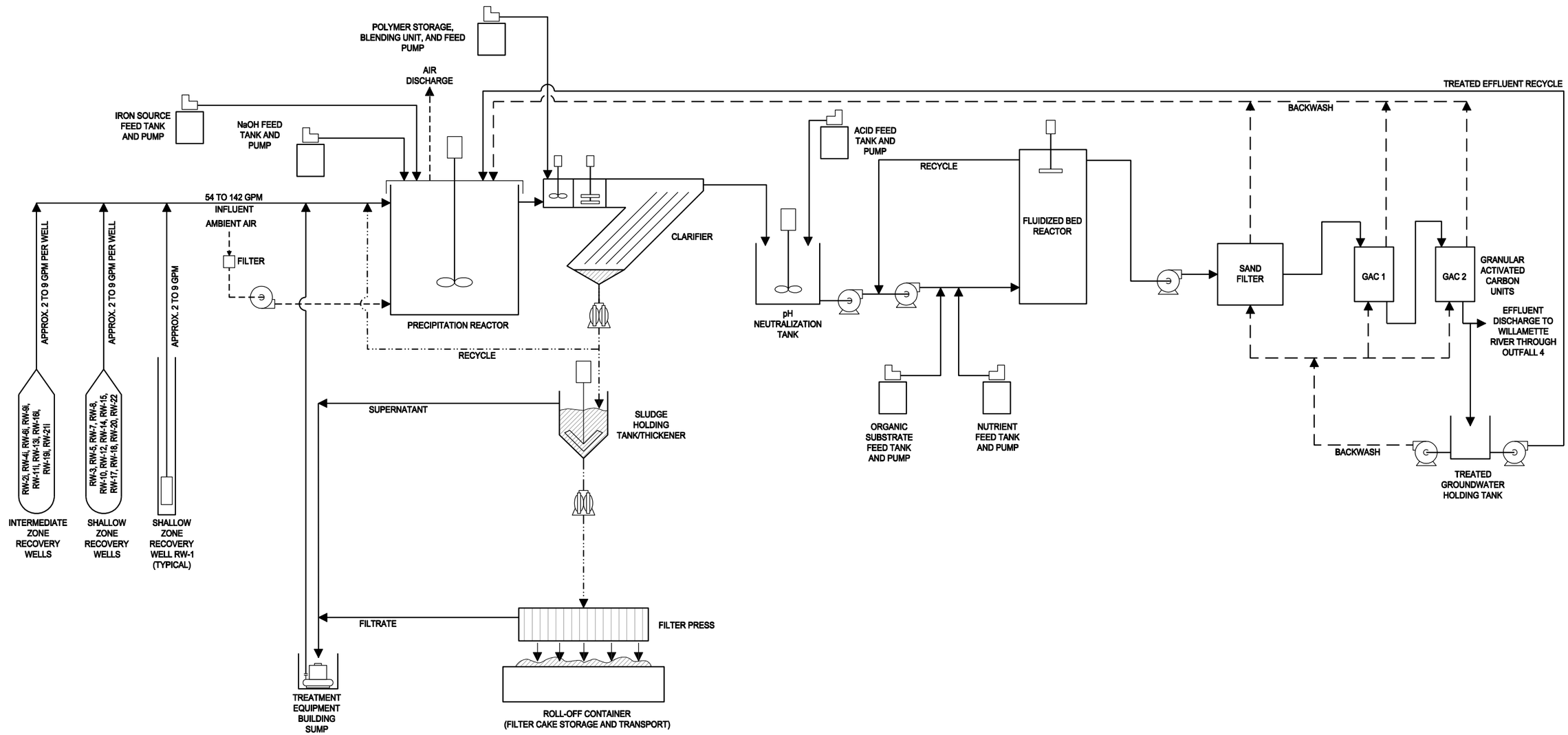
N

0 150 300 Feet

Data Sources: Aerial Photo: City of Portland, June 2008

Figure 3-4
Preliminary GWET System Layout
Preliminary Design Report
Groundwater Source Control Measure
Arkema, Inc.
Portland, Oregon

ERM 05/10



Legend

- - - - - -	Air Line
-··-··-··-	Sludge Line
— — —	Backwash Line
GAC	Granular Activated carbon
GPM	Gallons Per Minute
IEW	Intermediate Zone Extraction Well
NaOH	Sodium Hydroxide
SEW	Shallow Zone Extraction Well

Centrufugal Pump
Air Blower
Diaphragm Pump
Chemical Feed Pump
Submersible Well Pump
Mixer
Flocculater
Biosolids Separator
Sump Pump
Sludge Mixer / Scraper

Figure 3-5
Preliminary GWET System Process Flow Diagram
Preliminary Design Report
Groundwater Source Control Measure
Arkema, Inc.
Portland, Oregon

ERM 5/10

Project No. 0114849
Date: 05/18/2010
Drawn By: MLB
CAD File: G:\CAD\Drawings\Arkema-Portland\0093634\K201.dwg

Project No. 114849

Date: 5-17-10

Drawn By: EJK

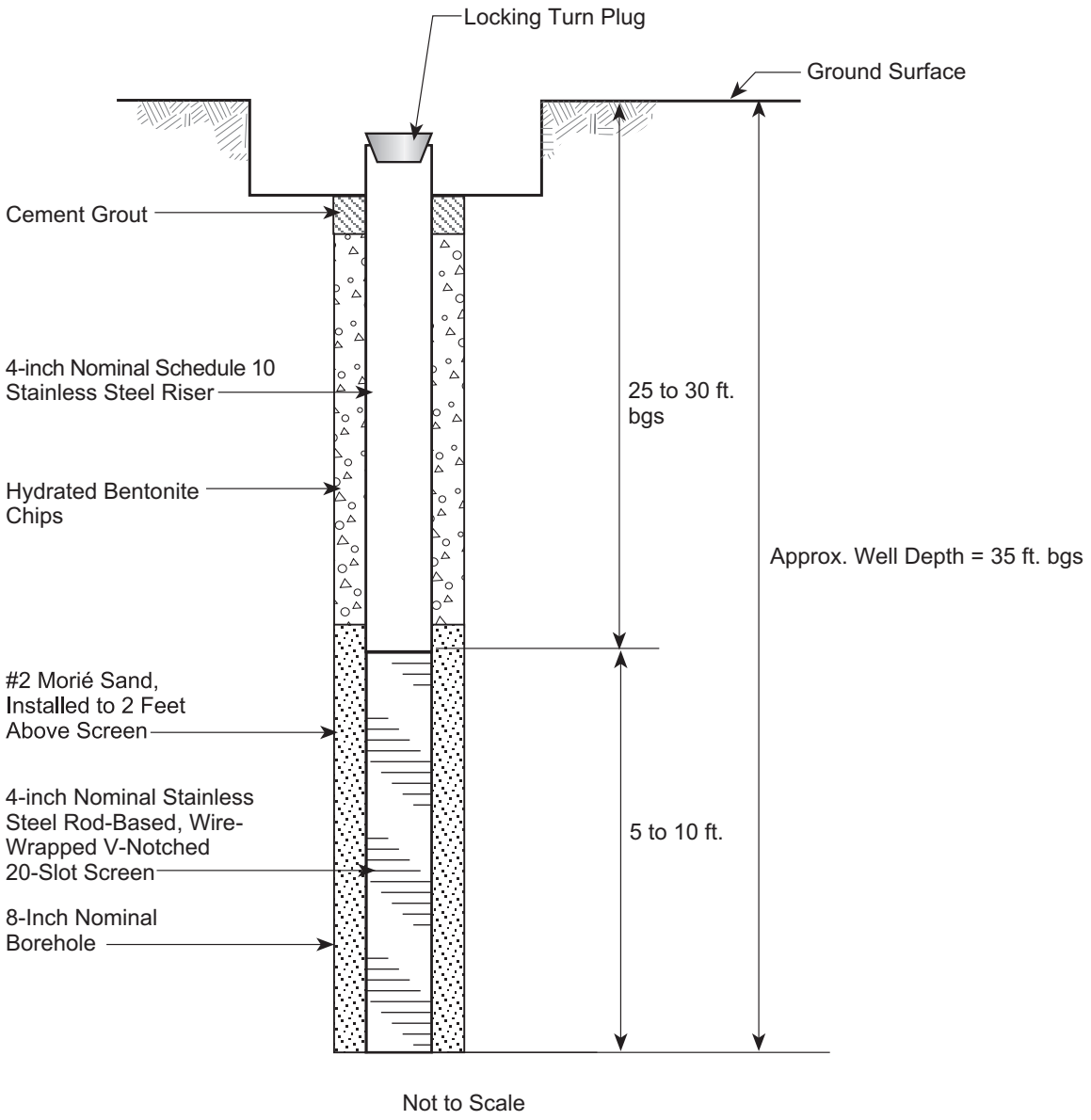


Figure 3-6
Shallow Zone Recovery Well Schematic
Preliminary Design Report
Groundwater Source Control Measure
Arkema, Inc.
Portland, Oregon

Note: bgs = Below Ground Surface

ERM *FIG 3-6 5-17-10*

Project No. 114849

Date: 5-17-10

Drawn By: EJK

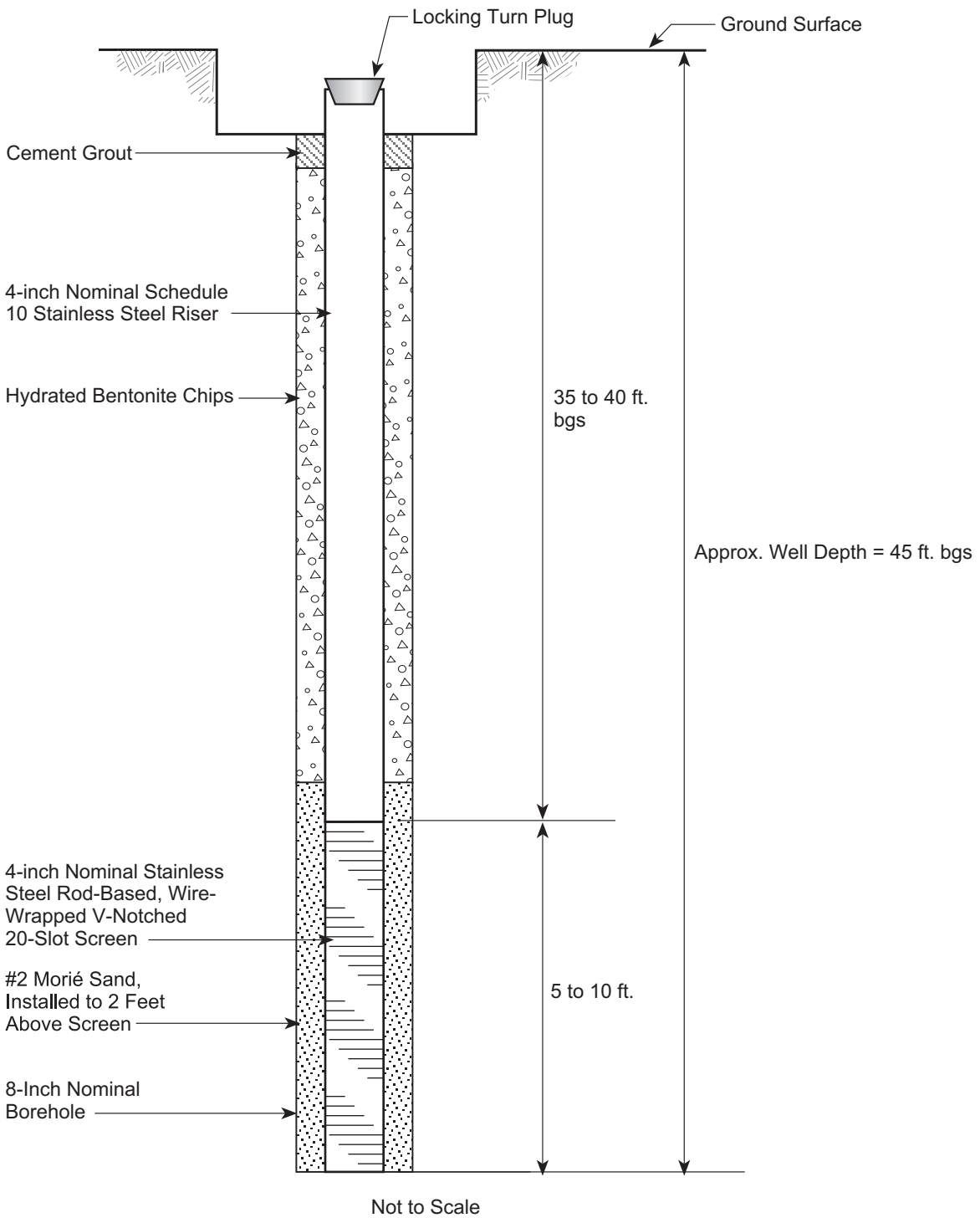


Figure 3-7
Intermediate Zone Recovery Well Schematic - Chlorate Area
Preliminary Design Report
Groundwater Source Control Measure
Arkema, Inc.
Portland, Oregon

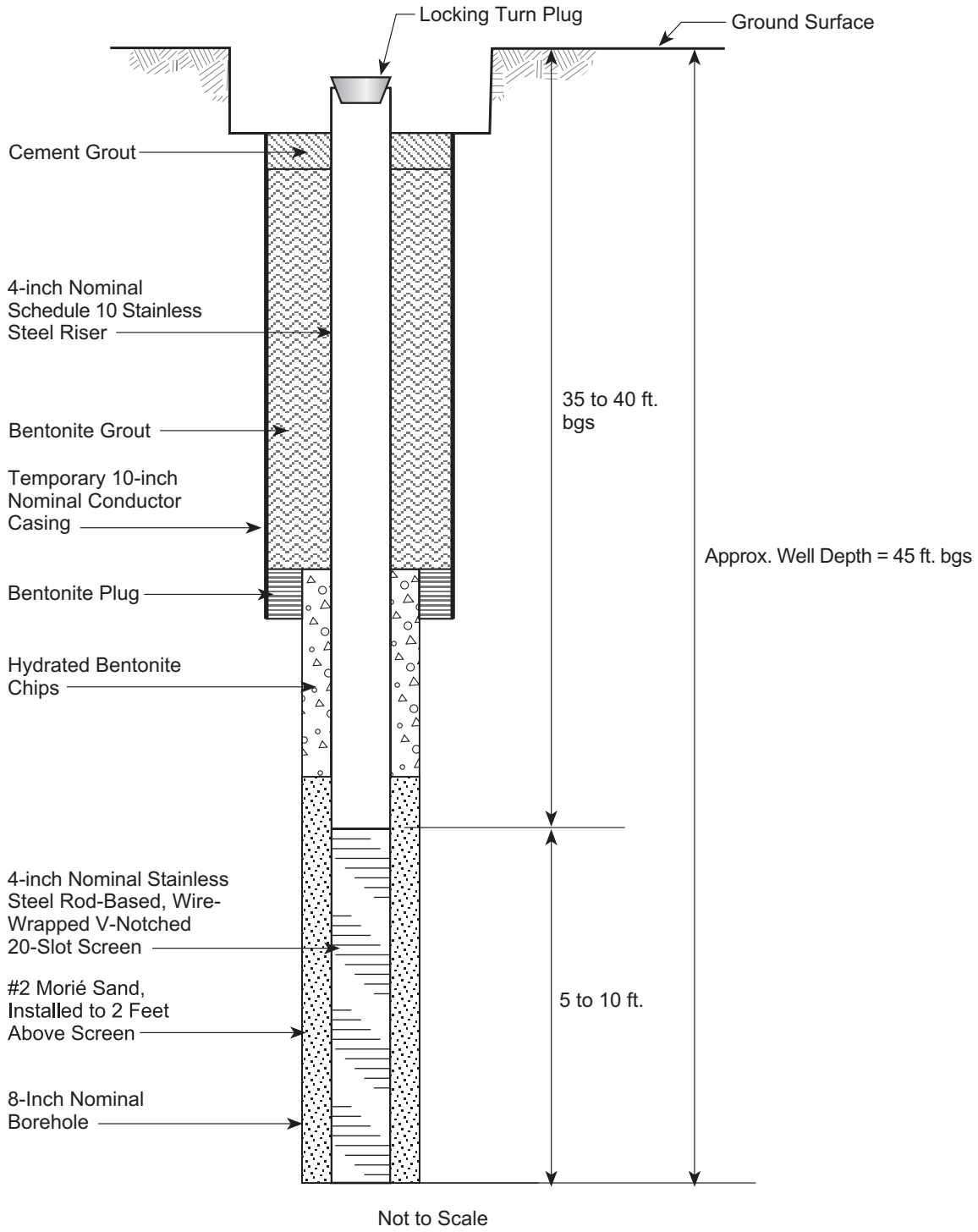
Note: bgs = Below Ground Surface

ERM *FIG 3-7 5-17-10*

Project No. 114849

Date: 5-17-10

Drawn By: EJK



Note: bgs = Below Ground Surface

Figure 3-8

Intermediate Zone Recovery Well Schematic - Acid Plant Area
Preliminary Design Report
Groundwater Source Control Measure
Arkema, Inc.
Portland, Oregon

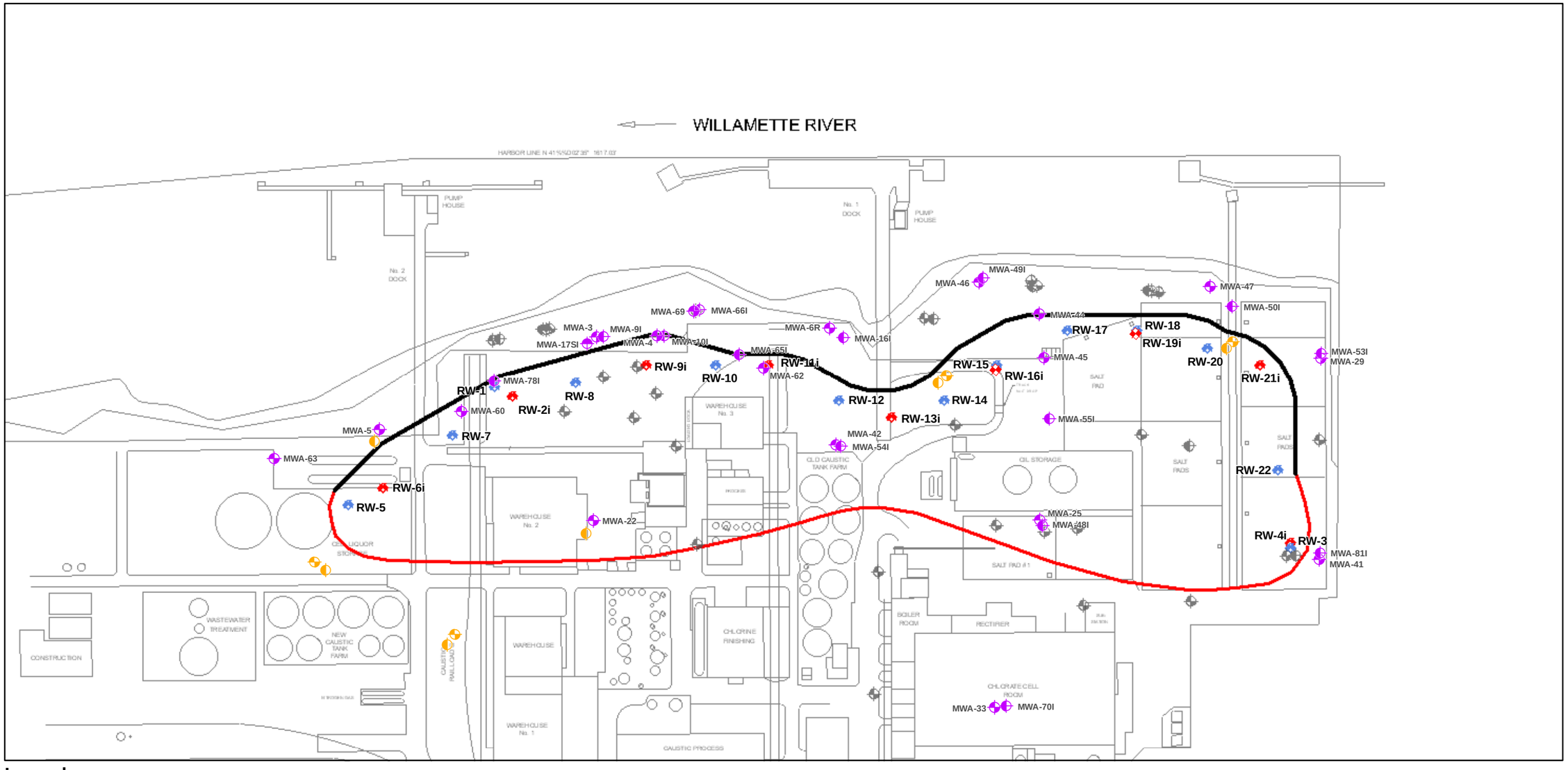
ERM *FIG 3-8 5-17-10*

Project: 0093634.05

Date: 05/18/2010

Drawn By: MSS

F:\RM106\A\Arkema\0057055 Groundwater Modeling\ArcGis\Arkema Performance Monitoring Well Network - Figure 4-1.mxd



Legend

- Shallow Zone Recovery Well
- Intermediate Zone Recovery Well
- Proposed Barrier Wall Alignment
- Target Capture Zone

Groundwater Elevation Monitoring Points

Existing Monitoring Wells
- Shallow Zone
- Shallow-Intermediate Zone
- Intermediate Zone

Proposed Piezometers
- Shallow Zone
- Intermediate Zone

Existing Wells Not Used for Monitoring
- Shallow Zone
- Shallow-Intermediate Zone
- Intermediate Zone
- Deep Zone
- Gravel Zone
- Basalt Zone

0 150 300 Feet

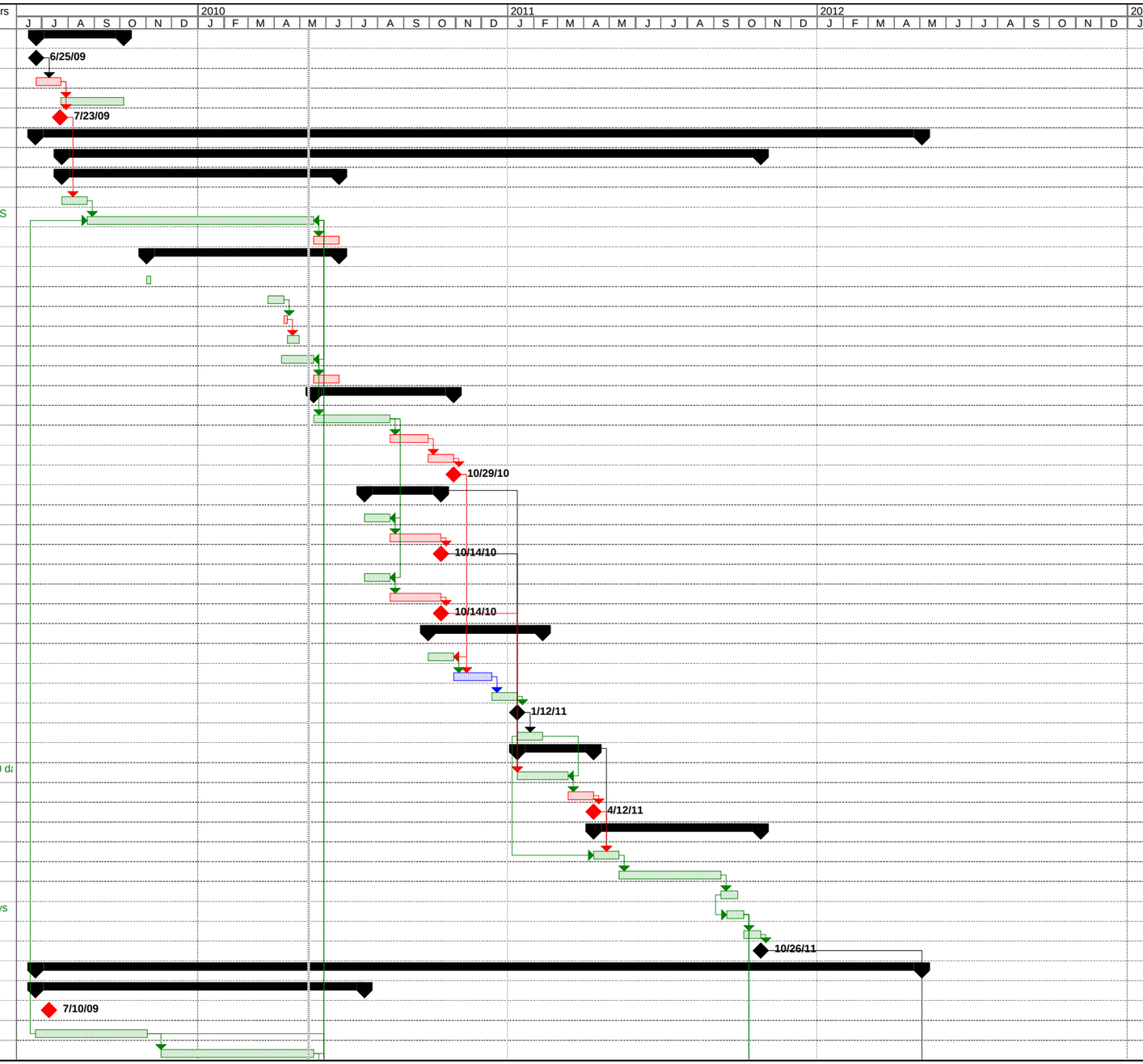
Figure 4-1

Preliminary Capture Zone Analysis Well Network
Preliminary Design Report
Groundwater Source Control Measure
Arkema, Inc.
Portland, Oregon

ERM 05/10

Figure 5-1
Project Schedule
Groundwater Source Control Measure Design and Implementation
Arkema, Inc. - Portland, Oregon

ID	Task Name	Duration	Start	Finish	Predecessors
1	**Groundwater Source Control Measure Work Plan**	**103 days**	**Thu 6/25/09**	**Mon 10/5/09**	
2	Submit GW SCM Work Plan	0 days	Thu 6/25/09	Thu 6/25/09	
3	ODEQ Review of GW SCM Work Plan	29 days	Thu 6/25/09	Thu 7/23/09	2
4	Response to Comments on GW SCM Work Plan	74 days	Fri 7/24/09	Mon 10/5/09	3
5	Approval of GW SCM Work Plan	0 days	Thu 7/23/09	Thu 7/23/09	3
6	**Groundwater Source Control Measure Design and Implementation**	**1045 days**	**Wed 6/24/09**	**Thu 5/3/12**	
7	**Groundwater Barrier Wall (GWBW)**	**824 days**	**Sat 7/25/09**	**Wed 10/26/11**	
8	**GWBW Pre-Design Investigation**	**327 days**	**Sat 7/25/09**	**Wed 6/16/10**	
9	Existing Data Review	30 days	Sat 7/25/09	Sun 8/23/09	5
10	Pre-Design Investigation Report	267 days	Mon 8/24/09	Mon 5/17/10	9,55FF,51SS
11	ODEQ Review of Pre-Design Investigation Report	30 days	Tue 5/18/10	Wed 6/16/10	10
12	**GWBW Preliminary Design**	**227 days**	**Mon 11/2/09**	**Wed 6/16/10**	
13	Design Team Kick Off Meeting	5 days	Mon 11/2/09	Fri 11/6/09	
14	Subsurface Clearance Investigation Work Plan	19 days	Thu 3/25/10	Mon 4/12/10	
15	ODEQ Subsurface Clearance Investigation Work Plan Review	4 days	Tue 4/13/10	Fri 4/16/10	14
16	Subsurface Clearance Investigation	14 days	Sat 4/17/10	Fri 4/30/10	15
17	Preliminary Design Summary Memorandum	38 days	Sat 4/10/10	Mon 5/17/10	10FF
18	ODEQ Preliminary Design Summary Memorandum Review	30 days	Tue 5/18/10	Wed 6/16/10	17
19	**GWBW Pre-Final Design**	**165 days**	**Tue 5/18/10**	**Fri 10/29/10**	
20	Pre-Final Design Preparation and Submittal	90 days	Tue 5/18/10	Sun 8/15/10	17
21	ODEQ Pre-Final Design Review	45 days	Mon 8/16/10	Wed 9/29/10	20
22	Negotiation and Finalization of Pre-Final Design	30 days	Thu 9/30/10	Fri 10/29/10	21
23	Approval of Pre-Final Design	0 days	Fri 10/29/10	Fri 10/29/10	22
24	**GWBW Permitting**	**90 days**	**Sat 7/17/10**	**Thu 10/14/10**	
25	NDPES 1200C General Construction Stormwater Permit Preparation	30 days	Sat 7/17/10	Sun 8/15/10	20FF
26	ODEQ NDPES 1200C Permit Application Review	60 days	Mon 8/16/10	Thu 10/14/10	25
27	Approval of NDPES 1200C Permit	0 days	Thu 10/14/10	Thu 10/14/10	26
28	City of Portland Permit Exempt Submittal Preparation	30 days	Sat 7/17/10	Sun 8/15/10	20FF
29	City of Portland Design Review	60 days	Mon 8/16/10	Thu 10/14/10	28
30	Letter of Determination Issued	0 days	Thu 10/14/10	Thu 10/14/10	29
31	**GWBW Contractor Bidding**	**135 days**	**Thu 9/30/10**	**Fri 2/11/11**	
32	Preparation of Bid Documents	30 days	Thu 9/30/10	Fri 10/29/10	23FF
33	Contractor Bid Submission	45 days	Sat 10/30/10	Mon 12/13/10	23,32
34	Evaluation of Contractor Bids	30 days	Tue 12/14/10	Wed 1/12/11	33
35	Contractor Selection	0 days	Wed 1/12/11	Wed 1/12/11	34
36	Contract Execution	30 days	Thu 1/13/11	Fri 2/11/11	35
37	**GWBW Final Design**	**90 days**	**Thu 1/13/11**	**Tue 4/12/11**	
38	Final Design Preparation (Incorporate Agency Pre-Final Design Comme	60 days	Thu 1/13/11	Sun 3/13/11	30,36FF+30 da
39	ODEQ Final Design Review	30 days	Mon 3/14/11	Tue 4/12/11	38
40	Approval of Final Design	0 days	Tue 4/12/11	Tue 4/12/11	39
41	**GWBW Construction (Estimated)**	**197 days**	**Wed 4/13/11**	**Wed 10/26/11**	
42	Pre-Construction Planning, Mobilization, and Site Preparation	30 days	Wed 4/13/11	Thu 5/12/11	40,37,36SS
43	Pre-Clearance Trenching and Slurry Wall Construction (Estimated)	120 days	Fri 5/13/11	Fri 9/9/11	42
44	Slurry Wall Capping	20 days	Sat 9/10/11	Thu 9/29/11	43
45	Monitoring Well Installation	20 days	Sat 9/17/11	Thu 10/6/11	44SS+7 days
46	Demobilization	20 days	Fri 10/7/11	Wed 10/26/11	45
47	Commence Long Term Operation and Maintenance	0 days	Wed 10/26/11	Wed 10/26/11	46
48	**Groundwater Extraction and Treatment (GWET) System**	**1045 days**	**Wed 6/24/09**	**Thu 5/3/12**	
49	**GWET Pre-Design Investigation**	**388 days**	**Wed 6/24/09**	**Fri 7/16/10**	
50	Approval of Data Gaps Assessment Work Plan	0 days	Fri 7/10/09	Fri 7/10/09	
51	Aquifer Pump Testing	132 days	Wed 6/24/09	Mon 11/2/09	
52	Groundwater Model Update and Evaluation	180 days	Thu 11/19/09	Mon 5/17/10	51

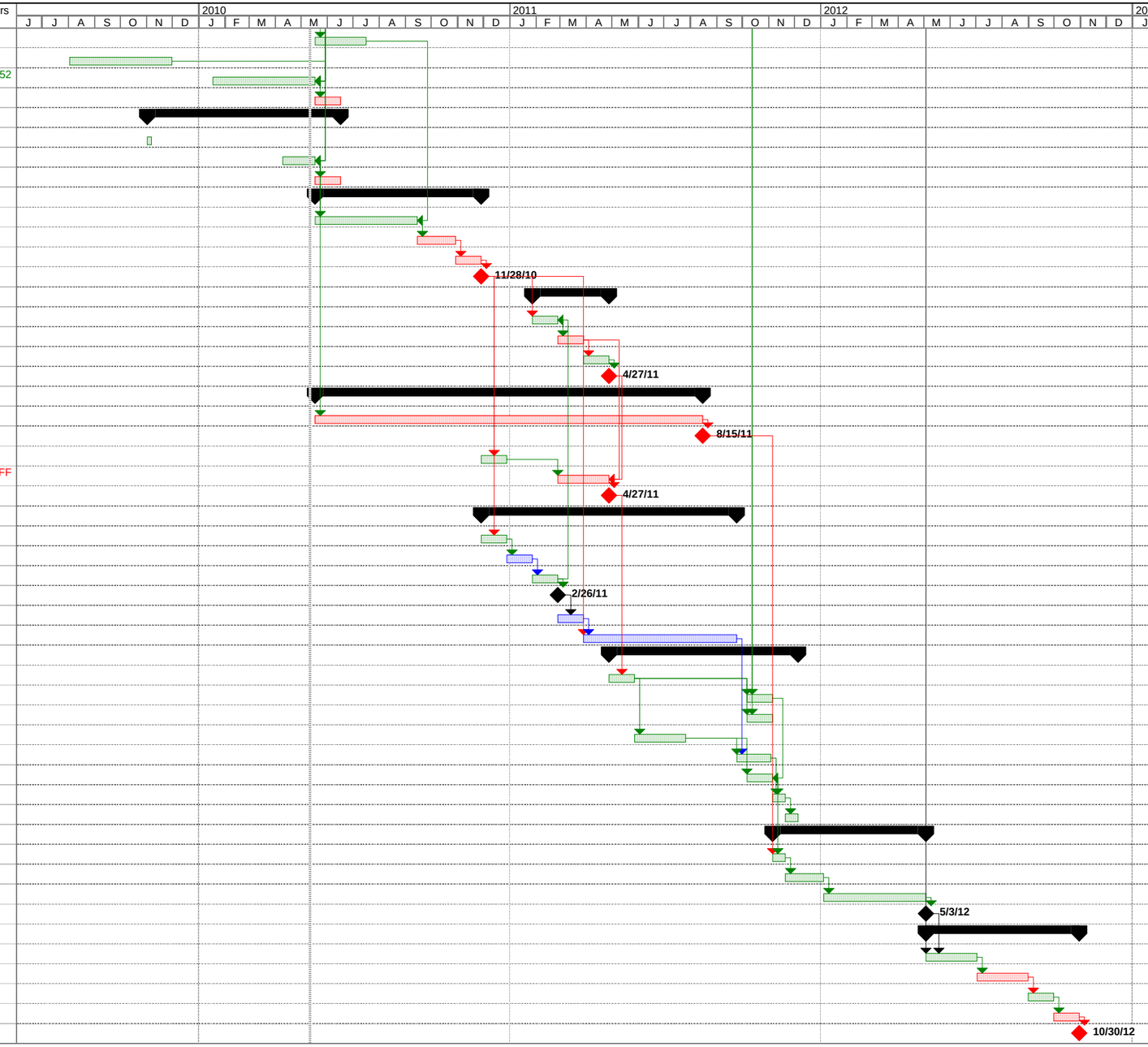


File: 2010.05.07_GW SCM Schedule.m
Date: Tue 5/11/10

Task | Summary | Rolled Up Milestone | DEQ Milestone | Baseline (12/15/08)
Baseline (12/15/08) | Milestone | DEQ Task | Public Review & Comment

Figure 5-1
Project Schedule
Groundwater Source Control Measure Design and Implementation
Arkema, Inc. - Portland, Oregon

ID	Task Name	Duration	Start	Finish	Predecessors
53	Evaluation of Contaminant Transport During Low Pumping	60 days	Tue 5/18/10	Fri 7/16/10	52
54	Sitewide Groundwater Monitoring	120 days	Mon 8/3/09	Mon 11/30/09	
55	Prepare Pre-design Investigation Report	120 days	Mon 1/18/10	Mon 5/17/10	51FF,54FF,52
56	Review of Pre-design Investigation Report	30 days	Tue 5/18/10	Wed 6/16/10	55
57	**GWET Preliminary Design**	**227 days**	**Mon 11/2/09**	**Wed 6/16/10**	
58	Design Team Kick Off Meeting	5 days	Mon 11/2/09	Fri 11/6/09	
59	Preliminary Design Summary Memorandum	38 days	Sat 4/10/10	Mon 5/17/10	10FF,55FF
60	ODEQ Preliminary Design Summary Memorandum Review	30 days	Tue 5/18/10	Wed 6/16/10	59
61	**GWET Pre-Final Design**	**195 days**	**Tue 5/18/10**	**Sun 11/28/10**	
62	Pre-Final Design Preparation and Submittal	120 days	Tue 5/18/10	Tue 9/14/10	59,53FF
63	ODEQ Pre-Final Design Review	45 days	Wed 9/15/10	Fri 10/29/10	62
64	Negotiation and Finalization of Pre-Final Design	30 days	Sat 10/30/10	Sun 11/28/10	63
65	Approval of Pre-Final Design	0 days	Sun 11/28/10	Sun 11/28/10	64
66	**GWET Final Design**	**90 days**	**Fri 1/28/11**	**Wed 4/27/11**	
67	Final Design Preparation (Incorporate Agency Pre-Final Design Comme	30 days	Fri 1/28/11	Sat 2/26/11	65,80FF
68	Final Design Review	30 days	Sun 2/27/11	Mon 3/28/11	67
69	Response to ODEQ Comments	30 days	Tue 3/29/11	Wed 4/27/11	68
70	Approval of Final Design	0 days	Wed 4/27/11	Wed 4/27/11	69
71	**GWET Permitting**	**455 days**	**Tue 5/18/10**	**Mon 8/15/11**	
72	Treatment System Effluent NPDES Permitting (Estimated)	455 days	Tue 5/18/10	Mon 8/15/11	59
73	Final NDPES Permit Issued	0 days	Mon 8/15/11	Mon 8/15/11	72
74	Construction Permit Application Submittal	30 days	Mon 11/29/10	Tue 12/28/10	65
75	Agency Construction Permit Application Review	60 days	Sun 2/27/11	Wed 4/27/11	68FF,74,70FF
76	Construction Permit Issued	0 days	Wed 4/27/11	Wed 4/27/11	75
77	**GWET Contractor Bidding and Equipment Procurement**	**300 days**	**Mon 11/29/10**	**Sat 9/24/11**	
78	Preparation of Bid Documents	30 days	Mon 11/29/10	Tue 12/28/10	65
79	Vendor Bid Submission	30 days	Wed 12/29/10	Thu 1/27/11	78
80	Vendor Bid Evaluation	30 days	Fri 1/28/11	Sat 2/26/11	79
81	Contractor Selection	0 days	Sat 2/26/11	Sat 2/26/11	80
82	Contract Execution	30 days	Sun 2/27/11	Mon 3/28/11	81
83	Equipment Fabrication and Delivery	180 days	Tue 3/29/11	Sat 9/24/11	82,65
84	**GWET Construction (Estimated)**	**222 days**	**Thu 4/28/11**	**Mon 12/5/11**	
85	Pre-Construction Planning, Mobilization, and Site Preparation	30 days	Thu 4/28/11	Fri 5/27/11	76
86	Recovery Well and Piping Installation	30 days	Fri 10/7/11	Sat 11/5/11	85,45
87	Performance Monitoring Well Installation	30 days	Fri 10/7/11	Sat 11/5/11	85,45
88	Treatment Equipment Building Construction	60 days	Sat 5/28/11	Tue 7/26/11	85
89	Installation of Treatment System Components	40 days	Sun 9/25/11	Thu 11/3/11	83,88
90	Installation of Discharge Piping	30 days	Fri 10/7/11	Sat 11/5/11	88,86FF
91	Site Restoration	15 days	Sun 11/6/11	Sun 11/20/11	90,89
92	Demobilization	15 days	Mon 11/21/11	Mon 12/5/11	91
93	**GWET System Startup**	**180 days**	**Sun 11/6/11**	**Thu 5/3/12**	
94	Bump Testing	15 days	Sun 11/6/11	Sun 11/20/11	90,73
95	Low Flow Performance Verification	45 days	Mon 11/21/11	Wed 1/4/12	94
96	System Optimization	120 days	Thu 1/5/12	Thu 5/3/12	95
97	Commence Long Term Operation and Maintenance	0 days	Thu 5/3/12	Thu 5/3/12	96
98	**Groundwater Source Control Measure Implementation Report**	**180 days**	**Fri 5/4/12**	**Tue 10/30/12**	
99	Construction Report Preparation and Submittal	60 days	Fri 5/4/12	Mon 7/2/12	47,97
100	Review of Construction Completion Report	60 days	Tue 7/3/12	Fri 8/31/12	99
101	Response to ODEQ Comments	30 days	Sat 9/1/12	Sun 9/30/12	100
102	Negotiation and Finalization of GW SCM Implementation Report	30 days	Mon 10/1/12	Tue 10/30/12	101
103	Approval of GW SCM Implementation Report	0 days	Tue 10/30/12	Tue 10/30/12	102



File: 2010.05.07_GW SCM Schedule.m
Date: Tue 5/11/10

Task | Summary | Rolled Up Milestone | DEQ Milestone | Baseline (12/15/08)
Baseline (12/15/08) | Milestone | DEQ Task | Public Review & Comment

Tables

Table 2-1
Slurry Backfill Mixture Test Results
Preliminary Design Report
Groundwater Source Control Measure
Arkema Inc.
Portland, Oregon

Sample Location	**Units**	**Chlorate Area**	**Acid Plant Area**	**Chlorate Area**	**Acid Plant Area**	**Acid Plant Area**	**Chlorate Area**	**Acid Plant Area**
Boring ID		**B-121**	**B-120**	**B-121**	**B-120**	**B-120**	**B-121**	**B-120**
Affected Soil Type		CA	OA	CA	OA	DA	CA	OA
Sample ID		CA-A-PW	OA-A-PW	CA-B-PW	OA-B-PW	DA-B-PW	Impermix/CAsoil	Impermix/OAsoil
Soil Interval		Full Depth Composite	Full Depth Composite	Full Depth Composite	Full Depth Composite	Shallow-Intermediate Silt	Full Depth Composite	Full Depth Composite
Clay Additive		Attapulgite	Attapulgite	Bentonite	Bentonite	Bentonite	Clay-Cement	Clay-Cement
Mix Water		PW	PW	PW	PW	PW	90% PW & 10% CGW	90% PW & 10% OGW
Unit Weight	(lbs/ft^3)	109.1	111.2	109.5	-----	109.2	-----	-----
Slump	(inches)	5.9	5.7	5.5	-----	7.0	-----	-----
Particle Size, Incl. Hydrometer	%<#40	98.1	86.0	94.1	87.9	-----	-----	-----
	%<#200	78.0	44.9	53.8	38.6	-----	-----	-----
	% Silt	57.7	28.1	43.1	24.8	-----	-----	-----
	% Clay	20.3	16.8	10.7	13.8	-----	-----	-----
Mixture Moisture Content[1]	%	47.8	39.7	43.7	31.7	43.4	-----	-----
DI Permeant								
Pre-Test Mositure Content[2]	%	31.9	27	31.1	24.9	-----	143.8	135.1
Unit Weight (Dry)	lbs/ft3	96.5	100.7	93.9	102.7	-----	31.8	32.3
Flow Volume	cc	6	4.25	11.8	2.75	-----	0.72	1.05
Height	cm	5.13	5.31	4.19	6.27	-----	7.7	8.2
Diameter	cm	5.08	5.08	5.08	5.08	-----	7.54	7.62
Water Mass	lbs	30.8	27.2	29.2	25.6	-----	45.7	43.6
Void Ratio		0.49	0.44	0.47	0.41	-----	0.73	0.70
Cell Volume	cc	104.0	107.6	84.9	127.1	-----	343.8	374.0
Void Volume	cc	51.3	46.9	39.7	52.1	-----	252.0	261.5
Flow Vol/Cell Volume		0.117	0.091	0.297	0.053	-----	0.003	0.004
Hydraulic Conductivity	cm/sec	2.34E-07	1.89E-07	1.25E-07	2.48E-07	-----	1.33E-08	1.77E-08
CGW Permeant								
Pre-Test Mositure Content[2]	%	30.4	-----	29.6	-----	-----	161.4	-----
Unit Weight (Dry)	lbs/ft3	96.2	-----	98.3	-----	-----	29.7	-----
Flow Volume	cc	3.4	-----	1.65	-----	-----	0.78	-----
Height	cm	5	-----	4.95	-----	-----	7.62	-----
Diameter	cm	5.08	-----	5.08	-----	-----	7.62	-----
Water Mass	lbs	29.2	-----	29.1	-----	-----	47.9	-----
Void Ratio		0.47	-----	0.47	-----	-----	0.77	-----
Cell Volume	cc	101.3	-----	100.3	-----	-----	347.5	-----
Void Volume	cc	47.5	-----	46.8	-----	-----	267.0	-----
Flow Vol/Cell Volume		0.105	-----	0.106	-----	-----	0.029	-----
Hydraulic Conductivity	cm/sec	7.85E-08	-----	3.93E-08	-----	-----	5.19E-08	-----
OGW Permeant								
Pre-Test Mositure Content[2]	%	-----	26.3	-----	-----	35.1	-----	126.3
Unit Weight (Dry)	lbs/ft3	-----	101.1	-----	-----	76	-----	34.4
Flow Volume	cc	-----	1.85	-----	-----	2.1	-----	0.34
Height	cm	-----	5.05	-----	-----	6.45	-----	7.75
Diameter	cm	-----	5.08	-----	-----	5.08	-----	7.62
Water Mass	lbs	-----	26.6	-----	-----	-----	-----	43.4
Void Ratio		-----	0.43	-----	-----	-----	-----	0.70
Cell Volume	cc	-----	102.4	-----	-----	-----	-----	353.4
Void Volume	cc	-----	43.6	-----	-----	-----	-----	246.1
Flow Vol/Cell Volume		-----	0.116	-----	-----	-----	-----	0.031
Hydraulic Conductivity	cm/sec	-----	3.76E-08	-----	-----	1.70E-08	-----	1.78E-08

Notes:
[1] - Moisture content measured immediately after mixing
[2] - Moisture content measured after sample extruded, pressurised, and allowed to dewater
lb/ft^3 = Pounds per cubic foot
% = Percent
----- = Not Analyzed
DI = Deionized Water
PW = Site Potable Water
CGW = Chloride affected groundwater
OGW = Organics affected groundwater
CA = Chloride Affected Soil
OA = Organics Affected Soil
DA = Dense Non-Aqueous Phase Liquid Affected Soil

Table 2-2
Groundwater Barrier Wall Quality Control and Quality Assurance Activities
Preliminary Design Report
Groundwater Source Control Measure
Arkema Inc.
Portland, Oregon

Construction Phase	Component	Testing
Pre-Construction	Bentonite/In Situ Groundwater	Free Swell
	Mix Water	Hardness pH Total Dissolved Solids
	Native Soil	Particle Size Analysis
	Clay Cap Material	Particle Size Analysis Atterberg Limits Hydraulic Conductivity Compaction
Construction	Bentonite Slurry (as mixed and in trench)	Viscosity Specific Gravity/Density pH
	Soil-Bentonite Backfill	Specific Gravity/Density (Field) Slump (Field) Particle Size Analysis Atterberg Limits
	Clay Cap	Density Moisture Content
	Wall Dimensions	Depth Width
Post-Construction	Soil-Bentonite Backfill	Hydraulic Conductivity
	Clay Cap	Hydraulic Conductivity

Table 3-1
Preliminary GWET System Recovery Wells
Groundwater Source Control Measure
Arkema Inc.
Portland, Oregon

Recovery Well Number	Aquifer Zone	Flow Rate (gpm)
RW-1	Shallow	5
RW-2i	Intermediate	5
RW-3	Shallow	5
RW-4i	Intermediate	5
RW-5	Shallow	5
RW-6i	Intermediate	5
RW-7	Shallow	5
RW-8	Shallow	5
RW-9i	Intermediate	5
RW-10	Shallow	5
RW-11i	Intermediate	5
RW-12	Shallow	5
RW-13i	Intermediate	5
RW-14	Shallow	6
RW-15	Shallow	5
RW-16i	Intermediate	5
RW-17	Shallow	5
RW-18	Shallow	3
RW-19i	Intermediate	5
RW-20	Shallow	5
RW-21i	Intermediate	5
RW-22	Shallow	5
Total Flow		109

Notes:
gpm = gallons per mintues

Table 3-2
Estimated Range of Influent Concentrations for GWET System Design
Groundwater Source Control Measure
Arkema Inc.
Portland, Oregon

Data Source	Groundwater Treatability Study[1]	Site-Wide Groundwater Sampling[2]				Recovery Well Pumping Tests[3]				Estimated Influent Concentration
Parameter	Blended	Average	Maximum	No. of Samples	No. of Detections	Average	Maximum	No. of Samples	No. of Detections	
VOCs (ug/L)										
Benzene	ND (6.4)	1.04	16.6	33	10	1.22	2.69	12	1	3
Chlorobenzene	1,700	948	12,500	33	30	80.5	286	12	6	2,000
Chloroform	9.9	298	9,800	33	17	NA	ND (5)	12	0	300
SVOCs (ug/L)										
Benzo(a)Anthracene	ND (1.7)	NA				NA				ND (1.7)
Benzo(a)Pyrene	ND (1.3)	NA				NA				ND (1.3)
Benzo(k)Fluoranthene	ND (0.46)	NA				NA				ND (0.46)
2-Chlorophenol	43	NA				NA				50
Chrysene	ND (1.0)	NA				NA				ND (1.0)
Dibenzo(a,h)Anthracene	ND (1.4)	NA				NA				ND (1.4)
Fluoranthene	ND (5.0)	NA				NA				ND (5.0)
Hexachlorobenzene	ND (2.1)	NA				NA				ND (2.1)
Pentachlorophenol	ND (20)	NA				NA				ND (20)
Pesticides (ug/L)										
Aldrin	ND (0.0059)	NA	ND (0.05)	36	0	NA				ND (0.0059)
Chlordane	ND (0.14)	NA	ND (0.5)	36	0	NA				ND (0.14)
DDD	0.027 COL	0.09	0.599	36	17	NA	ND (0.1)	12	0	0.1
DDE	ND (0.0075)	0.06	0.553	36	10	NA	ND (0.1)	12	0	0.1
DDT	0.015 COL	1.3	30.8	36	23	NA	ND (0.1)	12	0	1
Metals, total (ug/L)[4]										
Arsenic	ND (4.4)	NA	ND (3)	1	0	NA				10
Cadmium	5.6	NA	0.367 J	1	1	NA				5
Chromium, total	ND (2.6)	NA				NA				100
Chromium, hexavalent	ND (4.4)	98	1,100	30	15	NA				100
Copper	ND (4.5)	NA	ND (2)	1	0	NA				5
Iron	140,000	NA	205	1	1	NA				2,000
Lead	ND (2.6)	NA	ND (7)	1	0	NA				ND (2.6)
Manganese	NA	NA	641	1	1	NA				500
Nickel	ND (7.8)	NA	5.41 J	1	1	NA				5
Silver	ND (2.8)	NA				NA				ND (2.8)
Zinc	63	NA	2.25 J	1	1	NA				50
Metals, dissolved (ug/L)[4]										
Arsenic	ND (4.4)	45.4	892	31	17	13.2	51.9	12	9	10
Cadmium	4	NA	ND (0.7)	2	0	NA				5
Chromium, total	ND (2.6)	36.4	388	19	9	NA				100
Chromium, hexavalent	ND (4.4)	NA				NA				100
Copper	ND (4.5)	2.54	2.85 J	2	2	NA				5
Iron	110,000	1,637	17,800	31	28	500	1,940	12	9	2,000
Lead	ND (2.6)	NA	ND (7)	2	0	NA				ND (2.6)
Manganese	NA	471	4,190	21	20	616	2,090	12	12	500
Nickel	ND (7.8)	3.44	4.95 J	2	1	NA				5
Silver	ND (2.8)	NA				NA				ND (2.8)
Zinc	49	2.86	4.72 J	2	1	NA				50

Table 3-2
Estimated Range of Influent Concentrations for GWET System Design
Groundwater Source Control Measure
Arkema Inc.
Portland, Oregon

Data Source	Groundwater Treatability Study[1]	Site-Wide Groundwater Sampling[2]				Recovery Well Pumping Tests[3]				Estimated Influent Concentration
Parameter	Blended	Average	Maximum	No. of Samples	No. of Detections	Average	Maximum	No. of Samples	No. of Detections	
Inorganics (mg/L)										
Chlorate	45.5	NA				NA				50
Perchlorate	3.2 Q	5.2	119	40	15	NA	ND (0.68)	6	0	5
Chloride	1,600 Q	3,251	39,400	40	40	294	860	12	12	2,500
pH (s.u.)	6.54	6.15	5.02 - 9.71	20	20	NA				6.5
Other Parameters (mg/L)										
Alkalinity	200	NA				NA				200
Calcium	73	NA				NA				75
Nitrate as N	ND (0.21) G	NA				NA				2.5
Nitrogen, Ammonium	5.2	NA				NA				5
Nitrogen, Total Kjeldahl	6.1	NA				NA				5
Phosphate, Total as P	0.18	NA				NA				0.2
Sulfate	1,300 Q	NA				NA				1,000
Total Organic Carbon	10	NA				NA				10
Total Suspended Solids	220 Q	NA				NA				100
Total Volatile Solids	48 Q	NA				NA				25

Notes

(1) - Based on analytical results for groundwater samples collected from on-site monitoring wells for the groundwater treatability study during 2007. Blended sample represents composite samples from MWA-5, MWA-14i, MWA-34i, MWA-43, MWA-44, MWA-52i, MWA-66i, and MWA-68si).

(2) - Based on analytical results for groundwater samples collected from on-site monitoring wells during site-wide groundwater samplings event in 2007 and 2009 (except for total metals and pH, which are based on 2009 event only and dissolved chromium, total, which is based on 2007 event only). Hexavalent chromium, total concentrations based on 2007 and 2009 events.

(3) - Based on analytical results for groundwater samples collected from proposed recovery wells during pumping tests in 2009.

(4) - Dissolved metal concentration may exceed total metal concentration based on data set used to estimate influent concentration.

When necessary, average concentrations calculated assuming concentrations equal to one half of laboratory method detection limit and/or reporting limit for non-detect values.

Non-detect (ND) values reported with laboratory method detection limits (groundwater treatability study and site-wide groundwater sampling) or reporting limit (recovery well pumping tests).

mg/L = milligrams per liter

ug/L = micrograms per liter

s.u. = standard units

NA = data not available

J = Estimated result. Result is less than laboratory method detection limit.

COL = More than 40% RPD between primary and confirmation column results. The lower of the two results is reported.

Q = Elevated reporting limit. The reporting limit is elevated due to high analyte levels.

G = Elevated reporting limit. The reporting limit is elevated due to matrix interference.

V = Elevated reporting limit. The reporting limit is elevated due to limited sample volume.

Table 3-3
Effluent Quality Objectives for GWET System Design
Groundwater Source Control Measure
Arkema Inc.
Portland, Oregon

Parameter	ODEQ MQL[1]	Estimated Influent Concentration	Effluent Quality Objective	Comments
VOCs (ug/L)[2]				
Benzene	0.5	3	<0.7	Based on LPGAC vendor information
Chlorobenzene	0.5	2,000	<200	Based on LPGAC vendor information; however, FBR treatability study effluent data suggests removal to <130 ug/L
Chloroform	0.5	300	<30	Based on LPGAC vendor information
SVOCs (ug/L)[2]				
Benzo(a)Anthracene	1	ND (1.7)	No design criteria	No design criteria, not detected in influent[5]
Benzo(a)Pyrene	1	ND (1.3)	No design criteria	No design criteria, not detected in influent[5]
Benzo(k)Fluoranthene	1	ND (0.46)	No design criteria	No design criteria, not detected in influent at concentration above MQL
2-Chlorophenol	1	50	<5	Based on LPGAC vendor information
Chrysene	1	ND (1.0)	No design critera	No design criteria, not detected in influent at concentration above MQL
Dibenzo(a)Anthracene	1	ND (1.4)	No design critera	No design criteria, not detected in influent[5]
Fluoranthene	2	ND (5.0)	No design critera	No design criteria, not detected in influent[5]
Hexachlorobenzene	1	ND (2.1)	No design critera	No design criteria, not detected in influent[5]
Pentachlorophenol	2	ND (20)	No design critera	No design criteria, not detected in influent[5]
Pesticides (ug/L)[2]				
Aldrin	0.01	ND (0.0059)	No design criteria	No design criteria, not detected in influent at concentration above MQL
Chlordane	0.1	ND (0.14)	No design criteria	No design criteria, not detected in influent[5]
DDD	0.01	0.1	<0.01	Based on LPGAC vendor information
DDE	0.01	0.1	<0.01	Based on LPGAC vendor information
DDT	0.01	1	<0.1	Based on LPGAC vendor information
Metals (ug/L)[3]				
Arsenic	0.05	10	<10	Based on FBR treatability study effluent
Cadmium	0.1	5	No design criteria	No design criteria, naturally-occurring, incidental removal expected[5]
Chromium, total	10	100	No design criteria	No design criteria, incidental removal expected[6]
Chromium, hexavalent	10	100	<10	Based on FBR treatability study effluent
Copper	10	5	No design criteria	No design criteria, naturally-occurring, incidental removal expected[5]
Iron	100	2,000	No design criteria	No design criteria, naturally-occurring, incidental removal expected
Lead	5	ND (2.6)	No design criteria	No design criteria, naturally-occurring, incidental removal expected[5]
Manganese	2	500	No design criteria	No design criteria, naturally-occurring, incidental removal expected
Nickel	10	5	No design criteria	No design criteria, naturally-occurring, incidental removal expected[5]
Silver	1	ND (2.8)	No design criteria	No design criteria, naturally-occurring, incidental removal expected
Zinc	5	50	No design criteria	No design criteria, naturally-occurring, incidental removal expected

Table 3-3
Effluent Quality Objectives for GWET System Design
Groundwater Source Control Measure
Arkema Inc.
Portland, Oregon

Parameter	ODEQ MQL[1]	Estimated Influent Concentration	Effluent Quality Objective	Comments
Inorganics (mg/L)[4]				
Chlorate	NA	50	<0.015	Based on FBR treatability study effluent
Perchlorate	0.004	5	<0.015	Based on FBR treatability study effluent
Chloride	1	2,500	No design criteria	No treatment
pH (s.u.)	NA	6.5	6.5 to 8.5	Based on FBR treatability study effluent
Other Parameters (mg/L)[4]				
Alkalinity	1	200	No design criteria	No design criteria, naturally-occurring
Calcium	NA	75	No design criteria	No design criteria, naturally-occurring
Nitrate as N	0.1	2.5	<10	Total nitrogen based on FBR treatability study effluent
Nitrogen, Ammonium	1	5		
Nitrogen, Total Kjeldahl	NA	5		
Phosphate, Total as P	0.01	0.2	<1	Total phosphorus based on FBR treatability study effluent
Sulfate	NA	1,000	No design criteria	No treatment
Total Organic Carbon	NA	10	<10	Based on FBR treatability study effluent
Total Suspended Solids	NA	100	<25	Based on FBR treatability study effluent
Total Volatile Solids	NA	25	<25	Based on FBR treatability study effluent

Notes
(1) - Method Quantitation Limit (MQL) based on values published by Oregon Deparment of Environmental Quality (ODEQ) in guidance dated 16 November 2007.
(2) - Estimated effluent concentrations based on approximately 90% removal efficiency for liquid-phase granular activated carbon (LPGAC).
(3) - Estimated effluent concentrations assume iron co-precipitation with clarifier and optional solids filtration.
(4) - Estimated effluent concentrations based on documented performance of fluidized bed reactor.
(5) - Not detected in FBR treatability study effluent above MQL.
(6) - Assumes that majority of chromium present as hexavalent chromium, and total chromium concentrations will be reduced via removal of hexavalent chromium.
Non-detect (ND) values reported with laboratory method detection limits.
FBR = fluidized bed reactor
GWET = groundwater extraction and treatment
LPGAC = liquid-phase granular activated carbon
mg/L = milligrams per liter
ug/L = micrograms per liter
s.u. = standard units
NA = data not available

Table 3-4
Preliminary GWET System Design Parameters
Groundwater Source Control Measure
Arkema Inc.
Portland, Oregon

Parameter	Estimated Influent Concentration	Effluent Quality Objective
VOCs (ug/L)[2]		
Benzene	3	<0.7
Chlorobenzene	2,000	<200
Chloroform	300	<30
SVOCs (ug/L)[2]		
2-Chlorophenol	50	<5
Pesticides (ug/L)[2]		
DDD	0.1	<0.01
DDE	0.1	<0.01
DDT	1	<0.1
Metals (ug/L)[3]		
Arsenic	10	<10
Chromium, hexavalent	100	<10
Inorganics (mg/L)[4]		
Chlorate	50	<0.015
Perchlorate	5	<0.015
pH (s.u.)	6.5	6.5 to 8.5
Other Parameters (mg/L)[4]		
Nitrate as N	2.5	<10, Total as N
Nitrogen, Ammonium	5	
Nitrogen, Total Kjeldahl	5	
Phosphate, Total as P	0.2	<1
Total Organic Carbon	10	<10
Total Suspended Solids	100	<25
Total Volatile Solids	25	<25

Notes
mg/L = milligrams per liter
ug/L = micrograms per liter
s.u. = standard units

Appendix A
Distribution of Constituents of Potential Concern

Project Number: 0104584

Date: 01/13/2010

Created By: mike.appel

File: F:\RM106\EERM West\Arkema\0104584 GW Monitoring Aug 2009\1209Figures\HexChromeShallow.mxd

Legend

- Proposed Barrier Wall Alignment
- Target Capture
- Shallow Zone Recovery Well
- Intermediate Zone Recovery Well

Hexavalent Chromium Concentration (µg/l)

- Not detected
- < 11 (JSCS Screening Criteria = 11 µg/l)
- 11 - 110 (DEQ Screening Criteria = 110 µg/l)
- 110 - 1,000
- 1,000 - 10,000
- > 10,000

200 100 0 200 Feet

Scale 1:2,400

N

Aerial Photography: July 2005

FIGURE A-1
Hexavalent Chromium Groundwater Concentrations
Shallow Zone
August 2009
Arkema, Portland, OR

ERM 11/09

Project Number: 0104584

Date: 01/13/2010

Created By: mike.appel

File: F:\RM106\EERM West\Arkema\0104584 GW Monitoring Aug 2009\1209Figures\HexChromeIntermediate.mxd

Legend

- Proposed Barrier Wall Alignment
- Target Capture
- Shallow Zone Recovery Well
- Intermediate Zone Recovery Well

Hexavalent Chromium Concentration (µg/l)

- Not detected
- < 11 (JSCS Screening Criteria = 11 µg/l)
- 11 - 110 (DEQ Screening Criteria = 110 µg/l)
- 110 - 1,000
- 1,000 - 10,000
- > 10,000

200 100 0 200 Feet

Scale 1:2,400

N

Aerial Photography: July 2005

FIGURE A-2
Hexavalent Chromium Groundwater Concentrations
Intermediate Zone
August 2009
Arkema, Portland, OR

ERM 11/09

Project Number: 0104584

Date: 01/13/2010

Created By: mike.appel

File: F:\RM106\ERM West\Arkema\0104584 GW Monitoring Aug 2009\1209Figures\HexChromeDeep.mxd

Legend

- Proposed Barrier Wall Alignment
- Target Capture

Hexavalent Chromium Concentration (µg/l)

- Not detected
- < 11 (JSCS Screening Criteria = 11 µg/l)
- 11 - 110 (DEQ Screening Criteria = 110 µg/l)
- 110 - 1,000
- 1,000 - 10,000
- > 10,000

- Shallow Zone Recovery Well
- Intermediate Zone Recovery Well

200 100 0 200 Feet

Scale 1:2,400

N

Aerial Photography: July 2005

FIGURE A-3
Hexavalent Chromium Groundwater Concentrations
Deep Zone
August 2009
Arkema, Portland, OR

ERM 11/09

Project Number: 0104584

Date: 01/13/2010

Created By: simon.ross

File: F:\RM106\EIERM West\Arkema\0104584 GW Monitoring Aug 2009\1209Figures\PerchlorateShallow.mxd

Legend

- Proposed Barrier Wall Alignment
- Target Capture

Perchlorate Concentration (µg/l)

- Not detected
- < 36 (JSCS Screening Criteria = 36 µg/l) (DEQ Screening Criteria = 24.5 µg/l)
- 36 - 100
- 100 - 1,000
- Shallow Zone Recovery Well
- Intermediate Zone Recovery Well
- 1,000 - 10,000
- 10,000 - 100,000
- > 100,000

200 100 0 200 Feet

Scale 1:2,400

N

Aerial Photography: July 2005

FIGURE A-4
Perchlorate Groundwater Concentrations
Shallow Zone
August 2009
Arkema, Portland, OR

ERM 03/07

Project Number: 0104584

Date: 01/14/2010

Created By: mike.appel

File: F:\RM106\ERM West\Arkema\0104584 GW Monitoring Aug 2009\1209Figures\PerchlorateIntermediate.mxd

Legend

- Proposed Barrier Wall Alignment
- Target Capture
- Shallow Zone Recovery Well
- Intermediate Zone Recovery Well

Perchlorate Concentration (µg/l)

- Not detected
- < 36 (JSCS Screening Criteria = 36 µg/l) (DEQ Screening Criteria = 24.5 µg/l)
- 36 - 100
- 100 - 1,000
- 1,000 - 10,000
- 10,000 - 100,000
- > 100,000

200 100 0 200 Feet

Scale 1:2,400

N

Aerial Photography: July 2005

FIGURE A-5
Perchlorate Groundwater Concentrations
Intermediate Zone
August 2009
Arkema, Portland, OR

ERM 03/07

Project Number: 0104584

Date: 01/14/2010

Created By: mike.appel

File: F:\RM106\EIERM West\Arkema\0104584 GW Monitoring Aug 2009\1209Figures\PerchlorateDeep.mxd

Legend

- Proposed Barrier Wall Alignment
- Target Capture

Perchlorate Concentration (µg/l)

- Not detected
- < 36 (JSCS Screening Criteria = 36 µg/l) (DEQ Screening Criteria = 24.5 µg/l)
- 36 - 100
- 100 - 1,000

- Shallow Zone Recovery Well
- Intermediate Zone Recovery Well

- 1,000 - 10,000
- 10,000 - 100,000
- > 100,000

200 100 0 200 Feet

Scale 1:2,400

N

Aerial Photography: July 2005

FIGURE A-6
Perchlorate Groundwater Concentrations
Deep Zone
August 2009
Arkema, Portland, OR

ERM 03/07

Project Number: 0104584

Date: 01/14/2010

Created By: mike.appel

File: F:\RM106\EIERM West\Arkema\0104584 GW Monitoring Aug 2009\1209Figures\ChlorobenzeneShallow.mxd

Legend

- Proposed Barrier Wall Alignment
- Target Capture

Chlorobenzene Concentration (µg/l)

- Not detected
- < 50 (JSCS Screening Criteria = 50 µg/l)
- 50 - 100 (DEQ Screening Criteria = 100 µg/l)
- 100 - 1,000

- Shallow Zone Recovery Well
- Intermediate Zone Recovery Well

- 1,000 - 10,000
- 10,000 - 100,000
- > 100,000

200 100 0 200 Feet

Scale 1:2,400

N

Aerial Photography: July 2005

FIGURE A-7
Chlorobenzene Groundwater Concentrations
Shallow Zone
August 2009
Arkema, Portland, OR

ERM 03/07

Project Number: 0104584

Date: 01/14/2010

Created By: mike.appel

File: F:\RM106\E\ERM West\Arkema\0104584 GW Monitoring Aug 2009\1209Figures\ChlorobenzeneIntermediate.mxd

Legend

- Proposed Barrier Wall Alignment
- Target Capture

Chlorobenzene Concentration (µg/l)

- Not detected
- < 50 (JSCS Screening Criteria = 50 µg/l)
- 50 - 100 (DEQ Screening Criteria = 100 µg/l)
- 100 - 1,000

- Shallow Zone Recovery Well
- Intermediate Zone Recovery Well

- 1,000 - 10,000
- 10,000 - 100,000
- > 100,000

200 100 0 200 Feet

Scale 1:2,400

N

Aerial Photography: July 2005

FIGURE A-8
Chlorobenzene Groundwater Concentrations
Intermediate Zone
August 2009
Arkema, Portland, OR

ERM 11/09

Project Number: 0104584

Date: 01/14/2010

Created By: mike.appel

File: F:\RM106\ERM West\Arkema\0104584 GW Monitoring Aug 2009\1209Figures\ChlorobenzeneDeep.mxd

Legend

- Proposed Barrier Wall Alignment
- Target Capture

Chlorobenzene Concentration (µg/l)

- Not detected
- < 50 (JSCS Screening Criteria = 50 µg/l)
- 50 - 100 (DEQ Screening Criteria = 100 µg/l)
- 100 - 1,000

- Shallow Zone Recovery Well
- Intermediate Zone Recovery Well

- 1,000 - 10,000
- 10,000 - 100,000
- > 100,000

200 100 0 200 Feet

Scale 1:2,400

N

Aerial Photography: July 2005

FIGURE A-9
Chlorobenzene Groundwater Concentrations
Deep Zone
August 2009
Arkema, Portland, OR

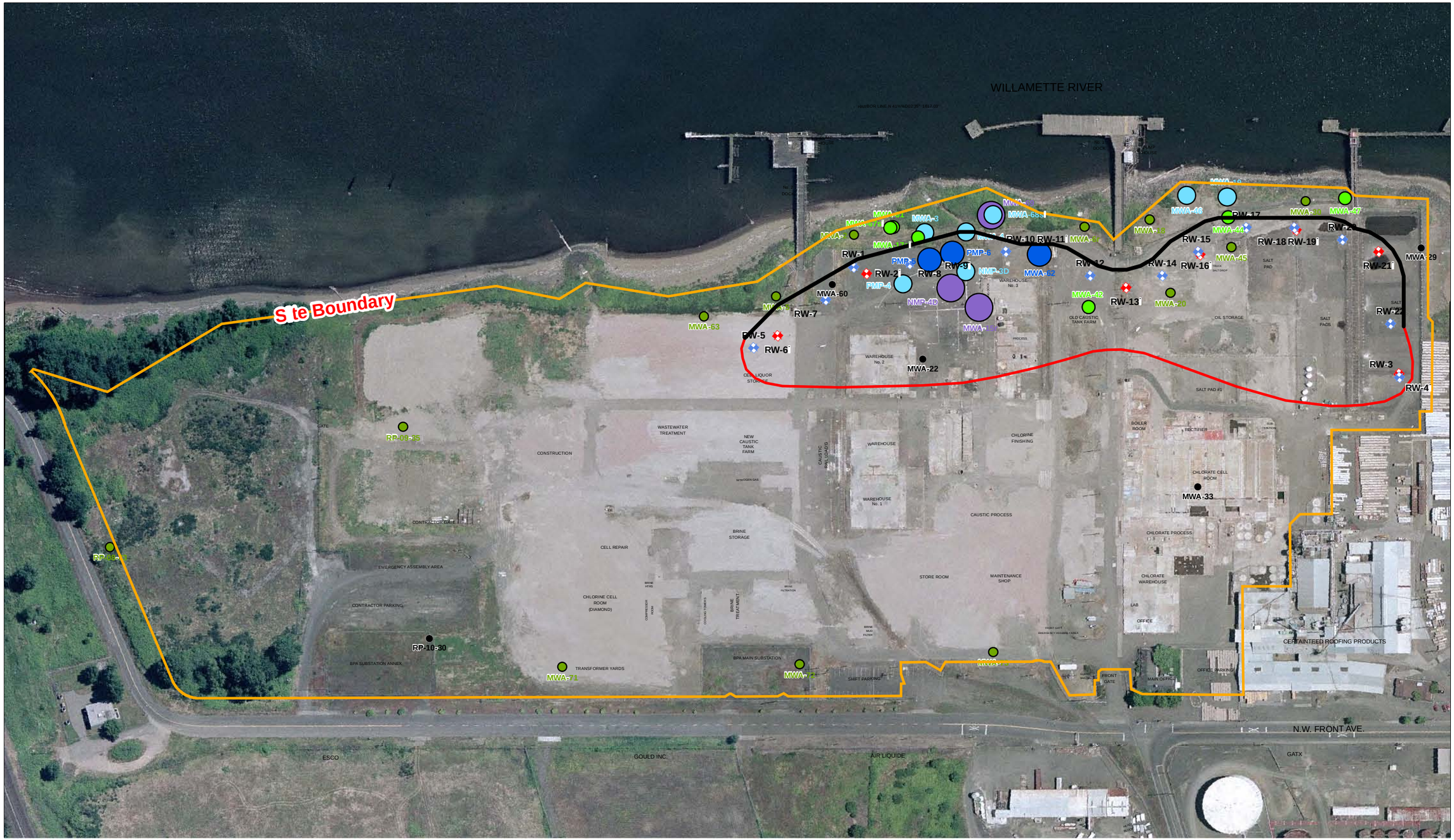
ERM 11/09

Project Number: 0104584

Date: 01/14/2010

Created By: mike.appel

File: F:\RM106\ERM West\Arkema\0104584 GW Monitoring Aug 2009\1209Figures\DDxShallow.mxd



Legend

- Proposed Barrier Wall Alignment
- Target Capture
- Shallow Zone Recovery Well
- Intermediate Zone Recovery Well

DDx Concentration (µg/l)

- Not detected
- < 0.2 (DEQ Screening Criteria = 0.2 µg/l)
- 0.2 - 1
- 1 - 10
- 10 - 100
- 100 - 1,000
- > 1,000

Scale 1:2,400

200 100 0 200 Feet

N

Note: DDX = Sum total of DDT, DDD, and DDE concentrations.

Aerial Photography: July 2005

FIGURE A-10
DDx Groundwater Concentrations
Shallow Zone
August 2009
Arkema, Portland, OR

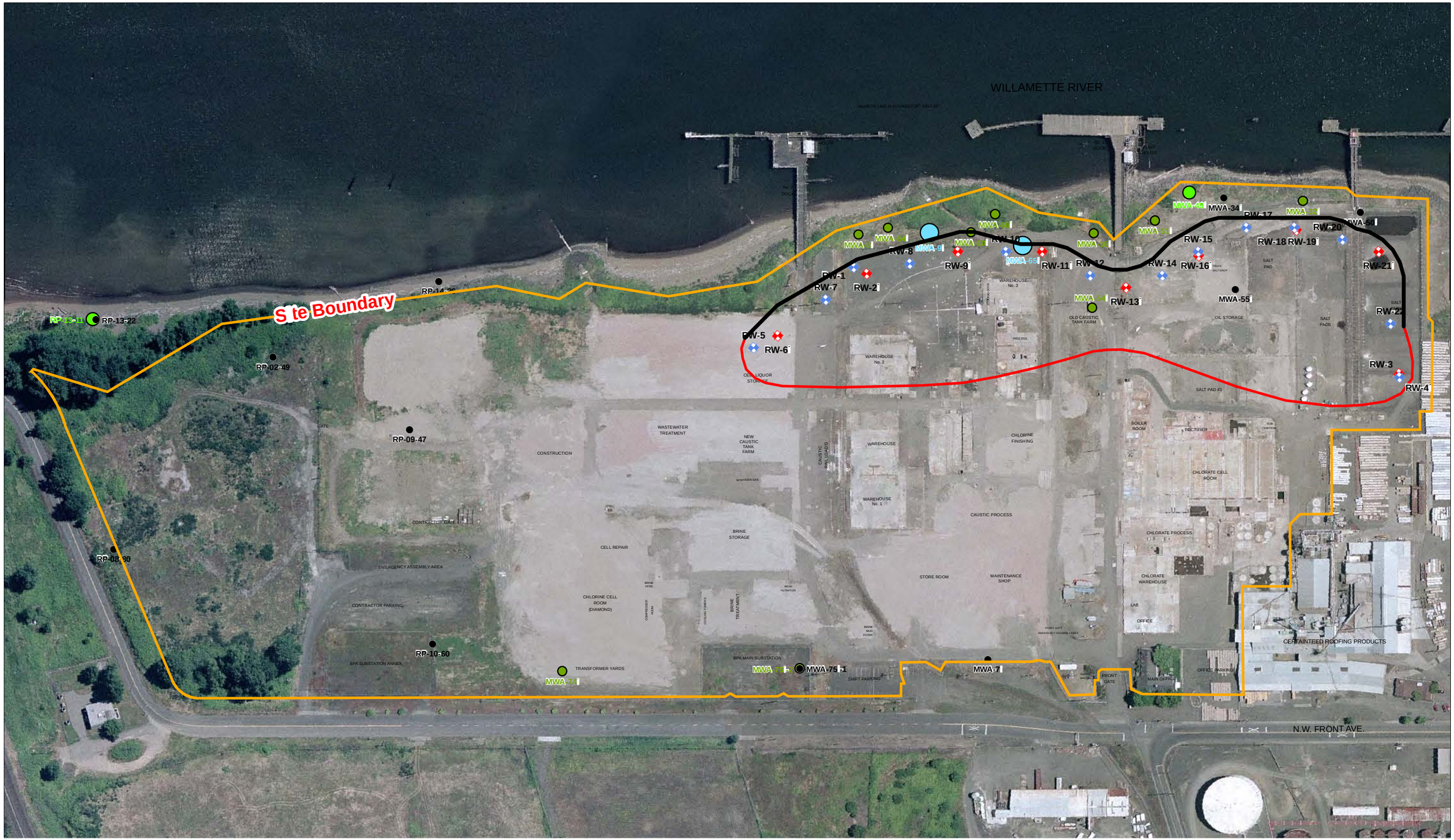
ERM 11/09

Project Number: 0104584

Date: 01/14/2010

Created By: mike.appel

File: F:\RM106\ERM West\Arkema\0104584 GW Monitoring Aug 2009\1209Figures\DDxIntermed.mxd



Legend

- Proposed Barrier Wall Alignment
- Target Capture

DDx Concentration (µg/l)

- Not detected
- < 0.2 (DEQ Screening Criteria = 0.2 µg/l)
- 0.2 - 1
- 1 - 10
- 10 - 100
- 100 - 1,000
- > 1,000

- Shallow Zone Recovery Well
- Intermediate Zone Recovery Well

200 100 0 200 Feet

Scale 1:2,400

N

Note: DDX = Sum total of DDT, DDD, and DDE concentrations.

Aerial Photography: July 2005

FIGURE A-11
DDx Groundwater Concentrations
Intermediate Zone
August 2009
Arkema, Portland, OR

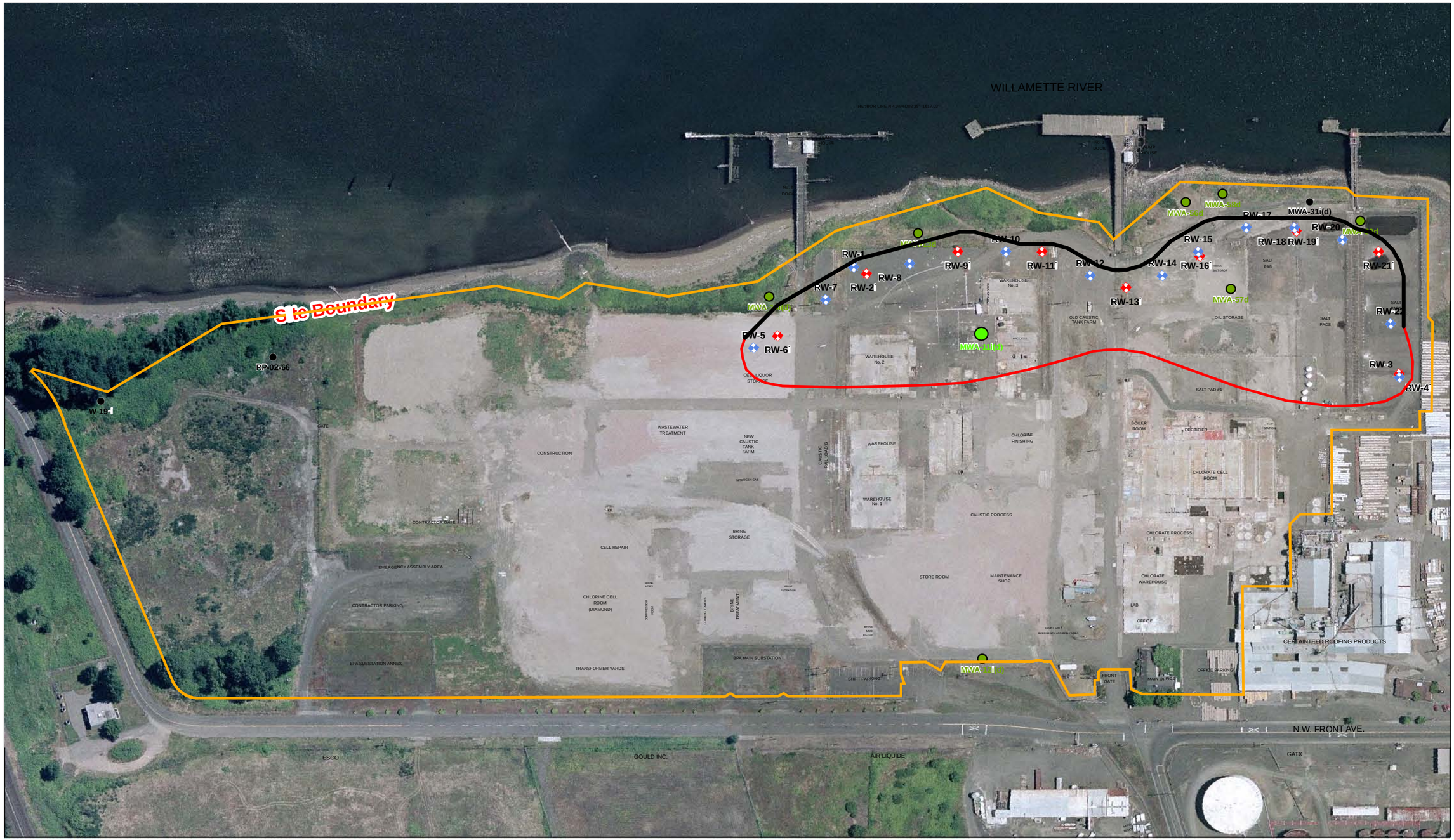
ERM 11/09

Project Number: 0104584

Date: 01/14/2010

Created By: mike.appel

File: F:\RM106\ERM West\Arkema\0104584 GW Monitoring Aug 2009\1209Figures\DDxDeep.mxd



Legend

- Proposed Barrier Wall Alignment
- Target Capture

DDx Concentration (µg/l)

- Not detected
- < 0.2 (DEQ Screening Criteria = 0.2 µg/l)
- 0.2 - 1
- 1 - 10
- 10 - 100
- 100 - 1,000
- > 1,000

- Shallow Zone Recovery Well
- Intermediate Zone Recovery Well

200 100 0 200 Feet

Scale 1:2,400

N

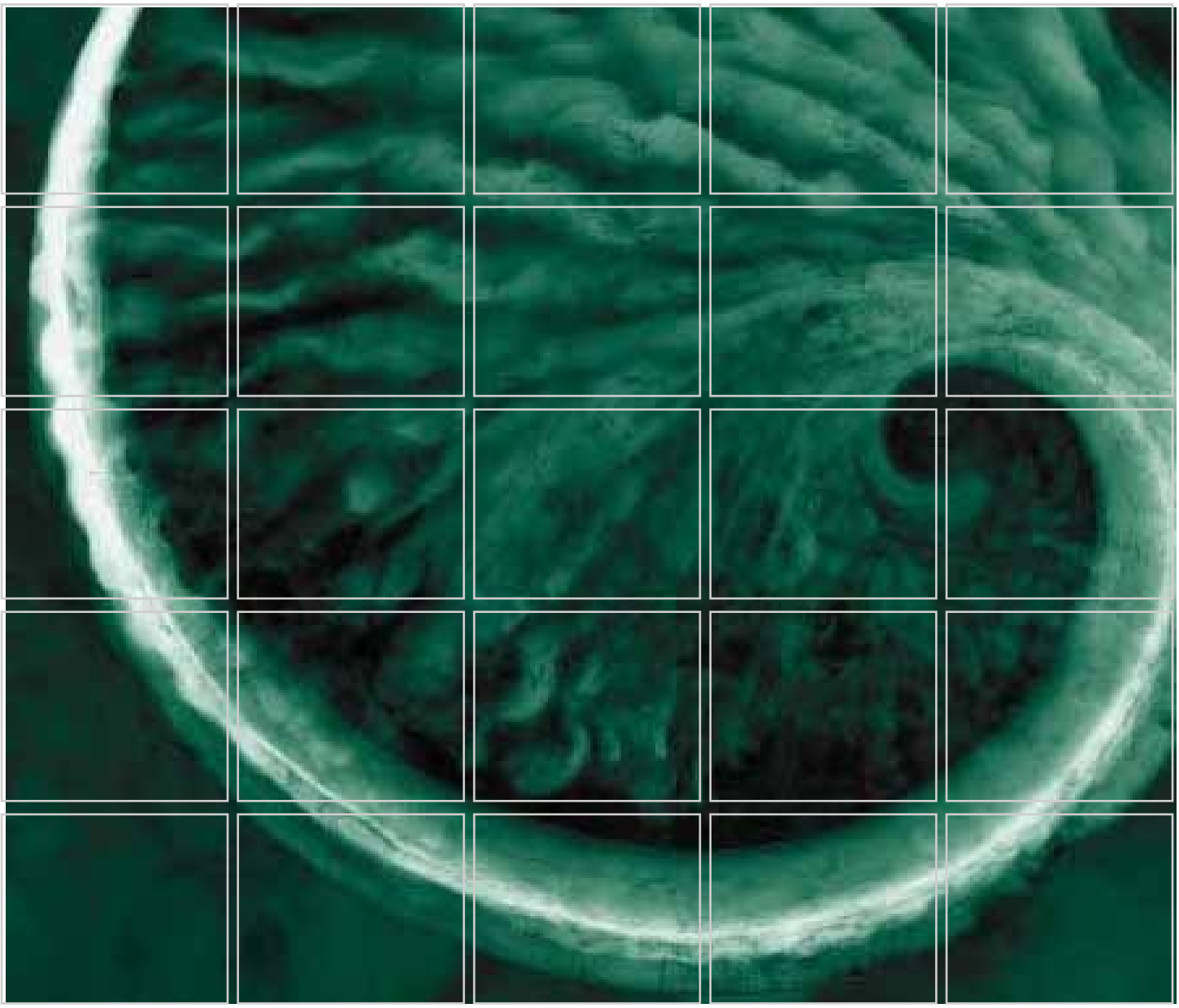
Note: DDx = Sum total of DDT, DDD, and DDE concentrations.

Aerial Photography: July 2005

FIGURE A-12
DDx Groundwater Concentrations
Deep Zone
August 2009
Arkema, Portland, OR

ERM 11/09

Appendix B
Aquifer Testing Pre-Design Investigation Report



Aquifer Testing Report - Groundwater Source Control Measure Pre-Design Investigation

Arkema, Inc. Facility
Portland, Oregon

Prepared for:
Legacy Site Services, LLC

May 2010

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Legacy Site Services, LLC

Aquifer Testing Report - Groundwater Source Control Measure Pre-Design Investigation

Arkema, Inc. Facility, Portland, Oregon

May 2010

Project No. 0104709

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1.0 INTRODUCTION

ERM-West, Inc. (ERM) has prepared this report on behalf of Legacy Site Services, LLC (LSS) to summarize the field activities and data generated during the 2009 aquifer testing event at the Arkema, Inc. (Arkema) facility in Portland, Oregon (the "site") (Figure 1).

The sampling was conducted in accordance with the *DRAFT – Data Gaps Assessment Work Plan* (Work Plan), dated March 2009 (ERM 2009a), and the *Former Arkema Portland Plant Responses to ODEQ/USEPA Comments on Pump Test Work Plan* (RTCs), dated 8 June 2009 (ERM 2009c) and approved by the Oregon Department of Environmental Quality (ODEQ)on 24 June 2009.

1.1 OBJECTIVES

The objectives of the aquifer testing event were to:

- Collect soil and groundwater data to support the design of the Groundwater Source Control Measure (SCM);
- Obtain better estimates of the hydraulic properties of the Shallow and Intermediate Zone aquifers; and
- Update the site-wide groundwater model developed in the Groundwater SCM Focused Feasibility Study (FFS), (ERM 2008b).

1.2 REPORT ORGANIZATION

The remainder of this report is organized as follows:

- Section 2.0 presents a summary of the procedures and field activities during the aquifer testing program;
- Section 3.0 presents the pumping test analysis procedures and data;
- Section 4.0 presents the results of the groundwater model update; and
- Section 5.0 lists the references cited in this report.

1.3 HYDROGEOLOGY

A detailed discussion of the site hydrogeology has been presented in the *Upland Remedial Investigation Report Lots 3 & 4 and Tract A – Revision 1* (ERM 2005) and the FFS (ERM 2008b). A site-wide groundwater model was created to support the alternatives evaluation conducted in the FFS. A full description of the groundwater model has been presented in the *DRAFT Groundwater Modeling Report* (ERM 2007). The groundwater model area is bounded to the west by Highway 30, to the north by the Siltronic property, the east by the Willamette River, and the south by the Certainteed property.

A brief description of the site hydrogeology is given below.

1.3.1 Hydrogeologic Zones

Groundwater occurs in six distinct water-bearing zones beneath the site (ERM 2007). These water-bearing zones have been designated as the Shallow Zone, Shallow-Intermediate Silt, Intermediate Zone, Deep Zone, Gravel Zone, and Fractured Basalt, as conceptualized in Figure 2. These zones are described below.

1.3.1.1 *Shallow Zone*

Groundwater in the Shallow Zone is unconfined, and occurs in the uppermost fill and sand at the site. In general, the depth to groundwater increases from 10 feet below ground surface (bgs) near NW Front Avenue, to 25 feet bgs near the Willamette River. The saturated thickness of the Shallow Zone is defined as the depth from the top of the water table to the upper surface of the Shallow-Intermediate Silt Zone, and ranges from approximately 10 feet near Front Avenue, to approximately 15 feet near the bank of the Willamette River.

1.3.1.2 *Shallow-Intermediate Silt Zone*

The Shallow Zone is underlain by the Shallow-Intermediate Silt Zone. This zone is comprised of silts, sandy silts, and clays. This layer is approximately 1 to 4 feet thick across the site and is discontinuous in the southern portion of the site (i.e. in the former Chlorate Manufacturing area). The Shallow-Intermediate Silt Zone tends to increase in thickness to the west of the site.

1.3.1.3 *Intermediate Zone*

Below the Shallow-Intermediate Silt Zone is a sand layer referred to as the Intermediate Zone. This zone comprises the upper portion of the semi-confined to confined Intermediate Zone at the site. This horizon occurs at depths between 36 and 50 feet bgs. The Intermediate Zone generally has a 5 to 10 foot saturation thickness across the site and is influenced by fluctuating river conditions (seasonal variations and daily tidal oscillations). The groundwater flow direction is to the northeast toward the Willamette River.

1.3.1.4 *Deep Zone*

Groundwater in the Deep Zone occurs in the finer-grained deposits below the alluvial sands and above the Columbia River Basalt. Below the sands, at depths from approximately 40 to 50 feet bgs, silt with some clay and fine sand is predominant. The depth and saturated thickness of the Deep Zone (approximately 5 to 45 feet) is controlled by the topography of the basalt bedrock.

1.3.1.5 *Gravel Zone*

In some portions of the site, alluvial gravel is present between the Deep Zone and the basalt bedrock. The Gravel Zone is typically approximately 10 feet thick, and tends to increase in thickness with proximity to the Willamette River (AMEC 2009).

The extent of this Gravel Zone throughout the site is still being investigated. The groundwater model was constructed and calibrated based on information available in June 2007. Additional investigations and interpretations are underway, and could lead to some revision of the extent of the Gravel Zone, particularly in the northern portion of the site on Lots 1 and 2 and the western portion of Lot 3 (ERM 2009b). The Gravel Zone has a significantly higher hydraulic conductivity than the overlying Deep Zone, and has been identified as a potential pathway of contaminant migration from the Rhone Poulenc (RP) site (AMEC 2007).

1.3.1.6 *Fractured Basalt*

The entire site is underlain by basalt bedrock that occurs at depths ranging between 47 and 105 feet bgs. Groundwater in the Fractured Basalt Zone is situated beneath the alluvial deposits to the maximum depth explored (approximately 216 feet bgs). Based on information presented in the *Stage*

1 Source Control Evaluation Technical Memorandum, *RP - Portland Site* (AMEC 2006) and *Stage 2 Source Control Evaluation Technical Memorandum, RP - Portland Site* (AMEC 2007), the basalt surface forms a large trough at the site that generally parallels Front Avenue. The Fractured Basalt Zone is characterized by fractured and weathered basalt with a low permeability relative to the Gravel Zone. The Fractured Basalt Zone is underlain by slightly weathered basalt bedrock.

The shallowest occurrence of basalt is located near the riverbank in the northeast corner of the site. A shallow ridge of basalt extends along the riverbank to the southeastern corner of the site, with the basalt contact sloping away steeply to the southwest toward Front Avenue.

1.3.2 Groundwater Flow

In general, the groundwater flow direction is toward the Willamette River. The water levels in the groundwater zones fluctuate seasonally, rising during periods of high rainfall in the winter months and falling during periods of low rainfall in mid to late summer. Shallow groundwater in close proximity to the Willamette River will also rise in direct response to large increases in the level of the Willamette River (e.g., during a flood). In general, these short-term fluctuations do not affect groundwater flow directions with the exception of short-term groundwater flow reversals in close proximity to the river.

2.0 FIELD PROCEDURES AND RESULTS

Field activities associated with the aquifer testing event occurred between August and October 2009 and included the following:

- Installation of pumping test recovery wells, observation wells, and piezometers;
- Development of new recovery wells and observation wells; and
- Performance of step discharge and constant rate discharge pumping tests.

This section summarizes the procedures for each activity and presents the data obtained during each activity.

2.1 WELL INSTALLATION AND SOIL SAMPLES

Four recovery wells, four observation wells, and two piezometers were installed following the methods described in the Work Plan and RTCs in preparation for the aquifer pumping tests. Well construction logs for all 10 locations are provided in Attachment A. Figure 3 identifies the location of the newly-installed wells/piezometers. The pumping test locations were selected to allow evaluation of conditions representative of the planned groundwater extraction wells, but also to minimize the constituent concentrations in the pumping test water, which required management. Table 1 summarizes the well/piezometer construction details.

The wells/piezometers were installed in general accordance with Oregon Administrative Rule (OAR) 690-200 and OAR 690-240. All wells/piezometers were installed by a licensed well driller (Cascade Drilling, Inc., of Clackamas, Oregon).

Recovery wells RW-1, RW-2i, RW-3, and RW-4i were installed between 27 August 2009 and 1 September 2009. RW-1 and RW-2i were installed at the north end of the proposed groundwater barrier wall (GWBW), and RW-3 and RW-4i were installed at the south end of the proposed GWBW (Figure 3). Observation wells MWA-78i, MWA-79, MWA-80i, and MWA-81i were installed between 24 and 26 August 2009. MWA-78i was installed on the north end of the proposed GWBW and the other three observation wells (MWA-79 through MWA-81i) were installed at the

south end. Piezometer PA-1d was installed at the north end of the proposed GWBW on 10 October 2009 and PA-2d was installed at the south end on 8 September 2009.

2.1.1 *Subsurface Clearance*

Prior to drilling, each location was cleared for subsurface utilities by:

- Creating an underground services alert dig ticket through the Oregon Utility Notification Center;
- Reviewing and inspecting the proposed locations with knowledgeable site personnel; and
- Hand-clearing borings to 5 feet bgs using a post-hole digger with a diameter greater than the drilling rod outer diameter.

2.1.2 *Drilling and Logging*

Wells/piezometers RW-2i, MWA-78i, MWA-79, MWA-80i, MWA-81i, and PA-1d were installed by a sonic drilling rig. Wells RW-1, RW-3, and RW-4i were installed by a hollow-stem-auger drilling rig. Piezometer PA-2d was installed by a direct-push drill rig. The total drilling depth for each borehole is provided in Table 1 and shown on the boring logs (Attachment A).

Wells/piezometers installed by sonic or by direct-push drilling rigs were sampled continuously. Recovery wells installed by hollow-stem-auger drill rigs (RW-1, RW-3, and RW-4i), were sampled at intervals identified in their respective well logs. Soil samples for geotechnical analysis were collected at depths identified in the well logs. Sample collection methods are detailed below.

Intermediate and Deep Zone wells installed at the north end of the GWBW in the Acid Plant area (RW-2i, MWA-78i, and PA-1d), were installed using temporary conductor casing to prevent potential downward migration of contaminants in the Shallow Zone. The conductor casing was installed approximately 0.5 feet into the Shallow-Intermediate Silt, as identified in the well logs.

2.1.3 *Well Installation*

Monitoring well construction was performed by an Oregon-licensed well driller from Cascade Drilling, Inc. Well construction details for each well

are provided in Table 1 and included in the boring logs (Attachment A). As indicated in the Work Plan, the final well construction depths were established based upon lithologic observations during drilling.

Recovery wells RW-1 through RW-4i were constructed of 4-inch diameter, 0.020-inch slot, wire-wrap type 304 stainless steel well screen, and were completed to ground surface with 4-inch diameter Schedule 40 polyvinyl chloride (PVC) blank casing. Observation wells MWA-78i through MWA-81i were constructed of 2-inch diameter, 0.010-inch slot Schedule 40 PVC screen and were completed to ground surface with 2-inch diameter Schedule 40 PVC blank casing. Piezometers PA-1d and PA-2d were constructed of 0.75-inch diameter, 0.010-inch slot Schedule 40 PVC screen and were completed to ground surface with 0.75-inch diameter Schedule 40 PVC blank casing.

The sand packs for recovery RW-1 through RW-4i and observation wells MWA-78i through MWA-81i, were constructed using Colorado 10/20 silica sand. The sand pack was generally installed to approximately 2.5 feet above the screened interval. In order to ensure that only the hydrogeologic unit of interest was screened, sand packs were installed in some wells to a short distance (a minimum of 1 foot) above the screened interval. In piezometers PA-1d and PA-2d, a pre-packed filter was installed around the screen prior to placing the well in the borehole. Because of the greater annulus caused by the sonic rig, additional sand was added to install PA-1d.

Well seals were constructed by placing 3/8-inch bentonite chips (Cetco PureGold® or Haliburton Holeplug®) from the top of the sand pack to approximately 2 feet bgs. The bentonite chips were hydrated according to OAR requirements. In piezometer PA-1d, the well seal consisted of approximately 13 feet of coated Enviroplug® 3/8-inch bentonite tablets placed on top of the sand pack, and 3/8-inch bentonite chips filled to ground surface. In piezometer PA-2d, the drill casing was first pulled up 10 feet to expose the well screen and the bottom 5 feet of blank casing to the surrounding formation. Once the formation had collapsed around the piezometer casing, the remaining annulus was filled with bentonite grout.

Each well and piezometer was completed at ground surface with a traffic-rated, flush-mounted well box set in concrete.

2.1.4 *Soil Sample Collection*

Multiple soil samples were collected during drilling of each recovery and observation well, as shown in the well construction logs (Attachment A). Selected samples were analyzed for geotechnical parameters, as detailed in Table 2.

Attachment B provides a technical memorandum summarizing the results of the geotechnical sample analyses and provides the geotechnical laboratory data reports.

2.1.5 *Decontamination Procedures*

The sample barrel and the outer drill casing were decontaminated after installation of each well/piezometer. The sample barrel and casing rods were decontaminated by spraying with a high-pressure steam washer. The decontamination water was collected and pumped into 55-gallon steel drums.

2.1.6 *Investigation-Derived Waste*

Soil cuttings were placed into 55-gallon steel drums for profiling and appropriate off-site disposal. The decontamination water was collected in 55-gallon steel drums and transferred to on-site storage tanks for subsequent treatment and disposal.

2.1.7 *Well Development*

Recovery wells and monitoring wells were developed using methods outlined in the Work Plan and RTCs. All wells were surged and bailed, and then pumped. Air jetting was also used during the development of recovery well RW-2i. Temperature, pH, and turbidity were monitored during pumping. Wells were pumped until parameters had stabilized, or until a minimum of 10 well volumes were removed.

2.2 *AQUIFER PUMPING TESTS*

Pumping tests were performed on four recovery wells, RW-1 through RW-4i. Wells RW-1 and RW-3 were screened in the Shallow Zone and wells RW-2i and RW-4i were screened in the Intermediate Zone. The pumping tests were performed sequentially in RW-4i, RW-3, RW-1, and then RW-2i, following methods provided in the Work Plan and RTCs.

Table 3 provides a summary of the monitoring wells where water levels were measured as part of each aquifer test. For each aquifer test, a transducer was installed in the recovery well, two observation wells, and one background well. Additional water levels were collected from surrounding wells by electronic water level meter.

Samples of the groundwater were collected during the pumping tests and analyzed for various groundwater analytical parameters, as detailed in Table 4. Attachment C provides the analytical data packages from analysis of groundwater samples. The pumping test discharge water was stored, treated, and then discharged to sanitary sewer. Attachment D provides the discharge report, as required under the city of Portland Batch Discharge Permit.

Attachment E includes the water levels collected by an electronic water level meter. Attachment F (electronic only) provides the transducer data obtained from each pumping test. Analysis of the pumping test data is presented in Section 3.0. The procedures followed during implementation of the pumping are detailed below.

2.2.1 General Testing Procedures

Aquifer testing consisted of conducting a step discharge test and a constant rate discharge test on each recovery well. The step discharge test and constant rate discharge test procedures are described below. These procedures were repeated for each recovery well, and associated observation and background wells.

1. Background water levels - Transducers were placed in the wells and water pressure/temperature was logged for a minimum of 3 days prior to pumping activities.
2. Step tests - For each recovery well, a low, medium, and high flow rate was determined based on flow rates measured during well development. The recovery wells were pumped at each flow rate until the water level in the recovery wells stabilized, for a maximum of 4 hours, or until the water level in the recovery wells dropped below the pump intake. Transducers recorded water pressure and temperature throughout the step tests. Water levels were also periodically measured with an electronic water level meter in all associated observation wells prior to, and during the low, medium, and high flow rate step discharge tests.
3. Recovery I - After completion of each step test, the pump was turned off and the aquifer was allowed to recover overnight. Transducers

recorded water pressure and temperature throughout the step discharge test recoveries. Water levels were also periodically measured with an electronic water level meter in all associated observation wells.

4. Constant rate discharge tests - Recovery wells were pumped at a constant rate determined based on the step test results. Pumping was continued for a minimum of 24 hours. Transducers recorded water pressure and temperature throughout the step tests. Water levels were also periodically measured with an electronic water level meter in all associated observation wells prior to, and during the constant rate discharge tests.
5. Recovery II - After completion of each constant rate discharge test, the pump was turned off and the aquifer was allowed to recover overnight. Transducers recorded water pressure and temperature throughout the constant rate discharge test recoveries. Water levels were also periodically measured with an electronic water level meter in all associated observation wells.

2.2.2 *Equipment*

All recovery wells were pumped using a 3-inch diameter, down-hole pump-fitted check valve and powered by an on-site generator. A ball valve and flow meter were placed in the pump discharge line to measure and control flow rate.

Transducers were placed in the recovery well and the associated observation and background wells noted on Table 3. The transducers were vented to allow equilibration with atmospheric pressure. Each transducer was lowered to approximately 2 inches from the bottom of the well. In the recovery well, the pump was placed in the well first and then the transducer was lowered so that it was sitting slightly above the pump. Barometric pressure was monitored during each aquifer test using a pressure transducer installed adjacent to the pumping well.

Water levels were measured in all observation wells and in the background well to the nearest 0.01 inch using an electronic water level meter. The measured depth to water and the time of measurement was recorded (Attachment E). Attachment E includes the times and rates of pumping and the water levels collected by an electronic water level meter. Attachment F (electronic only) provides the transducer data obtained during each step discharge test.

2.2.3 *Groundwater Sample Collection*

During each constant rate discharge test, three groundwater samples were collected from the recovery well. One sample was collected within 1 hour of beginning the pumping test, a second sample was collected approximately 12 hours after beginning the pumping test, and a third sample was collected within the hour prior to the end of the pumping test. These samples were intended to provide an indication of the changes in influent concentrations that may be expected during initial pumping of recovery wells.

Each sample was collected directly from a spigot in the pump discharge line. The sample containers were labeled and placed in coolers containing ice. The samples were transported under proper chain-of-custody procedures to Test America Laboratory in Beaverton, Oregon. Table 5 summarizes the analytical results for each sample. Laboratory analytical data packages for these groundwater samples are provided in Attachment C.

2.2.4 *Investigation-Derived Waste*

Purge water generated during well development and the pumping tests was treated by pumping it through a 5-micron bag filter to remove large solids, and a granular activated carbon unit to remove organic compounds. The treated discharge water was temporarily stored on site in polyethylene tanks, prior to discharging to the sanitary sewer under city of Portland Batch Discharge Permit (Attachment D). Prior to discharge, a sample of the treated water from each recovery well was collected from the storage tank and analyzed for compounds specified in the discharge permit. A copy of the discharge report provided to the city of Portland, including the laboratory analytical data package, is provided in Attachment D.

2.3 *DEVIATIONS FROM THE WORK PLAN*

The following deviations from the Work Plan and RTCs occurred while conducting activities related to the aquifer tests:

- Recovery well RW-2i was installed by sonic drill rig rather than hollow-stem auger in order to allow installation of conductor casing in the Shallow-Intermediate Silt Zone of the Acid Plant area. Conductor casing wide enough to accommodate a 4-inch diameter well plus an

auger was not available. To prevent any concerns related to the use of a sonic drill, additional care was taken during development of this well. No impact on data quality is expected from this deviation.

- PA-1d was initially installed on 10 September 2009 by direct-push drilling methods. However, drill tooling was lost below ground during the well installation process. As detailed in an email to ODEQ, dated 8 October 2009, ERM attempted to recover the tooling by over drilling with a sonic rig but was unsuccessful. Therefore, a replacement piezometer was installed by sonic rig approximately 5 feet south of the original location. The change in well installation location and drilling method did not impact aquifer testing.
- Barometric pressure readings were not logged during the final aquifer test at RW-1 due to field error. Since transducers were vented to the atmospheric air, additional correction for ambient pressure is not needed. Therefore, this error will not impact data quality.

3.0 AQUIFER PUMPING TEST ANALYSIS

The objective of the aquifer testing program was to obtain site-specific estimates of the hydraulic properties of the Shallow and Intermediate Zones, and estimate the radius of influence of pumping wells in this area. The drawdown data from the aquifer tests were also used to re-calibrate the groundwater flow model developed for the Groundwater SCM FFS (ERM 2008b).

Aquifer pumping tests were performed on four recovery wells and water levels in observation wells were monitored throughout the pumping tests. The background water levels in the recovery and two observation wells were monitored for approximately 3 days prior to the start of the step discharge test. Water level monitoring continued throughout the step discharge pumping test, the recovery phase of the step discharge test, the constant discharge test, and the recovery phase of the constant rate discharge test.

3.1 PUMPING TEST ANALYSIS PROCEDURES

The analysis of pumping test data was performed through the following procedures:

- Visual analysis of the 72-hour background monitoring data to determine if tidal fluctuations could potentially affect drawdown measurements during the pumping tests;
- Correction of the water level measurements taken during the constant rate discharge pumping tests, as necessary, for tidal fluctuation as described in Section 3.1.2; and
- Analysis of corrected tidal drawdown data to estimate hydraulic conductivity.

3.1.1 Hydrogeological Analysis

Data gathered during the pumping tests were analyzed in order to determine aquifer properties using the AQTESLOV™ aquifer test analysis software package. AQTESOLV™ software facilitates the use of graphics for analyzing pumping test data. Solutions were matched both visually and using automated parameter estimation tools, as appropriate.

A separate pumping test analysis was performed for each well and a distance drawdown analysis was performed for each pumping test. The analysis methods employed and the assumptions of each method are described below.

The site conditions within the area influenced by the pumping wells are generally consistent with the assumptions listed below. However, in reality, all aquifers have a finite aerial extent and some spatial variability in aquifer material and thickness. By using multiple observation wells, and several analysis methods, a range of hydraulic conductivity estimates can be calculated. These hydraulic conductivities can then be used to verify the hydraulic conductivity estimates used in the groundwater model.

3.1.1.1 *Shallow Zone*

Data collected from wells located in the Shallow Zone (i.e. RW-1 and RW-3) were analyzed using the Neuman solution for unconfined aquifers (Neuman 1974). The following assumptions apply to the Neuman solution:

- Aquifer has an infinite areal extent;
- Aquifer is homogeneous, isotropic, and of uniform thickness;
- Aquifer is unconfined;
- Flow is unsteady; and
- Diameter of pumping well is small so that storage in the well is negligible.

3.1.1.2 *Intermediate Zone*

Intermediate Zone data (i.e. wells RW-2i and RW-4i) were analyzed using the Hantush solution for leaky confined aquifers (Hantush 1960). The following assumptions apply to the Hantush solution:

- Aquifer has an infinite areal extent;
- Aquifer is homogeneous, isotropic, and of uniform thickness;
- Pumping well is fully or partially penetrating;
- Flow to pumping well is horizontal when pumping well is fully penetrating;
- Aquifer is leaky;

- Flow is unsteady;
- Water is released instantaneously from storage with decline of hydraulic head;
- Diameter of pumping well is small so that storage in the well is negligible;
- Confining bed(s) has infinite areal extent, uniform vertical hydraulic conductivity, and uniform thickness;
- Confining bed(s) is overlain or underlain by an infinite constant rate head plane source; and
- Flow in the aquitard(s) is vertical.

3.1.1.3 Distance Drawdown

Distance drawdown analysis was performed by analyzing data collected immediately prior to the recovery phase of the pumping test using the Cooper-Jacobs straight line method (Cooper and Jacob 1946). The straight line method can only be used to calculate transmissivity as long as enough time has passed for the effects of aquitard leakage, well storage, partial penetration, and delayed yield to have dissipated.

The estimated transmissivity calculated using the distance drawdown method was considered the more accurate method of estimating the hydraulic conductivity for the purpose of the groundwater extraction and treatment system design. This method reduces the effect of spatially variable soils on the analysis, and is more reflective of the long-term pumping rates that are achievable in the aquifers.

3.1.2 Tidal Correction of Data

The Willamette River adjacent to the site is influenced by tides. Historical groundwater monitoring data suggest that river fluctuations are propagated inland through the Intermediate and Deep Zones (ERM 2005). Analysis of the background monitoring and pumping test water level data indicated that wells screened in the Shallow Zone were not significantly affected by tidal fluctuations. However, wells screened in the Intermediate and Deep Zones were affected by tidal fluctuations. In order to estimate the hydraulic conductivity from the Intermediate Zone well data, it was necessary to remove the influence of tidal fluctuations (i.e. normalize) from the measured drawdowns in each Intermediate Zone observation and recovery well. The method used for correcting tidal effects consisted

of using background monitoring data from each well to calculate a "correction" factor that could be applied to the measured drawdowns as a function of time from the observed peak tide.

For the purpose of tidal correction, a daily tidal cycle consisted of two high tides and two low tides. A full tidal cycle was considered to start at the peak high tide and end at the next peak high tide. Background monitoring data were collected at one minute intervals for at least 72 hours prior to starting each step discharge test. Thus, each background data set contained either two or three full daily tidal cycles.

The average water level in an individual well was calculated for the available full tidal cycles. A normalizing value, or correction factor, was then calculated for each individual data point in the background data set. The normalizing values for data points in each tidal cycle were then averaged based on the time after the peak tide (i.e. an average normalizing value for every minute after the peak high tide).

The average normalizing values were then applied to the observed data set, based on the time from the observed peak tide. The data from the last full tidal background were normalized and visually compared to the observed data and the average background water levels.

The average normalizing values were then applied to the observed data set from the constant rate discharge tests. Hydrogeological analyses were then performed using the normalized data sets.

The estimates of hydraulic conductivity are also influenced by the efficiency of the recovery well. An estimate of the well efficiency was calculated by comparing the observed drawdown to the predicted drawdown.

3.2 *PUMPING TEST ANALYSIS RESULTS*

This section presents the results and analysis of the pumping tests.

Attachment E includes the times and rates of pumping, and the water level measurements collected by an electronic water level meter. Attachment F (electronic only) provides the pressure transducer data obtained during each step discharge test. Attachment G (electronic only) provides the results of tidal correction calculations. Attachment H provides plots of the pressure transducer data, including, where

necessary, tidal corrected data. Attachment I provides a summary of the AQTESOLV™ output files for each pumping test.

3.2.1 RW-1 Pumping Test

3.2.1.1 Pumping Rates

A step discharge test was performed at RW-1 on 13 October 2009. Prior to starting the test, water levels were measured using an electronic water level meter. The transducers were programmed to begin measuring water levels within the identified wells (Table 3) approximately 5 minutes prior to the beginning of the pumping test. The pump was turned on at 08:46 and set to discharge at approximately 2.5 gallons per minute (gpm). At 10:30, the flow rate was increased to approximately 8.5 gpm. The water level in RW-1 did not stabilize within 4 hours; therefore, at 15:00, the flow rate was increased to approximately 10.0 gpm. The water level in RW-1 dropped below the pump intake about 40 minutes later and the pump rate was decreased to approximately 9.0 gpm. Pumping continued for another hour to allow the water level to stabilize, and then the pump was turned off. Water levels were monitored during the recovery phase for approximately 24 hours.

The constant rate discharge test at RW-1was started on 14 October 2009 at 12:45. Water levels were measured in all associated wells using an electronic water level meter prior to starting the test. The transducers were programmed to begin measuring water levels within the identified wells (Table 3) approximately 1 minute prior to beginning the pumping test. The pump was initially set to discharge at approximately 7.7 gpm. At 11:05 on 15 October, the discharge rate was reduced to 6.49 gpm because the water level in RW-1 dropped to the pump intake and the pump was turned off at 12:45. Water levels were monitored during the recovery phase for approximately 24 hours.

3.2.1.2 Water Level Monitoring

The background monitoring data collected using pressure transducers in recovery well RW-1, observation wells MWA-2 and MWA-60, and the background observation well MWA-6r, are presented in Attachment F (electronic only). Plots of the background data from each of these wells are provided in Attachment H. The tidal fluctuations observed in the background data were negligible when compared to the observed drawdown during the constant rate discharge test.

A plot of the manual measurements of drawdown during the constant rate discharge test in recovery well RW-1, observation wells, background well, and additional observation wells is shown in Attachment E. Significant tidal fluctuations (0.7 feet) were observed in the Intermediate and Deep Zone wells, with smaller fluctuations observed in the Shallow-Intermediate Zone wells. No tidal fluctuations were observed in the Shallow Zone in either the observation wells or the background monitoring well, MWA-6r. Wells closer to the river generally had greater amplitude of tidal fluctuation.

A full round of water levels was collected at the end of the 24 hours of pumping (elapsed time approximately 1410 minutes). Approximately 0.29 feet of drawdown was observed in the closest observation well, MWA-60, located approximately 57 feet across gradient from RW-1. However, there was very little drawdown in MWA-2, which is located approximately 66 feet down gradient from RW-1. No drawdown was observed in the additional observation wells in the Intermediate or Deep Zone.

3.2.1.3 *Pumping Test Analysis Results*

The hydrogeological analysis of the RW-1 constant rate pumping test was performed using pressure transducer data. No barometric correction of the data was required because the pressure readings were collected using vented transducer cables. The pressure transducer data are provided in Attachment F (electronic only). Plots of the pressure transducer data are provided in Attachment H.

As described above, the Neuman solution for unconfined aquifers was used to calculate transmissivity and storativity for each individual well data set using the AQTESOLV™ software. Transmissivity and storativity were also calculated from the distance drawdown data using the Cooper Jacob method. The results of AQTESOLV™ calculations are presented in Attachment I. An average saturated thickness of 7.75 feet was used to calculate a hydraulic conductivity. The hydraulic conductivity results are summarized in Table 6. The calculated hydraulic conductivities varied between 25 feet per day and 268 feet per day. These values for hydraulic conductivity are within the normal range for fine- to medium-grained alluvial sands (Fetter 1994).

The distance drawdown estimate of hydraulic conductivity (46 feet per day) was considered the most accurate, as the effects of variability in soil type, saturated thickness, and excessive drawdown in the recovery well were minimized in this method. This value of hydraulic conductivity was

used to calculate the efficiency of the recovery well (Table 7). RW-1 had an efficiency of 52 percent, indicating that this well had a reasonable hydraulic connection to the aquifer. Additional development of this well may improve the pumping efficiency.

3.2.2 *RW-2i Pumping Test*

3.2.2.1 *Pumping Rates*

The step discharge test at RW-2i was performed on 20 October 2009. Prior to starting the test, water levels were measured using an electronic water level meter. The transducers were programmed to begin measuring water levels within the identified wells (Table 3) approximately 5 minutes prior to beginning the pumping test. The pump was turned on at 08:45 and set to discharge at approximately 3.0 gpm. At 11:30, the flow rate was increased to approximately 7.0 gpm. The water level in RW-2i did not stabilize within 4 hours; therefore, at 15:30 the flow rate was increased to approximately 9.0 gpm. The water level in RW-2i dropped below the pump intake almost immediately and the pump rate was decreased to approximately 6.8 gpm. Pumping was continued for another 30 minutes to allow the water level to stabilize. Water levels were monitored during the recovery phase for approximately 24 hours.

The constant rate discharge test at RW-2i was started on 21 October 2009 at 08:45. Water levels were measured in all wells using an electronic water level meter prior to starting the test. The transducers were programmed to begin measuring water levels within the identified wells (Table 3) approximately 1 minute prior to beginning the pumping test. The pump was initially set to discharge at approximately 6.0 gpm. The discharge rate was reduced to 5.8 gpm at 00:47on 22 October because the water level in RW-2i dropped to the pump intake. The pump was turned off at 09:45 on 22 October 2009. Water levels were monitored during the recovery phase.

3.2.2.2 *Water Level Monitoring*

The background monitoring data that were collected using pressure transducers in recovery well RW-2i, observation wells MWA-8i and MWA-78i, and background observation well MWA-16i, are presented in Attachment F (electronic only). Plots of the background data from each of these wells are provided in Attachment H. Significant tidal fluctuations were observed in the background data when compared to the observed drawdown during the constant rate discharge test.

The plot of the manual measurements of drawdown during the RW-2i constant rate discharge test from the recovery well, observation wells, background well, and additional observation wells, is shown in Attachment E. Significant tidal fluctuations (approximately 0.75 feet) were observed in the Intermediate and Deep Zone wells, with smaller fluctuations observed in the Shallow-Intermediate Zone wells. Wells closer to the river generally had greater amplitude of tidal fluctuation. No tidal fluctuations were observed in the Shallow Zone additional observation wells.

The tidal fluctuations were normalized as per the method described above in Section 3.1.2. The tidal correction factor calculation results are presented in Attachment G. Plots of the background monitoring data, observed data, and corrected pumping test data are presented in Attachment H.

A full round of water levels was collected at the end of the 24 hours of pumping (elapsed time approximately 1410 minutes). Approximately 0.55 feet of drawdown was observed in the closest observation well MWA-78i, located approximately 32 feet down gradient from RW-2i. Due to tidal influence, there was little drawdown observed in MWA-8i, located approximately 82 feet down gradient from RW-2i. No drawdown was observed in the additional observation wells in the Shallow, Intermediate or Deep Zone.

3.2.2.3 *Pumping Test Analysis Results*

The hydrogeological analysis of the RW-2i constant rate pumping test was performed using pressure transducer data. No barometric correction of the data was required because the pressure readings were collected using vented transducer cables. The pressure transducer data are provided in Attachment F (electronic only). Plots of the pressure transducer data are provided in Attachment H.

As described above, the Hantush solution for leaky confined aquifers was used to calculate transmissivity and storativity for each individual well data set using the AQTESOLV™ software. Transmissivity and storativity were also calculated from the distance drawdown data using the Cooper Jacob method. The results of AQTESOLV™ calculations are presented in Attachment I. An average saturated thickness of 5.0 feet was used to calculate a hydraulic conductivity. The hydraulic conductivity results are summarized in Table 8. The calculated hydraulic conductivities varied between 21 feet per day and 84 feet per day. These values for hydraulic

conductivity are within the normal range for fine to medium grained alluvial sands (Fetter 1994).

The distance drawdown estimate of hydraulic conductivity (31 feet per day) was considered the most accurate, as the effects of spatial variability in soil type, saturated thickness, and tidal fluctuation were minimized in this method. This value of hydraulic conductivity was used to calculate the efficiency of the recovery well (Table 7). RW-2i had an efficiency of 31 percent, indicating the well had a poor connection to the aquifer. However, the data from this well were still considered useable for simulation of the pumping test with the groundwater model. Additional development of this well may improve the pumping efficiency.

3.2.3 RW-3 Pumping Test

3.2.3.1 Pumping Rates

The step discharge test at RW-3 was performed on 6 October 2009. Prior to starting the test, water levels were measured using an electronic water level meter. The transducers were programmed to begin measuring water levels within the identified wells (Table 3) approximately 5 minutes prior to beginning the pumping test. The pump was turned on at 09:30 and set to discharge at approximately 1.8 gpm. At 10:51, the flow rate was increased to approximately 5.1 gpm. At 13:40, the flow rate was increased to approximately 7 gpm. The water level in RW-3 dropped below the pump intake almost immediately and the pump rate was decreased to approximately 5.1 gpm. Pumping continued for another 25 minutes to allow the water level to stabilize, and then the pump was turned off. Water levels were monitored during the recovery phase.

The constant rate discharge test at RW-3 was started on 7 October 2009 at 08:31. Water levels were measured in all wells using an electronic water level meter prior to starting the test. The transducers were programmed to begin measuring water levels within the identified wells (Table 3) approximately 1 minute prior to beginning the pumping test. The pump was turned on and discharged at approximately 4.9 gpm. The pump was turned off at 08:31 on 8 October 2009. Water levels were monitored during the recovery phase for approximately 24 hours.

3.2.3.2 Water Level Monitoring

The background monitoring data that were collected using pressure transducers in recovery well RW-3, observation wells MWA-41 and

MWA-79, and background observation well MWA-42, are presented in Attachment F (electronic only). Plots of the background data from each of these wells are provided in Attachment H. The tidal fluctuations observed in the background data were negligible when compared to the observed drawdown during the constant rate discharge test.

The plot of manual measurements of drawdown during the constant rate discharge test in recovery well RW-3, observation wells, background well, and additional observation wells is shown in Attachment E. Significant tidal fluctuations (0.15 feet) were observed in the Intermediate and Deep Zone wells. Minor (less than 0.02 feet) tidal fluctuations were observed in the Shallow Zone observation wells and background monitoring well MWA-42.

A full round of water levels was collected at the end of the 24 hours of pumping (elapsed time approximately 1420 minutes). Approximately 0.1 feet of drawdown was observed in the closest observation well MWA-79, located approximately 12 feet up gradient from RW-3. There was approximately 0.01 feet of drawdown observed in MWA-41, which is located approximately 46 feet across gradient from RW-1. No drawdown was observed in the additional observation wells in the Shallow, Intermediate, or Deep Zone.

3.2.3.3 *Pumping Test Analysis Results*

The hydrogeological analysis of the RW-3 constant rate pumping test was performed using pressure transducer data. No barometric correction of the data was required because the pressure readings were collected using vented transducer cables. The pressure transducer data are provided in Attachment F (electronic only). Plots of the pressure transducer data are provided in Attachment H.

As described above, the Neuman solution for unconfined aquifers was used to calculate transmissivity and storativity for each individual well data set using the AQTESOLV™ software. Transmissivity and storativity were also calculated from the distance drawdown data using the Cooper Jacob method. The AQTESOLV™ calculations are presented in Attachment I. An average saturated thickness of 5.35 feet was used to calculate a hydraulic conductivity. The hydraulic conductivity results are summarized in Table 8. The calculated hydraulic conductivities varied between 165 feet per day and 399 feet per day. These values for hydraulic conductivity are consistent with the values used in the groundwater

model development and within the normal range for well sorted clean sands (Fetter 1994).

The distance drawdown estimate of hydraulic conductivity (165 feet per day) was considered the most accurate, as the effects of spatial variability in soil type, saturated thickness, and excessive drawdown were minimized in this method. This value of hydraulic conductivity was used to calculate the efficiency of the recovery well (Table 7). RW-3 had an efficiency of 88 percent, indicating that this well has a good hydraulic connection to the aquifer.

3.2.4 *RW-4i Pumping Test*

3.2.4.1 *Pumping Rates*

The step discharge test at RW-4i was initiated on 30 September 2009. Prior to starting the test, water levels were measured using an electronic water level meter. The transducers were programmed to begin measuring water levels within the identified wells (Table 3) approximately 5 minutes prior to beginning the pumping test. The pump was turned on at 12:00 and set to discharge at approximately 4.0 gpm. At 13:03, the flow rate was increased to approximately 8.1 gpm. The water level in RW-4i dropped below the pump intake about 50 minutes later and the pump rate was decreased to approximately 7.3 gpm. Pumping continued until 16:30 and then the pump was turned off. Water levels were monitored during the recovery phase.

The constant rate discharge test at RW-4i was started on 1 October 2009 at 11:02. Water levels were measured in all wells using an electronic water level meter prior to starting the test. The transducers were programmed to begin measuring water levels within the identified wells (Table 3) approximately 1 minute prior to beginning the pumping test. The pump was set to discharge at approximately 5.5 gpm. The pump was turned off on 2 October 2009 at 11:02. Water levels were monitored during the recovery phase.

3.2.4.2 *Water Level Monitoring*

The background monitoring data collected using pressure transducers in recovery well RW-4i, observation wells MWA-80i and MWA-81i, and background observation well MWA-52i, are presented in Attachment F (electronic only). Plots of the background data from each of these wells are provided in Attachment H. Significant tidal fluctuations were observed in

the background data when compared to the observed drawdown during the constant rate discharge test.

The plot of hand measurements of drawdown during the RW-4i constant rate discharge test from the recovery well, observation wells, background well, and additional observation wells, is shown in Attachment H. Significant tidal fluctuations (approximately 0.15 feet) were observed in the Intermediate and Deep Zone wells. Wells closer to the river generally had greater amplitude of tidal fluctuation. No tidal fluctuations were observed in the Shallow Zone additional observation wells.

The tidal fluctuations were normalized as per the method described above in Section 3.1.2. The tidal correction factor calculation results are presented in Attachment G. Plots of the background monitoring data, observed data, and corrected pumping test data are presented in Attachment H.

A full round of water levels was collected at the end of the 24 hours of pumping (elapsed time approximately 1410 minutes). Approximately 0.32 feet of drawdown was observed in the closest observation well MWA-80i, located approximately 21 feet across gradient from RW-4i. Approximately 0.20 feet of drawdown was observed in the observation well MWA-81i, located approximately 125 feet across gradient from RW-4i. No drawdown was observed in the additional observation wells in the Shallow, Intermediate, or Deep Zone.

3.2.4.3 *Pumping Test Analysis Results*

The hydrogeological analysis of the RW-4i constant rate pumping test was performed using pressure transducer data. No barometric correction of the data was required because the pressure readings were collected using vented transducers. The pressure transducer data are provided in Attachment F (electronic only). Plots of the pressure transducer data are provided in Attachment H.

As described above, the Hantush solution for leaky confined aquifers was used to calculate transmissivity and storativity for each individual well data set using the AQTESOLV™ software. Transmissivity and storativity were also calculated from the distance drawdown data using the Cooper Jacob method. The results of the AQTESOLV™ calculations are presented in Attachment I. An average saturated thickness of 7.5 feet was used to calculate a hydraulic conductivity. The hydraulic conductivity results are summarized in Table 8. The calculated hydraulic conductivities varied

between 3 feet per day and 28 feet per day. These values for hydraulic conductivity are within the normal range for fine alluvial sands (Fetter 1994).

The distance drawdown estimate of hydraulic conductivity (14 feet per day) was considered the most accurate, as the effects of spatial variability in soil type, saturated thickness, and tidal fluctuation were minimized in this method. This value of hydraulic conductivity was used to calculate the efficiency of the recovery well (Table 7). RW-4i had an efficiency of 22 percent. As discussed in Section 4.1 below, the low efficiency, (i.e., high well loss) prevented the groundwater model simulation of this pumping test. Additional development of this well may improve the pumping efficiency.

4.0 GROUNDWATER MODEL UPDATE

A site-wide groundwater model was developed in support of the design of the GW SCM (ERM 2008a). However, limited site-specific hydrogeological data were available for calibration of the groundwater model developed in the FFS. One of the objectives of the aquifer testing program was to provide sufficient site-specific data to confirm or, if necessary, update the calibration of the existing groundwater model.

4.1 PUMPING TEST MODEL SIMULATION

The groundwater flow model developed for the site was updated based on the results of the 24-hour pumping tests of RW-1, RW-2i, RW-3, and RW-4i. Transient calibration simulations of these four pumping tests were performed using the steady-state flow model, which was previously calibrated to water levels at the site measured in May 2007 (ERM 2007).

For the simulation of each pumping test, the model grid spacing was reduced 1 foot around the pumping and observation wells to more accurately simulate the drawdown measured in the pumping and observation wells during the test. A well node was added to the model grid to represent the pumping well. For the simulations of the RW-1 and RW-3 pumping tests, a well node was added to layer 1 of the model, which represents the Shallow Zone. For the simulations of the RW-2i and RW-4i pumping tests, a well node was added to layer 3 of the model, which represents the Intermediate Zone. The discharge rate of the well nodes was set at the average discharge rate recorded during the pumping test. The flow model was then calibrated to the pumping water levels by using the estimated input parameters and head solution from the calibrated steady-state model. The model was then solved for transient flow conditions with a total simulation time equal to the duration of the pumping test.

The input parameters of the model were then varied in successive simulations until the transient drawdown solutions of the model most closely matched the drawdown in water levels measured in the observation wells during the pumping tests. The transient drawdown solutions of the model for the recovery wells were not expected to closely match the measured drawdowns due to well losses that typically occur in pumping wells, which are not simulated by the model (Anderson and

Woessner 1992). As noted in below the well losses are significant in some recovery wells.

The results of the transient calibration of the groundwater flow model to the pumping tests of RW-1, RW-2i, RW-3, and RW-4i were evaluated by graphically comparing the drawdown in water levels measured in the pumping and observation wells during the tests to the model drawdown solutions (Attachment J). The model drawdown solutions reasonably match the measured drawdowns in the observation wells during the pumping tests. The drawdown simulated by the model is somewhat less than the observed drawdown in RW-2i, RW-3, and RW-4 due to well losses that occurred in pumping wells, which are not simulated by the model. The losses in the wells are minor, except for RW-4i (Attachment J).

Only minor changes to the hydraulic conductivities used in the model layers were required during the transient calibration simulations of the pumping tests. The hydraulic conductivity of layer 1 (Shallow Zone) was increased from 5 feet per day to 18 feet per day near RW-1 (Figure 4) and was decreased from 190 feet per day to 170 feet per day near RW-3. The hydraulic conductivity of layer 3 (Intermediate Zone) was decreased from 20 feet per day to 8 feet per day in the vicinity of RW-2i (Figure 5). The changes to the hydraulic conductivities used in model layers representing the Shallow and Intermediate Zones did not result in any significant changes to the steady-state model calibration (Attachment K).

The hydraulic conductivities calculated from distance drawdown data were compared to the values calculated from the model simulation of the pumping tests (Table 8). The updated model results were similar to the values calculated from pumping test data. The updated groundwater model was used to determine the location of the GW SCM recovery wells and anticipated extraction flow rates.

5.0 REFERENCES

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Figures

Project No. 0114849.01

Date: 05/17/10

Drawn By: R. Olson

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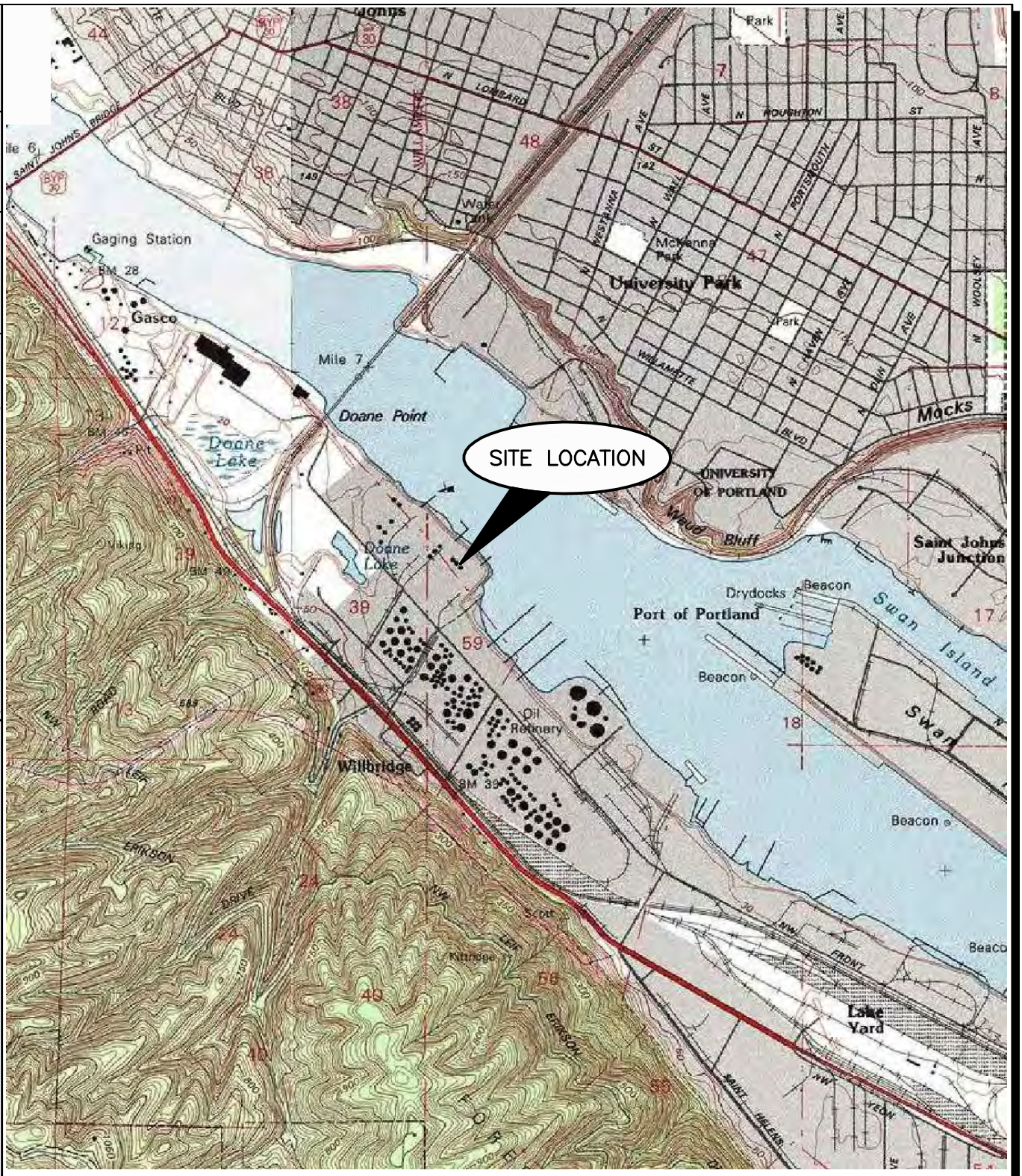

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1 .5 0 1 KILOMETER

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Portland, OR WA Version: 1990; Current: 1990

Figure 1
Site Location
Arkema, Inc.
Portland, Oregon

ERM 05/10

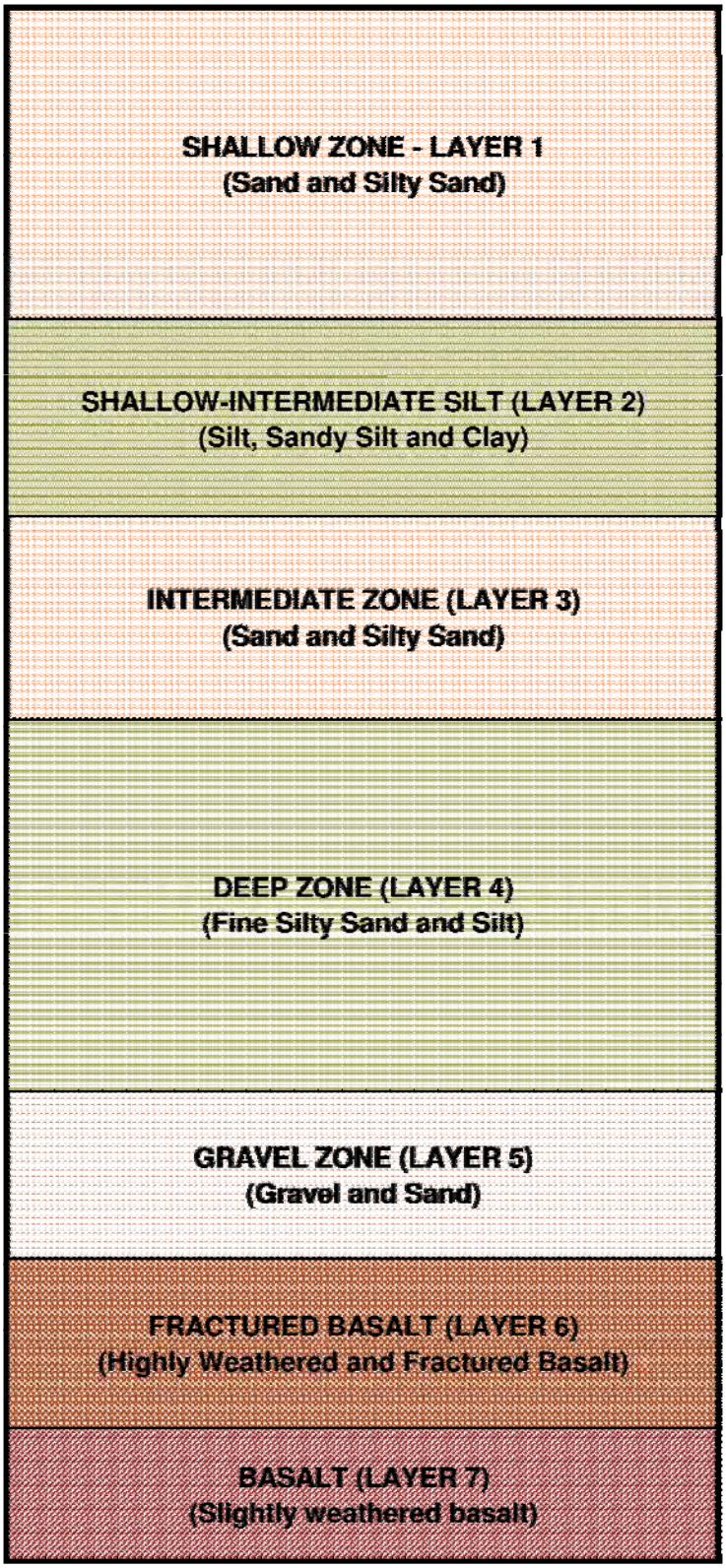

Figure 2
Conceptual Hydrostatic Units
Arkema Inc.
Portland, Oregon

ERM *04/10*

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Date: 04/26/10
Project No. 0093634.06

Project Number: 0104584

Date: 04/28/2010

Created By: mike.appel

File: F:\RM106\ERM West\Arkema\0104584 GW Monitoring Aug 2009\PumpTestLocations.mxd

New Wells

- Shallow Zone Monitoring Well
- Intermediate Zone Monitoring Well
- Deep Zone Piezometer
- Shallow Zone Recovery Well
- Intermediate Zone Recovery Well

Existing Monitoring Wells

- Shallow Zone
- Shallow-Intermediate Zone
- Intermediate Zone
- Deep Zone
- Gravel Zone
- Basalt Zone

200 100 0 200 Feet

Scale 1:2,400

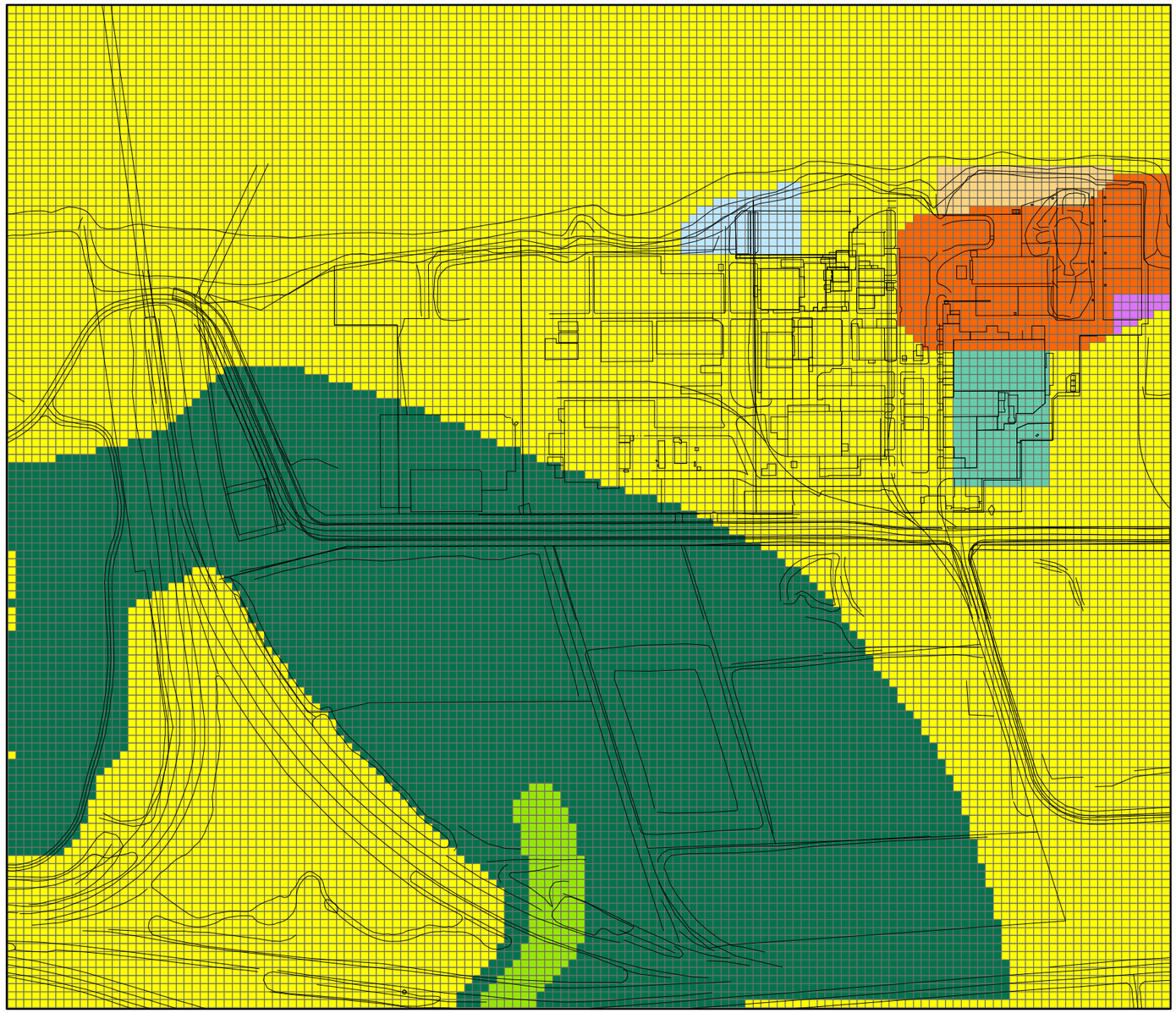
N

FIGURE 3
Aquifer Testing Well Locations
Arkema, Inc
Portland, Oregon

Aerial Photography: City of Portland, June 2008

ERM 04/10

GIS File:	Drawn By: T. Cota	Date: 01/19/10	Project No. 0104709



LEGEND

Hydraulic Conductivity	
190 ft/day	5.0 ft/day
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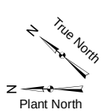
18 ft/day	Kh 8.0, Kv 0.008 ft/day
10 ft/day	Kh 2.0, Kv 0.002 ft/day



0 400 800
Feet

Figure 4
Revised Hydraulic Conductivity Zonation
Shallow Zone (Layer 1)
Arkema, Inc.
Portland, Oregon

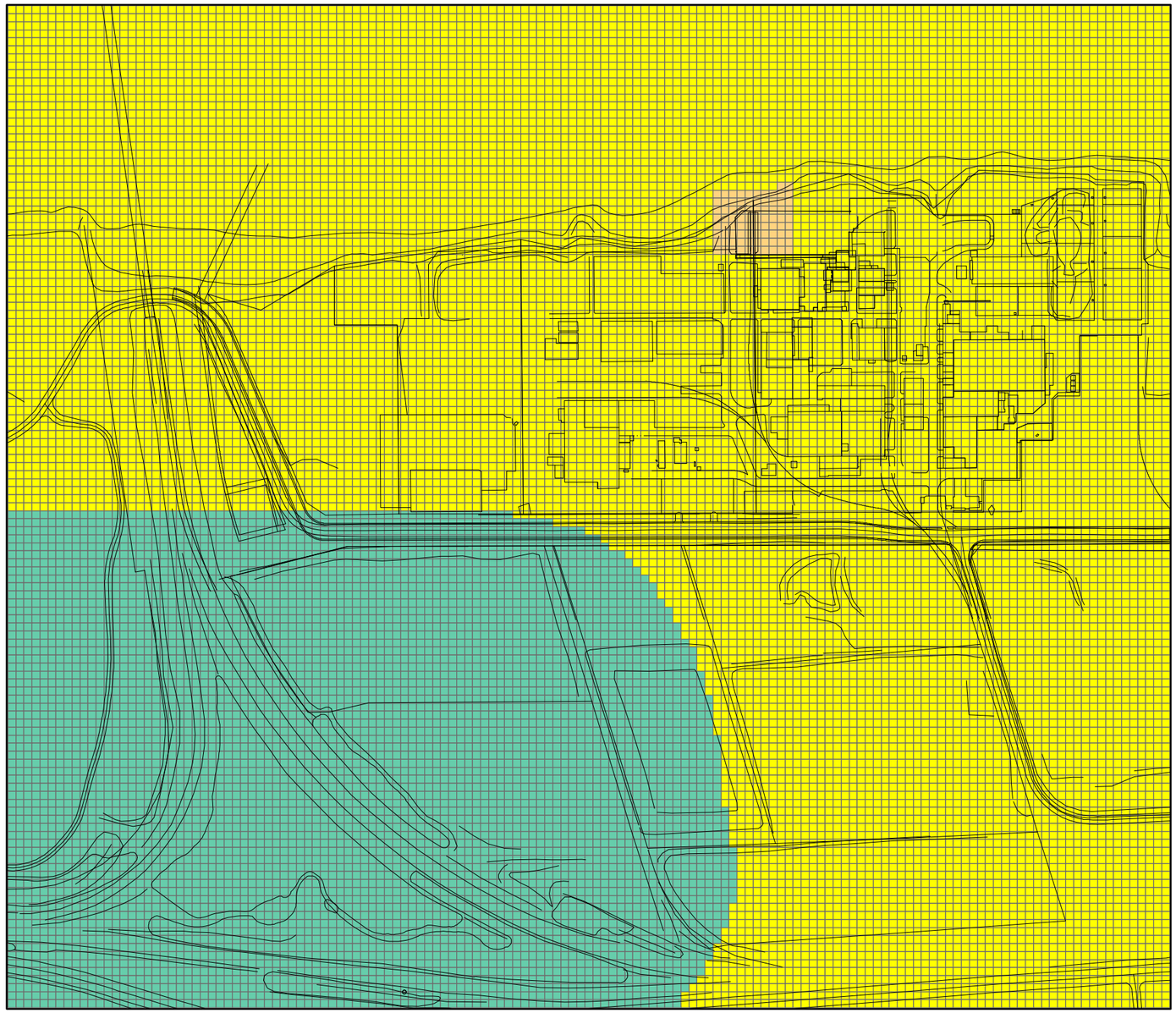
ERM 01/10

GIS File:

Drawn By: T. Cota

Date: 01/19/10

Project No. 0104709



LEGEND
Hydraulic Conductivity
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- 8 ft/day
- 2.0 ft/day

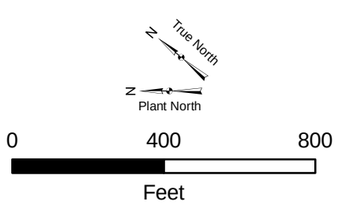


Figure 5
Revised Hydraulic Conductivity Zonation
Intermediate Zone (Layer 3)
Arkema, Inc.
Portland, Oregon

ERM 01/10

Tables

Table 1
Well Construction Information
Aquifer Testing Report
Arkema, Inc. Facility
Portland, Oregon

Well Number	Installation Date	Northing	Easting	Aquifer Classification	Depth Drilled (ft)	Measuring Point Elevation [a] (ft)	Ground Surface Elevation [a] (ft)	Well Diameter (in)	Screen Material	Screen Slot Size (in)	Screened Interval Depth Below Surface Bottom (ft)	Screened Interval Depth Below Surface Top (ft)	Sandpack Interval Depth Below Surface Bottom (ft)	Sandpack Interval Depth Below Surface Top (ft)	Sandpack Thickness (ft)
MWA-2	12/11/96	702507.29	7627621.41	Shallow	32.3	38.46	35.22	2	304 S.S.	0.010	31.5	21.5	32.3	18.5	13.8
MWA-8i	1/11/99	702500.54	7627628.33	Intermediate	47.3	38.09	35.43	2	304 S.S	0.010	47.0	42.0	47.3	39.8	7.5
MWA-41	4/6/05	701404.34	7628138.42	Shallow	35.0	37.77	38.01	2	Sch 40 PVC	0.010	34.3	25.1	35.0	23.0	12.0
MWA-60	7/26/05	702476.30	7627514.40	Shallow	38.0	35.59	35.73	2	Sch 40 PVC	0.010	36.8	27.0	37.6	25.2	12.4
MWA-78i	8/24/09	702468.19	7627576.94	Internediate	50.0	35.26	35.56	2	Sch 40 PVC	0.010	46.3	43.3	47.0	41.0	6.0
MWA-79	8/25/09	701443.36	7628113.24	Shallow	34.0	36.51	36.90	2	Sch 40 PVC	0.010	32.5	22.5	33.0	21.0	12.0
MWA-80i	8/25/09	701434.89	7628120.65	Intermediate	50.0	36.96	37.18	2	Sch 40 PVC	0.010	39.3	34.3	40.0	33.0	7.0
MWA-81i	8/26/09	701408.82	7628145.87	Intermediate	48.0	37.50	37.96	2	Sch 40 PVC	0.010	44.0	39.0	45.0	37.5	7.5
PA-1d	10/9/09	702446.58	7627587.38	Deep	50.0	34.92	35.37	1	Sch 40 PVC	0.010	49.0	48.0	50.0	48.0	2.0
PA-2d	9/8/09	701447.40	7628102.71	Deep	65.0	36.43	36.79	1	Sch 40 PVC	0.010	64.5	60.5	64.5	59.5	5.0
RW-1	8/31/09	702465.21	7627570.01	Shallow	41.5	35.07	35.48	4	304 S.S	0.020	34.7	19.8	35.0	17.0	18.0
RW-2i	8/27/09	702436.05	7627577.08	Intermediate	47.0	35.07	35.40	4	304 S.S	0.020	44.0	39.0	45.0	38.0	7.0
RW-3	8/31/09	701448.44	7628123.99	Shallow	34.0	36.63	36.96	4	304 S.S	0.020	30.3	15.3	31.0	13.5	17.5
RW-4i	9/1/09	701453.65	7628128.93	Intermediate	47.0	36.53	36.96	4	304 S.S	0.020	45.5	40.5	47.0	38.3	8.8

Notes:

[a] Vertical survey data from Hydrogeolical Investigation of the Doane Lake Area (G&M, 1991). Datum used is NAVD29, converted to NAVD88 (added 3.325 ft)
ft = feet
in = inch
Sch 40 PVC = Schedule 40 polyvinylchloride screen
304 S.S. = Wire-wrap type 304 stainless steel screen

Table 2
Geotechnical Sample Schedule
Aquifer Testing Report
Arkema, Inc. Facility
Portland, Oregon

Sample Location	Sample ID	Sample Depth (ft-bgs)	Collection Method	Sample Collection Date and Time	Geotechnical Analyses					
					Atterberg Limits	Shear Strength	Moisture	Dry Density	Soil Classification	Grain Size
MWA-80i	80i (33-35')	33-35	Shelby tube	8/25/2009 13:34	--	X	X	X	X	X
MWA-81i	81i (22-25')	22-25	Sonic	8/26/2009 11:35	X	--	X	--	X	X
MWA-81i	81i (46-48')	46-48	Shelby tube	8/26/2009 11:22	X	X	X	X	X	X
RW-1	RW-1 (30.5-31')	30.5-31	HSA-Brass tube	8/31/2009 9:45	--	X	X	X	X	X
RW-2i	RW-2i (45-47')	45-47	Shelby tube	8/27/2009 13:54	--	X	X	X	X	X
RW-4i	RW-4i (40-40.5)	40-40.5	HSA-Brass tube	9/1/2009 10:13	--	X	X	X	X	X

Notes:

ft-bgs = feet below ground surface

HSA =Collected by hollow stem auger

Sonic = Collected by sonic drill rig

Table 3
Aquifer Pumping Test Observation Wells
Arkema Inc. Facility
Portland, Oregon

Recovery Well[1]		Observation Well[1]		Background Well[1]		Additional Observation Well[2]	
Well ID	**Aquifer Zone**	**Well ID**	**Aquifer Zone**	**Well ID**	**Aquifer Zone**	**Well ID**	**Aquifer Zone**
RW-1	Shallow	MWA-2	Shallow	MWA-6	Shallow	MWA-3	Shallow
		MWA-60	Shallow			MWA-5	Shallow
						MWA-8i	Intermediate
						MWA-9i	Intermediate
						MWA-13d	Deep
						MWA-14i(d)	Deep
						MWA-17si	Shallow
						MWA-61	Shallow
						MWA-64i	Intermediate
						MWA-67si	Shallow
						PMP-4	Shallow
						PMP-5	Shallow
						MWA-78i	Intermediate
						PA-1d	Deep
RW-2i	Intermediate	MWA-8i	Intermediate	MWA-16i	Intermediate	MWA-5	Shallow
		MWA-78i	Intermediate			RW-1	Shallow
						MWA-2	Shallow
						MWA-61	Shallow
						MWA-64i	Intermediate
						MWA-67si	Shallow
						MWA-60	Shallow
						PA-1d	Deep
						PMP-4	Shallow
						MWA-3	Shallow
						MWA-9i	Intermediate
						MWA-17si	Shallow
						PMP-5	Shallow
						MWA-13d	Deep
						MWA-14i(d)	Deep
RW-3	Shallow	MWA-41	Shallow	MWA-42	Shallow	MWA-26	Shallow
		MWA-79	Shallow			MWA-80i	Intermediate
						MWA-52i	Intermediate
						MWA-81i	Intermediate
						PA-2d	Deep
						RW-4i	Intermediate
						MWA-43	Shallow
RW-4i	Intermediate	MWA-80i	Intermediate	MWA-54i	Intermediate	MWA-26	Shallow
		MWA-81i	Intermediate			MWA-41	Shallow
						RW-3	Shallow
						MWA-79	Shallow
						MWA-52i	Intermediate
						PA-2d	Deep

Notes:
1 - Water levels monitored using pressure transducers
2 - Water levels measured using an electronic water level meter

Table 4
Groundwater Sample Schedule
Aquifer Testing Report
Arkema, Inc. Facility
Portland, Oregon

Sample Location	Sample ID	Sample Depth (ft-bgs)	Sample Collection Date and Time	Chemical Analyses					
				VOC	TPH	Pesticides	Dissolved As, Fe, Mn	Perchlorate	Chloride
RW-1	RW-1-1	19.8-34.7	10/14/2009 13:30	X		X	X	X	X
RW-1	RW-1-2	19.8-34.7	10/15/2009 0:05	X		X	X	X	X
RW-1	RW-1-3	19.8-34.7	10/15/2009 12:00	X		X	X	X	X
RW-2i	RW-2i-1	39-44	10/21/2009 9:45	X		X	X	X	X
RW-2i	RW-2i-2	39-44	10/21/2009 20:45	X		X	X	X	X
RW-2i	RW-2i-3	39-44	10/21/2009 8:45	X		X	X	X	X
RW-3	RW-3-1	15.3-30.3	10/7/2009 9:00	X	X	X	X	X	X
RW-3	RW-3-2	15.3-30.3	10/7/2009 9:25	X	X	X	X	X	X
RW-3	RW-3-3	15.3-30.3	10/7/2009 20:30	X	X	X	X	X	X
RW-4i	RW-4i-1	40.5-45.5	10/1/2009 14:35	X		X	X	X	X
RW-4i	RW-4i-2	40.5-45.5	10/2/2009 0:35	X		X	X	X	X
RW-4i	RW-4i-3	40.5-45.5	10/2/2009 10:45	X		X	X	X	X

Notes:

As, Fe, Mn = Arsenic, Iron, and Manganese, respectively

ft-bgs = feet below ground surface

VOC = Volatile organic comppound

Table 5
Groundwater Analytical Results
Aquifer Pump Tests
Arkema Portland

Sample Location	RW-1			RW-2i			RW-3			RW-4i		
Sample ID	RW-1-1	RW-1-2	RW-1-3	RW-2i-1	RW-2i-2	RW-2i-3	RW-3-1	RW-3-2	RW-3-3	RW-4i-1	RW-4i-2	RW-4i-3
Sample Depth (ft-bgs)	19.8-34.7	19.8-34.7	19.8-34.7	39-44	39-44	39-44	15.3-30.3	15.3-30.3	15.3-30.3	40.5-45.5	40.5-45.5	40.5-45.5
Date/Time	10/14/2009 13:30	10/15/2009 0:05	10/15/2009 12:00	10/21/2009 9:45	10/21/2009 20:45	10/21/2009 8:45	10/7/2009 9:00	10/7/2009 9:25	10/7/2009 20:30	10/1/2009 14:35	10/2/2009 0:35	10/2/2009 10:45
Benzene	< 5.00	< 5.00	< 5.00	< 1.00	< 1.00	< 2.00	**2.69**	< 1.00	< 1.00	< 1.00	< 1.00	< 1.00
Toluene	< 5.00	< 5.00	< 5.00	< 1.00	< 1.00	< 2.00	**10**	< 1.00	< 1.00	< 1.00	**1.28**	< 1.00
Ethylbenzene	< 5.00	< 5.00	< 5.00	< 1.00	< 1.00	< 2.00	**1.05**	< 1.00	< 1.00	< 1.00	< 1.00	< 1.00
o-Xylene	< 5.00	< 5.00	< 5.00	< 1.00	< 1.00	< 2.00	**1.5**	< 1.00	< 1.00	< 1.00	< 1.00	< 1.00
m,p-Xylene	< 10.0	< 10.0	< 10.0	< 2.00	< 2.00	< 4.00	**4.43**	< 2.00	< 2.00	< 2.00	< 2.00	< 2.00
Acetone	< 125	< 125	< 125	< 25.0	< 25.0	< 50.0	**264**	< 25.0	< 25.0	< 25.0	< 25.0	< 25.0
2-Butanone	< 50.0	< 50.0	< 50.0	< 10.0	< 10.0	<20.0	**10.9**	< 10.0	< 10.0	< 10.0	< 10.0	< 10.0
Chloro- benzene	**184**	**248**	**286**	**54.2**	**82.5**	**108**	< 1.00	< 1.00	< 1.00	< 1.00	< 1.00	< 1.00
Chloroethane	< 5.00	< 5.00	< 5.00	< 1.00	< 1.00	< 2.00	< 1.00	< 1.00	< 1.00	< 1.00	< 1.00	< 1.00
Chloroform	< 5.00	< 5.00	< 5.00	< 1.00	< 1.00	< 2.00	< 1.00	< 1.00	< 1.00	< 1.00	< 1.00	< 1.00
Chloromethane	< 25.0	< 25.0	< 25.0	< 5.00	< 5.00	< 10.0	< 5.00	< 5.00	< 5.00	< 5.00	< 5.00	< 5.00
cis-1,2-Dichloroethene	**5.3**	**7.75**	**8.3**	< 1.00	< 1.00	< 2.00	< 1.00	< 1.00	< 1.00	< 1.00	< 1.00	< 1.00
TPH-g	NS	NS	NS	NS	NS	NS	< 80.0	< 80.0	< 80.0	NS	NS	NS
TPH-d	NS	NS	NS	NS	NS	NS	< 250	< 238 n2	< 500 n1	NS	NS	NS
TPH-h	NS	NS	NS	NS	NS	NS	< 500	< 476	< 500 n1	NS	NS	NS
4,4-DDE	< 0.0952	< 0.0952	< 0.0952	< 0.0952	< 0.0962	< 0.0943	< 0.0099	< 0.0101	< 0.00966	< 0.00952	< 0.00952	< 0.00952
4,4-DDD	< 0.0952	< 0.0952	< 0.0952	< 0.0952	< 0.0962	< 0.0943	< 0.0099	< 0.0101	< 0.00966	< 0.00952	< 0.00952	< 0.00952
4,4-DDT	< 0.0952	< 0.0952	< 0.0952	< 0.0952	< 0.0962	< 0.0943	< 0.0099	< 0.0101	< 0.00966	< 0.00952	< 0.00952	< 0.00952
4,4-DDx	< 0.0952	< 0.0952	< 0.0952	< 0.0952	< 0.0962	< 0.0943	< 0.0099	< 0.0101	< 0.00966	< 0.00952	< 0.00952	< 0.00952
As	**3.28**	**4.17**	**4.06**	**43.1**	**44.6**	**51.9**	< 1.00	< 1.00	< 1.00	**1.79**	**1.73**	**1.71**
Fe	**187**	**196**	**136**	**1540**	**1940**	**1530**	< 100	< 100	< 100	**105**	**102**	**113**
Mn	**74**	**200**	**216**	**268**	**319**	**259**	**2090**	**1620**	**1710**	**179**	**205**	**254**
Perchlorate	< 0.34*	< 0.34*	< 0.34*	NS	NS	NS	NS	NS	NS	< 0.68*	< 0.68*	< 0.68*
Chloride	**70300**	**140000**	**134000**	**852000**	**839000**	**860000**	**101000**	**87400**	**83800**	**116000**	**120000**	**123000**

Notes:

All compounds reported in µg/L
< = Compound not detected above Method Reporting Limit
* Constituent not detected above Method Detection Limit.
(1) = Batch sample collected after partial treatment with Granular Activated Carbon.
Bold text indicates that compound was detected above reporting limit
ft-bgs = feet below ground surface
NS = Not sampled
TPH = Total petroleum hydrocarbons
TPH-d = Diesel-range TPH
TPH-g = Gasoline-range TPH
TPH-h = Heavy-oil-range TPH
JSCS = Portland Harbor Joint Source Control Strategy
As = Arsenic
Fe = Iron
Mn = Manganese
DDX = Sum of 4,4-Dichlorodiphenyltrichloroethane (DDT), 4,4-Dichlorodiphenyldichloroethane (DDD), and 4,4-Dichlorodiphenylchloroethylene (DDE) concentrations

Data Qualifiers:

n1 = Sample was cross-contaminated by another client's sample with relatively high diesel compounds. Reporting limit was raised above the suspected cross-contamination.
n2 = Silica gel/acid cleanup performed on this sample.

Table 6
Aquifer Pumping Test Analysis Results
Aquifer Testing Report
Arkema, Inc. Facility
Portland, Oregon

Recovery Well	Pumping Rate (gpm)	Observation Well	Analysis Method	Distance from Well (ft)	Transmissivity (ft^2/day)	Storativity	Saturated Thickness (ft)	Hydraulic Conductivity (ft/day)
RW-1	6.54 - 7.78	RW-1	Neuman	0	193.3	0.08512	7.75	25
		MWA-2	Neuman	66.43	2076	0.3759	7.75	268
		MWA-60	Neuman	56.71	1839	0.001103	7.75	237
		Distance Drawdown	Cooper-Jacob	--	356.8	0.1727	7.75	46
RW-2i	4.97 - 6.05	RW-2i	Hantush	0	105.3	4.382×10^{-18}	5	21
		MWA-8i	Hantush	82.42	418.464	0.0003718	5	84
		MWA-78i	Hantush	32.17	141.0192	0.0006897	5	28
		Distance Drawdown	Cooper-Jacob	--	153.3	0.06894	5	31
RW-3	4.47 - 4.93	RW-3	Neuman	0	1185.4	0.001417	5.35	222
		MWA-41	Neuman	46.4	1984.4	0.004557	5.35	371
		MWA-79	Neuman	11.89	2133.6	0.1649	5.35	399
		Distance Drawdown	Cooper-Jacob	--	881.9	0.4992	5.35	165
RW-4i	5.37 - 5.75	RW-4i	Hantush	0	24.92	0.2544	7.5	3
		MWA-80i	Hantush	20.51	179.8	0.001032	7.5	24
		MWA-81i	Hantush	125.24	212.6	2.763×10^{-5}	7.5	28
		Distance Drawdown	Cooper-Jacob	--	104.3	0.04856	7.5	14

Notes:
ft = feet
ft/day = feet per day
ft^2/day = $feet^2$ per day
gpm = gallons per minute

Table 7
Recovery Well Efficiency
Aquifer Testing Report
Arkema, Inc. Facility
Portland, Oregon

Well	Transmissivity (ft^2/day)	Storativity	Observed Drawdown (ft)	Predicted Drawdown (ft)	Well Efficiency
RW-1	356.8	0.1727	5.14461	2.7	52%
RW-2i	153.3	0.06894	16.1167	5.0	31%
RW-3	881.9	0.4992	0.962	0.85	88%
RW-4i	104.3	0.04856	10.68	2.4	22%

Notes:
ft = feet
ft^2/day = $feet^2$ per day

Table 8
Hydraulic Conductivity Results
Aquifer Testing Report
Arkema, Inc. Facility
Portland, Oregon

Well	Pumping Rate (feet/day)	Calculated Hydraulic Conductivity (feet/day)	Modeled Hydraulic Conductivity	
			Original (feet)	Updated (feet)
RW-1	356.8	46	5	18
RW-2i	153.3	31	20	8
RW-3	881.9	165	190	170
RW-4i	104.3	14	20	--

Table 9
Preliminary GWET System Recovery Wells
Aquifer Testing Report
Arkema, Inc. Facility
Portland, Oregon

Recovery Well Number	Northing	Easting	Aquifer Zone	Flow Rate (gpm)
RW-1	702465.206	7627570.010	Shallow	5
RW-2i	702436.053	7627577.075	Intermediate	5
RW-3	701448.440	7628123.989	Shallow	5
RW-4i	701453.647	7628128.934	Intermediate	5
RW-5	702516.887	7627307.134	Shallow	5
RW-6i	702494.654	7627358.425	Intermediate	5
RW-7	702466.259	7627480.157	Shallow	5
RW-8	702380.410	7627650.098	Shallow	5
RW-9i	702319.876	7627733.528	Intermediate	5
RW-10	702243.271	7627797.806	Shallow	5
RW-11i	702185.818	7627846.016	Intermediate	5
RW-12	702077.074	7627871.992	Shallow	5
RW-13i	702003.551	7627901.050	Intermediate	5
RW-14	701962.167	7627968.410	Shallow	6
RW-15	701936.853	7628054.921	Shallow	5
RW-16i	701936.853	7628054.921	Intermediate	5
RW-17	701892.388	7628157.502	Shallow	5
RW-18	701815.784	7628221.781	Shallow	3
RW-19i	701815.784	7628221.781	Intermediate	5
RW-20	701723.110	7628266.909	Shallow	5
RW-21i	701649.587	7628295.967	Intermediate	5
RW-22	701534.017	7628197.130	Shallow	5
Total Flow				109

Notes:
gpm = gallons per mintues

Attachment A
Well Construction Logs

ERM
101 SW Main Street, Suite 804
Portland, OR 97204
Phone: (503) 488-5282
Fax: (503) 488-5142

LOG OF MONITORING WELL: MWA-78i

Project Number: 104709
Project Name: Arkema, Inc.
Client Name: Legacy Site Services
Location:
Contractor: Cascade Drilling Inc. (Portland, Oregon)
Drilling Method: Sonic
Logged By: S. DeGrood

Date Started: 8/24/2009
Date Completed: 8/24/2009
Total Depth: 50 feet
Borehole Diameter: 6 inches

Notes: Borehole cased off to 8-inch borehole from 0 to 44 feet. Screened from 43.25 to 46.25 feet.

Depth (ft)	Graphic Log	USCS Code	PID (ppm)	Sample Interval	Sample Number	Soil Descriptions and Observations
						Gravel fill with geotextile liner at 0.25 feet below ground surface.
		GM				SILTY GRAVEL WITH SAND (GM): brown, fine to coarse sand, fine to coarse gravel, well-graded, subrounded to angular, slightly moist. Fill material.
		SW				WELL-GRADED SAND (SW): dark brown (7.5YR 3/2), fine to coarse sand, approximately 10% fine to coarse gravel, well-graded, slightly moist. Fill material.
5			0.3			
		ML				SILT (ML): dark grayish brown (2.5Y 4/2), 10% fine to coarse sand, with large chunks of decomposed wood, low plasticity, low toughness, wet.
10		ML				SANDY SILT (ML): brown (7.5Y 4/2), 20% fine to coarse sand, 10% fine to coarse gravel, non-plastic, low toughness, sweet odor, wet.
		ML	0.3			SILT WITH SAND (ML): dark grayish brown (2.5Y 4/2), 15% fine to coarse sand, 5% fine to coarse gravel, medium plasticity, low toughness, sweet odor, wet.
		ML				SILT (ML): dark grayish brown (2.5Y 4/2), 5% fine to coarse sand, less than 5% fine root hairs medium plasticity, low toughness, sweet odor, very moist. Color changes to very dark grayish brown (2.5Y 3/2) at 15 feet below ground surface.
15			0.2			
		ML				SANDY SILT (ML): very dark grayish brown (2.5Y 3/2), 20% fine to coarse sand, 10% fine gravel, low plasticity, low toughness, slight sweet odor, moist. Gravel content decreases to 0% after19 feet below ground surface. Large rock at 19.5 feet below ground surface. Rock is basalt and angular.
20		SP				POORLY GRADED SAND (SP): very dark grayish brown (10YR 3/2), fine sand, poorly graded, beach sand odor, slightly moist.

WELL DIAGRAM

MW TO 25 FEET W SAMPLES 2 PDX - - 12/3/09 11:48 - C:\PROGRAM FILES\GINT\PROJECTS\104709 PORTLAND ARKEMA PUMP TEST.GPJ

ERM
101 SW Main Street, Suite 804
Portland, OR 97204
Phone: (503) 488-5282
Fax: (503) 488-5142

LOG OF MONITORING WELL: MWA-78i

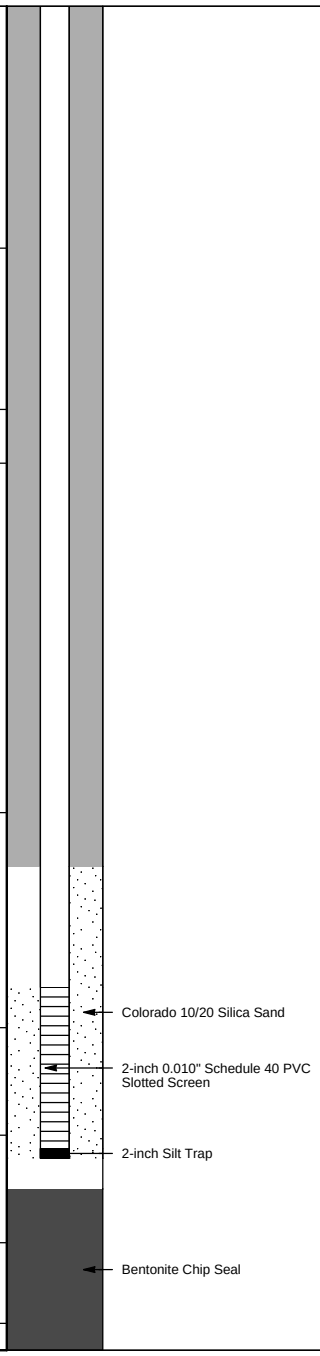
Project Number: 104709
Project Name: Arkema, Inc.
Client Name: Legacy Site Services
Location:
Contractor: Cascade Drilling Inc. (Portland, Oregon)
Drilling Method: Sonic
Logged By: S. DeGrood

Date Started: 8/24/2009
Date Completed: 8/24/2009
Total Depth: 50 feet
Borehole Diameter: 6 inches

Notes: Borehole cased off to 8-inch borehole from 0 to 44 feet. Screened from 43.25 to 46.25 feet.

Depth (ft)	Graphic Log	USCS Code	PID (ppm)	Sample Interval	Sample Number	Soil Descriptions and Observations
			0.3			POORLY GRADED SAND (SP): very dark grayish brown (10YR 3/2), fine sand, poorly graded, beach sand odor, slightly moist. Becomes moist at 26.5 feet below ground surface.
			0.6			0.5-inch layer of fine sand except with trace clay at 29 feet below ground surface; overlying 0.5-inch layer of fine sand with weak cementation and color change to dark reddish grey (5YR 4/2).
30		SP-SM	0.8		Grain Size	POORLY GRADED SAND WITH SILT (SP): dark brown (10YR 3/3), fine sand, trace fine gravel, 10% silt, poorly graded, strong sweet odor, wet. Becomes moist at 31.5 feet below ground surface.
		SM				SILTY SAND (SM): dark brown (10YR 3/3), fine sand, trace fine gravel, 30% silt, poorly graded, strong sweet odor, moist.
		SP				Color changes to very dark gray (10YR 3/1), slight sweet odor at 33 feet below ground surface.
35			0.5		Grain Size	POORLY GRADED SAND (SP): very dark gray (10YR 3/1), fine sand, poorly graded, moist. 1-centimeter silt layer at 34.75 feet below ground surface.
						Poor recovery from 38 to 46 feet below ground surface.
40		ML				Poor recovery, silt noted in core barrel at a depth between 40 and 44 feet below ground surface.
45						Poor recovery, driller notes fine sand with slight percentage of silt, very soft.
		SP				POORLY GRADED SAND (SP): black (2.5Y 2.5/1), fine sand, poorly graded, no odor, wet. Becomes very fine sand after 47 feet below ground surface.
		MH				ELASTIC SILT WITH GRAVEL (MH): black (2.5Y 2.5/1), 10% very fine sand, 15% fine to coarse gravel, medium plasticity, medium toughness, gravel is subangular to angular, wet.

WELL DIAGRAM



MW TO 25 FEET W SAMPLES 2 PDX - - 12/3/09 11:48 - C:\PROGRAM FILES\GINT\PROJECTS\104709 PORTLAND ARKEMA PUMP TEST.GPJ

ERM
101 SW Main Street, Suite 804
Portland, OR 97204
Phone: (503) 488-5282
Fax: (503) 488-5142

LOG OF MONITORING WELL: MWA-78i

Project Number: 104709
Project Name: Arkema, Inc.
Client Name: Legacy Site Services
Location:
Contractor: Cascade Drilling Inc. (Portland, Oregon)
Drilling Method: Sonic
Logged By: S. DeGrood

Date Started: 8/24/2009
Date Completed: 8/24/2009
Total Depth: 50 feet
Borehole Diameter: 6 inches

Notes: Borehole cased off to 8-inch borehole from 0 to 44 feet. Screened from 43.25 to 46.25 feet.

Depth (ft)	Graphic Log	USCS Code	PID (ppm)	Sample Interval	Sample Number	Soil Descriptions and Observations	WELL DIAGRAM
						Basalt fragments, angular or in shape of core barrel. Likely basalt bedrock.	
						Total Depth - 50 feet bgs	
55							
60							
65							
70							

MW TO 25 FEET W SAMPLES 2 PDX - - 12/3/09 11:48 - C:\PROGRAM FILES\GINT\PROJECTS\104709 PORTLAND ARKEMA PUMP TEST.GPJ

ERM
101 SW Main Street, Suite 804
Portland, OR 97204
Phone: (503) 488-5282
Fax: (503) 488-5142

LOG OF MONITORING WELL: MWA-79

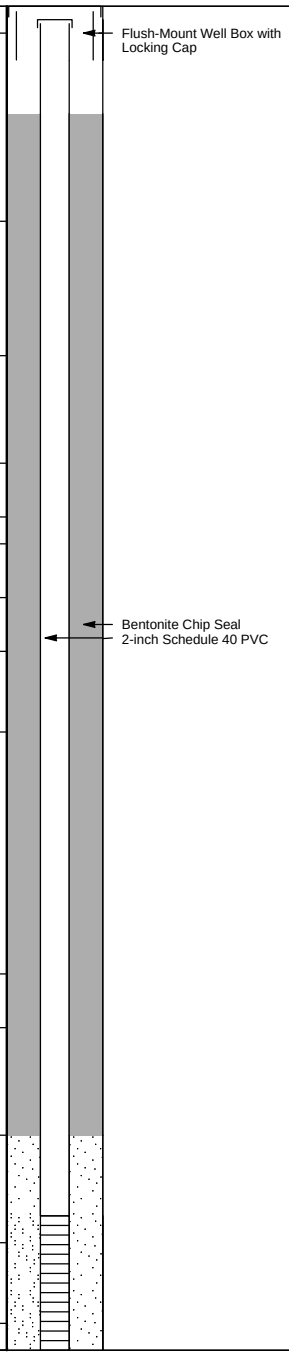
Project Number: 104709
Project Name: Arkema, Inc.
Client Name: Legacy Site Services
Location:
Contractor: Cascade Drilling Inc. (Portland, Oregon)
Drilling Method: Sonic
Logged By: S. DeGrood

Date Started: 8/25/2009
Date Completed: 8/25/2009
Total Depth: 34 feet
Borehole Diameter: 6 inches

Notes: Centralizers at top and bottom of screen. Screened from 22.5 to 32.5 feet.

Depth (ft)	Graphic Log	USCS Code	PID (ppm)	Sample Interval	Sample Number	Soil Descriptions and Observations
						Asphalt over geotextile liner.
		SP				POORLY GRADED SAND (SP): dark olive brown (2.5Y 3/3), fine sand, intermittent rocks of 1- to 4-inch diameter, poorly graded, dry. Fill material
5						No recovery.
		SP	0			POORLY GRADED SAND WITH GRAVEL (SP): dark brown (10YR 3/3), fine sand, 15% fine to coarse gravel, poorly graded, no odor, slightly moist.
		ML	0			SILT (ML): very dark grayish brown (10YR 3/2), 0.2-centimeter laminations of very fine sand, low plasticity, medium toughness, slightly moist.
10		SP				
		ML	0			POORLY GRADED SAND WITH GRAVEL (SP): dark brown (10YR 3/3), fine sand, 15% fine to coarse gravel, poorly graded, no odor, slightly moist.
		SP				
		ML				SANDY SILT (ML): dark grayish brown (10YR 4/2) with 0.25-centimeter mottles of red, 30% fine sand, 0.25-centimeter inclusions of fine sand, medium plasticity, low toughness, no odor, moist.
		SP				POORLY GRADED SAND WITH GRAVEL (SP): dark brown (10YR 3/3), fine sand, 15% fine to coarse gravel, poorly graded, no odor, slightly moist.
15						SANDY SILT (ML): dark grayish brown (10YR 4/2), 30% fine sand, medium plasticity, low toughness, no odor, moist.
			0			POORLY GRADED SAND WITH GRAVEL (SP): dark brown (10YR 3/3), fine sand, 15% fine to coarse gravel, poorly graded, no odor, slightly moist.
		SW				No recovery from 14 to 16 feet below ground surface.
		SP				WELL-GRADED SAND WITH GRAVEL (SW): fine to coarse sand, 30% fine to coarse gravel, well-graded, rounded to subangular, moist.
20						POORLY-GRADED SAND (SP): dark brown (10YR 3/3), fine sand, poorly graded, moist.
						2-centimeter layer of fine sand with moderate cementation, overlying 4-centimeter layer of SILT (ML): low plasticity, medium toughness, slightly moist. Top half is black and bottom half is brown (7.5YR 4/4).
						No recovery.
		SM				SILTY SAND (SM): dark brown (7.5YR 3/2), fine to coarse sand, 15% silt, well-graded sand, subrounded, moist. Coarse sand is pink to gray.
		GP				Hardpan with moderate cementation overlying POORLY GRADED

WELL DIAGRAM



MW TO 25 FEET W SAMPLES 2 PDX - - 12/3/09 11:45 - C:\PROGRAM FILES\GINT\PROJECTS\104709 PORTLAND ARKEMA PUMP TEST.GPJ

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Phone: (503) 488-5282
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LOG OF MONITORING WELL: MWA-79

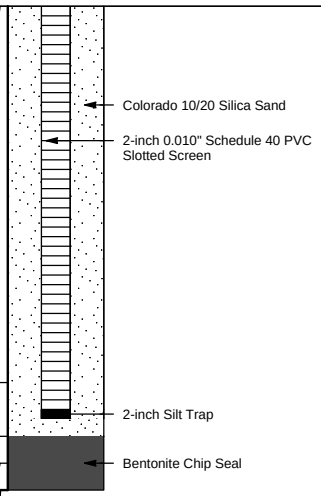
Project Number: 104709
Project Name: Arkema, Inc.
Client Name: Legacy Site Services
Location:
Contractor: Cascade Drilling Inc. (Portland, Oregon)
Drilling Method: Sonic
Logged By: S. DeGrood

Date Started: 8/25/2009
Date Completed: 8/25/2009
Total Depth: 34 feet
Borehole Diameter: 6 inches

Notes: Centralizers at top and bottom of screen. Screened from 22.5 to 32.5 feet.

Depth (ft)	Graphic Log	USCS Code	PID (ppm)	Sample Interval	Sample Number	Soil Descriptions and Observations
		SP	0.5			GRAVEL (GP): dark gray, coarse gravel to cobbles, poorly graded, subangular, moist.
					Grain Size	POORLY GRADED SAND (SP): very dark grayish brown (10YR 3/2), fine sand, trace silt, few inclusions of silt, poorly graded, wet. Silt decreases to 0% and without silt inclusions after 26 feet below ground surface. Silt increases to trace after 27.5 feet below ground surface. Many wood fragments at 28.5 feet below ground surface.
30			0.2			
					Grain Size	Trace wood fragments at 31 feet below ground surface.
		SM				SILTY SAND (SM): very dark gray (2.5Y 3/1), fine sand, 20% silt, 10% wood fragments, poorly graded, wet.
		ML			Grain Size	SANDY SILT (ML): very dark gray (2.5Y 3/1), 0.2-centimeter inclusions of silty sand, low plasticity, medium toughness, wet.
		SP				POORLY GRADED SAND (SP): very dark gray (10YR 3/1), fine sand with trace coarse sand, poorly graded, subrounded, wet. Some yellow grains.
35						Total Depth - 34 feet bgs
40						
45						

WELL DIAGRAM



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LOG OF MONITORING WELL: MWA-80i

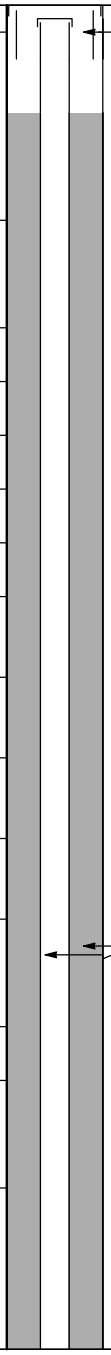
Project Number: 104709
Project Name: Arkema, Inc.
Client Name: Legacy Site Services
Location:
Contractor: Cascade Drilling Inc. (Portland, Oregon)
Drilling Method: Sonic
Logged By: S. DeGrood

Date Started: 8/25/2009
Date Completed: 8/25/2009
Total Depth: 50 feet
Borehole Diameter: 6 inches

Notes: Centralizers at top and bottom of screen. Screened from 34.33 to 39.33 feet.

Depth (ft)	Graphic Log	USCS Code	PID (ppm)	Sample Interval	Sample Number	Soil Descriptions and Observations
						Asphalt over geotextile liner.
		SP				POORLY GRADED SAND (SP): dark olive brown (2.5Y 3/3), fine sand, intermittent rocks of 1- to 4-inch diameter, poorly graded, dry. Fill material
5						No recovery.
		SW				WELL-GRADED SAND WITH GRAVEL (SW): dark brown (10YR 3/3), fine to coarse sand, 25% fine to coarse gravel, well-graded, rounded to subrounded, slightly moist.
		SP				POORLY GRADED SAND (SP): dark brown (10YR 3/3), fine sand, poorly graded, slightly moist.
		SP				
		ML	4.4			1-inch interbeds of: POORLY GRADED SAND (SP): dark brown (10YR 3/3), fine sand, poorly graded, slightly moist; and SILT (ML): dark brown (10YR 3/3), trace fine sand, low plasticity, medium toughness, slightly moist.
10		SP				
		SW				SILT (ML): 1-centimeter mottles of dark brown (10YR 3/3) and gray with few mottles of red, 0.5-centimter inclusions of fine sand, medium plasticity, medium toughness, moist.
		SP				POORLY GRADED SAND (SP): dark brown (10YR 3/3), fine sand, poorly graded, slightly moist.
		SW	5.7			WELL-GRADED SAND WITH GRAVEL (SW): dark brown (10YR 3/3), fine to coarse sand, 25% fine to coarse gravel, well-graded, rounded to subrounded, moist. Coarse sand and gravel is gray to pink.
15		SP				POORLY GRADED SAND (SP): dark brown (10YR 3/3), fine sand, poorly graded, slightly moist.
		SW				WELL-GRADED SAND WITH GRAVEL (SW): dark brown (10YR 3/3), fine to coarse sand, 25% fine to coarse gravel, well-graded, rounded to subrounded, moist. Coarse sand and gravel is gray to pink.
		SP				POORLY GRADED SAND (SP): dark brown (10YR 3/3), fine sand, poorly graded, slightly moist.
20		SW	6.3			WELL-GRADED SAND WITH GRAVEL (SW): dark brown (10YR 3/3), fine to coarse sand, 25% fine to coarse gravel, well-graded, rounded to subrounded, moist. Coarse sand and gravel is gray to pink.
		SP				POORLY GRADED SAND (SP): dark brown (10YR 3/3), fine sand, poorly graded, slightly moist.
						WELL-GRADED SAND WITH GRAVEL (SW): dark brown (10YR 3/3), fine to coarse sand, 25% fine to coarse gravel, well-graded, rounded to subrounded, moist. Coarse sand and gravel is gray to pink.
						Trace silt starting at 23 feet below ground surface.

WELL DIAGRAM



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LOG OF MONITORING WELL: MWA-80i

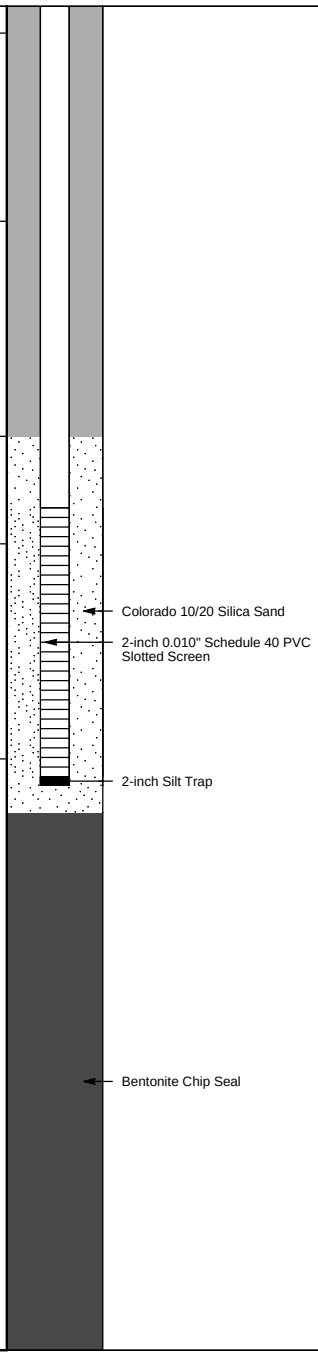
Project Number: 104709
Project Name: Arkema, Inc.
Client Name: Legacy Site Services
Location:
Contractor: Cascade Drilling Inc. (Portland, Oregon)
Drilling Method: Sonic
Logged By: S. DeGrood

Date Started: 8/25/2009
Date Completed: 8/25/2009
Total Depth: 50 feet
Borehole Diameter: 6 inches

Notes: Centralizers at top and bottom of screen. Screened from 34.33 to 39.33 feet.

Depth (ft)	Graphic Log	USCS Code	PID (ppm)	Sample Interval	Sample Number	Soil Descriptions and Observations
		SW-SM	4.1			POORLY GRADED SAND (SP): dark brown (10YR 3/3), fine sand, poorly graded, slightly moist. WELL-GRADED SAND WITH SILT AND GRAVEL (SW-SM): dark brown (10YR 3/3), fine to coarse sand, 25% fine to coarse gravel, 10% silt, well-graded, rounded to subrounded, lightly cemented, moist. Coarse sand and gravel is gray to pink.
30		SP	3.9			POORLY GRADED SAND (SP): very dark grayish brown (2.5Y 3/2), fine sand, poorly graded, wet.
		ML			Shelby Tube	Wood fragments at 32.5 feet below ground surface. Shelby tube sample collected, could not log. Assumed to be silt based on surrounding borings and change in lithology above 33 feet below ground surface and below 35 feet below ground surface.
35		SP	4.1		Grain Size	POORLY GRADED SAND (SP): black (2.5Y 2.5/1), fine sand, trace silt, poorly graded, wet.
40		CL	5.2		Grain Size	LEAN CLAY (CL): very dark gray (2.5Y 3/1), medium-high plasticity, high toughness, wet. Many charcoal flakes at 39.5 feet below ground surface. LEAN CLAY (CL): dark gray (2.5Y 4/1), medium-high plasticity, medium toughness, wet. Frequent lenses of light brownish gray (2.5Y 5/1) from 40.5 to 41 feet below ground surface.
45			3.4		Grain Size	LEAN CLAY (CL): dark gray (2.5Y 4/1), 10% very fine sand, medium-high plasticity, medium toughness, wet. Many wood and charcoal fragments at 45 feet below ground surface. 2-centimeter mottles of dark grayish brown (2.5Y 4/2) after 47 feet below ground surface. 4-centimeter mottles of dark grayish brown (2.5Y 4/2) after 48.5 feet below ground surface.

WELL DIAGRAM



Total Depth - 50 feet bgs

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Phone: (503) 488-5282
Fax: (503) 488-5142

LOG OF MONITORING WELL: MWA-81i

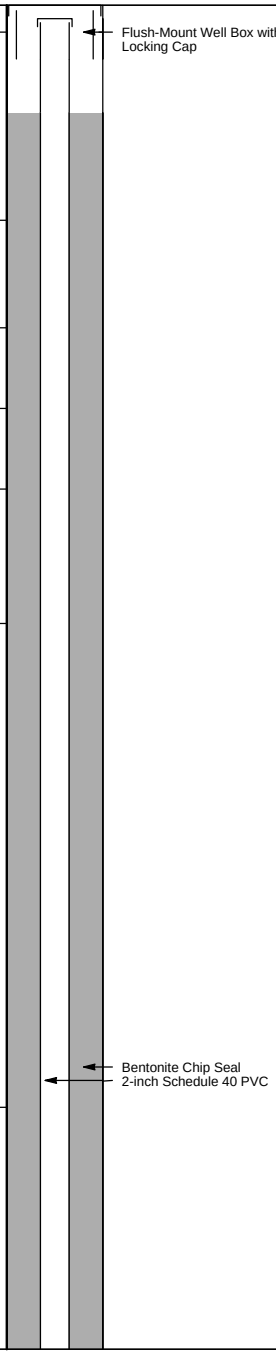
Project Number: 104709
Project Name: Arkema, Inc.
Client Name: Legacy Site Services
Location:
Contractor: Cascade Drilling Inc. (Portland, Oregon)
Drilling Method: Sonic
Logged By: S. DeGrood

Date Started: 8/26/2009
Date Completed: 8/26/2009
Total Depth: 48 feet
Borehole Diameter: 6 inches

Notes: Centralizers at top and bottom of screen. Screened from 39 to 41 feet.

Depth (ft)	Graphic Log	USCS Code	PID (ppm)	Sample Interval	Sample Number	Soil Descriptions and Observations
						Asphalt over geotextile liner.
		SP				POORLY GRADED SAND (SP): dark olive brown (2.5Y 3/3), fine sand, intermittent rocks of 1- to 4-inch diameter, poorly graded, dry. Fill material
5		MH	3.2			ELASTIC SILT WITH SAND (MH): brown (10YR 4/3), 20% very fine sand, medium plasticity, medium toughness, moist. 1-inch lens of SILTY SAND (SM): fine sand, 30% silt, poorly graded at 4.5 feet below ground surface.
		MH				1-inch lens of SILTY SAND (SM): fine sand, 30% silt, poorly graded at 5 feet below ground surface.
		MH				1-inch lens of SILTY SAND (SM): fine sand, 30% silt, poorly graded at 5.5 feet below ground surface.
		SM	1.1			ELASTIC SILT (MH): gray (10YR 5/1) with many 1-centimeter mottles of red, trace very fine sand, medium plasticity, medium toughness, moist.
10						ELASTIC SILT WITH SAND (MH): brown (10YR 4/3), 20% very fine sand, medium plasticity, medium toughness, moist. 1-inch lens of SILTY SAND (SM): fine sand, 30% silt, poorly graded at 8.5 feet below ground surface.
		SP				1-inch lens of SILTY SAND (SM): fine sand, 30% silt, poorly graded at 8.75 feet below ground surface.
		SP				SILTY SAND (SM): dark brown (10YR 3/3), fine to coarse sand, 10% fine gravel, 15% silt, well-graded, rounded, moist. Coarse sand to gravel is gray.
15						POORLY GRADED SAND (SP): dark brown (10YR 3/3), fine sand, trace silt, poorly graded, moist. Strong cementation from 11.5 to 11.75 feet below ground surface. Sand at 11.5 feet is hot and dry due to sonic drilling.
			2.1			POORLY GRADED SAND (SP): dark brown (10YR 3/3), fine sand, trace silt, poorly graded, moist.
20		SM	3			SILTY SAND (SM): dark brown (10YR 3/3), very fine sand, 20% silt, poorly graded, moist.
				Grain Size		Poor recovery from 22 to 32 feet below ground surface due to very soft material that didn't pack into sampler barrel. Depths are approximate. Becomes wet after 23 feet below ground surface.
						Trace wood fragments at 24 feet below ground surface.

WELL DIAGRAM



MW TO 25 FEET W SAMPLES 2 PDX - - 12/3/09 11:48 - C:\PROGRAM FILES\GINT\PROJECTS\104709 PORTLAND ARKEMA PUMP TEST.GPJ

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101 SW Main Street, Suite 804
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Phone: (503) 488-5282
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LOG OF MONITORING WELL: MWA-81i

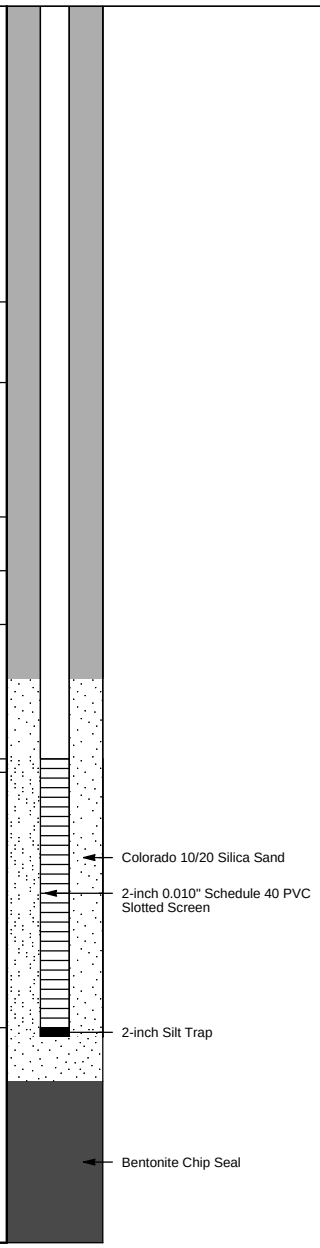
Project Number: 104709
Project Name: Arkema, Inc.
Client Name: Legacy Site Services
Location:
Contractor: Cascade Drilling Inc. (Portland, Oregon)
Drilling Method: Sonic
Logged By: S. DeGrood

Date Started: 8/26/2009
Date Completed: 8/26/2009
Total Depth: 48 feet
Borehole Diameter: 6 inches

Notes: Centralizers at top and bottom of screen. Screened from 39 to 41 feet.

Depth (ft)	Graphic Log	USCS Code	PID (ppm)	Sample Interval	Sample Number	Soil Descriptions and Observations
			1.4			SILTY SAND (SM): dark brown (10YR 3/3), very fine sand, 20% silt, poorly graded, moist. SILTY SAND (SM): dark brown (10YR 3/3) with 1.5-centimeter dark gray mottles, very fine sand, 20% silt, many wood fragments, poorly graded, moist. SILTY SAND (SM): very dark grayish brown (10YR 3/2), fine sand, 20% silt, poorly graded, wet. Moderate cementation at 29 feet below ground surface.
30		SP-SM				POORLY GRADED SAND WITH SILT (SP-SM): very dark grayish brown (10YR 3/2), fine sand, 10% silt, poorly graded, moist.
		SW	0.4		Grain Size	WELL-GRADED SAND (SW): very dark gray (10YR 3/1), medium to coarse sand, 15% fine to coarse gravel, 5% silt, well-graded, wet.
					Grain Size	
35		SM				SILTY SAND (SM): very dark gray (10YR 3/1), fine sand, 30% silt, poorly graded, wet.
		SW				WELL-GRADED SAND (SW): very dark gray (2.5Y 3/1), medium to coarse sand, 5% fine gravel, well-graded, subrounded to rounded, wet.
		SP	0.5		Grain Size	POORLY GRADED SAND (SP): very dark gray (2.5Y 3/1), fine sand, trace silt, poorly graded, wet.
						Wood fragments at 38.75 feet below ground surface.
		ML				Three-inch layer of SANDY SILT (ML): low plasticity, low toughness.
40		SP-SM			Grain Size	POORLY GRADED SAND WITH SILT (SP-SM): very dark gray (2.5Y 3/1), fine sand, 10% silt, poorly graded, wet.
						Poor recovery from 43 to 44 feet below ground surface. Sample recovered from bottom of shoe.
45		CL	2.7		Grain Size	LEAN CLAY (CL): dark gray (2.5Y 4/1), high plasticity, medium toughness, wet.
					Shelby Tube	
						Total Depth - 48 feet bgs

WELL DIAGRAM



MW TO 25 FEET W SAMPLES 2 PDX - - 12/3/09 11:48 - C:\PROGRAM FILES\GINT\PROJECTS\104709 PORTLAND ARKEMA PUMP TEST.GPJ

ERM
101 SW Main Street, Suite 804
Portland, OR 97204
Phone: (503) 488-5282
Fax: (503) 488-5142

LOG OF MONITORING WELL: PA-1d

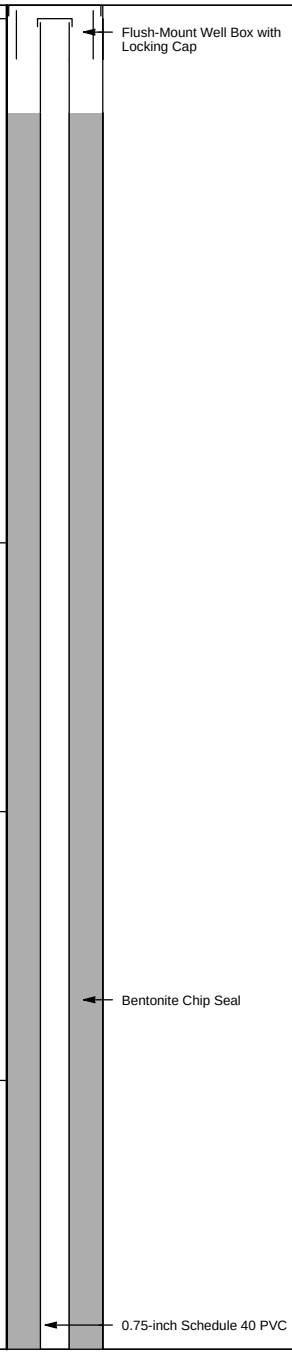
Project Number: 104709
Project Name: Arkema, Inc.
Client Name: Legacy Site Services
Location:
Contractor: Cascade Drilling Inc. (Portland, Oregon)
Drilling Method: Sonic
Logged By: S. DeGrood

Date Started: 10/10/2009
Date Completed: 10/10/2009
Total Depth: 50 feet
Borehole Diameter: 5.75 inches

Notes: Borehole cased off to 7.25-inch borehole from 0 to 38 feet. Screened from 48.1 to 48.85 feet.

Depth (ft)	Graphic Log	USCS Code	PID (ppm)	Sample Interval	Sample Number	Soil Descriptions and Observations
		SW-SM				Gravel fill with geotextile liner at 0.25 feet below ground surface. WELL-GRADED SAND WITH GRAVEL AND SILT (SW-SM): fill material.
5						
10		SP				POORLY GRADED SAND (SP)
15		SM				SILTY SAND (SM)
20		SP				POORLY GRADED SAND (SP): intermittent interbeds of sand with silt

WELL DIAGRAM



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101 SW Main Street, Suite 804
Portland, OR 97204
Phone: (503) 488-5282
Fax: (503) 488-5142

LOG OF MONITORING WELL: PA-1d

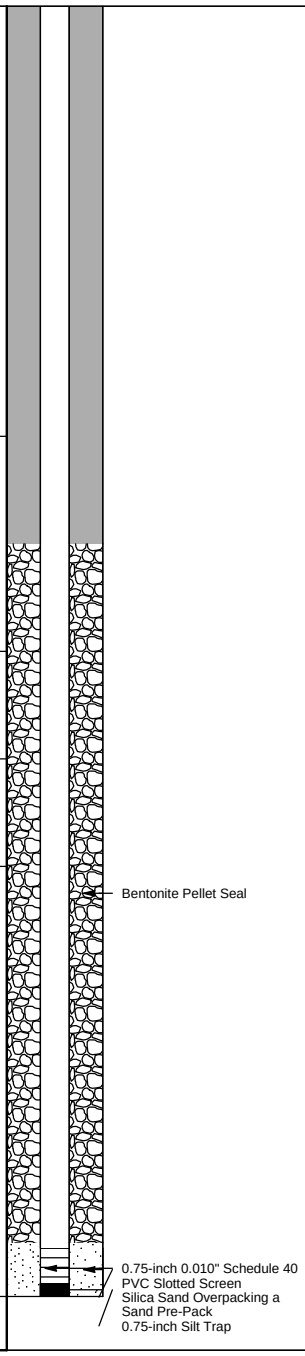
Project Number: 104709
Project Name: Arkema, Inc.
Client Name: Legacy Site Services
Location:
Contractor: Cascade Drilling Inc. (Portland, Oregon)
Drilling Method: Sonic
Logged By: S. DeGrood

Date Started: 10/10/2009
Date Completed: 10/10/2009
Total Depth: 50 feet
Borehole Diameter: 5.75 inches

Notes: Borehole cased off to 7.25-inch borehole from 0 to 38 feet. Screened from 48.1 to 48.85 feet.

Depth (ft)	Graphic Log	USCS Code	PID (ppm)	Sample Interval	Sample Number	Soil Descriptions and Observations
						POORLY GRADED SAND (SP): intermittent interbeds of sand with silt
30						
		SM				SILTY SAND (SM)
35						
		MH				ELASTIC SILT (MH): some sand and some gravel, high plasticity.
		SP				POORLY GRADED SAND (SP): fine, poorly graded sand.
40						
						No recovery.
45						
						Weathered basalt: Cuttings not recovered, but implied based on surrounding borelogs and difference in drilling.

WELL DIAGRAM



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Phone: (503) 488-5282
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LOG OF MONITORING WELL: PA-1d

Project Number: 104709
Project Name: Arkema, Inc.
Client Name: Legacy Site Services
Location:
Contractor: Cascade Drilling Inc. (Portland, Oregon)
Drilling Method: Sonic
Logged By: S. DeGrood

Date Started: 10/10/2009
Date Completed: 10/10/2009
Total Depth: 50 feet
Borehole Diameter: 5.75 inches

Notes: Borehole cased off to 7.25-inch borehole from 0 to 38 feet. Screened from 48.1 to 48.85 feet.

Depth (ft)	Graphic Log	USCS Code	PID (ppm)	Sample Interval	Sample Number	Soil Descriptions and Observations	WELL DIAGRAM
						Total Depth - 50 feet bgs	
55							
60							
65							
70							

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LOG OF MONITORING WELL: PA-2d

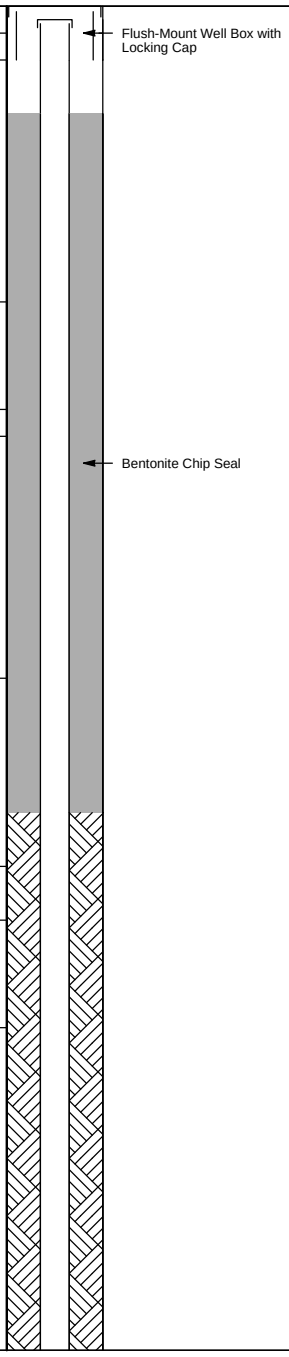
Project Number: 104709
Project Name: Arkema, Inc.
Client Name: Legacy Site Services
Location:
Contractor: Cascade Drilling Inc. (Portland, Oregon)
Drilling Method: Direct Push
Logged By: S. DeGrood

Date Started: 9/8/2009
Date Completed: 9/8/2009
Total Depth: 65 feet
Borehole Diameter: 2.25 inches

Notes: Screened from 60.5 to 64.5 feet.

Depth (ft)	Graphic Log	USCS Code	PID (ppm)	Sample Interval	Sample Number	Soil Descriptions and Observations
						Asphalt over geotextile liner.
						Gravel fill.
		SP				POORLY GRADED SAND (SP): dark olive brown (2.5Y 3/3), intermittent rocks of 1- to 4-inch diameter, poorly graded, dry. Fill material.
						Large rock, greater than 5-inch diameter, at 3.5 feet below ground surface.
5						
		SP				POORLY GRADED SAND (SP): dark olive brown (2.5Y 3/3), fine sand, poorly graded, no odor, dry.
		SM ML				SILTY SAND (SM): dark brown (10YR 3/3), very fine sand, 20% silt, poorly graded, slightly moist.
10			0.7			One-inch interbeds of sand and silt. Sand is: POORLY GRADED SAND (SP): dark olive brown (2.5Y 3/3), fine sand, poorly graded, no odor, dry. Silt is: ELASTIC SILT (MH): dark yellowish brown (10YR 3/4) with 1-centimeter lenses of red and light gray, medium-high plasticity, medium toughness, stiff, no odor, slightly moist. Silt interbeds increase in length after 10 feet below ground surface
		SP				POORLY GRADED SAND (SP): dark olive brown (2.5Y 3/3), fine sand, poorly graded, no odor, slightly moist. Many 1.5-centimeter lenses of sandy silt.
15						
		MH	10.9			One-inch interbeds of sand and silt. Sand is: POORLY GRADED SAND (SP): dark olive brown (2.5Y 3/3), fine sand, poorly graded, petroleum odor, dry. Silt is: ELASTIC SILT (MH): dark yellowish brown (10YR 3/4) with 1-centimeter lenses of red and light gray, medium-high plasticity, medium toughness, stiff, petroleum odor, slightly moist.
		SP				
		SP				POORLY GRADED SAND (SP): dark brown (10YR 3/3), medium sand, poorly graded, petroleum odor, slightly moist. Many fine gravel at 17.75 feet below ground surface. Gravel is pink to gray, subangular to rounded.
20						
						POORLY GRADED SAND (SP): dark brown (10YR 3/3), medium sand, poorly graded, weak cementation, slight petroleum odor, slightly moist. POORLY GRADED SAND (SP): dark brown (10YR 3/3), fine sand, poorly graded, no odor, slightly moist. One-inch lens of medium to coarse sand at 21.75 feet below ground surface Moisture increases to wet at 22.25 feet below ground surface.

WELL DIAGRAM



MW TO 25 FEET W SAMPLES 2 PDX - - 12/3/09 11:48 - C:\PROGRAM FILES\GINT\PROJECTS\104709 PORTLAND ARKEMA PUMP TEST.GPJ

ERM
101 SW Main Street, Suite 804
Portland, OR 97204
Phone: (503) 488-5282
Fax: (503) 488-5142

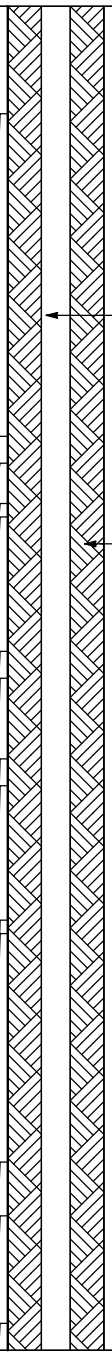
LOG OF MONITORING WELL: PA-2d

Project Number: 104709
Project Name: Arkema, Inc.
Client Name: Legacy Site Services
Location:
Contractor: Cascade Drilling Inc. (Portland, Oregon)
Drilling Method: Direct Push
Logged By: S. DeGrood

Date Started: 9/8/2009
Date Completed: 9/8/2009
Total Depth: 65 feet
Borehole Diameter: 2.25 inches
Notes: Screened from 60.5 to 64.5 feet.

Depth (ft)	Graphic Log	USCS Code	PID (ppm)	Sample Interval	Sample Number	Soil Descriptions and Observations
						Two-inch layer of ELASTIC SILT (MH): high plasticity, low toughness, firm, no odor, wet. Top half is dark gray (10YR 4/1), bottom half is dark yellowish brown (10YR 4/4).
		SP				POORLY GRADED SAND (SP): dark brown (10YR 3/3), medium sand, poorly graded, weak cementation, slight petroleum odor, slightly moist. Few coarse gravel at 25.5 feet below ground surface. Gravel is basalt with gas vesicles. One-centimeter silt layer at 26 feet below ground surface. Quartz and wood fragments at 26.25 feet below ground surface. One-centimeter silt layer at 27 feet below ground surface.
30						POORLY GRADED SAND (SP): very dark brown (10YR 2/2), medium sand, poorly graded, no odor, wet. One-centimeter silt layer at 31 feet below ground surface. One-inch lens of medium to coarse sand at 31.25 feet below ground surface.
		SM				SILTY SAND (SM): dark brown (10YR 3/3), fine sand, 40% silt, poorly graded, no odor, moist.
		SP				POORLY GRADED SAND (SP): black (2.5Y 2.5/1), fine sand, poorly graded, no odor, saturated. Wood fragments at 33.75 feet below ground surface.
		ML				SILT WITH SAND (ML): black (2.5Y 2.5/1), 15% very fine sand, medium plasticity, low toughness, soft, wet.
35		SP				POORLY GRADED SAND (SP): very dark gray (2.5Y 3/1), medium sand, poorly graded, no odor, wet. Wood fragments at 35 feet below ground surface. Color changes to black (2.5Y 2.5/1) at 35.25 feet below ground surface.
		SM				
		SP				
		SP-SM				Color changes to black (2.5Y 2.5/1) at 35.25 feet below ground surface.
40		SP				SILTY SAND (SM): black (2.5Y 2.5/1), fine sand, 15% silt, poorly graded, wet. Color changes to very dark gray (2.5Y 3/1) at 37.25 feet below ground surface.
		SM				POORLY GRADED SAND (SP): fine sand, poorly graded, no odor, wet. Two-inch interbeds of black (2.5Y 2.5/1) and very dark gray (2.5Y 3/1).
		ML				POORLY GRADED SAND WITH SILT (SP-SM): black (2.5Y 2.5/1), fine sand, 10% silt, poorly graded, no odor, wet.
45						POORLY GRADED SAND (SP): very dark gray (2.5Y 3/1), fine sand, poorly graded, no odor, wet. Three-centimeter lens of silty sand at 41 feet below ground surface.
		CL				SILTY SAND (SM): fine sand, 15% silt, poorly graded, wet.
		MH				SILT (ML): dark gray (5Y 4/1), medium plasticity, low toughness, firm, wet. Consistency is soft after 43 feet below ground surface
		CL				SILT (ML): dark gray (2.5Y 4/1), 10% very fine sand, low plasticity, low toughness, very soft, wet.

WELL DIAGRAM



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Portland, OR 97204
Phone: (503) 488-5282
Fax: (503) 488-5142

LOG OF MONITORING WELL: PA-2d

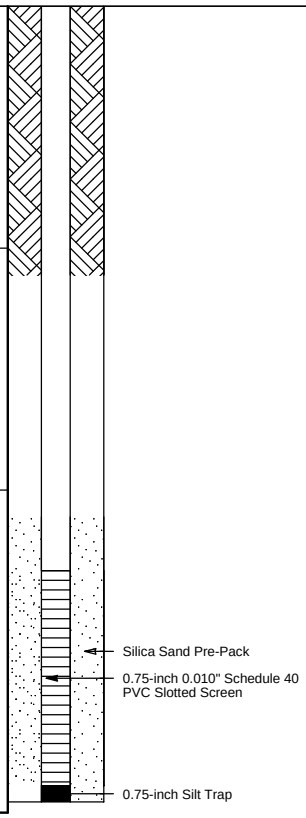
Project Number: 104709
Project Name: Arkema, Inc.
Client Name: Legacy Site Services
Location:
Contractor: Cascade Drilling Inc. (Portland, Oregon)
Drilling Method: Direct Push
Logged By: S. DeGrood

Date Started: 9/8/2009
Date Completed: 9/8/2009
Total Depth: 65 feet
Borehole Diameter: 2.25 inches

Notes: Screened from 60.5 to 64.5 feet.

Depth (ft)	Graphic Log	USCS Code	PID (ppm)	Sample Interval	Sample Number	Soil Descriptions and Observations
						LEAN CLAY (CL): dark gray (2.5Y 4/1) with many black streaks, medium plasticity, high toughness, firm, wet.
						ELASTIC SILT (MH): dark grey (7.5YR 4/1) with many black streaks, medium plasticity, high toughness, soft, wet.
				Grain Size		LEAN CLAY (CL): dark gray (2.5Y 4/1), medium plasticity, high toughness, firm, wet.
55		MH				ELASTIC SILT (MH): grayish brown (2.5Y 5/2) with many 0.5-centimeter mottles of gray and red, medium plasticity, low toughness, firm, wet.
						Mottles not noted after 57 feet below ground surface.
60		MH				SANDY ELASTIC SILT (MH): grayish brown (2.5Y 5/2), 30% very fine sand, low plasticity, low toughness, firm, wet. No recovery from 60 to 65. Slight amount of silt, as at 59 feet below ground surface, recovered from shoe.
65						Total Depth - 65 feet bgs
70						

WELL DIAGRAM



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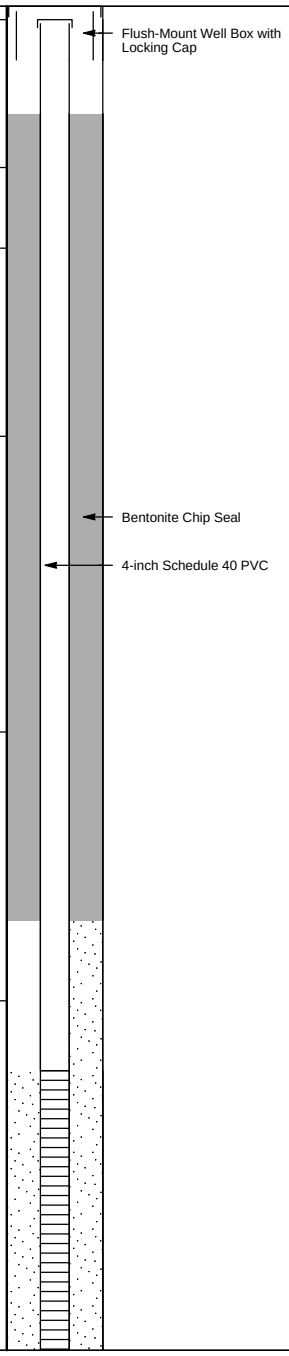
LOG OF MONITORING WELL: RW-1

Project Number: 104709
Project Name: Arkema, Inc.
Client Name: Legacy Site Services
Location:
Contractor: Cascade Drilling Inc. (Portland, Oregon)
Drilling Method: Hollow Stem Auger
Logged By: S. DeGrood

Date Started: 8/31/2009
Date Completed: 8/31/2009
Total Depth: 41.5 feet
Borehole Diameter: 10 inches
Initial Water Level: 25.81 feet bgs
Notes: Screened from 19.8 to 34.8 feet.

Depth (ft)	Graphic Log	USCS Code	PID (ppm)	Sample Interval	Sample Number	BLOW COUNTS (N VALUE)	Soil Descriptions and Observations
		SW					Gravel fill with geotextile liner at 0.25 feet below ground surface. WELL-GRADED SAND WITH GRAVEL (SW): dark brown (7.5YR 3/2), fine to coarse sand, approximately 20% fine to coarse gravel, well-graded, slightly moist. Fill material. Wire with green plastic coating noted at 2 feet below ground surface.
		SP					POORLY GRADED SAND (SP): dark brown (7.5YR 3/2), fine sand, 5% coarse sand, moderate grading, coarse sand is angular, moist.
5		SP		X		8-16-5 (21)	POORLY GRADED SAND WITH GRAVEL (SP): dark brown (7.5YR 3/2), fine sand, 5% coarse sand, 30% fine to coarse gravel, moderate grading, angular to subangular, moist.
		ML					SILT (ML): dark grayish brown (10YR 4/2), 10% medium sand to coarse gravel, medium plasticity, low toughness, slight odor, moist. Sand and gravel is pink to gray and includes concrete fragments.
10				X		1-2-4 (6)	
		SP-SM					POORLY GRADED SAND WITH SILT (SP-SM): dark grayish brown (10YR 4/2), very fine sand, few coarse gravel, 10% silt, poorly graded, few wood fragments, slight odor, wet.
15			11.5	X		9-11-16 (27)	No gravel or wood fragments after 16 feet below ground surface.
		SP					POORLY GRADED SAND (SP): dark grayish brown (10YR 4/2), very fine sand, trace silt, poorly graded, slight odor, wet.
20			14.5	X		8-8-9 (17)	

WELL DIAGRAM



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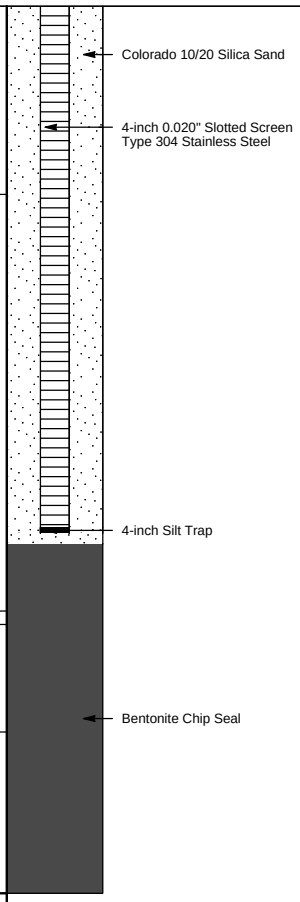
LOG OF MONITORING WELL: RW-1

Project Number: 104709
Project Name: Arkema, Inc.
Client Name: Legacy Site Services
Location:
Contractor: Cascade Drilling Inc. (Portland, Oregon)
Drilling Method: Hollow Stem Auger
Logged By: S. DeGrood

Date Started: 8/31/2009
Date Completed: 8/31/2009
Total Depth: 41.5 feet
Borehole Diameter: 10 inches
Initial Water Level: 25.81 feet bgs
Notes: Screened from 19.8 to 34.8 feet.

Depth (ft)	USCS Code	PID (ppm)	Sample Interval	Sample Number	BLOW COUNTS (N VALUE)	Soil Descriptions and Observations
	SP	4.5			7-8-10 (18)	POORLY GRADED SAND (SP): dark grayish brown (10YR 4/2), very fine sand, trace silt, poorly graded, slight odor, wet.
	SP					POORLY GRADED SAND (SP): very dark gray (2.5Y 3/1), fine sand, poorly graded, slight sweet odor, wet.
30	SP		Steel Tube Steel Tube		8-11-13 (24)	
	SP	30.5			3-4-5 (9)	Wood fragments at 32.75 feet below ground surface. Not sampled from 33 to 34 feet below ground surface.
35	SP		Steel Tube		7-7-7 (14)	
	ML SP	12.7	Steel Tube		6-14-17 (31)	SANDY SILT (ML): very dark gray (2.5Y 3/1), 40% very fine sand, medium plasticity, low toughness, slight sweet odor, wet.
	SP				2-3-3 (6)	POORLY GRADED SAND (SP): black (2.5Y 2.5/1), fine sand, poorly graded, no odor, wet.
	SP				3-3-4 (7)	No recovery from 38.5 to 40 feet below ground surface, large rock in sampler.
40	SP				9-6-6 (12)	
						Total Depth - 41.5 feet bgs
45						

WELL DIAGRAM



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LOG OF MONITORING WELL: RW-2i

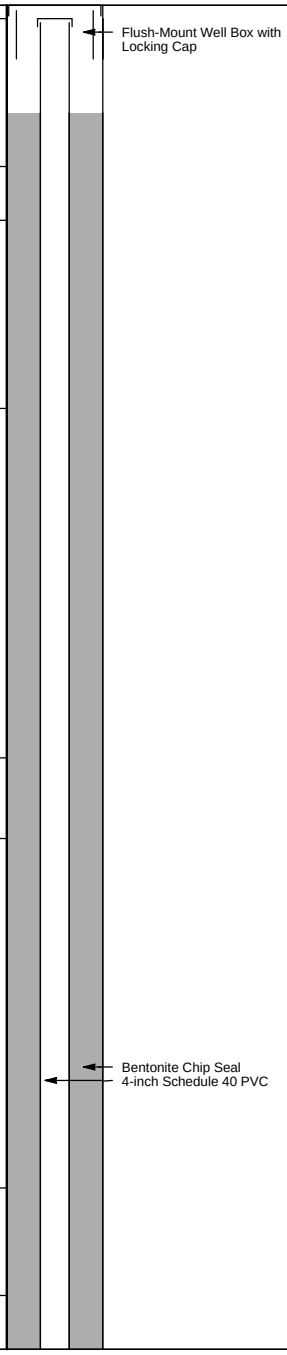
Project Number: 104709
Project Name: Arkema, Inc.
Client Name: Legacy Site Services
Location:
Contractor: Cascade Drilling Inc. (Portland, Oregon)
Drilling Method: Sonic
Logged By: S. DeGrood

Date Started: 8/27/2009
Date Completed: 8/27/2009
Total Depth: 47 feet
Borehole Diameter: 8 inches

Notes: Centralizers at top and bottom of screen. Borehole cased off to 9-inch borehole from 0 to 37.5 feet. Screened from 39 to 44 feet.

Depth (ft)	Graphic Log	USCS Code	PID (ppm)	Sample Interval	Sample Number	Soil Descriptions and Observations
		SW	0			Gravel fill with geotextile liner at 0.25 feet below ground surface. WELL-GRADED SAND WITH GRAVEL (SW): dark brown (7.5YR 3/2), fine to coarse sand, approximately 20% fine to coarse gravel, well-graded, citrus odor, slightly moist. Fill material. No odor after 1.5 feet below ground surface.
		ML				GRAVELLY SILT (ML): brown (10YR 4/3), 40% fine gravel, low plasticity, medium toughness, slight odor, moist. Gravel is subrounded to rounded.
		ML	61.2			SILT WITH GRAVEL (ML): very dark gray (2.5Y 3/1), 20% fine gravel, medium plasticity, medium toughness, petroleum odor, moist. Gravel is subangular to subrounded. Wood fragments at 5.5 feet below ground surface.
5						
		ML	67.5			GRAVELLY SILT (ML): 3-centimeter mottles of dark yellowish brown (10YR 4/4) and very dark gray (2.5Y 3/1), 10% fine to coarse sand, 30% fine to coarse gravel, few root hairs, medium plasticity, medium toughness, no odor, moist. Sand and gravel are subangular to rounded.
10						
		SM	50.1			SILTY SAND (SM): very dark grayish brown (10YR 3/2), fine sand, 35% silt, poorly graded, no odor, moist.
15						
		SP				Many coarse gravel at 15.5 feet below ground surface. POORLY GRADED SAND (SP): dark brown (10YR 3/3), fine sand, poorly graded, no odor, moist.
			70.2			
20						
		SP-SM				Poor recovery from 22 to 30 feet below ground surface due to blockage in shoe. Depths are approximate. POORLY GRADED SAND WITH SILT (SP-SM): dark grayish brown (2.5Y 4/2), fine sand, 10% silt, poorly graded, weak cementation, no odor, wet.
		SP				

WELL DIAGRAM



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101 SW Main Street, Suite 804
Portland, OR 97204
Phone: (503) 488-5282
Fax: (503) 488-5142

LOG OF MONITORING WELL: RW-2i

Project Number: 104709
Project Name: Arkema, Inc.
Client Name: Legacy Site Services
Location:
Contractor: Cascade Drilling Inc. (Portland, Oregon)
Drilling Method: Sonic
Logged By: S. DeGrood

Date Started: 8/27/2009
Date Completed: 8/27/2009
Total Depth: 47 feet
Borehole Diameter: 8 inches

Notes: Centralizers at top and bottom of screen. Borehole cased off to 9-inch borehole from 0 to 37.5 feet. Screened from 39 to 44 feet.

Depth (ft)	Graphic Log	USCS Code	PID (ppm)	Sample Interval	Sample Number	Soil Descriptions and Observations
			30.4		Grain Size	POORLY GRADED SAND (SP): dark grayish brown (2.5Y 4/2), fine sand, 5% silt, poorly graded, slight sweet odor, wet.
						No recovery.
30		SP				POORLY GRADED SAND (SP): very dark gray (2.5Y 3/1), fine sand, 5% silt, poorly graded, no odor, wet.
					Grain Size	
			39.2			0.5-inch wood fragments at 34 feet below ground surface.
35						
		ML	23.4		Grain Size	SILT WITH SAND (ML): very dark gray (2.5Y 3/1), 20% very fine to fine sand, low plasticity, medium toughness, slight sweet odor, wet.
		SM				SILTY SAND (SM): black (10YR 2/1), fine sand, 30% silt, poorly graded, slight organic/septic odor, wet.
		SP				POORLY GRADED SAND (SP): black (10YR 2/1), fine sand, poorly graded, slight septic odor, wet.
					Grain Size	
40		SP-SM				Silt increases to 5% and wood fragments increase to 20% after 39 feet below ground surface.
			7.5			
		SP				POORLY GRADED SAND WITH SILT (SP-SM): black (10YR 2/1), fine sand, 10% silt, poorly graded, organic/septic odor, wet.
					Grain Size	POORLY GRADED SAND (SP): black (10YR 2/1), fine sand, 5% silt, poorly graded, slight septic odor, wet.
		ML				SILT (ML): grades from dark gray (2.5Y 4/1) to dark grayish brown (2.5Y 4/2), low plasticity, medium toughness, wet.
			9.1		Grain Size	
45					Shelby Tube	Shelby tube sample collected, could not log.
						Total Depth - 47 feet bgs

WELL DIAGRAM

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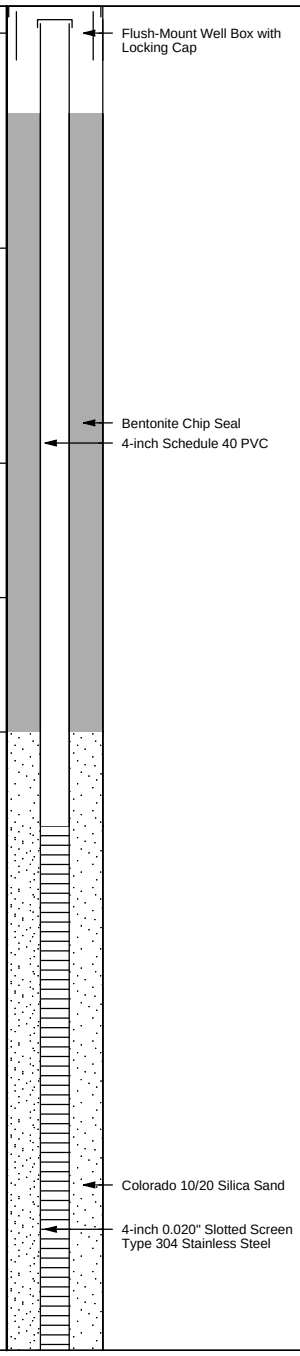
LOG OF MONITORING WELL: RW-3

Project Number: 104709
Project Name: Arkema, Inc.
Client Name: Legacy Site Services
Location:
Contractor: Cascade Drilling Inc. (Portland, Oregon)
Drilling Method: Hollow Stem Auger
Logged By: S. DeGrood

Date Started: 8/31/2009
Date Completed: 8/31/2009
Total Depth: 34 feet
Borehole Diameter: 10 inches
Initial Water Level: 26.65 feet bgs
Notes: Screened from 15.25 to 30.25 feet.

Depth (ft)	Graphic Log	USCS Code	PID (ppm)	Sample Interval	Sample Number	BLOW COUNTS (N VALUE)	Soil Descriptions and Observations
							Asphalt over geotextile liner.
		SP					POORLY GRADED SAND (SP): dark olive brown (2.5Y 3/3), fine sand, intermittent rocks of 1- to 4-inch diameter, poorly graded, dry. Fill material
5		SP				7-15-12 (27)	POORLY GRADED SAND (SP): dark brown (10YR 3/3), fine sand, 5% fine to coarse gravel, poorly graded, gravel is angular to subrounded and light gray, no odor, slightly moist.
		SP					As above except gravel content decreases to trace.
10						4-8-8 (16)	
		ML	1.8				SILT (ML): dark brown (10YR 3/3) with 0.25 centimeter mottles of red and gray, 5% very fine sand, low plasticity, low toughness, no odor, slightly moist.
		SP-SM					POORLY GRADED SAND WITH SILT (SP-SM): dark brown (10YR 3/3), fine sand, 10% silt, poorly graded, slight petroleum odor, slightly moist.
15			0.5			10-15-20 (35)	Gravel increases to 5% fine gravel, pink to gray and subrounded, after 16 feet below ground surface.
20			0.7			4-6-9 (15)	Multiple 0.5-inch lenses of silt starting at 20.5 feet below ground surface

WELL DIAGRAM



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Phone: (503) 488-5282
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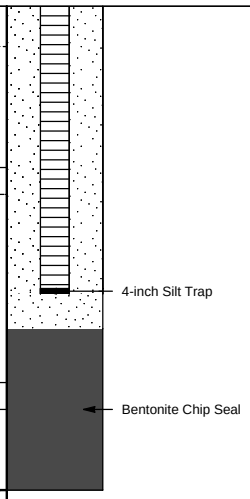
LOG OF MONITORING WELL: RW-3

Project Number: 104709
Project Name: Arkema, Inc.
Client Name: Legacy Site Services
Location:
Contractor: Cascade Drilling Inc. (Portland, Oregon)
Drilling Method: Hollow Stem Auger
Logged By: S. DeGrood

Date Started: 8/31/2009
Date Completed: 8/31/2009
Total Depth: 34 feet
Borehole Diameter: 10 inches
Initial Water Level: 26.65 feet bgs
Notes: Screened from 15.25 to 30.25 feet.

Depth (ft)	Graphic Log	USCS Code	PID (ppm)	Sample Interval	Sample Number	BLOW COUNTS (N VALUE)	Soil Descriptions and Observations
		SP	0.5			5-8-12 (20)	1-inch layer of SANDY SILT (ML): mottles of dark gray (10YR 4/1) and brown (10YR 4/3), very fine sand, non-plastic, medium toughness, no odor, wet.
			0.9			5-9-12 (21)	POORLY GRADED SAND (SP): dark brown (10YR 3/3), medium sand, poorly graded, no odor, wet.
		SW SP			Steel Tube Steel Tube	5-10-12 (22)	WELL-GRADED SAND (SW): dark brown (10YR 3/3), medium to coarse sand, 5% fine gravel, well-graded, no odor, wet.
30						7-7-9 (16)	POORLY GRADED SAND (SP): dark brown (10YR 3/3), medium sand, poorly graded, no odor, wet.
		ML SP			Steel Tube	6-8-10 (18)	SILT (ML). All available sample is inside steel tube. Silt noted at base of sample.
						8-8-15 (23)	POORLY GRADED SAND (SP): black (10YR 2/1), fine sand, poorly graded, no odor, wet. Wood fragment at 33.5 feet below ground surface.
35							Total Depth - 34 feet bgs
40							
45							

WELL DIAGRAM



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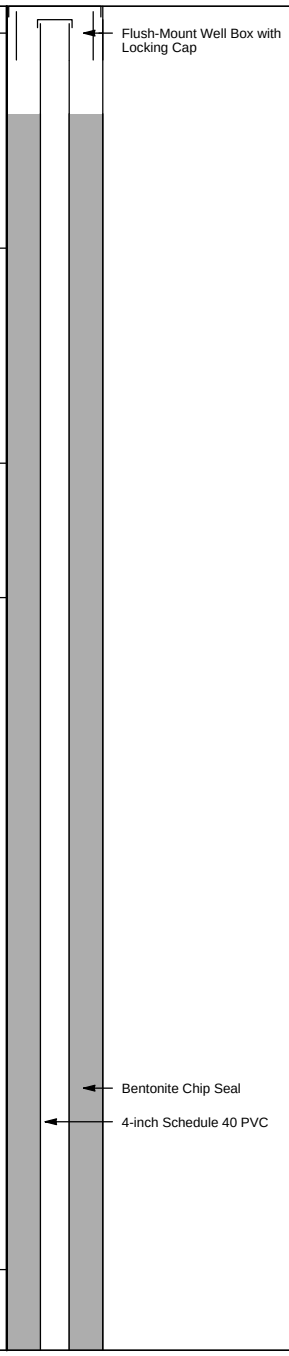
LOG OF MONITORING WELL: RW-4i

Project Number: 104709
Project Name: Arkema, Inc.
Client Name: Legacy Site Services
Location:
Contractor: Cascade Drilling Inc. (Portland, Oregon)
Drilling Method: Hollow Stem Auger
Logged By: S. DeGrood

Date Started: 9/1/2009
Date Completed: 9/1/2009
Total Depth: 47 feet
Borehole Diameter: 10 inches
Initial Water Level: 27.78 feet bgs
Notes: Screened from 40.5 to 45.5 feet.

Depth (ft)	Graphic Log	USCS Code	PID (ppm)	Sample Interval	Sample Number	BLOW COUNTS (N VALUE)	Soil Descriptions and Observations
							Asphalt over geotextile liner.
		SP					POORLY GRADED SAND (SP): dark olive brown (2.5Y 3/3), intermittent rocks of 1- to 4-inch diameter, poorly graded, dry. Fill material
5		SW		X		8-8-11 (19)	WELL-GRADED SAND (SW): dark brown (10YR 3/3), fine to coarse sand, 5% fine to coarse gravel, well-graded, asphalt odor, dry. 1-inch inclusions of silt at 6.25 feet below ground surface.
		ML					SILT WITH SAND (ML): dark brown (10YR 3/3), 20% fine sand, non-plastic, low toughness, friable, asphalt odor, dry.
10		SP		X		4-6-7 (13)	POORLY GRADED SAND (SP): dark brown (10YR 3/3), fine to medium sand, moderate grading, dry.
15				X		6-6-8 (14)	
20			0.7	X		7-6-7 (13)	
		SM					SILTY SAND (SM): dark brown (10YR 3/3), very fine to fine sand, 15% silt, moderate cementation, moist.

WELL DIAGRAM



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ERM
101 SW Main Street, Suite 804
Portland, OR 97204
Phone: (503) 488-5282
Fax: (503) 488-5142

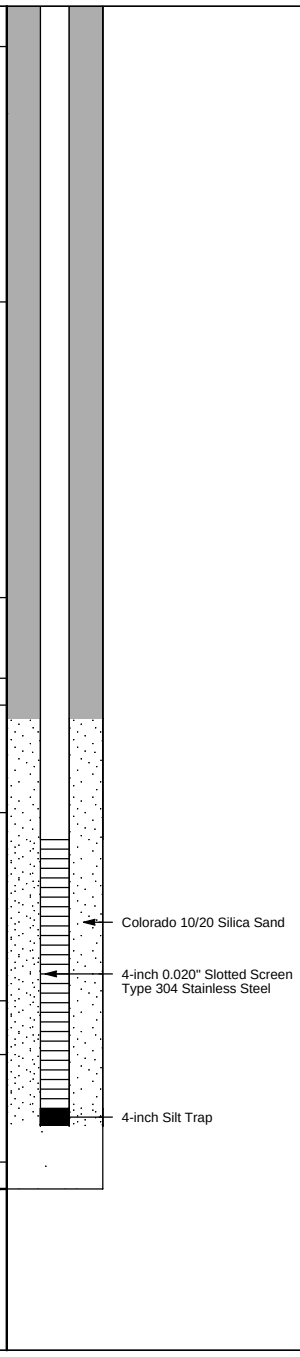
LOG OF MONITORING WELL: RW-4i

Project Number: 104709
Project Name: Arkema, Inc.
Client Name: Legacy Site Services
Location:
Contractor: Cascade Drilling Inc. (Portland, Oregon)
Drilling Method: Hollow Stem Auger
Logged By: S. DeGrood

Date Started: 9/1/2009
Date Completed: 9/1/2009
Total Depth: 47 feet
Borehole Diameter: 10 inches
Initial Water Level: 27.78 feet bgs
Notes: Screened from 40.5 to 45.5 feet.

Depth (ft)	USCS Code	PID (ppm)	Sample Interval	Sample Number	BLOW COUNTS (N VALUE)	Soil Descriptions and Observations
	SW				7-10-16 (26)	3-inch layer of wood fragments at 25.5 feet below ground surface.
	SW					WELL-GRADED SAND (SW): dark brown (10YR 3/3), fine to coarse sand, slight petroleum odor, moist.
		0.2	Steel Tube		6-7-8 (15)	As above except color changes to very dark grayish brown (10YR 3/2) and moisture increases to wet.
30					4-6-12 (18)	
	SW				6-9-16 (25)	WELL-GRADED SAND (SW): very dark grayish brown (10YR 3/2), fine to coarse sand, fine to coarse gravel, well-graded, subrounded, wet. Gravel is pink to gray, basalt, quartz and ash.
						Not sampled from 32.5 to 33 feet below ground surface.
		1.2			8-12-15 (27)	
35						Not sampled from 34.5 to 35 feet below ground surface.
					4-6-9 (15)	
	SP	4.2	Steel Tube			POORLY GRADED SAND (SP): very dark brown (10YR 2/2), fine sand, poorly graded, wet.
					8-12-29 (41)	Gravel increases to 10% and few wood fragments present after 36.5 feet below ground surface.
	SM		Steel Tube			
	SP	1.9			8-6-10 (16)	SILTY SAND (SM): very fine sand, poorly graded, wet.
40						5-inch interbeds of POORLY-GRADED SAND (SP): very dark brown (10YR 2/2) with some yellow flecks, medium sand, poorly graded, wet and
	SP		Steel Tube		10-12-20 (32)	
					6-14-14 (28)	POORLY-GRADED SAND (SP): very dark brown (10YR 2/2), fine sand, poorly graded, wet.
		1	Steel Tube			POORLY-GRADED SAND (SP): very dark brown (10YR 2/2), medium sand, poorly graded, wet.
					6-7-14 (21)	
	SP-SM					POORLY-GRADED SAND WITH SILT (SP-SM): very dark grayish brown (10YR 3/2), fine sand, 10% silt, poorly graded, wet.
45	SP				3-4-7 (11)	
						POORLY-GRADED SAND (SP): very dark brown (10YR 2/2), medium sand, poorly graded, wet.
			Steel Tube		8-9-12 (21)	
	CL	0.5				3-inch lens of 20% gravel at 45 feet below ground surface
						LEAN CLAY (CL): dark gray (10YR 4/1), medium plasticity, high toughness, wet.
						Total Depth - 47 feet bgs

WELL DIAGRAM



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Attachment B
Geotechnical Analysis Memo

Draft Memorandum

Environmental Resources Management

200 Harry S Truman Parkway, Suite 400
Annapolis, MD 21401
(410) 266-0006
(410) 266-8912 (fax)

To: Erik Ipsen, Brendan Robinson

Company: ERM – Portland, Oregon

From: Stephen Lindsay, Darren Quillen

File number: 0093634.5.1

Date: January 8, 2010

Subject: August/September 2009 Geotechnical Sampling and Testing Summary
Arkema, Inc. – Portland Facility
Portland, Oregon

Soil samples were collected for geotechnical testing during installation of observation/recovery wells MWA-80i, MWA-81i, RW-1, RW-2i, and RW-4i at the former Arkema, Inc. facility in Portland, Oregon ("Site"). The sampling locations are depicted on Figure 3 (included as Attachment 1). Observation/Recovery well installation and sample collection occurred between August 25 and September 1, 2009 and was performed in accordance with the Data Gaps Assessment Work Plan, dated March 2009 ("Work Plan"), prepared by Environmental Resources Management (ERM). The wells were installed using a combination of hollow stem auger and sonic drilling methods. Shelby tubes were utilized to collect relatively undisturbed samples for subsequent geotechnical testing. The observation/recovery well boring logs are included as Attachment 2.

In accordance with historical investigation, the subsurface strata generally include, in descending order, silty sand (shallow zone), silt (shallow-intermediate zone), sand (intermediate zone), silty sand (deep zone), and basalt. Soil samples representative of these various soil types encountered at the Site were selected for testing in order to obtain geotechnical engineering properties for use in the design of the groundwater barrier wall. A total of six (6) soil samples were sent to GEOCON, Inc. for determination of index properties and strength parameters. The results of the geotechnical testing are summarized in the table below; detailed laboratory test results are provided in Attachment 3.

Sample Location	Soil Classification (ASTM D-2487)	Moisture Content (ASTM D-2216)		Atterberg Limits (ASTM D-4318			Shear Strength (ASTM D-4767 or ASTM D-3080)	
		Moisture (%)	Dry Density (lb/ft^3)	Liquid Limit	Plastic Limit	Plasticity Index	Cohesion (lb/ft^2)	Friction Angle (˚)
80i (33-35′)	SP	25.0	93.2	-	-	-	324	35
81i (22-25′)	CL-ML	21.3	-	28	24	4	-	-
81i (46-48′)	CL	27.0	101	29	20	9	630	31
RW-1 (30.5-31′)	SM	21.4	104	-	-	-	480	38
RW-2i (45-47′)	SM	36.1	87.8	-	-	-	0	36
RW-4i (40-40.5′)	SP-SM	31.7	90.7	-	-	-	414	39

Notes:
1. A "–" indicates that the test was not performed
2. SP = poorly graded sand
CL-ML = sandy silty clay
CL = lean clay
SM = silty sand
SP-SM = poorly graded sand with silt

It is important to note that the proposed slurry wall will be installed through a fill layer that is present to a depth of approximately 25 feet in the vicinity of the riverbank, and extending from the riverbank to the west approximately 300 feet at the north end of the wall and 150 feet at the south end. RW-1 and RW-2i were installed through the fill layer, although a sample of the fill material was not available for geotechnical testing. However, all of the available geotechnical data, including laboratory test results described herein and information from other borings (e.g. blow counts and soil classification), and engineering experience will be considered in the design of the groundwater barrier wall.

Attachment 1
Figure 3

Project Number: 0104584

Date: 04/28/2010

Created By: mike.appel

File: F:\RM106\ERM West\Arkema\0104584 GW Monitoring Aug 2009\PumpTestLocations.mxd

New Wells

- Shallow Zone Monitoring Well
- Intermediate Zone Monitoring Well
- Deep Zone Piezometer
- Shallow Zone Recovery Well
- Intermediate Zone Recovery Well

Existing Monitoring Wells

- Shallow Zone
- Shallow-Intermediate Zone
- Intermediate Zone
- Deep Zone
- Gravel Zone
- Basalt Zone

200 100 0 200 Feet

Scale 1:2,400

N

FIGURE 3
Aquifer Testing Well Locations
Arkema, Inc
Portland, Oregon

Aerial Photography: City of Portland, June 2008

ERM 04/10

Attachment 2
Boring Logs

ERM
101 SW Main Street, Suite 804
Portland, OR 97204
Phone: (503) 488-5282
Fax: (503) 488-5142

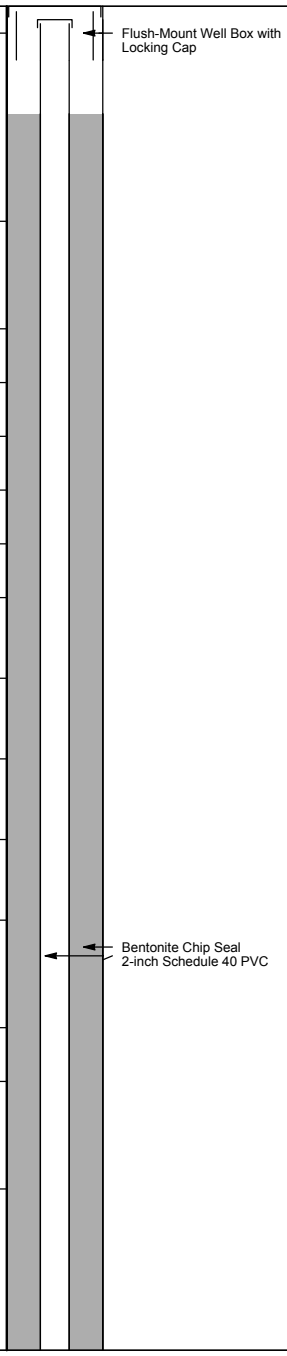
LOG OF MONITORING WELL: MWA-80i

Project Number: 104709
Project Name: Arkema, Inc.
Client Name: Legacy Site Services
Location:
Contractor: Cascade Drilling Inc. (Portland, Oregon)
Drilling Method: Sonic
Logged By: S. DeGrood

Date Started: 8/25/2009
Date Completed: 8/25/2009
Total Depth: 50 feet
Borehole Diameter: 6 inches
Initial Water Level: 18.21 feet bgs
Notes: Centralizers at top and bottom of screen.

Depth (ft)	Graphic Log	USCS Code	PID (ppm)	Sample Interval	Sample Number	Soil Descriptions and Observations
						Asphalt over geotextile liner.
		SP				POORLY GRADED SAND (SP): dark olive brown (2.5Y 3/3), fine sand, intermittent rocks of 1- to 4-inch diameter, poorly graded, dry. Fill material
5						No recovery.
		SW				WELL-GRADED SAND WITH GRAVEL (SW): dark brown (10YR 3/3), fine to coarse sand, 25% fine to coarse gravel, well-graded, rounded to subrounded, slightly moist.
		SP				POORLY GRADED SAND (SP): dark brown (10YR 3/3), fine sand, poorly graded, slightly moist.
		SP				
		ML	4.4			1-inch interbeds of: POORLY GRADED SAND (SP): dark brown (10YR 3/3), fine sand, poorly graded, slightly moist; and SILT (ML): dark brown (10YR 3/3), trace fine sand, low plasticity, medium toughness, slightly moist.
10		SP				
		SW				SILT (ML): 1-centimeter mottles of dark brown (10YR 3/3) and gray with few mottles of red, 0.5-centimter inclusions of fine sand, medium plasticity, medium toughness, moist.
		SP				POORLY GRADED SAND (SP): dark brown (10YR 3/3), fine sand, poorly graded, slightly moist.
		SW	5.7			WELL-GRADED SAND WITH GRAVEL (SW): dark brown (10YR 3/3), fine to coarse sand, 25% fine to coarse gravel, well-graded, rounded to subrounded, moist. Coarse sand and gravel is gray to pink.
15		SP				POORLY GRADED SAND (SP): dark brown (10YR 3/3), fine sand, poorly graded, slightly moist.
		SW				WELL-GRADED SAND WITH GRAVEL (SW): dark brown (10YR 3/3), fine to coarse sand, 25% fine to coarse gravel, well-graded, rounded to subrounded, moist. Coarse sand and gravel is gray to pink.
		SP				POORLY GRADED SAND (SP): dark brown (10YR 3/3), fine sand, poorly graded, slightly moist.
20		SW	6.3			WELL-GRADED SAND WITH GRAVEL (SW): dark brown (10YR 3/3), fine to coarse sand, 25% fine to coarse gravel, well-graded, rounded to subrounded, moist. Coarse sand and gravel is gray to pink.
		SP				POORLY GRADED SAND (SP): dark brown (10YR 3/3), fine sand, poorly graded, slightly moist.
						WELL-GRADED SAND WITH GRAVEL (SW): dark brown (10YR 3/3), fine to coarse sand, 25% fine to coarse gravel, well-graded, rounded to subrounded, moist. Coarse sand and gravel is gray to pink.
						Trace silt starting at 23 feet below ground surface.

WELL DIAGRAM



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ERM
101 SW Main Street, Suite 804
Portland, OR 97204
Phone: (503) 488-5282
Fax: (503) 488-5142

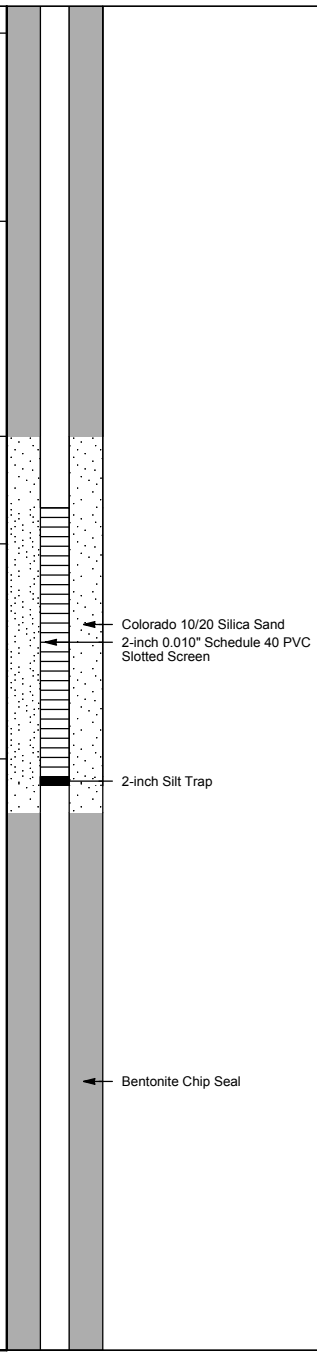
LOG OF MONITORING WELL: MWA-80i

Project Number: 104709
Project Name: Arkema, Inc.
Client Name: Legacy Site Services
Location:
Contractor: Cascade Drilling Inc. (Portland, Oregon)
Drilling Method: Sonic
Logged By: S. DeGrood

Date Started: 8/25/2009
Date Completed: 8/25/2009
Total Depth: 50 feet
Borehole Diameter: 6 inches
Initial Water Level: 18.21 feet bgs
Notes: Centralizers at top and bottom of screen.

Depth (ft)	Graphic Log	USCS Code	PID (ppm)	Sample Interval	Sample Number	Soil Descriptions and Observations
		SW-SM	4.1			POORLY GRADED SAND (SP): dark brown (10YR 3/3), fine sand, poorly graded, slightly moist. WELL-GRADED SAND WITH SILT AND GRAVEL (SW-SM): dark brown (10YR 3/3), fine to coarse sand, 25% fine to coarse gravel, 10% silt, well-graded, rounded to subrounded, lightly cemented, moist. Coarse sand and gravel is gray to pink.
30		SP	3.9			POORLY GRADED SAND (SP): very dark grayish brown (2.5Y 3/2), fine sand, poorly graded, wet.
		ML			Shelby Tube	Wood fragments at 32.5 feet below ground surface. Shelby tube sample collected, could not log. Assumed to be silt based on surrounding borings and change in lithology above 33 feet below ground surface and below 35 feet below ground surface.
35		SP	4.1		Grain Size	POORLY GRADED SAND (SP): black (2.5Y 2.5/1), fine sand, trace silt, poorly graded, wet.
40		CL	5.2		Grain Size	LEAN CLAY (CL): very dark gray (2.5Y 3/1), medium-high plasticity, high toughness, wet. Many charcoal flakes at 39.5 feet below ground surface. LEAN CLAY (CL): dark gray (2.5Y 4/1), medium-high plasticity, medium toughness, wet. Frequent lenses of light brownish gray (2.5Y 5/1) from 40.5 to 41 feet below ground surface.
45			3.4		Grain Size	LEAN CLAY (CL): dark gray (2.5Y 4/1), 10% very fine sand, medium-high plasticity, medium toughness, wet. Many wood and charcoal fragments at 45 feet below ground surface. 2-centimeter mottles of dark grayish brown (2.5Y 4/2) after 47 feet below ground surface. 4-centimeter mottles of dark grayish brown (2.5Y 4/2) after 48.5 feet below ground surface.

WELL DIAGRAM



Total Depth - 50 feet bgs

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ERM
101 SW Main Street, Suite 804
Portland, OR 97204
Phone: (503) 488-5282
Fax: (503) 488-5142

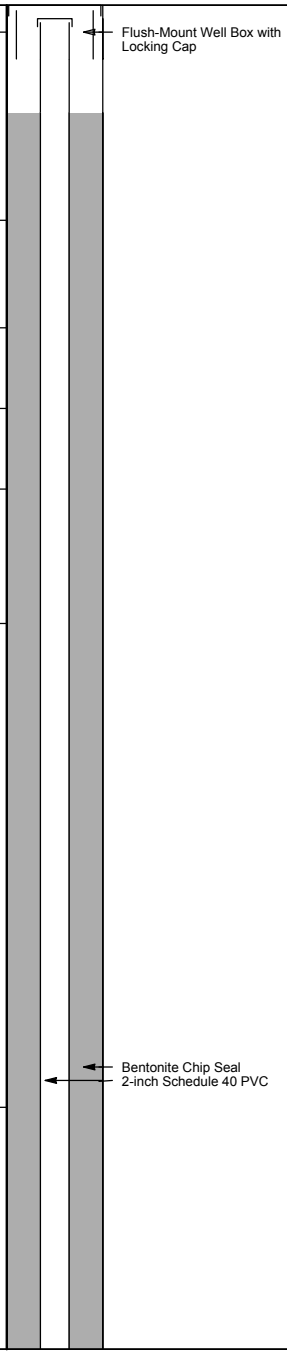
LOG OF MONITORING WELL: MWA-81i

Project Number: 104709
Project Name: Arkema, Inc.
Client Name: Legacy Site Services
Location:
Contractor: Cascade Drilling Inc. (Portland, Oregon)
Drilling Method: Sonic
Logged By: S. DeGrood

Date Started: 8/26/2009
Date Completed: 8/26/2009
Total Depth: 48 feet
Borehole Diameter: 6 inches
Initial Water Level: 28.1 feet bgs
Notes: Centralizers at top and bottom of screen.

Depth (ft)	Graphic Log	USCS Code	PID (ppm)	Sample Interval	Sample Number	Soil Descriptions and Observations
						Asphalt over geotextile liner.
		SP				POORLY GRADED SAND (SP): dark olive brown (2.5Y 3/3), fine sand, intermittent rocks of 1- to 4-inch diameter, poorly graded, dry. Fill material
5		MH	3.2			ELASTIC SILT WITH SAND (MH): brown (10YR 4/3), 20% very fine sand, medium plasticity, medium toughness, moist. 1-inch lens of SILTY SAND (SM): fine sand, 30% silt, poorly graded at 4.5 feet below ground surface.
		MH				1-inch lens of SILTY SAND (SM): fine sand, 30% silt, poorly graded at 5 feet below ground surface.
		MH				1-inch lens of SILTY SAND (SM): fine sand, 30% silt, poorly graded at 5.5 feet below ground surface.
		SM	1.1			ELASTIC SILT (MH): gray (10YR 5/1) with many 1-centimeter mottles of red, trace very fine sand, medium plasticity, medium toughness, moist.
10						ELASTIC SILT WITH SAND (MH): brown (10YR 4/3), 20% very fine sand, medium plasticity, medium toughness, moist. 1-inch lens of SILTY SAND (SM): fine sand, 30% silt, poorly graded at 8.5 feet below ground surface.
		SP				1-inch lens of SILTY SAND (SM): fine sand, 30% silt, poorly graded at 8.75 feet below ground surface.
		SP				SILTY SAND (SM): dark brown (10YR 3/3), fine to coarse sand, 10% fine gravel, 15% silt, well-graded, rounded, moist. Coarse sand to gravel is gray.
15						POORLY GRADED SAND (SP): dark brown (10YR 3/3), fine sand, trace silt, poorly graded, moist. Strong cementation from 11.5 to 11.75 feet below ground surface. Sand at 11.5 feet is hot and dry due to sonic drilling.
			2.1			POORLY GRADED SAND (SP): dark brown (10YR 3/3), fine sand, trace silt, poorly graded, moist.
20		SM	3			SILTY SAND (SM): dark brown (10YR 3/3), very fine sand, 20% silt, poorly graded, moist.
				Grain Size		Poor recovery from 22 to 32 feet below ground surface due to very soft material that didn't pack into sampler barrel. Depths are approximate. Becomes wet after 23 feet below ground surface.
						Trace wood fragments at 24 feet below ground surface.

WELL DIAGRAM



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ERM
101 SW Main Street, Suite 804
Portland, OR 97204
Phone: (503) 488-5282
Fax: (503) 488-5142

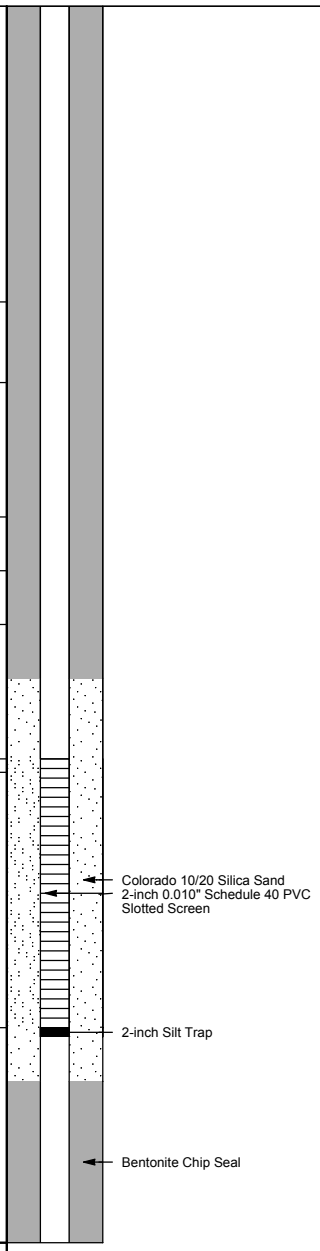
LOG OF MONITORING WELL: MWA-81i

Project Number: 104709
Project Name: Arkema, Inc.
Client Name: Legacy Site Services
Location:
Contractor: Cascade Drilling Inc. (Portland, Oregon)
Drilling Method: Sonic
Logged By: S. DeGrood

Date Started: 8/26/2009
Date Completed: 8/26/2009
Total Depth: 48 feet
Borehole Diameter: 6 inches
Initial Water Level: 28.1 feet bgs
Notes: Centralizers at top and bottom of screen.

Depth (ft)	Graphic Log	USCS Code	PID (ppm)	Sample Interval	Sample Number	Soil Descriptions and Observations
			1.4			SILTY SAND (SM): dark brown (10YR 3/3), very fine sand, 20% silt, poorly graded, moist. SILTY SAND (SM): dark brown (10YR 3/3) with 1.5-centimeter dark gray mottles, very fine sand, 20% silt, many wood fragments, poorly graded, moist. SILTY SAND (SM): very dark grayish brown (10YR 3/2), fine sand, 20% silt, poorly graded, wet. Moderate cementation at 29 feet below ground surface.
30		SP-SM				POORLY GRADED SAND WITH SILT (SP-SM): very dark grayish brown (10YR 3/2), fine sand, 10% silt, poorly graded, moist.
		SW	0.4		Grain Size	WELL-GRADED SAND (SW): very dark gray (10YR 3/1), medium to coarse sand, 15% fine to coarse gravel, 5% silt, well-graded, wet.
					Grain Size	
35		SM				SILTY SAND (SM): very dark gray (10YR 3/1), fine sand, 30% silt, poorly graded, wet.
		SW				WELL-GRADED SAND (SW): very dark gray (2.5Y 3/1), medium to coarse sand, 5% fine gravel, well-graded, subrounded to rounded, wet.
		SP	0.5		Grain Size	POORLY GRADED SAND (SP): very dark gray (2.5Y 3/1), fine sand, trace silt, poorly graded, wet.
						Wood fragments at 38.75 feet below ground surface.
		ML				Three-inch layer of SANDY SILT (ML): low plasticity, low toughness.
40		SP-SM			Grain Size	POORLY GRADED SAND WITH SILT (SP-SM): very dark gray (2.5Y 3/1), fine sand, 10% silt, poorly graded, wet.
						Poor recovery from 43 to 44 feet below ground surface. Sample recovered from bottom of shoe.
		CL	2.7		Grain Size	LEAN CLAY (CL): dark gray (2.5Y 4/1), high plasticity, medium toughness, wet.
45					Shelby Tube	
						Total Depth - 48 feet bgs

WELL DIAGRAM



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ERM
101 SW Main Street, Suite 804
Portland, OR 97204
Phone: (503) 488-5282
Fax: (503) 488-5142

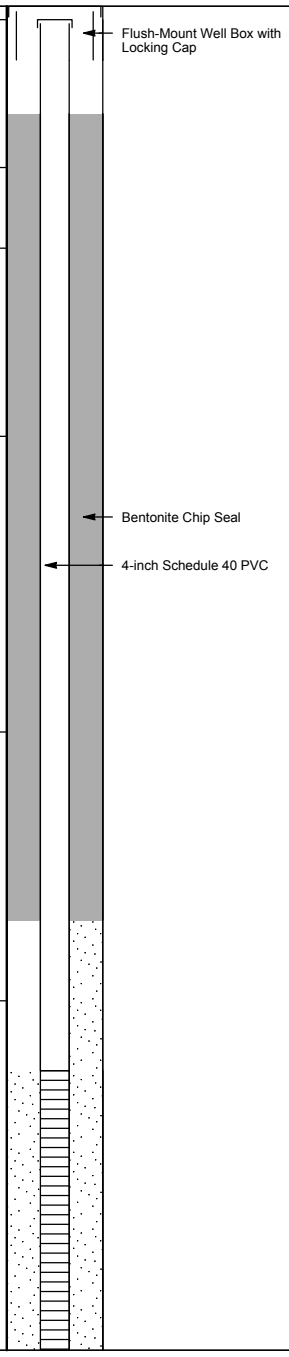
LOG OF MONITORING WELL: RW-1

Project Number: 104709
Project Name: Arkema, Inc.
Client Name: Legacy Site Services
Location:
Contractor: Cascade Drilling Inc. (Portland, Oregon)
Drilling Method: Hollow Stem Auger
Logged By: S. DeGrood

Date Started: 8/31/2009
Date Completed: 8/31/2009
Total Depth: 41.5 feet
Borehole Diameter: 10 inches
Initial Water Level: 25.81 feet bgs
Notes:

Depth (ft)	Graphic Log	USCS Code	PID (ppm)	Sample Interval	Sample Number	BLOW COUNTS (N VALUE)	Soil Descriptions and Observations
		SW					Gravel fill with geotextile liner at 0.25 feet below ground surface. WELL-GRADED SAND WITH GRAVEL (SW): dark brown (7.5YR 3/2), fine to coarse sand, approximately 20% fine to coarse gravel, well-graded, slightly moist. Fill material. Wire with green plastic coating noted at 2 feet below ground surface.
		SP					POORLY GRADED SAND (SP): dark brown (7.5YR 3/2), fine sand, 5% coarse sand, moderate grading, coarse sand is angular, moist.
5		SP		X		8-16-5 (21)	POORLY GRADED SAND WITH GRAVEL (SP): dark brown (7.5YR 3/2), fine sand, 5% coarse sand, 30% fine to coarse gravel, moderate grading, angular to subangular, moist.
		ML					SILT (ML): dark grayish brown (10YR 4/2), 10% medium sand to coarse gravel, medium plasticity, low toughness, slight odor, moist. Sand and gravel is pink to gray and includes concrete fragments.
10				X		1-2-4 (6)	
		SP-SM					POORLY GRADED SAND WITH SILT (SP-SM): dark grayish brown (10YR 4/2), very fine sand, few coarse gravel, 10% silt, poorly graded, few wood fragments, slight odor, wet.
15			11.5	X		9-11-16 (27)	No gravel or wood fragments after 16 feet below ground surface.
		SP					POORLY GRADED SAND (SP): dark grayish brown (10YR 4/2), very fine sand, trace silt, poorly graded, slight odor, wet.
20			14.5	X		8-8-9 (17)	

WELL DIAGRAM



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ERM
101 SW Main Street, Suite 804
Portland, OR 97204
Phone: (503) 488-5282
Fax: (503) 488-5142

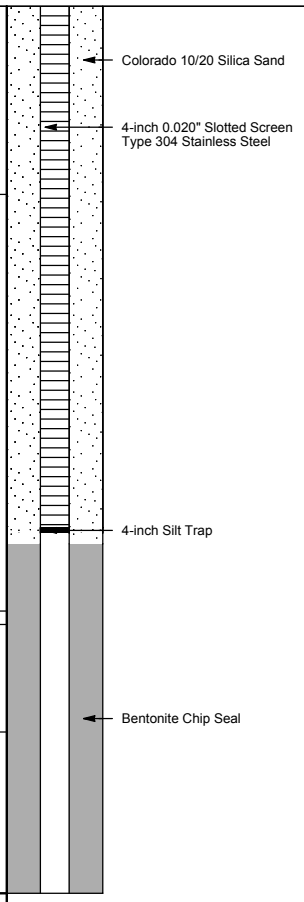
LOG OF MONITORING WELL: RW-1

Project Number: 104709
Project Name: Arkema, Inc.
Client Name: Legacy Site Services
Location:
Contractor: Cascade Drilling Inc. (Portland, Oregon)
Drilling Method: Hollow Stem Auger
Logged By: S. DeGrood

Date Started: 8/31/2009
Date Completed: 8/31/2009
Total Depth: 41.5 feet
Borehole Diameter: 10 inches
Initial Water Level: 25.81 feet bgs
Notes:

Depth (ft)	USCS Code	PID (ppm)	Sample Interval	Sample Number	BLOW COUNTS (N VALUE)	Soil Descriptions and Observations
	SP	4.5			7-8-10 (18)	POORLY GRADED SAND (SP): dark grayish brown (10YR 4/2), very fine sand, trace silt, poorly graded, slight odor, wet.
	SP					POORLY GRADED SAND (SP): very dark gray (2.5Y 3/1), fine sand, poorly graded, slight sweet odor, wet.
30	SP		Steel Tube, Steel Tube		8-11-13 (24)	
	SP	30.5			3-4-5 (9)	Wood fragments at 32.75 feet below ground surface. Not sampled from 33 to 34 feet below ground surface.
35	SP		Steel Tube		7-7-7 (14)	
	ML SP	12.7	Steel Tube		6-14-17 (31)	SANDY SILT (ML): very dark gray (2.5Y 3/1), 40% very fine sand, medium plasticity, low toughness, slight sweet odor, wet.
	SP				2-3-3 (6)	POORLY GRADED SAND (SP): black (2.5Y 2.5/1), fine sand, poorly graded, no odor, wet.
40					3-3-4 (7)	No recovery from 38.5 to 40 feet below ground surface, large rock in sampler.
					9-6-6 (12)	
45						Total Depth - 41.5 feet bgs

WELL DIAGRAM



MW TO 25 FEET W SAMPLES 3 PDX - - 9/14/09 17:02 - C:\PROGRAM FILES\GINT\PROJECTS\104709 PORTLAND ARKEMA PUMP TEST.GPJ

ERM
101 SW Main Street, Suite 804
Portland, OR 97204
Phone: (503) 488-5282
Fax: (503) 488-5142

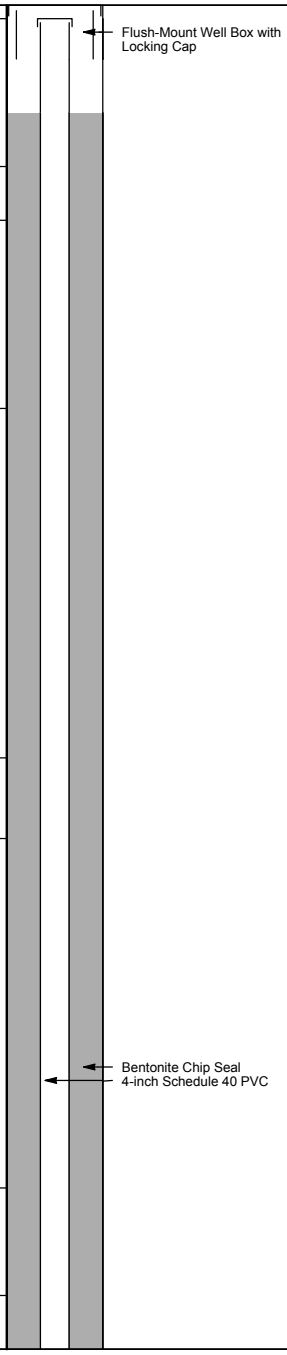
LOG OF MONITORING WELL: RW-2i

Project Number: 104709
Project Name: Arkema, Inc.
Client Name: Legacy Site Services
Location:
Contractor: Cascade Drilling Inc. (Portland, Oregon)
Drilling Method: Sonic
Logged By: S. DeGrood

Date Started: 8/27/2009
Date Completed: 8/27/2009
Total Depth: 47 feet
Borehole Diameter: 8 inches
Initial Water Level: 23.04 feet bgs
Notes: Centralizers at top and bottom of screen. Borehole cased off to 9-inch borehole from 0 to 37.5 feet.

Depth (ft)	Graphic Log	USCS Code	PID (ppm)	Sample Interval	Sample Number	Soil Descriptions and Observations
						Gravel fill with geotextile liner at 0.25 feet below ground surface.
		SW	0			WELL-GRADED SAND WITH GRAVEL (SW): dark brown (7.5YR 3/2), fine to coarse sand, approximately 20% fine to coarse gravel, well-graded, citrus odor, slightly moist. Fill material. No odor after 1.5 feet below ground surface.
		ML				GRAVELLY SILT (ML): brown (10YR 4/3), 40% fine gravel, low plasticity, medium toughness, slight odor, moist. Gravel is subrounded to rounded.
		ML	61.2			SILT WITH GRAVEL (ML): very dark gray (2.5Y 3/1), 20% fine gravel, medium plasticity, medium toughness, petroleum odor, moist. Gravel is subangular to subrounded. Wood fragments at 5.5 feet below ground surface.
5						
		ML	67.5			GRAVELLY SILT (ML): 3-centimeter mottles of dark yellowish brown (10YR 4/4) and very dark gray (2.5Y 3/1), 10% fine to coarse sand, 30% fine to coarse gravel, few root hairs, medium plasticity, medium toughness, no odor, moist. Sand and gravel are subangular to rounded.
10						
		SM	50.1			SILTY SAND (SM): very dark grayish brown (10YR 3/2), fine sand, 35% silt, poorly graded, no odor, moist.
15						
		SP				Many coarse gravel at 15.5 feet below ground surface. POORLY GRADED SAND (SP): dark brown (10YR 3/3), fine sand, poorly graded, no odor, moist.
			70.2			
20						
		SP-SM				Poor recovery from 22 to 30 feet below ground surface due to blockage in shoe. Depths are approximate. POORLY GRADED SAND WITH SILT (SP-SM): dark grayish brown (2.5Y 4/2), fine sand, 10% silt, poorly graded, weak cementation, no odor, wet.
		SP				

WELL DIAGRAM



MW TO 25 FEET W SAMPLES PDX - - 9/14/09 17:04 - C:\PROGRAM FILES\GINT\PROJECTS\104709 PORTLAND ARKEMA PUMP TEST.GPJ

ERM
101 SW Main Street, Suite 804
Portland, OR 97204
Phone: (503) 488-5282
Fax: (503) 488-5142

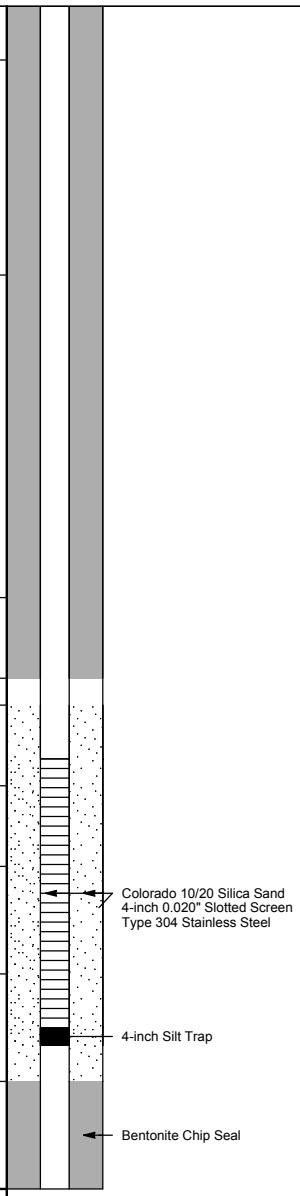
LOG OF MONITORING WELL: RW-2i

Project Number: 104709
Project Name: Arkema, Inc.
Client Name: Legacy Site Services
Location:
Contractor: Cascade Drilling Inc. (Portland, Oregon)
Drilling Method: Sonic
Logged By: S. DeGrood

Date Started: 8/27/2009
Date Completed: 8/27/2009
Total Depth: 47 feet
Borehole Diameter: 8 inches
Initial Water Level: 23.04 feet bgs
Notes: Centralizers at top and bottom of screen. Borehole cased off to 9-inch borehole from 0 to 37.5 feet.

Depth (ft)	Graphic Log	USCS Code	PID (ppm)	Sample Interval	Sample Number	Soil Descriptions and Observations
			30.4		Grain Size	POORLY GRADED SAND (SP): dark grayish brown (2.5Y 4/2), fine sand, 5% silt, poorly graded, slight sweet odor, wet.
						No recovery.
30		SP				POORLY GRADED SAND (SP): very dark gray (2.5Y 3/1), fine sand, 5% silt, poorly graded, no odor, wet.
					Grain Size	
			39.2			0.5-inch wood fragments at 34 feet below ground surface.
35						
		ML	23.4		Grain Size	SILT WITH SAND (ML): very dark gray (2.5Y 3/1), 20% very fine to fine sand, low plasticity, medium toughness, slight sweet odor, wet.
		SM				SILTY SAND (SM): black (10YR 2/1), fine sand, 30% silt, poorly graded, slight organic/septic odor, wet.
		SP				POORLY GRADED SAND (SP): black (10YR 2/1), fine sand, poorly graded, slight septic odor, wet.
					Grain Size	
40		SP-SM				Silt increases to 5% and wood fragments increase to 20% after 39 feet below ground surface.
			7.5			
		SP				POORLY GRADED SAND WITH SILT (SP-SM): black (10YR 2/1), fine sand, 10% silt, poorly graded, organic/septic odor, wet.
					Grain Size	POORLY GRADED SAND (SP): black (10YR 2/1), fine sand, 5% silt, poorly graded, slight septic odor, wet.
		ML				SILT (ML): grades from dark gray (2.5Y 4/1) to dark grayish brown (2.5Y 4/2), low plasticity, medium toughness, wet.
			9.1		Grain Size	
45					Shelby Tube	Shelby tube sample collected, could not log.
						Total Depth - 47 feet bgs

WELL DIAGRAM



MW TO 25 FEET W SAMPLES PDX - - 9/14/09 17:04 - C:\PROGRAM FILES\GINT\PROJECTS\104709 PORTLAND ARKEMA PUMP TEST.GPJ

ERM
101 SW Main Street, Suite 804
Portland, OR 97204
Phone: (503) 488-5282
Fax: (503) 488-5142

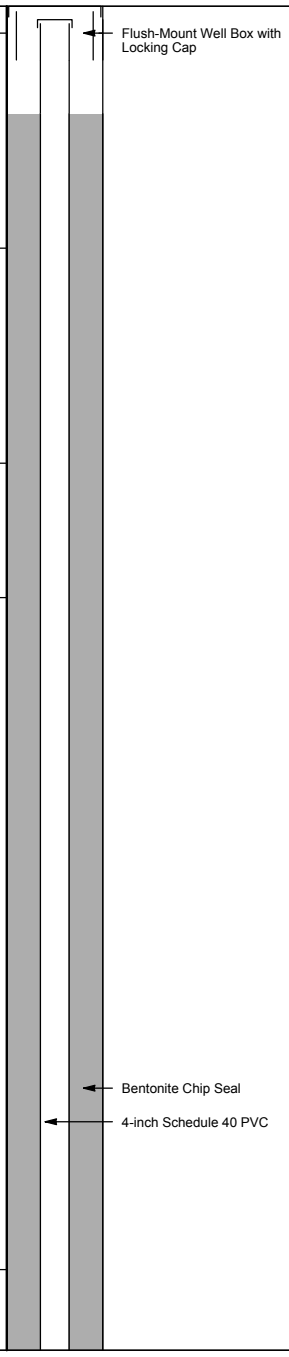
LOG OF MONITORING WELL: RW-4i

Project Number: 104709
Project Name: Arkema, Inc.
Client Name: Legacy Site Services
Location:
Contractor: Cascade Drilling Inc. (Portland, Oregon)
Drilling Method: Hollow Stem Auger
Logged By: S. DeGrood

Date Started: 9/1/2009
Date Completed: 9/1/2009
Total Depth: 47 feet
Borehole Diameter: 10 inches
Initial Water Level: 27.78 feet bgs
Notes:

Depth (ft)	Graphic Log	USCS Code	PID (ppm)	Sample Interval	Sample Number	BLOW COUNTS (N VALUE)	Soil Descriptions and Observations
							Asphalt over geotextile liner.
		SP					POORLY GRADED SAND (SP): dark olive brown (2.5Y 3/3), intermittent rocks of 1- to 4-inch diameter, poorly graded, dry. Fill material
5		SW		X		8-8-11 (19)	WELL-GRADED SAND (SW): dark brown (10YR 3/3), fine to coarse sand, 5% fine to coarse gravel, well-graded, asphalt odor, dry. 1-inch inclusions of silt at 6.25 feet below ground surface.
		ML					SILT WITH SAND (ML): dark brown (10YR 3/3), 20% fine sand, non-plastic, low toughness, friable, asphalt odor, dry.
10		SP		X		4-6-7 (13)	POORLY GRADED SAND (SP): dark brown (10YR 3/3), fine to medium sand, moderate grading, dry.
15				X		6-6-8 (14)	
20			0.7	X		7-6-7 (13)	
		SM					SILTY SAND (SM): dark brown (10YR 3/3), very fine to fine sand, 15% silt, moderate cementation, moist.

WELL DIAGRAM



MW TO 25 FEET W SAMPLES 3 PDX - - 9/14/09 17:02 - C:\PROGRAM FILES\GINT\PROJECTS\104709 PORTLAND ARKEMA PUMP TEST.GPJ

ERM
101 SW Main Street, Suite 804
Portland, OR 97204
Phone: (503) 488-5282
Fax: (503) 488-5142

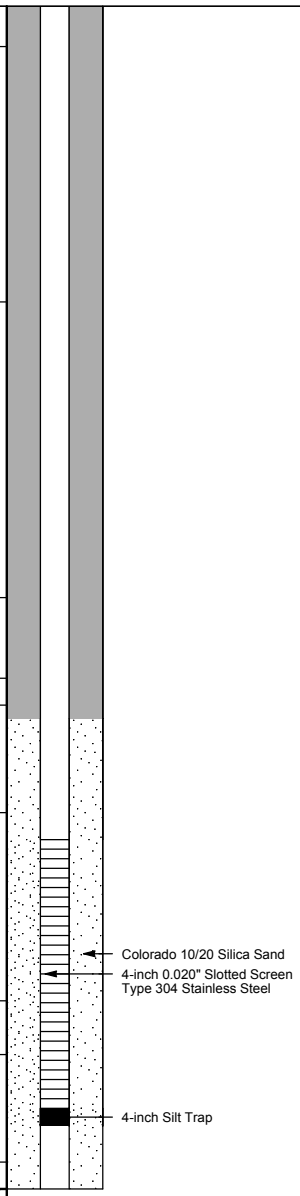
LOG OF MONITORING WELL: RW-4i

Project Number: 104709
Project Name: Arkema, Inc.
Client Name: Legacy Site Services
Location:
Contractor: Cascade Drilling Inc. (Portland, Oregon)
Drilling Method: Hollow Stem Auger
Logged By: S. DeGrood

Date Started: 9/1/2009
Date Completed: 9/1/2009
Total Depth: 47 feet
Borehole Diameter: 10 inches
Initial Water Level: 27.78 feet bgs
Notes:

Depth (ft)	Graphic Log	USCS Code	PID (ppm)	Sample Interval	Sample Number	BLOW COUNTS (N VALUE)	Soil Descriptions and Observations
		SW				7-10-16 (26)	3-inch layer of wood fragments at 25.5 feet below ground surface.
		SW					WELL-GRADED SAND (SW): dark brown (10YR 3/3), fine to coarse sand, slight petroleum odor, moist.
			0.2		Steel Tube	6-7-8 (15)	As above except color changes to very dark grayish brown (10YR 3/2) and moisture increases to wet.
30						4-6-12 (18)	
		SW				6-9-16 (25)	WELL-GRADED SAND (SW): very dark grayish brown (10YR 3/2), fine to coarse sand, fine to coarse gravel, well-graded, subrounded, wet. Gravel is pink to gray, basalt, quartz and ash.
							Not sampled from 32.5 to 33 feet below ground surface.
			1.2			8-12-15 (27)	
35							Not sampled from 34.5 to 35 feet below ground surface.
						4-6-9 (15)	
		SP	4.2		Steel Tube		POORLY GRADED SAND (SP): very dark brown (10YR 2/2), fine sand, poorly graded, wet.
						8-12-29 (41)	Gravel increases to 10% and few wood fragments present after 36.5 feet below ground surface.
		SM			Steel Tube		
		SP	1.9			8-6-10 (16)	SILTY SAND (SM): very fine sand, poorly graded, wet.
40		SP			Steel Tube	10-12-20 (32)	5-inch interbeds of POORLY-GRADED SAND (SP): very dark brown (10YR 2/2) with some yellow flecks, medium sand, poorly graded, wet and
						6-14-14 (28)	POORLY-GRADED SAND (SP): very dark brown (10YR 2/2), fine sand, poorly graded, wet.
			1		Steel Tube		POORLY-GRADED SAND (SP): very dark brown (10YR 2/2), medium sand, poorly graded, wet.
						6-7-14 (21)	
		SP-SM				3-4-7 (11)	POORLY-GRADED SAND WITH SILT (SP-SM): very dark grayish brown (10YR 3/2), fine sand, 10% silt, poorly graded, wet.
45		SP					POORLY-GRADED SAND (SP): very dark brown (10YR 2/2), medium sand, poorly graded, wet.
					Steel Tube	8-9-12 (21)	3-inch lens of 20% gravel at 45 feet below ground surface
		CL	0.5				LEAN CLAY (CL): dark gray (10YR 4/1), medium plasticity, high toughness, wet.
							Total Depth - 47 feet bgs

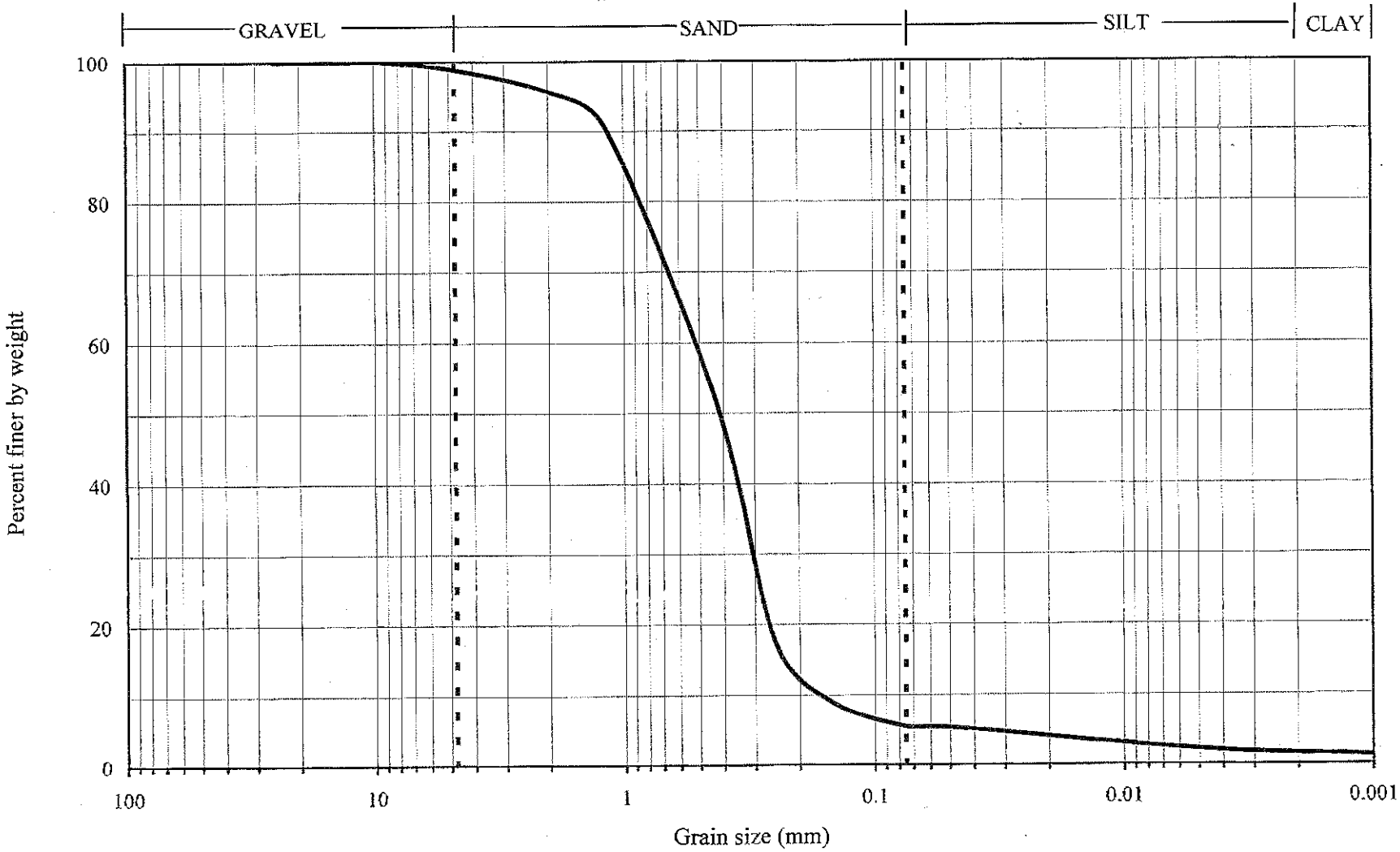
WELL DIAGRAM



MW TO 25 FEET W SAMPLES 3 PDX - - 9/14/09 17:02 - C:\PROGRAM FILES\GINT\PROJECTS\104709 PORTLAND ARKEMA PUMP TEST.GPJ

Attachment 3
Geotechnical Laboratory Test Results

Grain Size Distribution (ASTM D1140 and D 422)
6400 Front Avenue
Sample 80i Depth = 33-35 feet



GEOCON
INCORPORATED

DIRECT SHEAR TEST REPORT

6400 Front Street

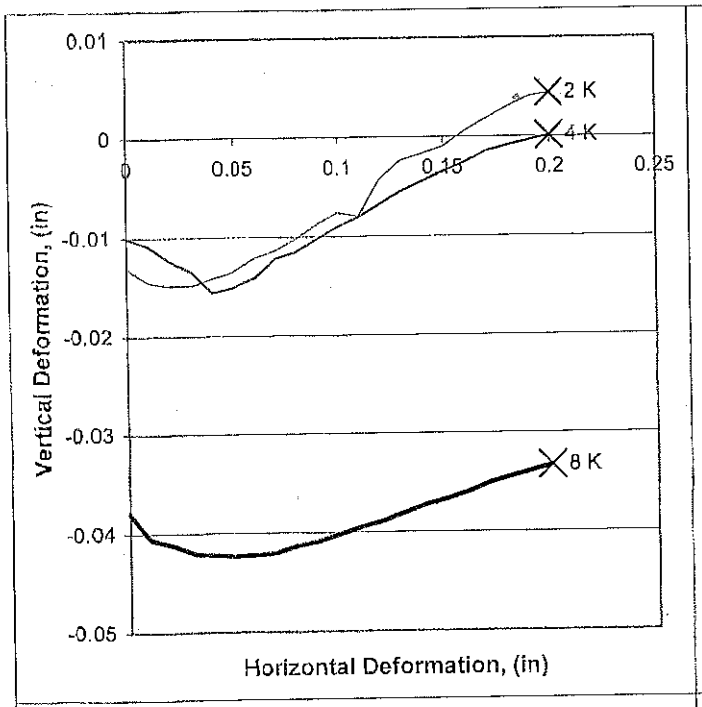
P1701-05-01

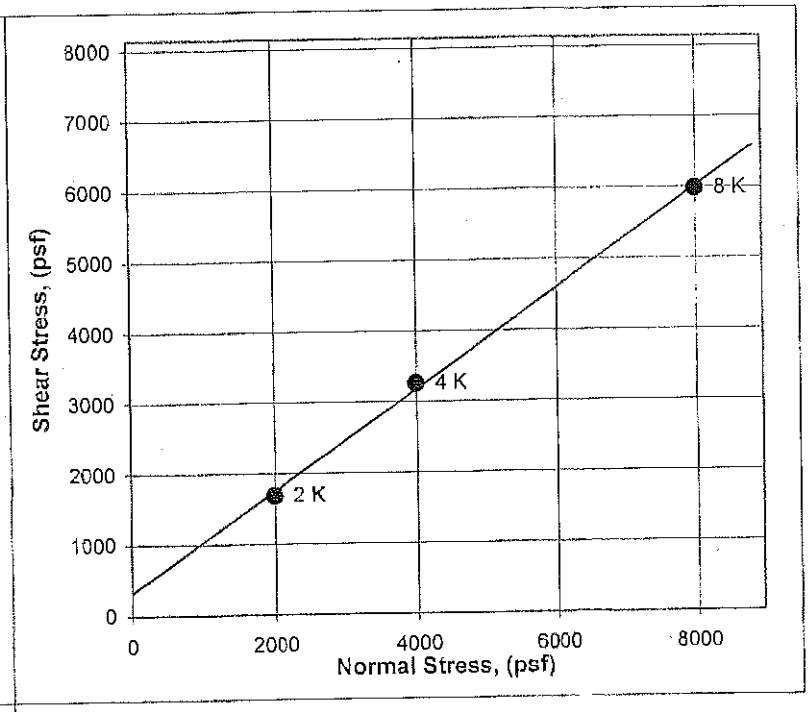
Date: Thursday, October 29, 2009 By: JD

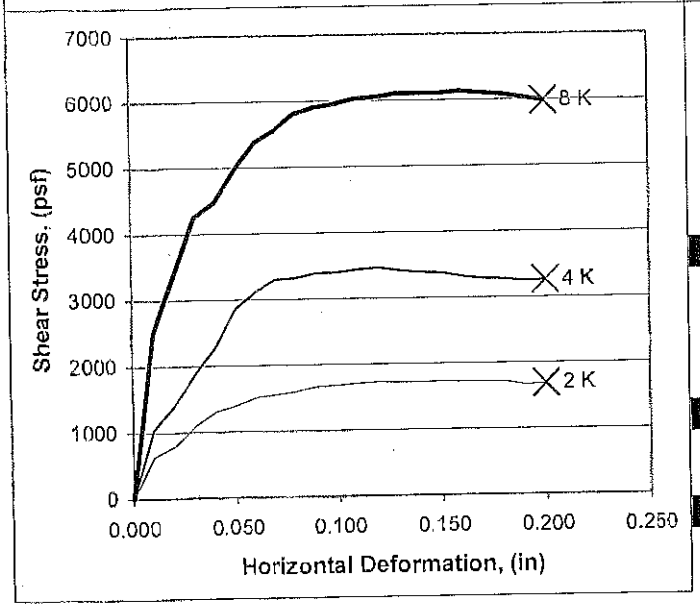
Sample No.: 80i Natural or Remold: Natural

Description: SM

Remarks:





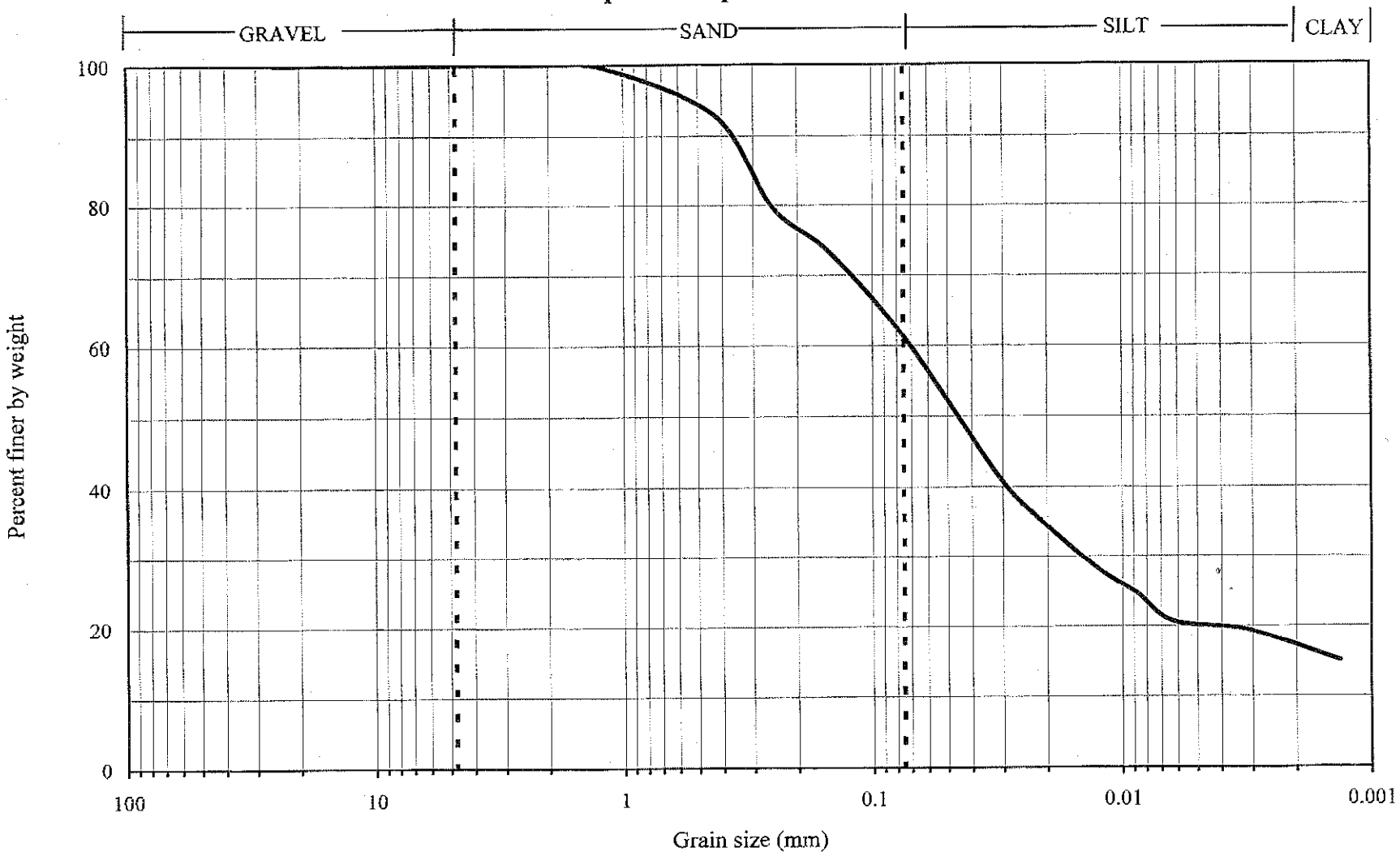


ϕ (Degrees)	35.4
c (psf)	324
Tan ϕ	0.711
Method	Calc

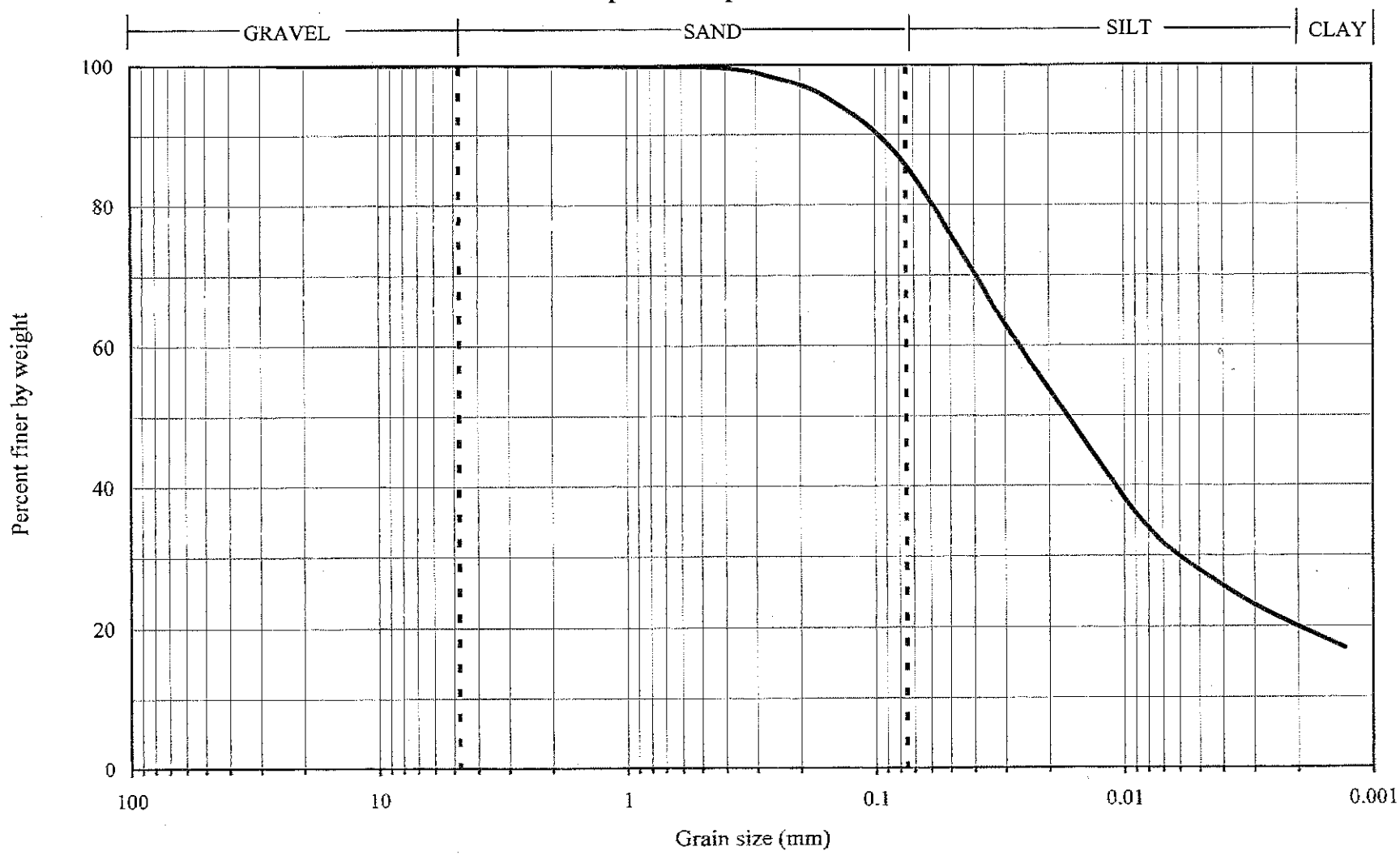
Load	2 K	4 K	8 K
INITIAL			
Water Content	23.3%	27.0%	25.0%
Dry Density (pcf)	97.4	88.8	93.0
Saturation*	88.5%	83.0%	84.9%
Height (inches)	1.00	1.00	1.00
AFTER TEST			
Water Content	24.1%	29.9%	28.3%
Dry Density (pcf)	97.0	88.8	96.2
FAILURE			
Normal Stress (psf)	2000	4000	8000
Failure Stress (psf)	1685	3260	5982
Failure Deffinition	User	User	User
Displacement (in)	0.20	0.20	0.20
Rate (in/min)	0.0050	0.0050	0.0050

* Degree of saturation calculated with a specific gravity of 2.65

Grain Size Distribution (ASTM D1140 and D 422)
6400 Front Avenue
Sample 8li Depth = 22-25 feet



Grain Size Distribution (ASTM D1140 and D 422)
6400 Front Avenue
Sample 8li Depth = 46-48 feet



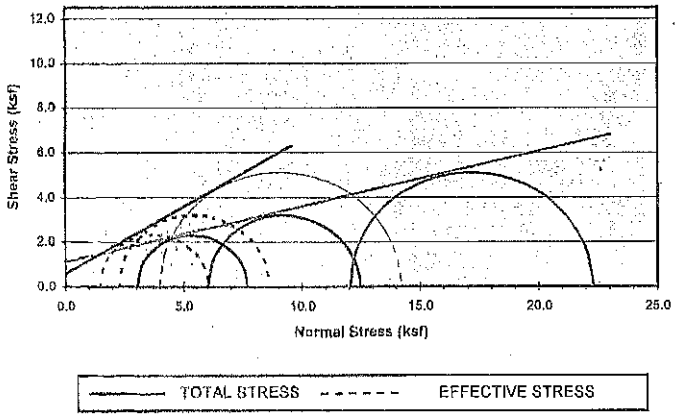
TRIAXIAL SHEAR STRENGTH - CU TEST

ASTM D4767

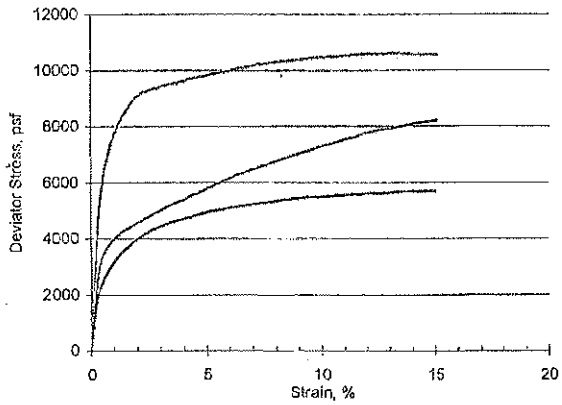
Project Name: 6400 Front Avenue
Project Number: P1701-05-01
Sample Number: MWA 81I 46-48

	SAMPLE ID:	1	2	3
INITIAL CONDITIONS AT START OF TEST	HEIGHT (in.)	4.90	4.90	4.90
	DIAMETER (in.)	2.38	2.40	2.40
	MOISTURE CONTENT (%)	27.0	24.2	26.2
	SATURATION (%)	99.7	99.6	99.8
	DRY DENSITY (pcf)	101.0	103.3	99.7
AFTER SATURATION	DRY DENSITY (pcf)	101.0	103.3	99.7
AFTER CONSOLIDATION	DRY DENSITY (pcf)	103.6	109.1	107.0
SHEAR TEST CONDITIONS	DRY DENSITY (pcf)	103.7	109.3	107.3
	MOISTURE CONTENT (%)	24.6	19.9	20.5
	SATURATION (%)	96.7	94.8	94.0
	STRAIN RATE (%/min)	0.0165	0.0169	#DIV/0!
	CELL PRESSURE (psf)	8880	11820	16380
	INITIAL BACK PRESSURE (psf)	5870	5810	4380
	INITIAL EFF CONFINING PRESS (psf)	3010	6010	12010
	TOTAL MAJOR PRIN STR AT FAIL (psf)	7680	12450	22270
	EFF MAJOR PRIN STR AT FAIL (psf)	6060	8650	14210
	PORE PRESSURE AT FAIL (psf)	1620	3800	8060
	EFF MINOR PRIN STR AT FAIL (psf)	1390	2210	3950

MOHR'S CIRCLES



STRESS-STRAIN

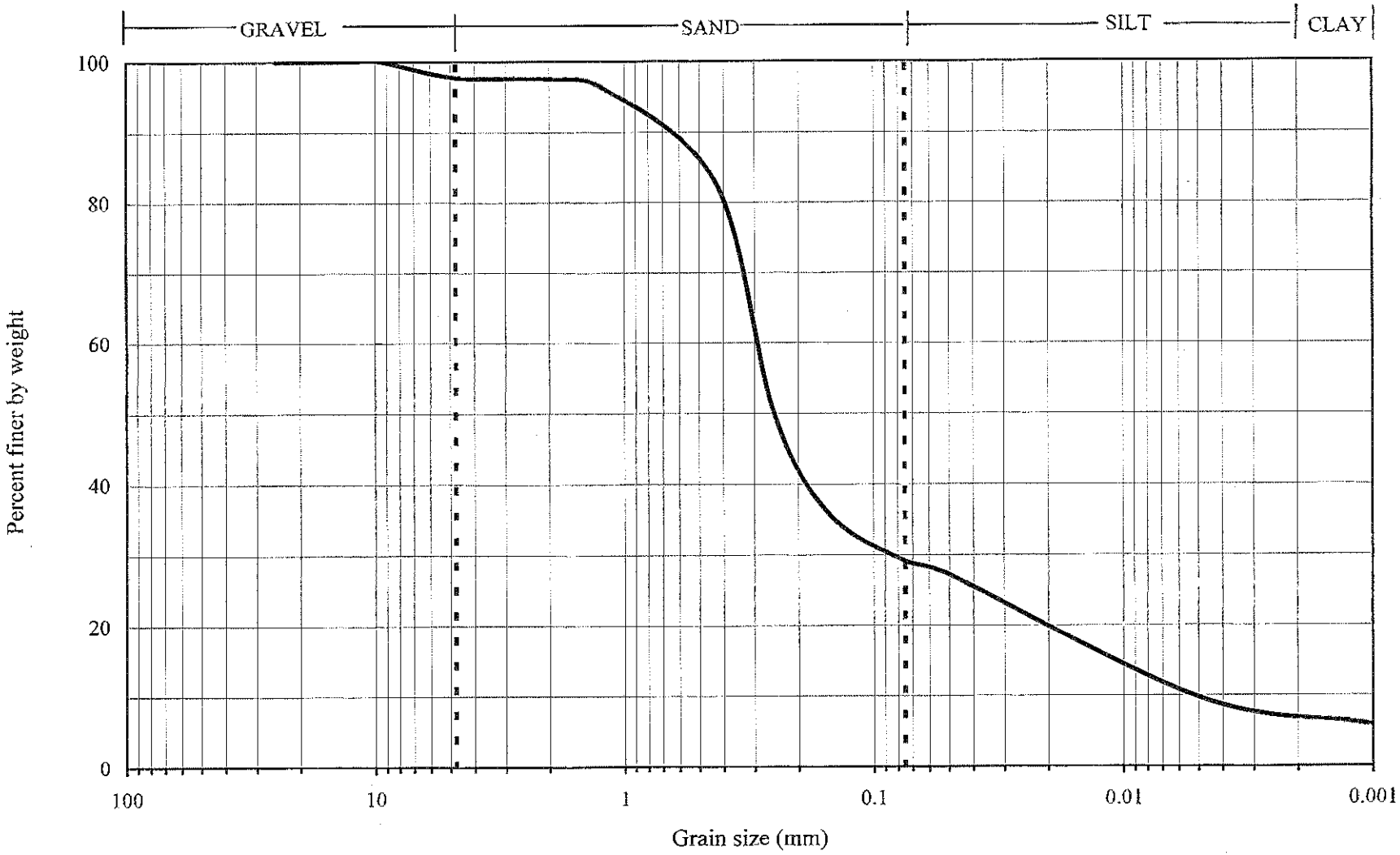


Strength Parameters: At maximum principal stress ratio

	TOTAL	EFFECTIVE:
ϕ, degrees	13.9	30.8
c, psf	1160	630

GEOCON

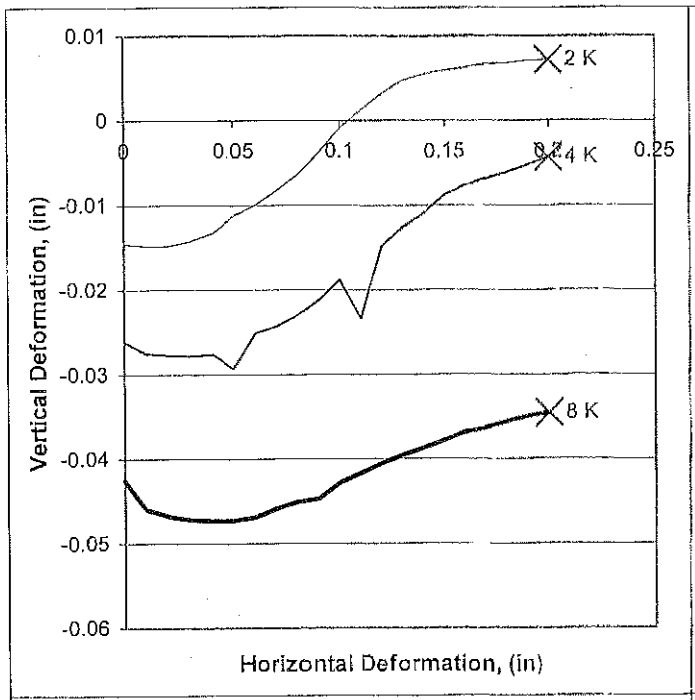
Grain Size Distribution (ASTM D1140 and D 422)
6400 Front Avenue
Sample RW-1 Depth = 30.5-31 feet

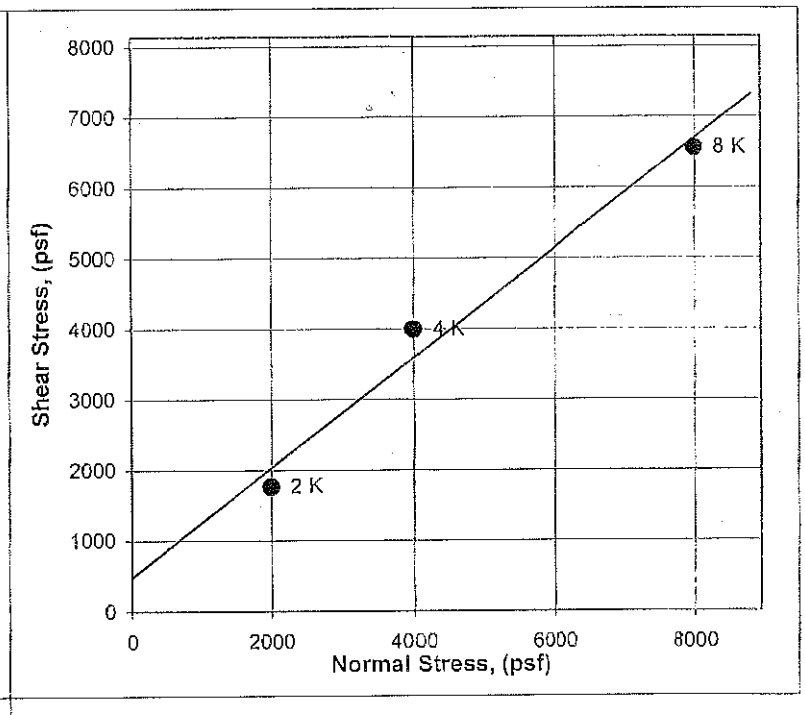


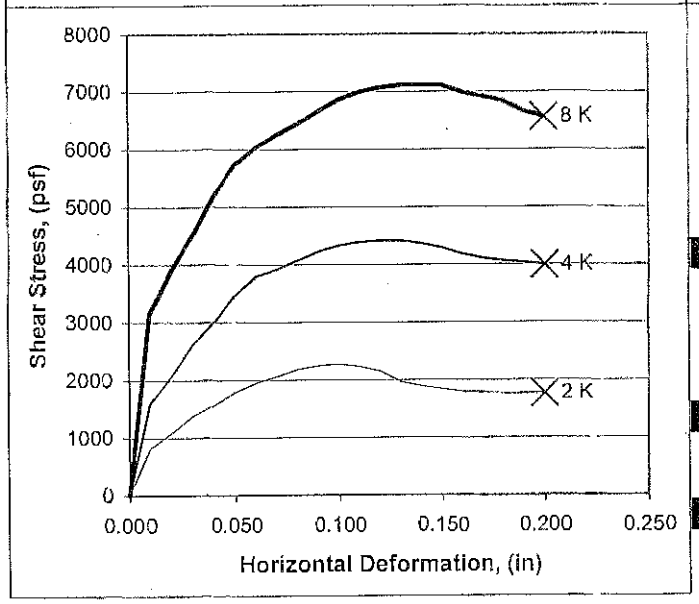
GEOCON
INCORPORATED

DIRECT SHEAR TEST REPORT

P1701-05-01 Date: Monday, October 26, 2009 By: TG
Sample No.: RW-1 30.5-31" Natural or Remold: Natural
Description: SM
Remarks:





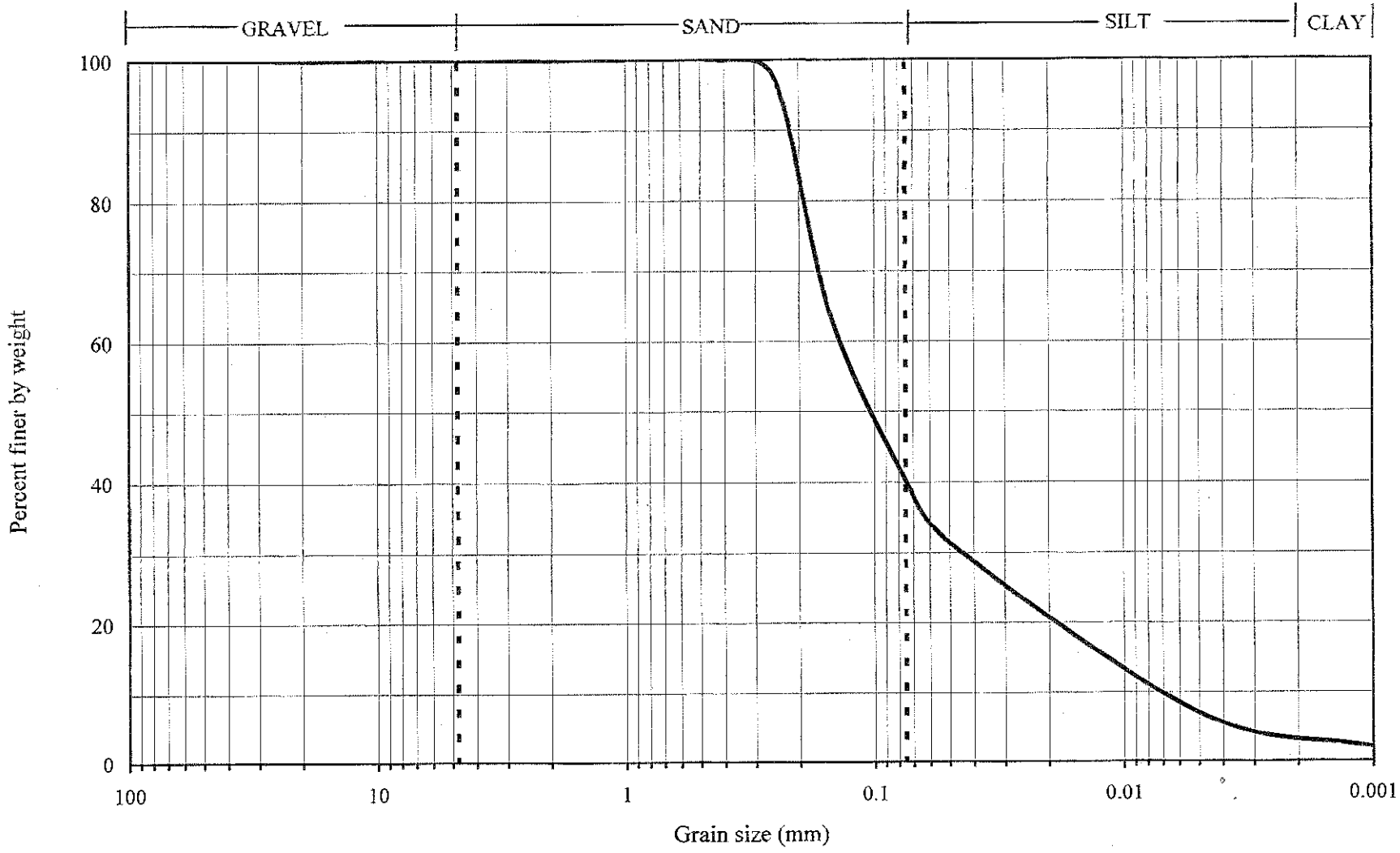


ϕ (Degrees)	37.8
c (psf)	480
Tan ϕ	0.777
Method	Calc

Load	2 K	4 K	8 K
INITIAL			
Water Content	21.4%	21.7%	21.7%
Dry Density (pcf)	103.8	105.9	103.8
Saturation*	95.4%	102.1%	96.9%
Height (inches)	1.00	1.00	1.00
AFTER TEST			
Water Content	22.3%	21.5%	21.6%
Dry Density (pcf)	103.1	106.3	107.5
FAILURE			
Normal Stress (psf)	2000	4000	8000
Failure Stress (psf)	1764	3994	6561
Failure Deffinition	User	User	User
Displacement (in)	0.20	0.20	0.20
Rate (in/min)	0.0050	0.0050	0.0050

* Degree of saturation calculated with a specific gravity of 2.65

Grain Size Distribution (ASTM D1140 and D 422)
6400 Front Avenue
Sample RW-2i Depth = 45-47 feet



GEOCON
INCORPORATED

DIRECT SHEAR TEST REPORT

6400 Front Street

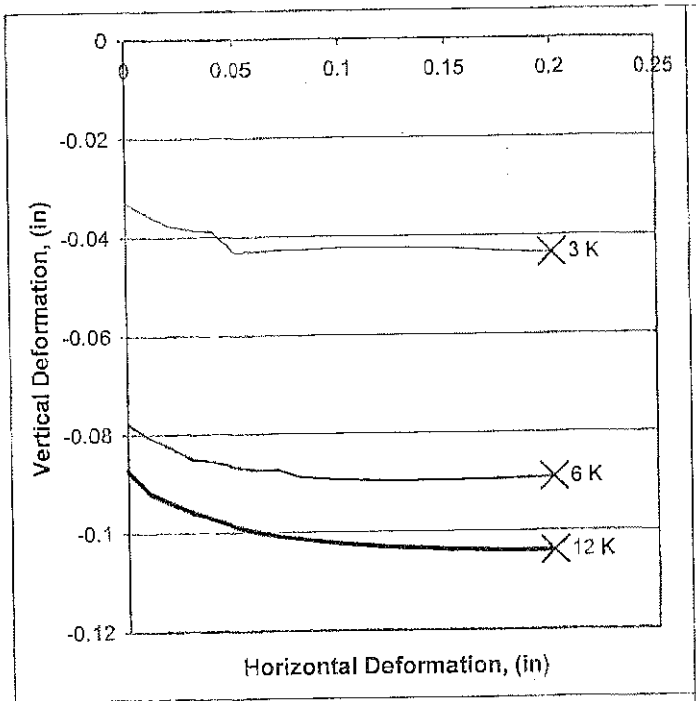
P1701-05-01

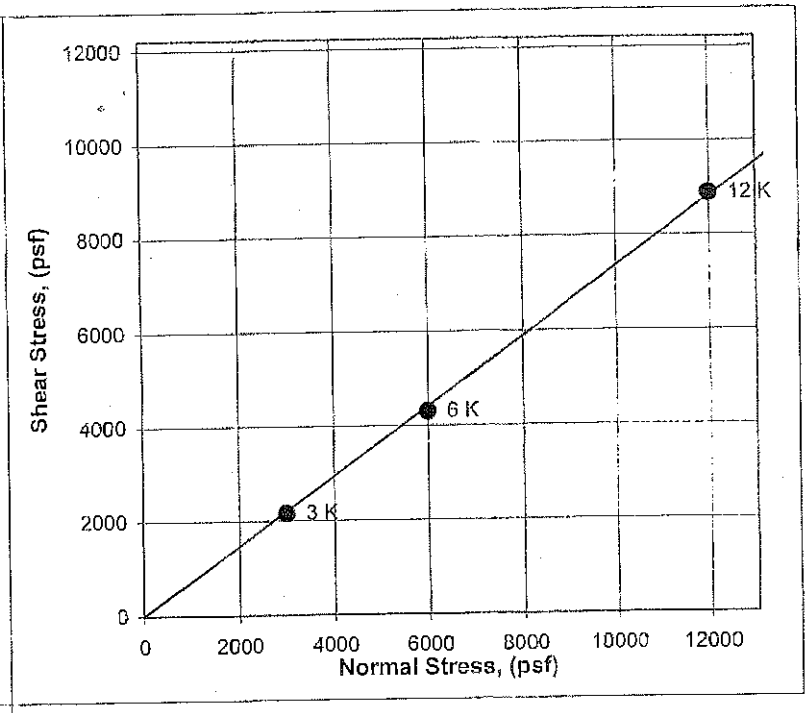
Date: Wednesday, October 28, 2009 By: J.D.

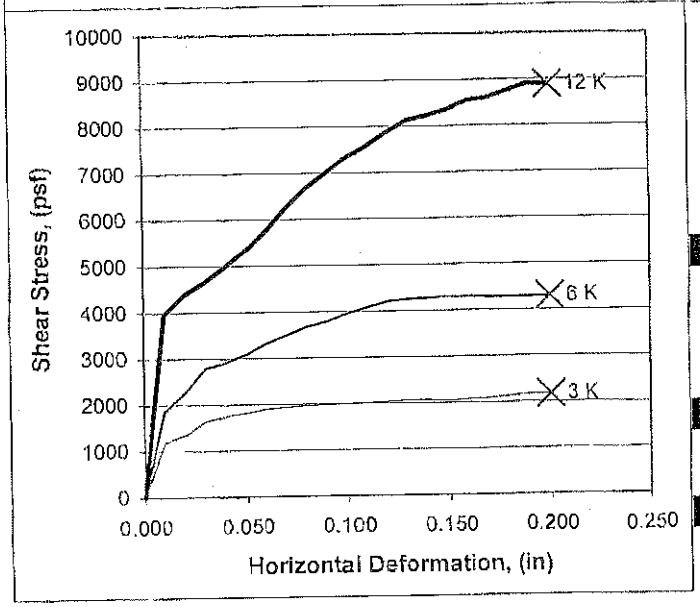
Sample No.: RW-2 45'-47' Natural or Remold: Natural

Description: SM

Remarks:





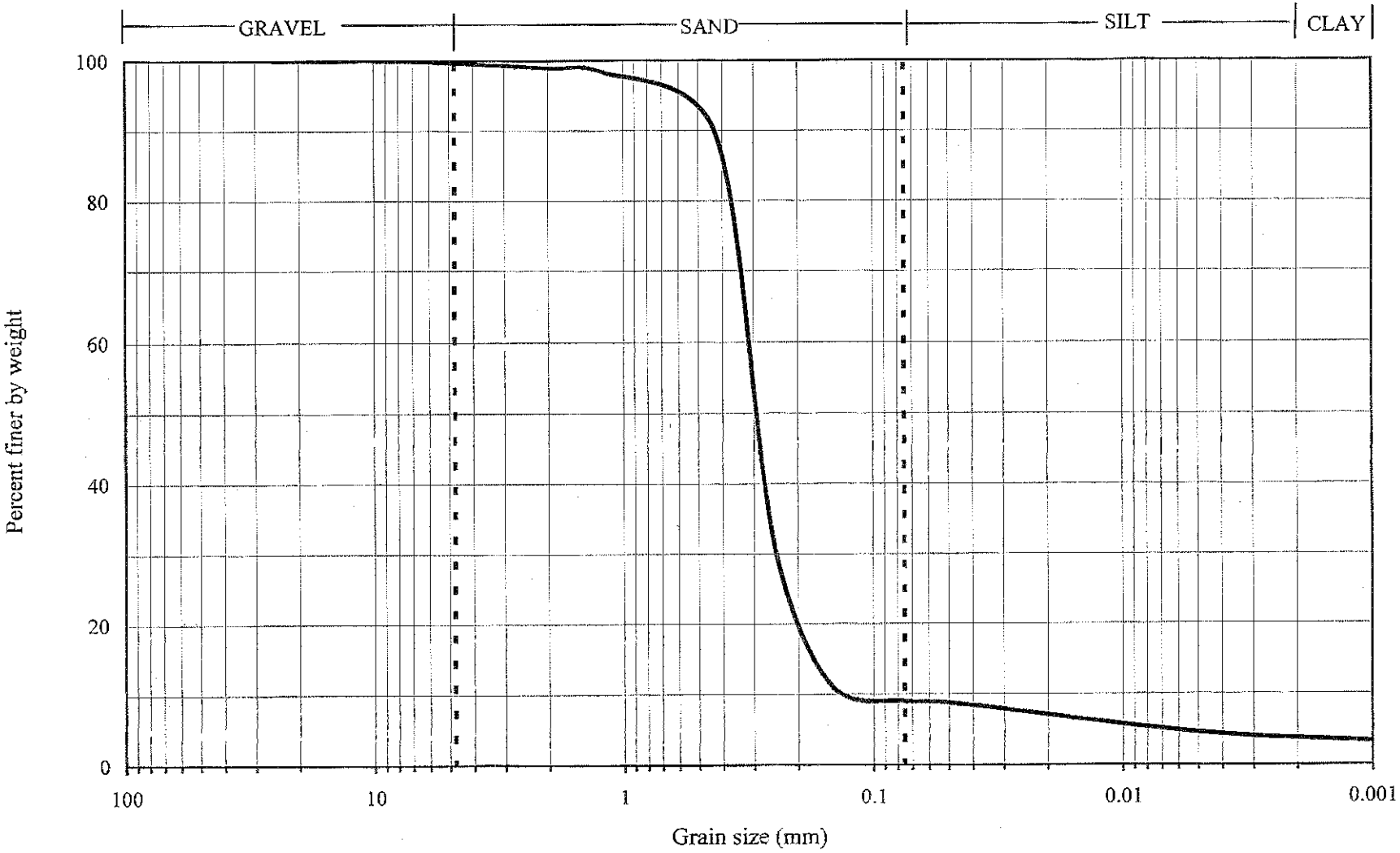


ϕ (Degrees)	36.3
c (psf)	0
Tan ϕ	0.734
Method	Calc

Load	3 K	6 K	12 K
INITIAL			
Water Content	34.4%	37.4%	36.1%
Dry Density (pcf)	89.5	86.6	87.5
Saturation*	107.5%	109.0%	107.4%
Height (inches)	1.00	1.00	1.00
AFTER TEST			
Water Content	33.6%	35.7%	34.0%
Dry Density (pcf)	93.6	95.1	97.7
FAILURE			
Normal Stress (psf)	3000	6000	12000
Failure Stress (psf)	2160	4301	8878
Failure Deffinition	User	User	User
Displacement (in)	0.20	0.20	0.20
Rate (in/min)	0.0050	0.0050	0.0050

* Degree of saturation calculated with a specific gravity of 2.65

Grain Size Distribution (ASTM D1140 and D 422)
6400 Front Avenue
Sample RW-4i Depth = 40-40.5 feet



GEOCON
INCORPORATED

DIRECT SHEAR TEST REPORT

6400 Front Street

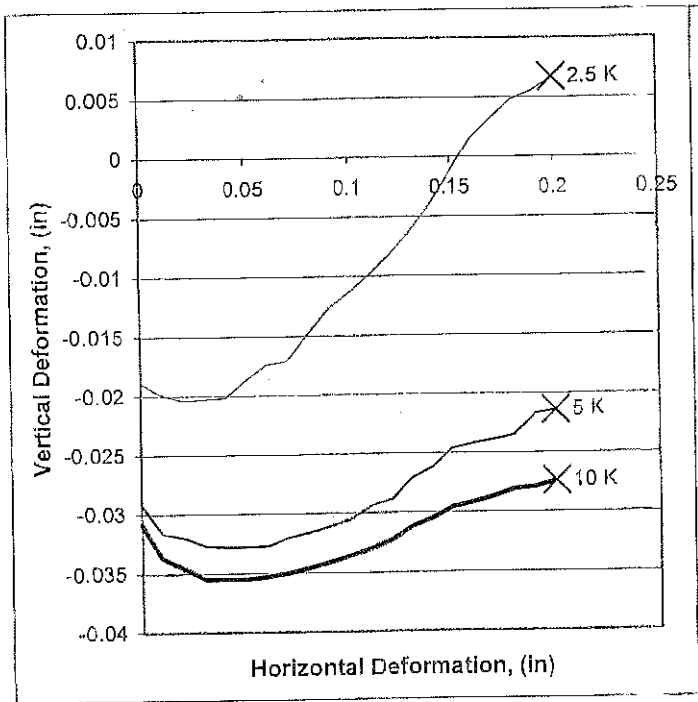
P1701-05-01

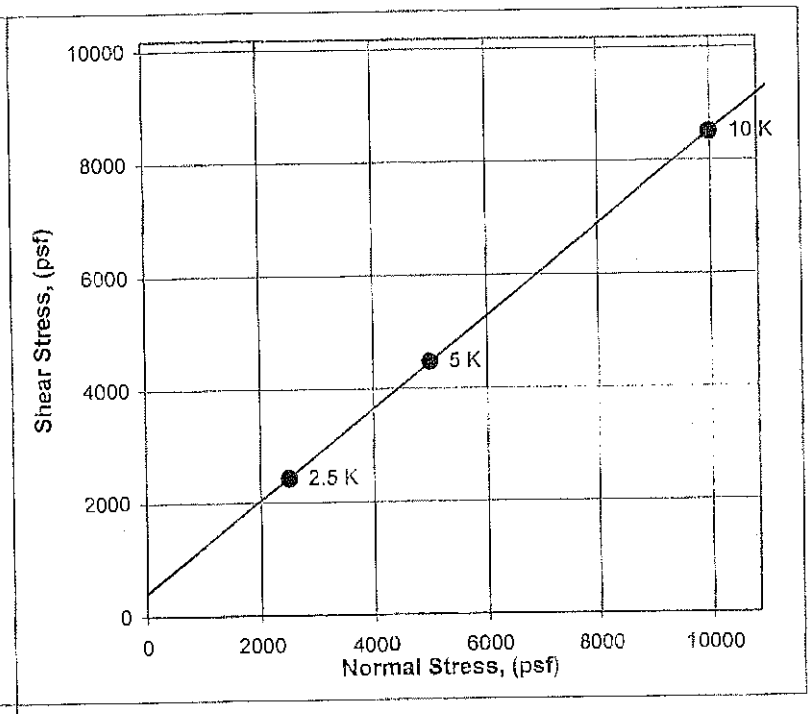
Date: Monday, October 26, 2009 **By:** Tom G.

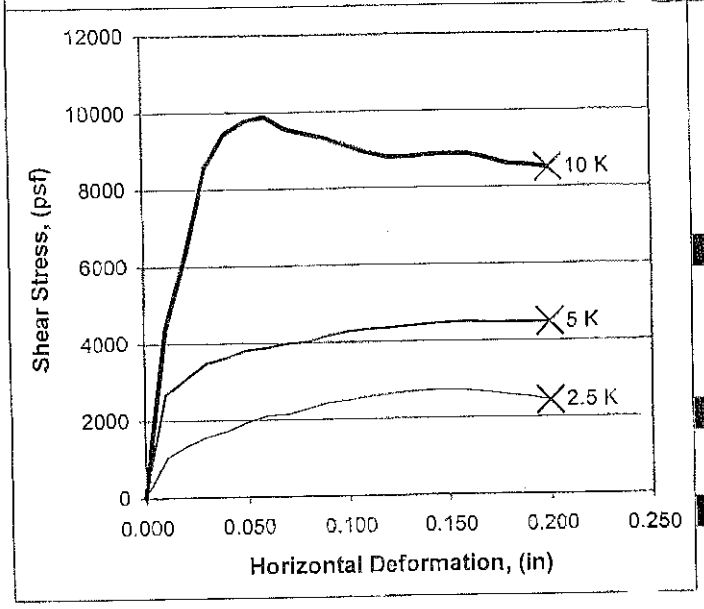
Sample No.: RW-4 40'-40.5' **Natural or Remold:** Natural

Description: SM

Remarks:







ϕ (Degrees)	39.0
c (psf)	414
Tan ϕ	0.809
Method	Calc

Load	2.5 K	5 K	10 K
INITIAL			
Water Content	30.5%	32.3%	31.7%
Dry Density (pcf)	92.0	88.3	90.5
Saturation*	101.2%	98.1%	101.5%
Height (inches)	1.00	1.00	1.00
AFTER TEST			
Water Content	29.4%	32.1%	31.7%
Dry Density (pcf)	91.4	90.2	93.0
FAILURE			
Normal Stress (psf)	2500	5000	10000
Failure Stress (psf)	2428	4472	8500
Failure Deffinition	User	User	User
Displacement (in)	0.20	0.20	0.20
Rate (in/min)	0.0100	0.0100	0.0100

* Degree of saturation calculated with a specific gravity of 2.65

Attachment C
Groundwater Laboratory
Analytical Data

DUE TO THE LARGE VOLUME, THIS ATTACHMENT IS NOT INCLUDED IN THIS VERSION OF THE REPORT

Attachment D
Treated Water Discharge Report

CITY OF PORTLAND
ENVIRONMENTAL SERVICES
Water Pollution Control Laboratory
6543 N. Burlington Avenue, Bldg. 217, Portland, Oregon 97203 • Dan Saltzman, Commissioner • Dean Marriott, Director

BATCH DISCHARGE REPORTING FORM

Site Information

Company Name	Arkema, Inc.
Address	6400 NW Front Avenue
Batch Number	2009-038
Proposed Discharge Volume (gallons)	200,000
Date Started	2 October 2009
Date Finished	27 October 2009

Contact Information

Name	Mr. Brendan Robinson
Company Name	ERM-West, Inc.
Address	101 SW Main Street, Suite 804 Portland, OR 97204
Telephone	(503) 488-5282
Facsimile	(503) 488-5142
Cellular	(503) 310-8463
Discharged Volume (gallons)	47,140
Time Started	12:30 pm
Time Finished	4:00 pm

I certify under penalty of law that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to ensure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations.

Signature: _____ Date: 24 November 2009

Submit report to:

Batch Discharges
Industrial Source Control Division
Water Pollution Control Laboratory
Bureau of Environmental Services
City of Portland
6543 N. Burlington Avenue
Portland, Oregon 97203-5452

facsimile 503-823-5559

Table 1
Treated Groundwater Discharge
Results Summary

Table 1

Treated Groundwater Discharge Results Summary
Groundwater Source Control Measure
Arkema Inc. - Portland, Oregon

Constituent[m]	Units	Discharge to POTW Limits		Development-092909		RW-1-Treated		RW-2i-Treated		RW-3-Treated		RW-4i-Treated 2	
			Sample Date	9/29/2009		10/15/2009		10/22/2009		10/8/2009		10/9/2009	
			Discharge Date	10/2/2009		10/20/2009		10/27/2009		10/13/2009		10/14/2009	
			Discharge Volume (gallons)	4,181		18,115		12,531		2,031		10,282	
		Value	Note	Value	MDL	Value	MDL	Value	MDL	Value	MDL	Value	MDL
Pesticides													
alpha-BHC	µg/L	ND(<1)	d	ND	0.0952	ND	0.0952	ND	0.2	ND	0.0952	ND	0.0962
beta-BHC	µg/L	ND(<1)	d	ND	0.0952	ND	0.0952	ND	0.2	ND	0.0952	ND	0.0962
gamma-BHC [Lindane]	µg/L	ND(<1)	d	ND	0.0952	ND	0.0952	ND	0.2	ND	0.0952	ND	0.0962
Chlordane	µg/L	30	a,b	ND	0.952	ND	0.952	ND	2	ND	0.952	ND	0.962
4,4'-DDD	µg/L	ND(<1)	d	ND	0.0952	ND	0.0952	ND	0.2	ND	0.0952	ND	0.0962
4,4'-DDE	µg/L	ND(<1)	d	ND	0.0952	ND	0.0952	ND	0.2	ND	0.0952	ND	0.0962
4,4'-DDT	µg/L	ND(<1)	d	ND	0.0952	ND	0.0952	ND	0.2	ND	0.0952	ND	0.0962
Endrin	µg/L	ND(<1)	d	ND	0.0952	ND	0.0952	ND	0.2	ND	0.0952	ND	0.0962
Heptachlor epoxide	µg/L	ND(<1)	d	ND	0.0952	ND	0.0952	ND	0.2	ND	0.0952	ND	0.0962
Volatile Organic Compounds													
1,2-Dichloroethane	µg/L	500	b	ND	1	ND	1	ND	1	ND	1	ND	1
Acetone	µg/L	NA	e	ND	25	ND	25	ND	25	ND	25	ND	25
Benzene	µg/L	140	c	ND	1	ND	1	ND	1	ND	1	ND	1
Bromodichloromethane	µg/L	ND(<10)	d	ND	1	ND	1	ND	1	ND	1	ND	1
Carbon disulfide	µg/L	NA	e	ND	10	ND	10	ND	10	ND	10	ND	10
Carbon tetrachloride	µg/L	30	c	ND	1	ND	1	ND	1	ND	1	ND	1
Chlorobenzene	µg/L	200	b	ND	1	ND	1	ND	1	ND	1	ND	1
Chloroethane	µg/L	ND(<50)	d	ND	1	ND	1	ND	1	ND	1	ND	1
Chloroform	µg/L	200	b	ND	1	ND	1	ND	1	ND	1	ND	1
Chloromethane	µg/L	ND(<10)	d	ND	1	ND	1	ND	1	ND	1	ND	1
cis-1,2-Dichloroethene	µg/L	NA	e	ND	1	ND	1	ND	1	ND	1	ND	1
Ethylbenzene	µg/L	NA	e	ND	1	ND	1	ND	1	ND	1	ND	1
Methylene chloride	µg/L	2,100	c	ND	5	ND	5	ND	5	ND	5	ND	5
Tetrachloroethene	µg/L	300	c	ND	1	ND	1	ND	1	ND	1	ND	1
Toluene	µg/L	1,400	c	ND	1	ND	1	ND	1	ND	1	ND	1
Trichloroethene	µg/L	200	b	ND	1	ND	1	ND	1	ND	1	ND	1
m,p-Xylene	µg/L	NA	e	ND	2	ND	2	ND	2	ND	2	ND	2

Table 1

Treated Groundwater Discharge Results Summary
Groundwater Source Control Measure
Arkema Inc. - Portland, Oregon

Constituent[m]	Units	Discharge to POTW Limits		Development-092909		RW-1-Treated		RW-2i-Treated		RW-3-Treated		RW-4i-Treated 2	
			Sample Date	9/29/2009		10/15/2009		10/22/2009		10/8/2009		10/9/2009	
			Discharge Date	10/2/2009		10/20/2009		10/27/2009		10/13/2009		10/14/2009	
			Discharge Volume (gallons)	4,181		18,115		12,531		2,031		10,282	
		Value	Note	Value	MDL	Value	MDL	Value	MDL	Value	MDL	Value	MDL
Metals (Criteria Based on Total Metals, Unless Otherwise Specified)													
Arsenic	µg/L	200	b	**19.5**	1	**5.73**	1	**111**	5	**4.75**	1	**8.44**	1
Cadmium	µg/L	700	b	ND	0.5	ND	0.5	ND	2.5	ND	0.5	**0.857**	0.5
Chromium	µg/L	5,000	b	**18**	2	ND	2	**30.2**	10	ND	2	ND	2
Copper	µg/L	3,700	b	**23.1**	2	ND	2	40.4	10	ND	2	ND	2
Lead	µg/L	700	b	**8.88**	1	ND	1	7.92	5	ND	1	ND	1
Mercury	µg/L	10	b	ND	0.2	ND	0.2	ND	0.2	ND	0.2	ND	0.2
Molybdenum	µg/L	1400	b	**12.1**	5	ND	5	ND	25	ND	5	**8.49**	5
Nickel	µg/L	2,800	b	**14.2**	1	**2.54**	1	**27.6**	5	**4.6**	1	**3.12**	1
Selenium	µg/L	600	b	**0.69**	0.5	**1.3**	0.5	ND	2.5	**4.5**	0.5	**7.6**	0.5
Silver	µg/L	400	b	ND	1	ND	1	ND	5	ND	1	ND	1
Zinc	µg/L	3,700	b	**78.6**	5	**18.2**	5	**42.2**	25	**15.2**	5	**20.5**	5
Conventional Parameters and Miscellaneous Compounds													
Oil & Grease	mg/L	110	b	-		-		-		ND	4.76	ND	4.81
Total Suspended Solids	mg/L	400	b	**138**	10	ND	10	ND	10	ND	10	ND	10
Total Dissolved Solids	mg/L	-	f	**800**	10	**520**	10	**2,700**	10	**510**	10	**570**	10
Total Dissolved Solids	lbs/day	1,721	f	28		79		282		9		49	

Notes:
a - Value for chlordane (cis- and trans-) used
b - City of Portland POTW Discharge Limits.
c - City of Portland POTW Screening Value
d - City of Portland Prohibited Discharge. Values in parentheses are maximum method detection limits allowed.
e - No local limit, screening value, or prohibited discharge detection requirement available.
f - No concentration limit. There is a total dissolved solids mass discharge limit of 1,721 lbs/day. All discharge event duration were less than one day

mg/L = milligrams per liter
ug/L = micrograms per liter
lbs = pounds
NA = Not available
POTW - Publicly owned treatment works
USEPA = United States Environmental Protection Agency

bold text indicates a detection
shaded cells = Exceedance of POTW Limits

Attachment A
Laboratory Analytical Data

DUE TO THE LARGE VOLUME, THIS ATTACHMENT IS NOT INCLUDED IN THIS VERSION OF THE REPORT

Attachment E
Pumping Test Manual Water Level Measurements

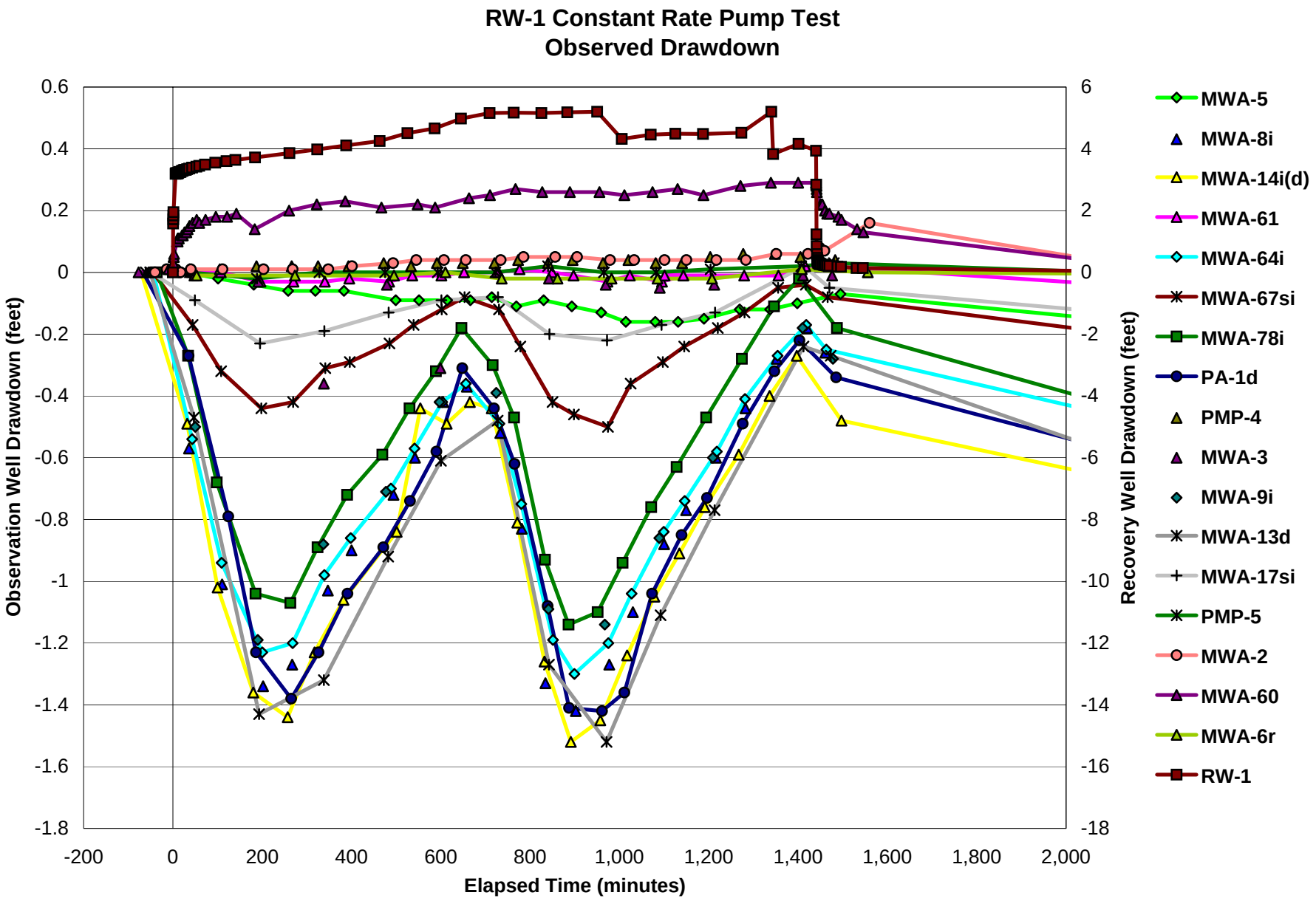


Figure E-1
Attachment E: Pumping Test Water Level Measurements
Groundwater Source Control Measure Pre-Design Investigation

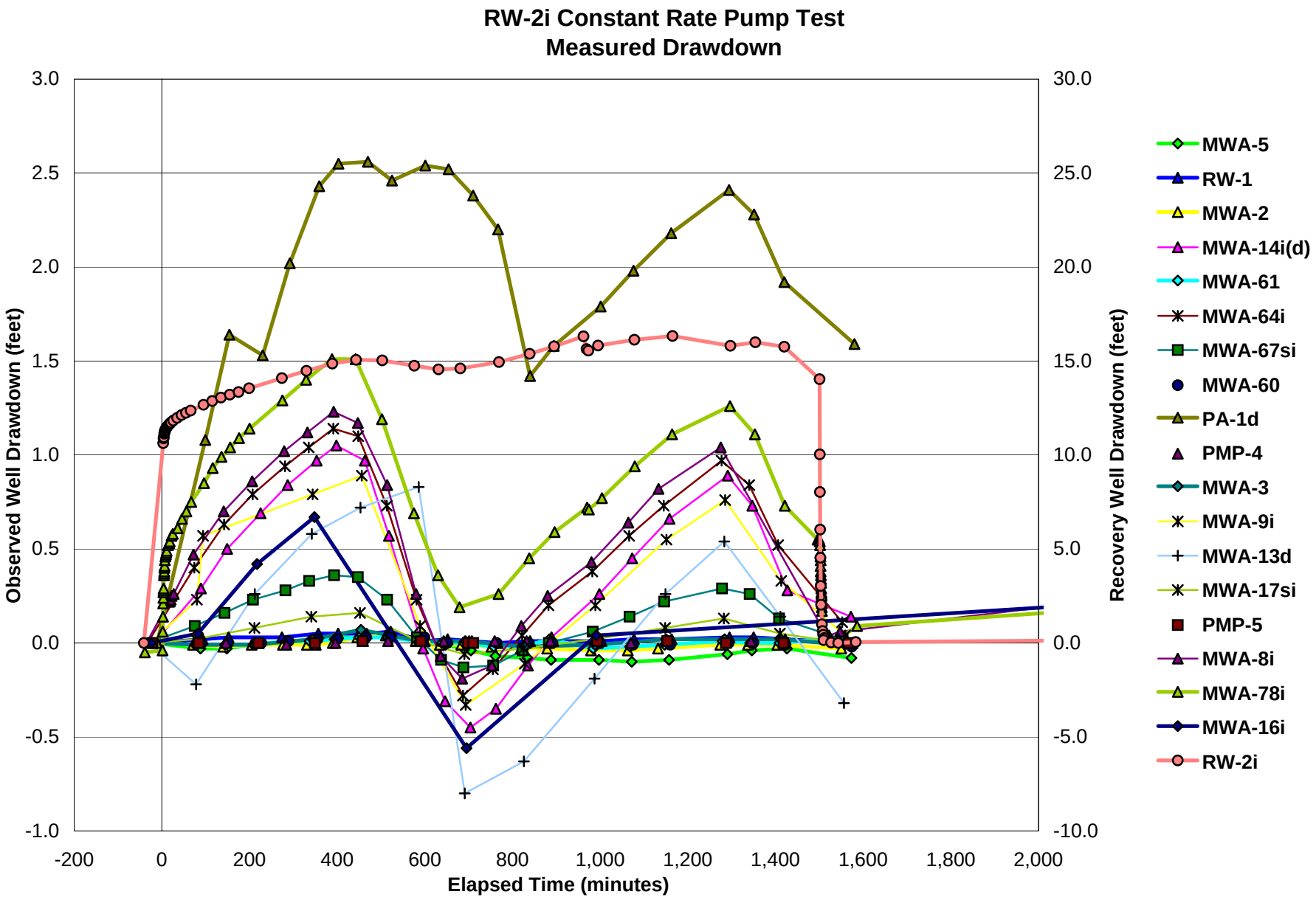


Figure E-2
Attachment E: Pumping Test Water Level Measurements
Groundwater Source Control Measure Pre-Design Investigation

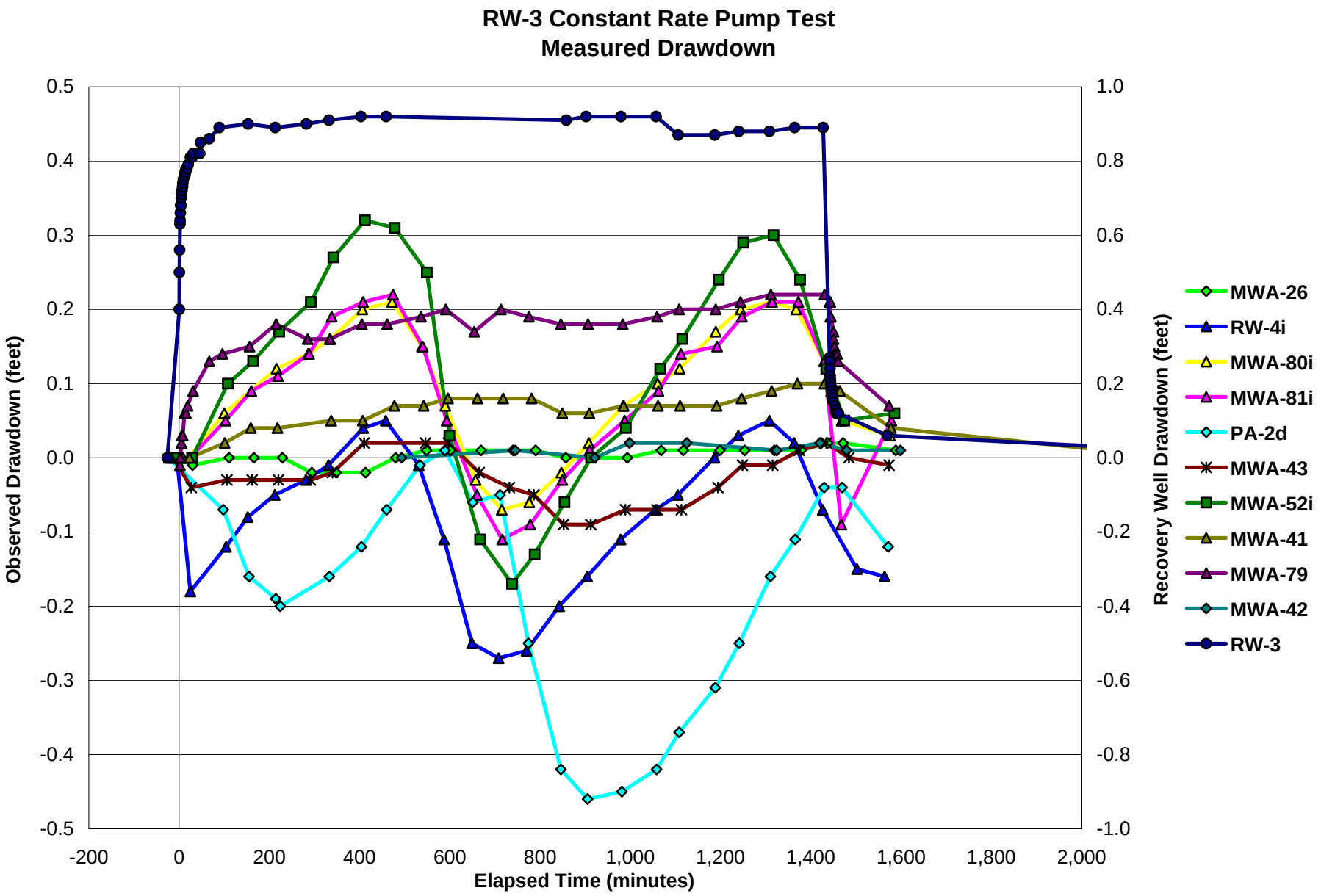


Figure E-3
Attachment E: Pumping Test Water Level Measurements
Groundwater Source Control Measure Pre-Design Investigation

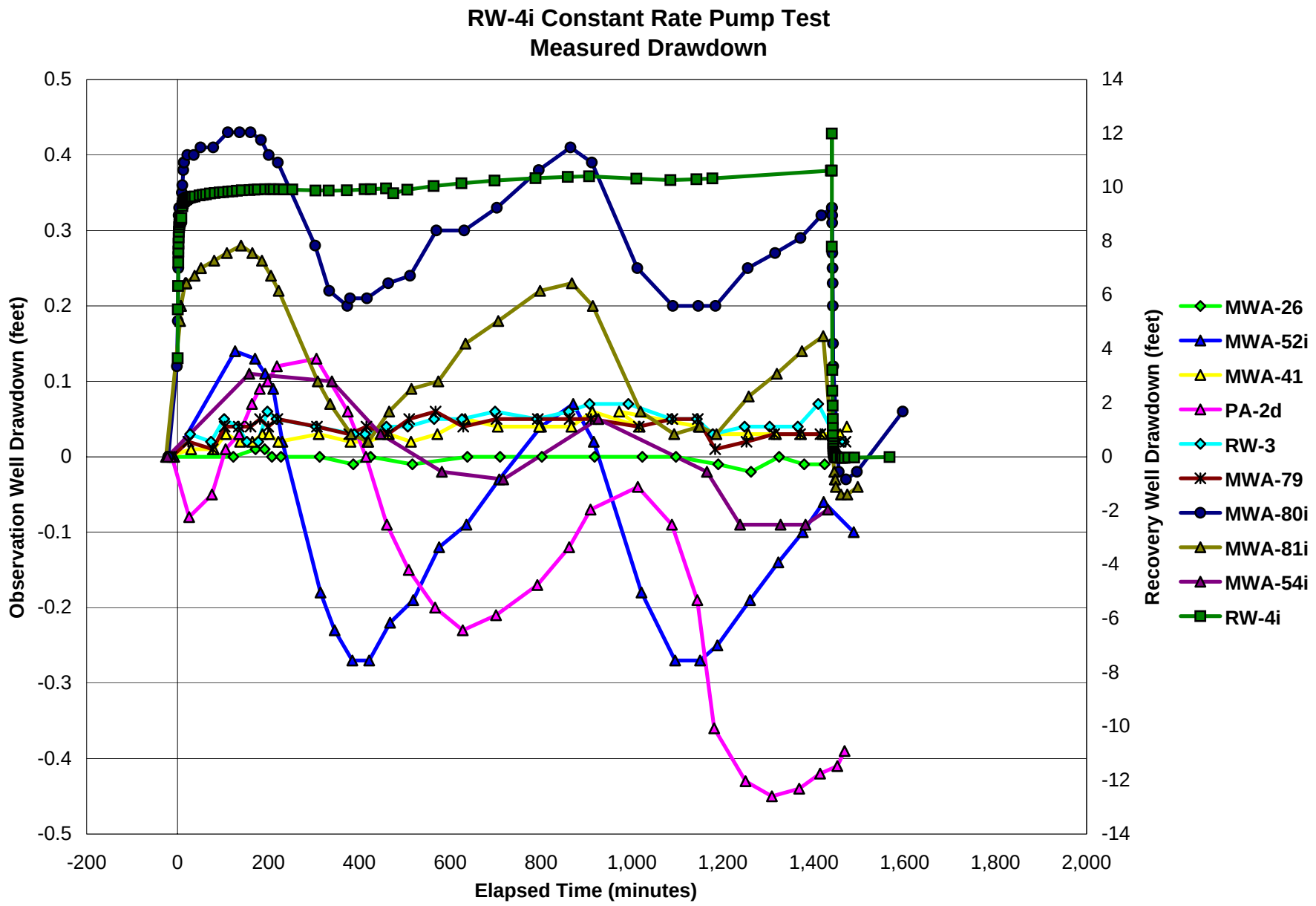


Figure E-4
Attachment E: Pumping Test Water Level Measurements
Groundwater Source Control Measure Pre-Design Investigation

Attachment F
Pumping Test Transducer Data
(Electronic Only)

DUE TO THE LARGE VOLUME, THIS APPENDIX
IS INCLUDED AS A SEPARATE EXCEL FILE ON CD-ROM ONLY

Attachment G
Tidal Correction Calculations
(Electronic Only)

DUE TO THE LARGE VOLUME, THIS APPENDIX
IS INCLUDED AS A SEPARATE EXCEL FILE ON CD-ROM ONLY

Attachment H
Groundwater Level Transducer
Data Plots

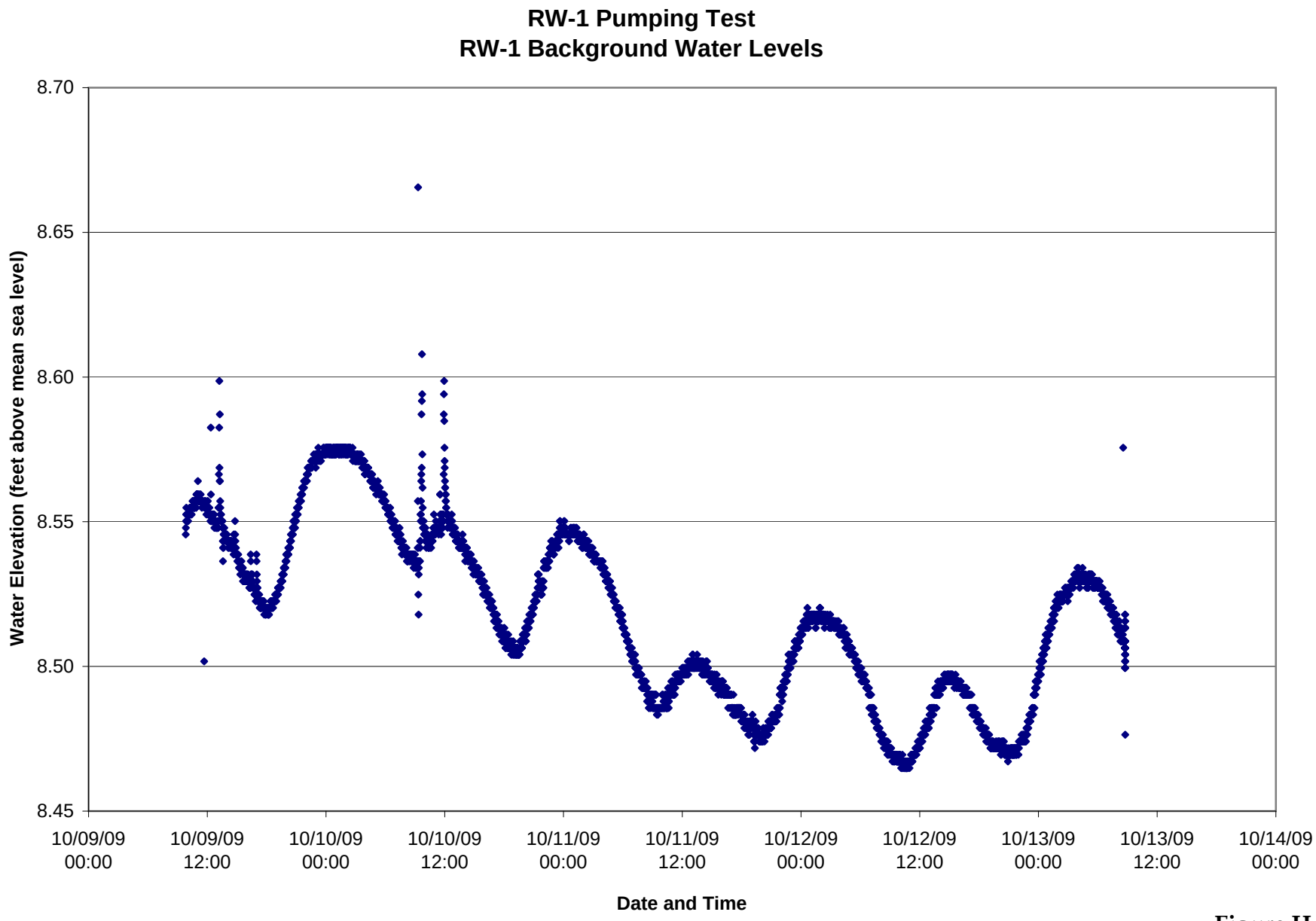
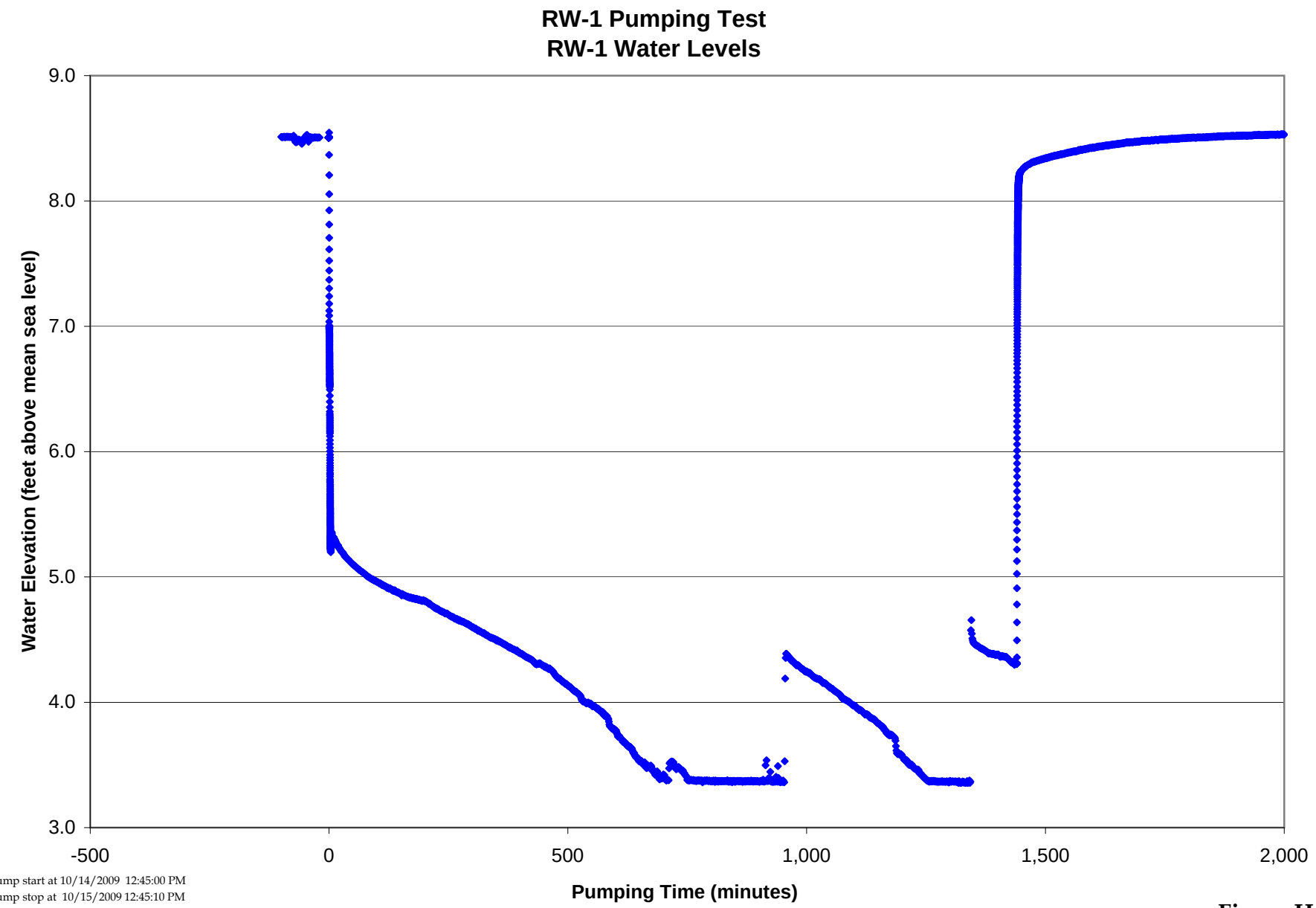


Figure H-1
Attachment H: Groundwater Level Data Plots
Groundwater Source Control Measure Pre-Design Investigation



Pump start at 10/14/2009 12:45:00 PM
Pump stop at 10/15/2009 12:45:10 PM

Figure H-2
Attachment H: Groundwater Level Data Plots
Groundwater Source Control Measure Pre-Design Investigation

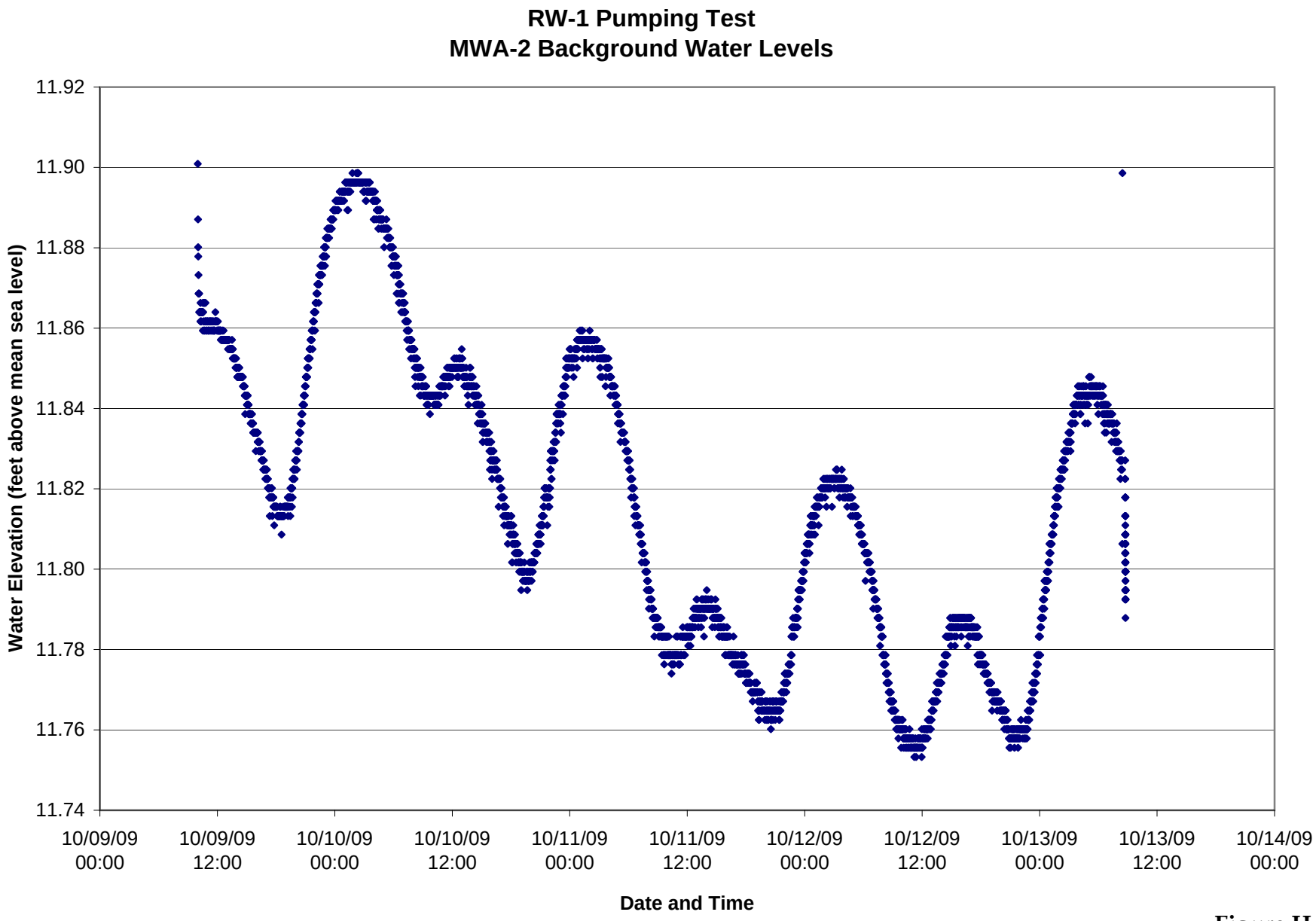
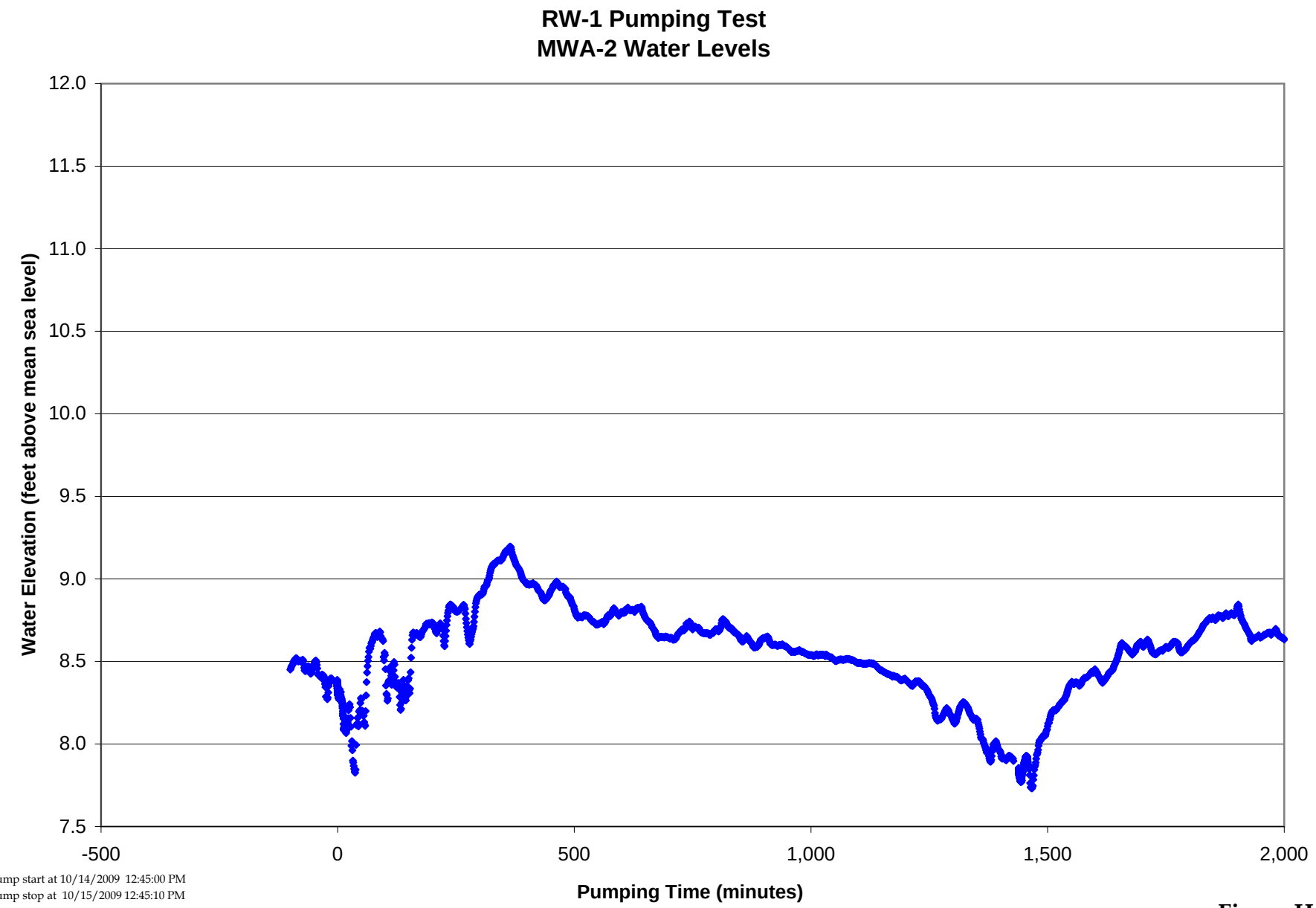


Figure H-3
Attachment H: Groundwater Level Data Plots
Groundwater Source Control Measure Pre-Design Investigation



Pump start at 10/14/2009 12:45:00 PM
Pump stop at 10/15/2009 12:45:10 PM

Figure H-4
Attachment H: Groundwater Level Data Plots
Groundwater Source Control Measure Pre-Design Investigation

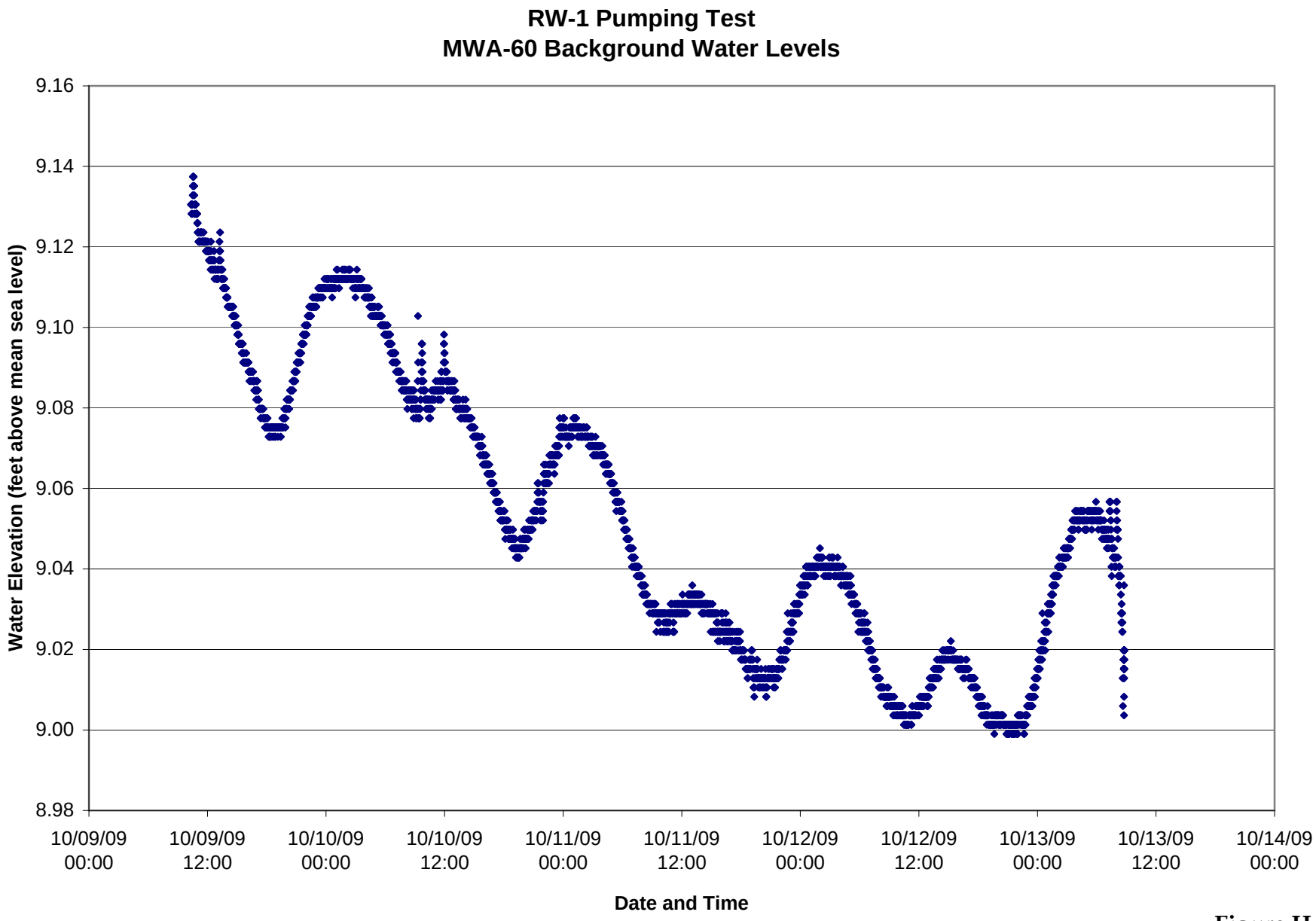
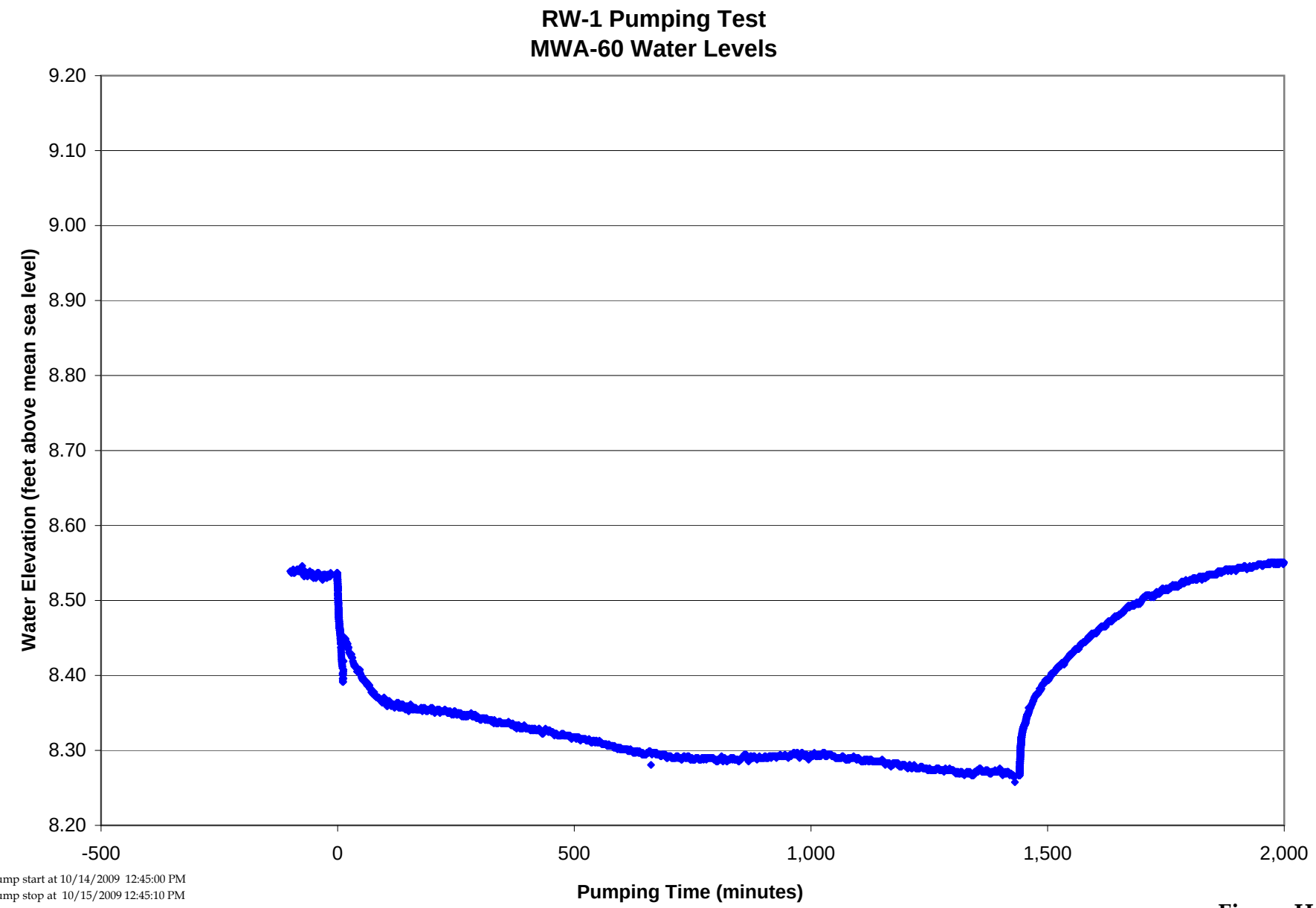


Figure H-5
Attachment H: Groundwater Level Data Plots
Groundwater Source Control Measure Pre-Design Investigation



Pump start at 10/14/2009 12:45:00 PM
Pump stop at 10/15/2009 12:45:10 PM

Figure H-6
Attachment H: Groundwater Level Data Plots
Groundwater Source Control Measure Pre-Design Investigation

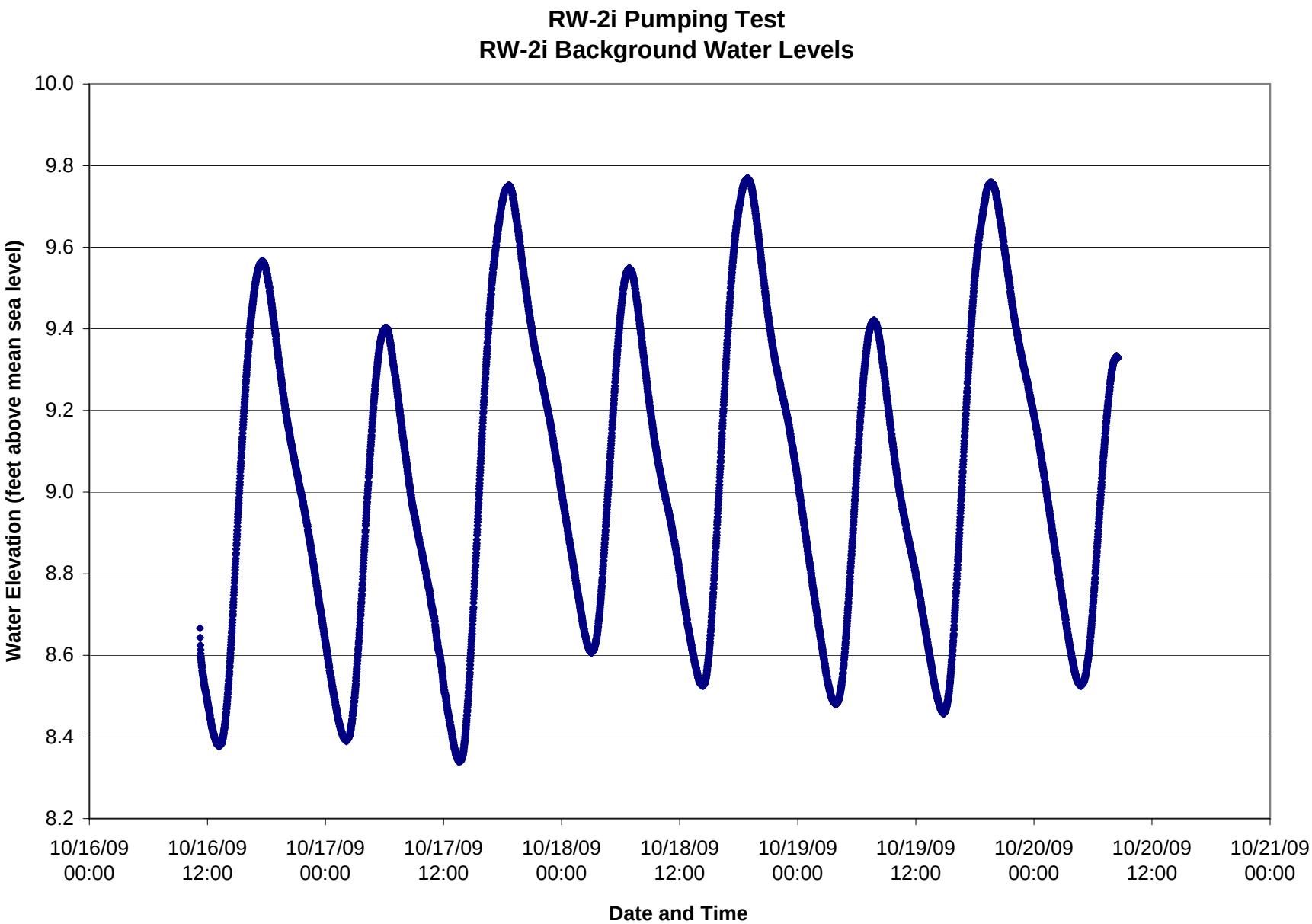
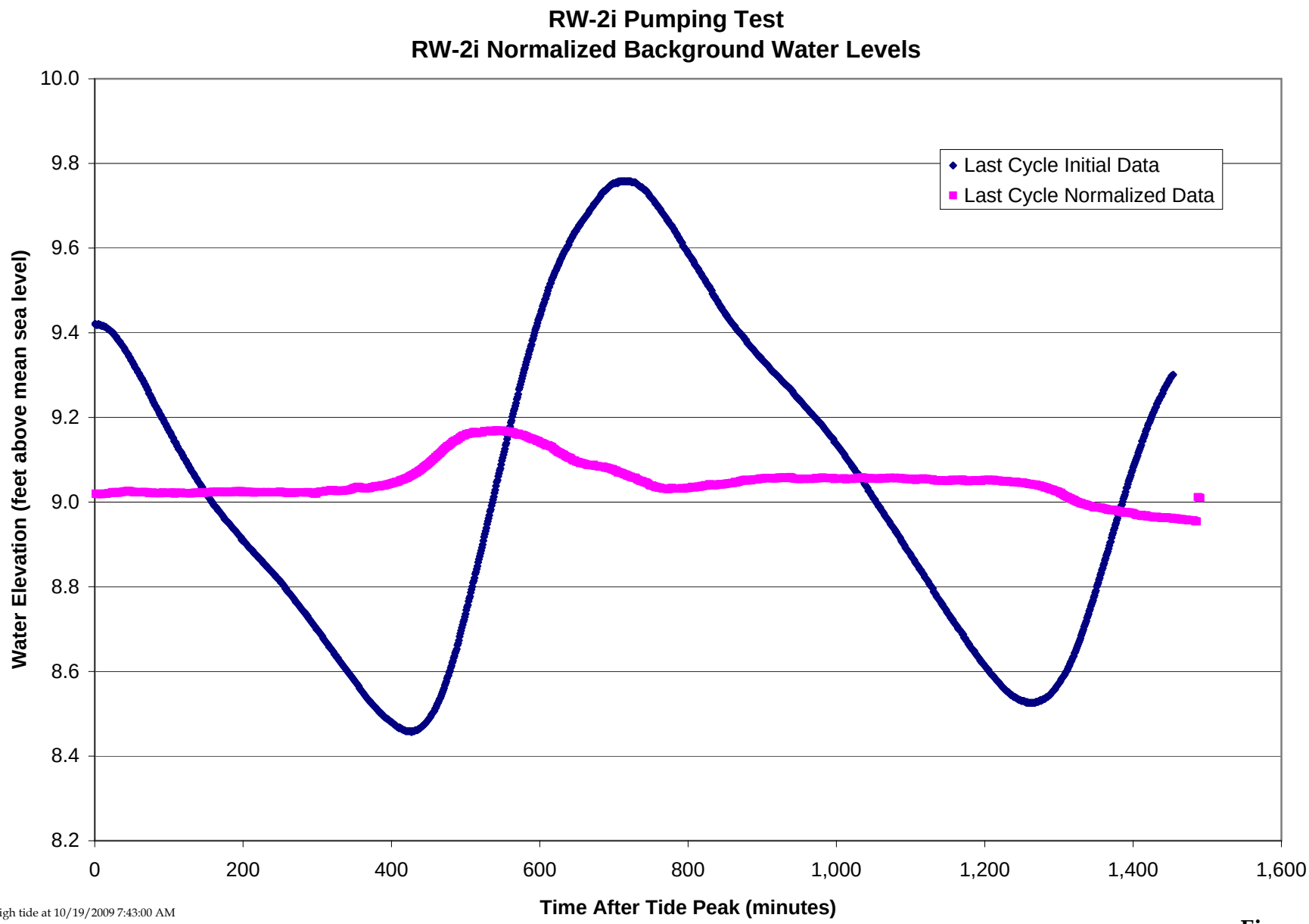
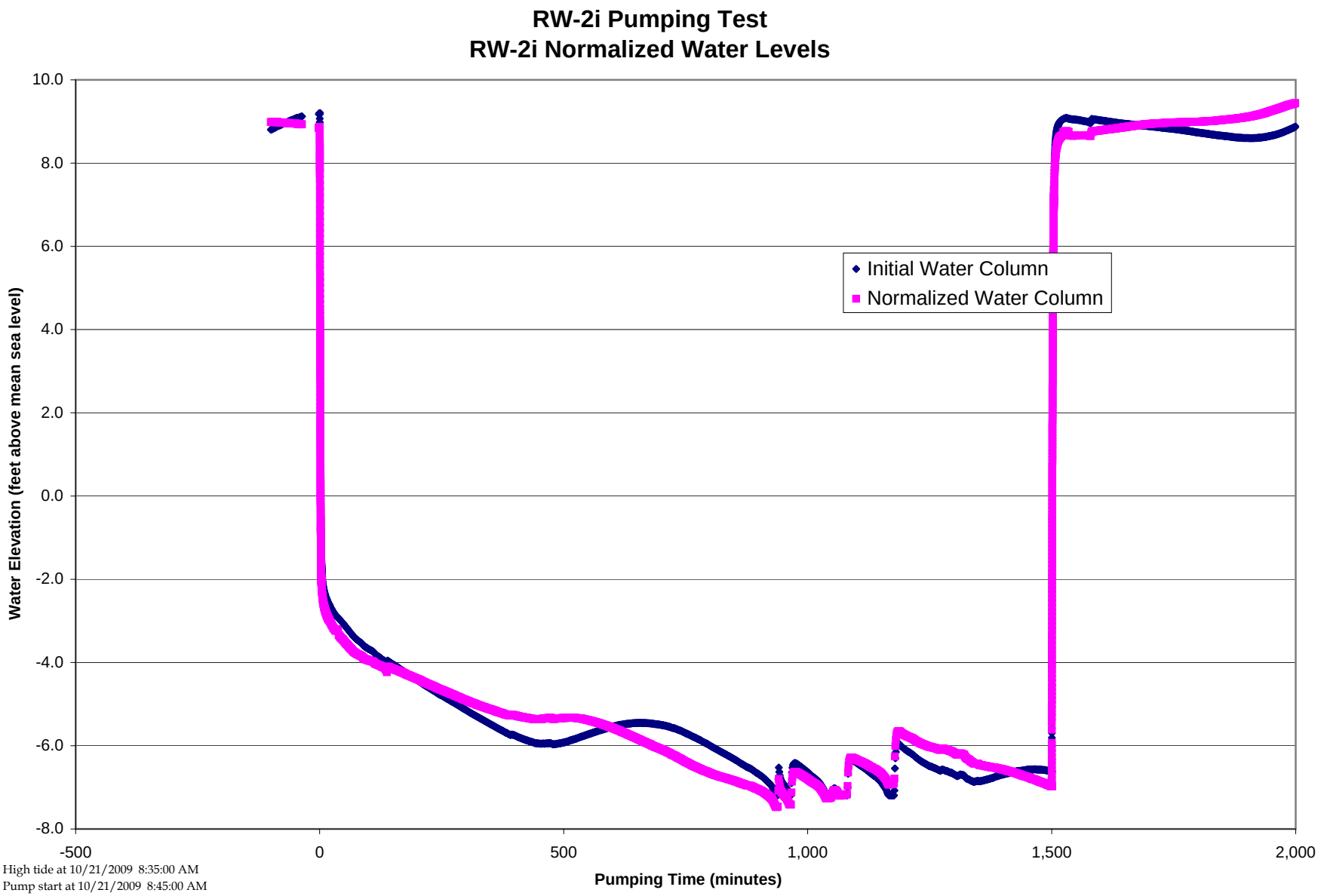


Figure H-7
Attachment H: Groundwater Level Data Plots
Groundwater Source Control Measure Pre-Design Investigation



High tide at 10/19/2009 7:43:00 AM

Figure H-8
Attachment H: Groundwater Level Data Plots
Groundwater Source Control Measure Pre-Design Investigation



High tide at 10/21/2009 8:35:00 AM
Pump start at 10/21/2009 8:45:00 AM
Pump stop at 10/22/2009 9:45:08 AM

Figure H-9
Attachment H: Groundwater Level Data Plots
Groundwater Source Control Measure Pre-Design Investigation

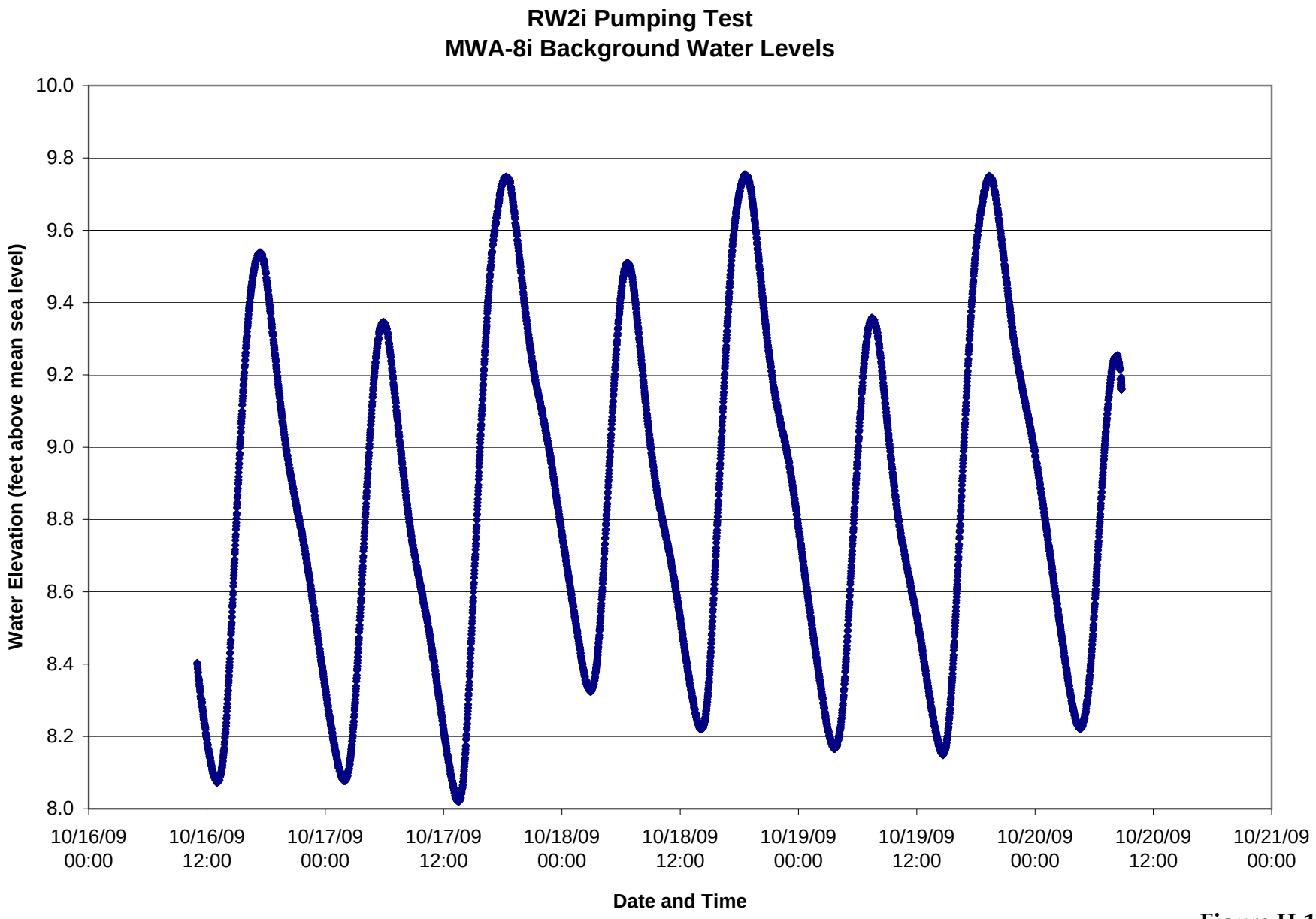
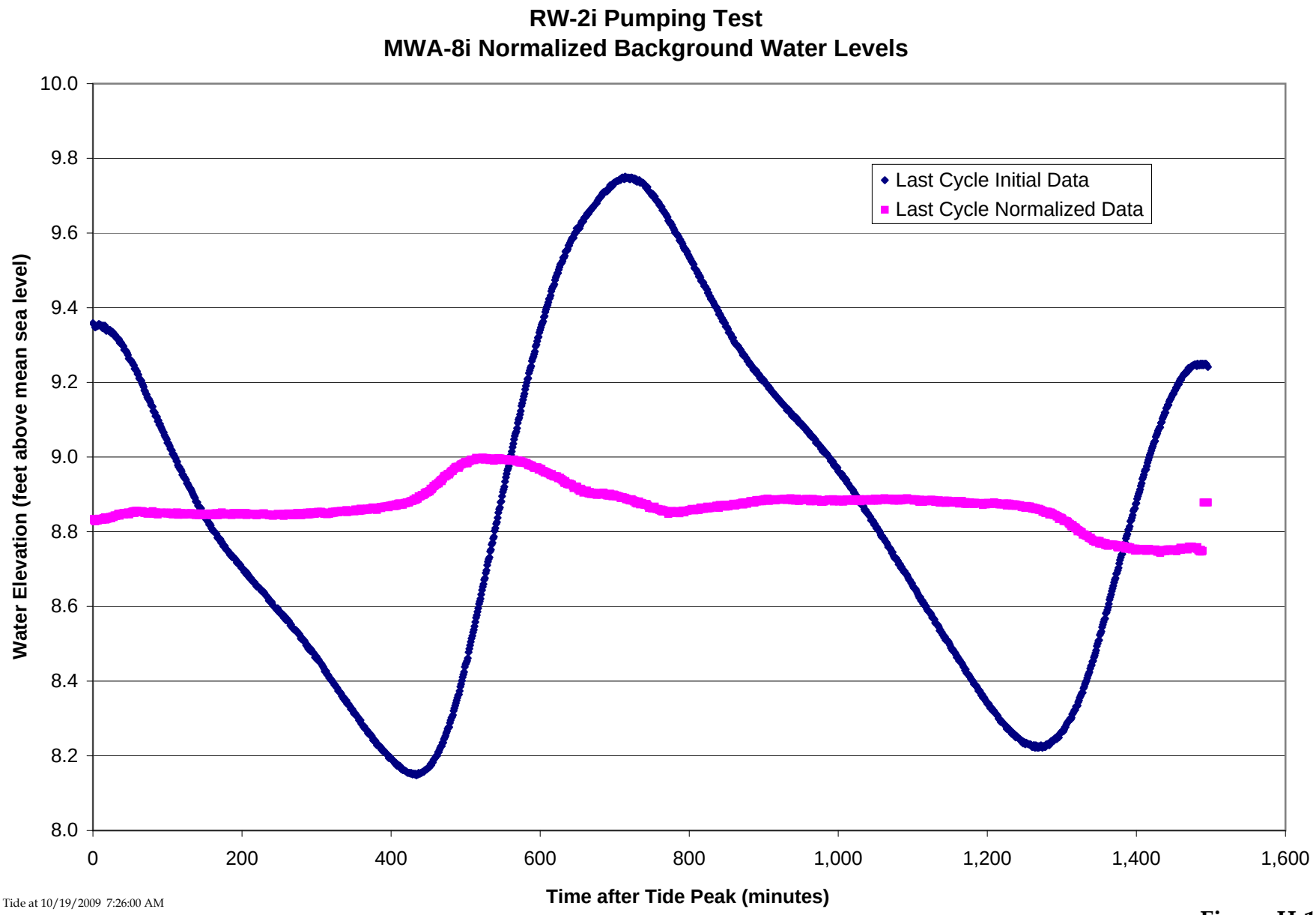
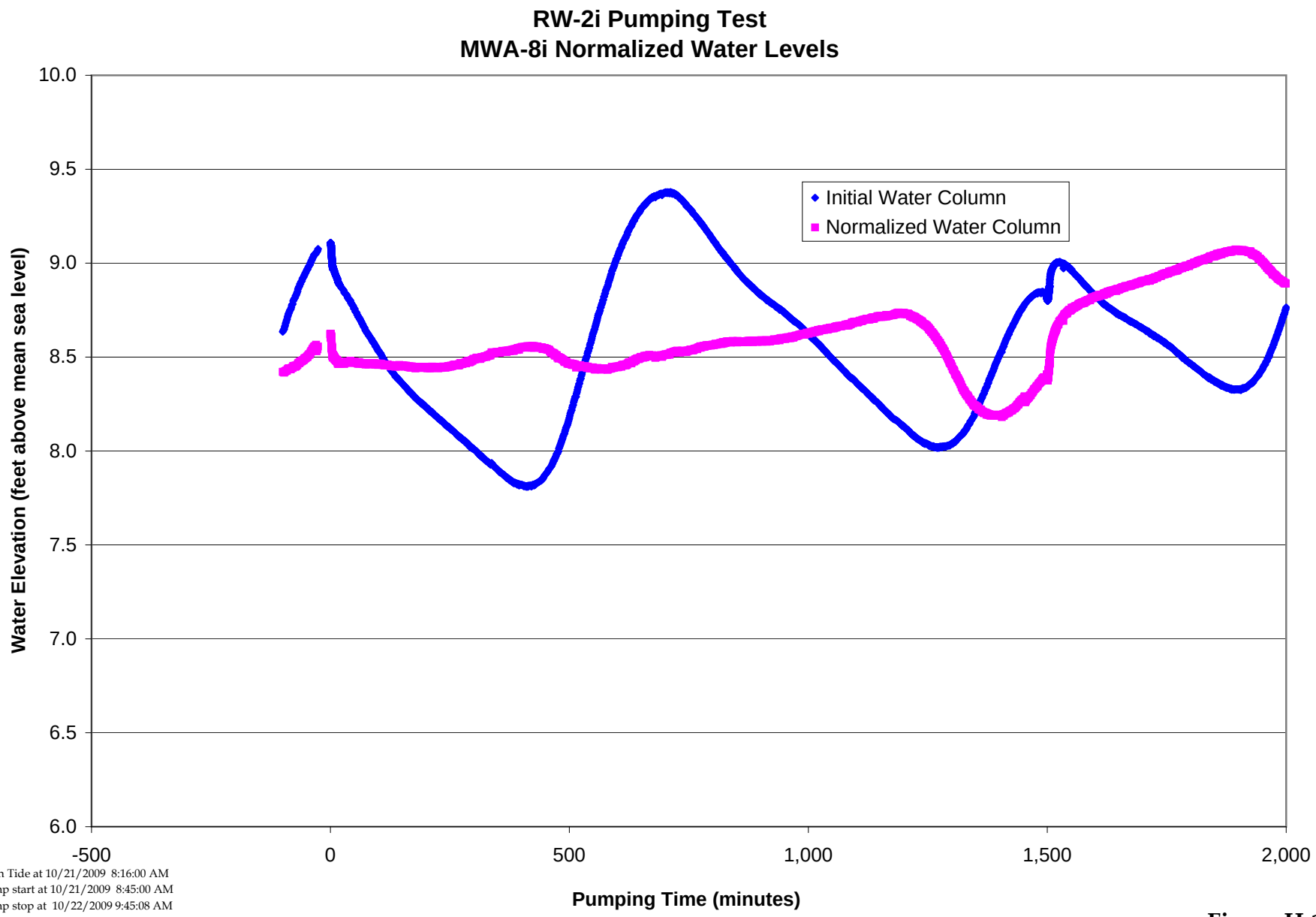


Figure H-10
Attachment H: Groundwater Level Data Plots
Groundwater Source Control Measure Pre-Design Investigation



High Tide at 10/19/2009 7:26:00 AM

Figure H-11
Attachment H: Groundwater Level Data Plots
Groundwater Source Control Measure Pre-Design Investigation



High Tide at 10/21/2009 8:16:00 AM
Pump start at 10/21/2009 8:45:00 AM
Pump stop at 10/22/2009 9:45:08 AM

Figure H-12
Attachment H: Groundwater Level Data Plots
Groundwater Source Control Measure Pre-Design Investigation

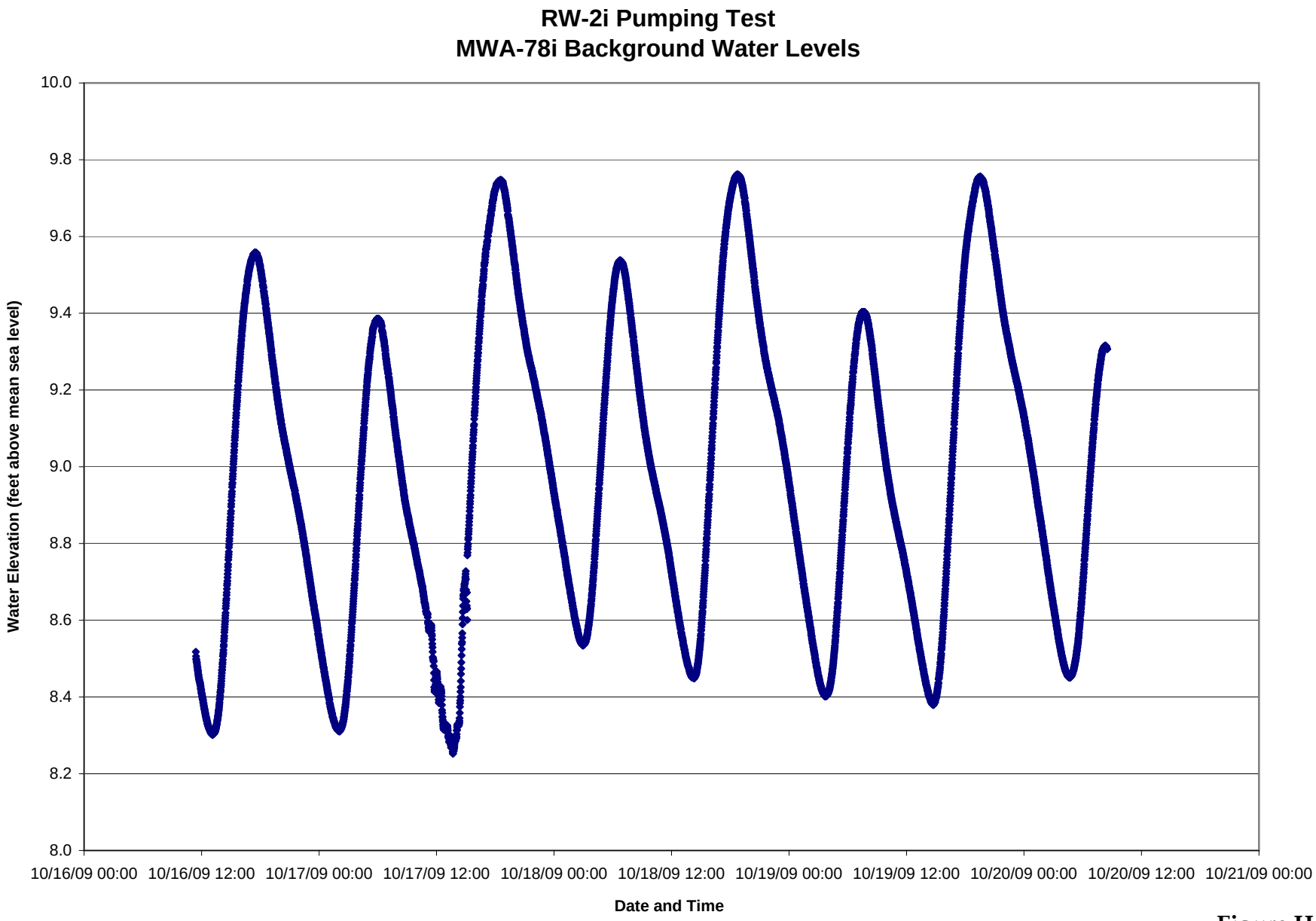
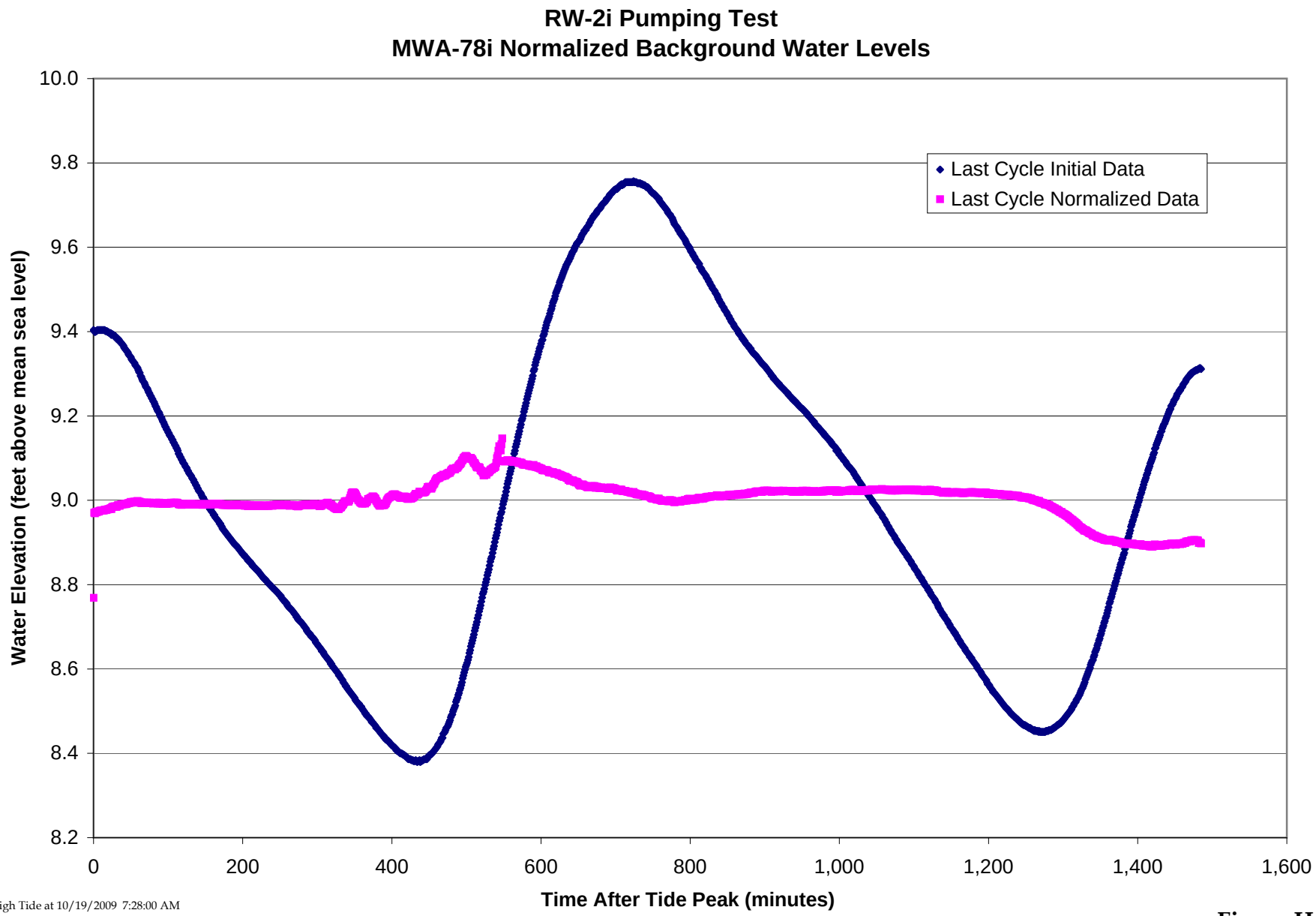
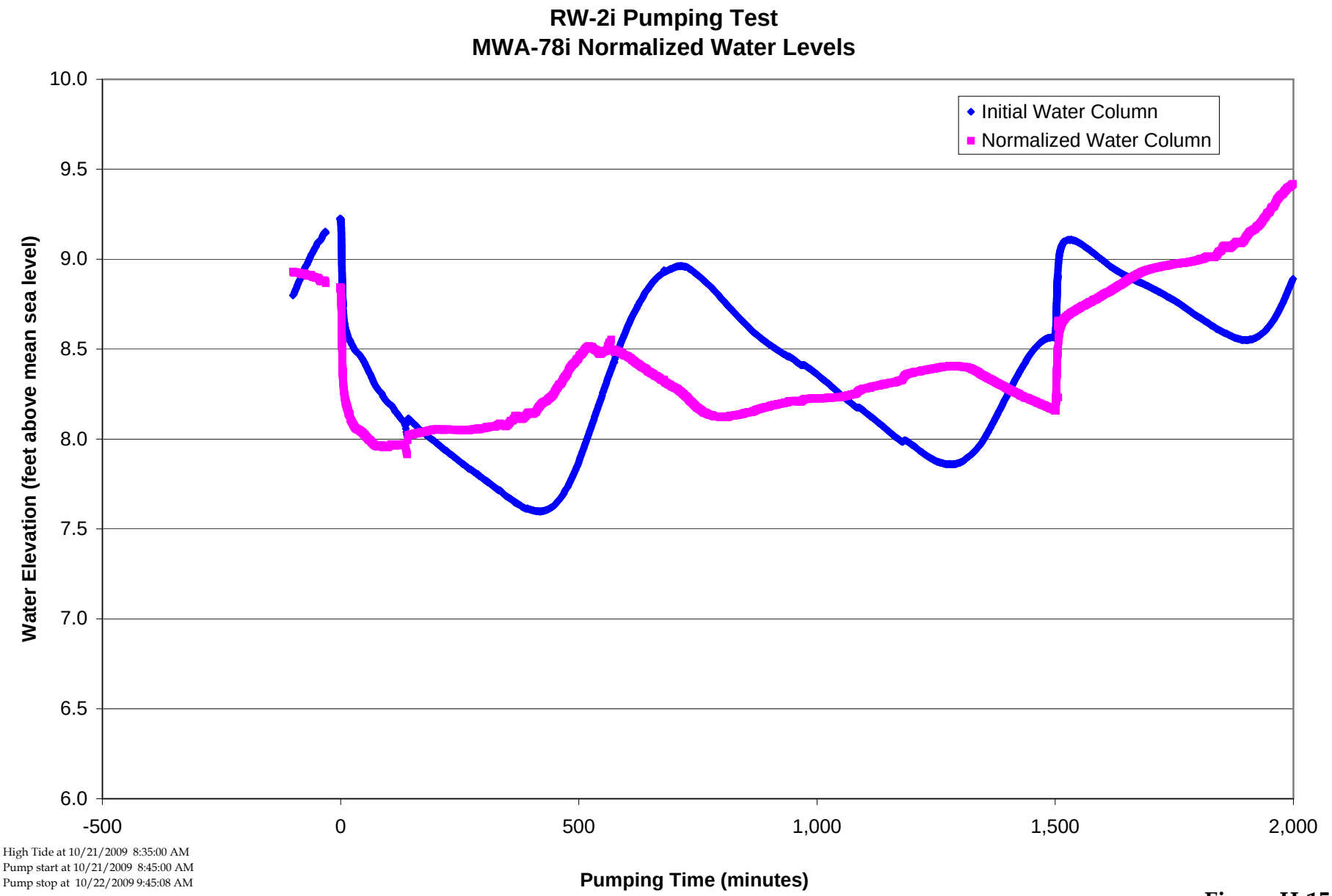


Figure H-13
Attachment H: Groundwater Level Data Plots
Groundwater Source Control Measure Pre-Design Investigation



High Tide at 10/19/2009 7:28:00 AM

Figure H-14
Attachment H: Groundwater Level Data Plots
Groundwater Source Control Measure Pre-Design Investigation



High Tide at 10/21/2009 8:35:00 AM
Pump start at 10/21/2009 8:45:00 AM
Pump stop at 10/22/2009 9:45:08 AM

Figure H-15
Attachment H: Groundwater Level Data Plots
Groundwater Source Control Measure Pre-Design Investigation

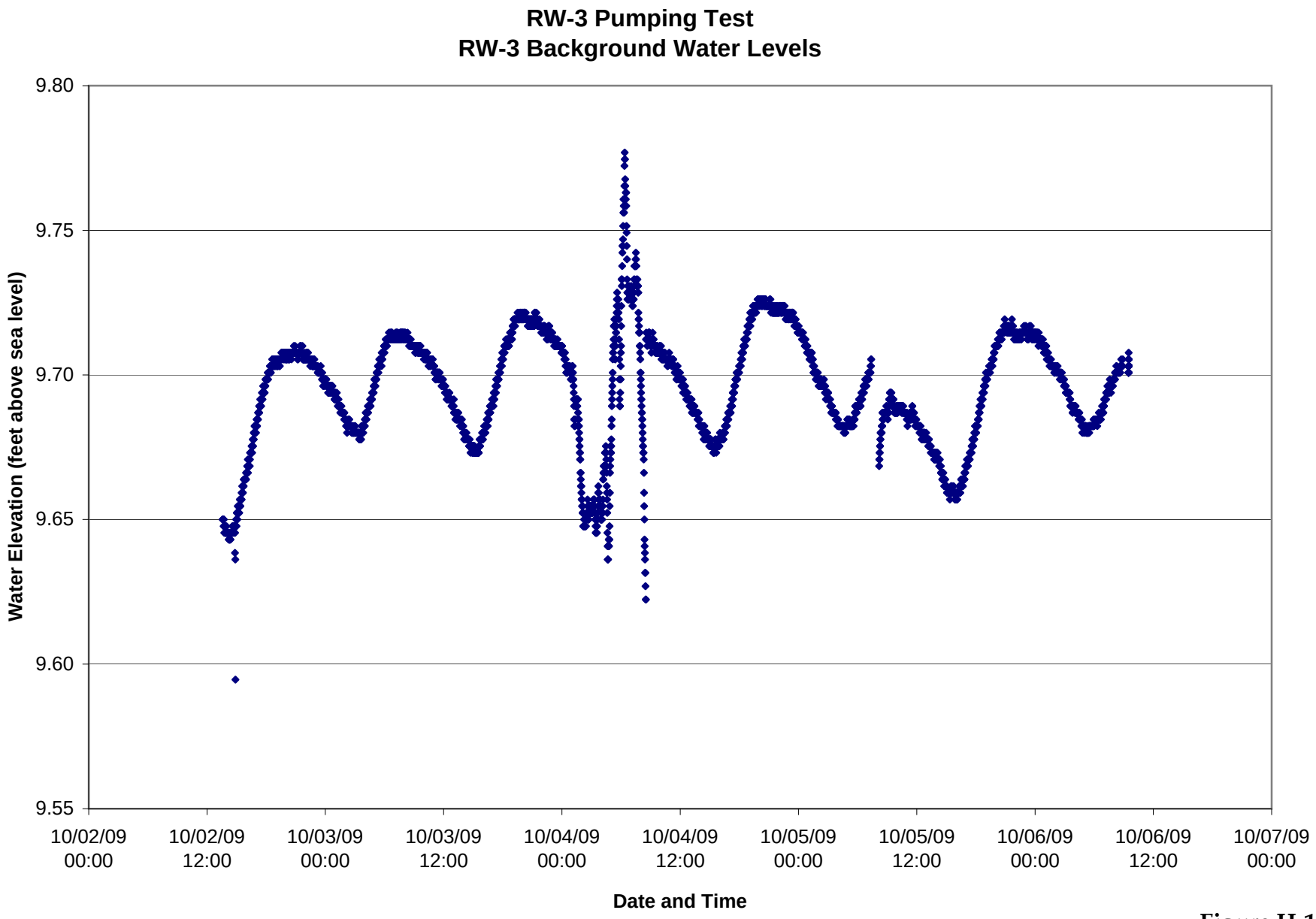
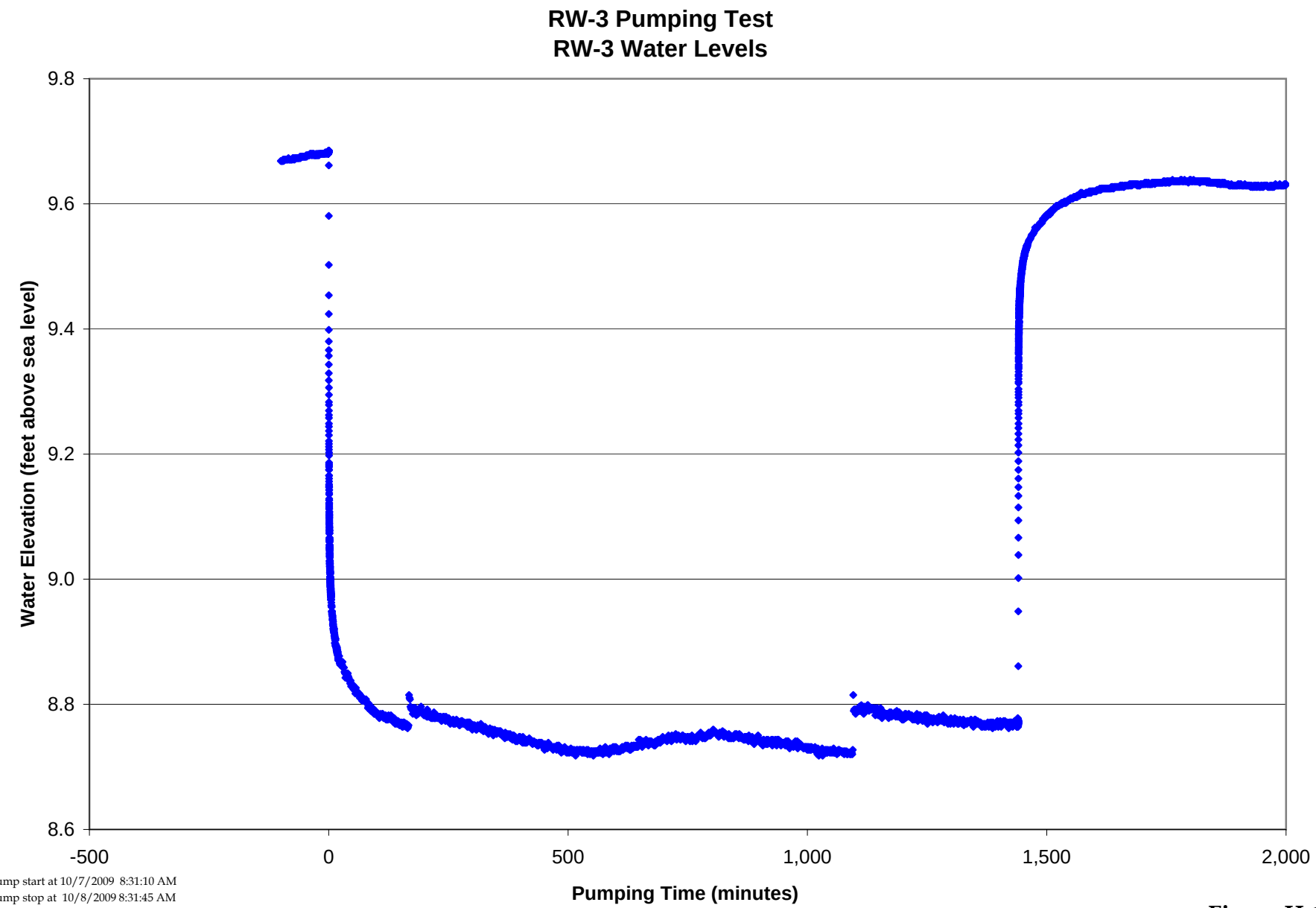


Figure H-16
Attachment H: Groundwater Level Data Plots
Groundwater Source Control Measure Pre-Design Investigation



Pump start at 10/7/2009 8:31:10 AM
Pump stop at 10/8/2009 8:31:45 AM

Figure H-17
Attachment H: Groundwater Level Data Plots
Groundwater Source Control Measure Pre-Design Investigation

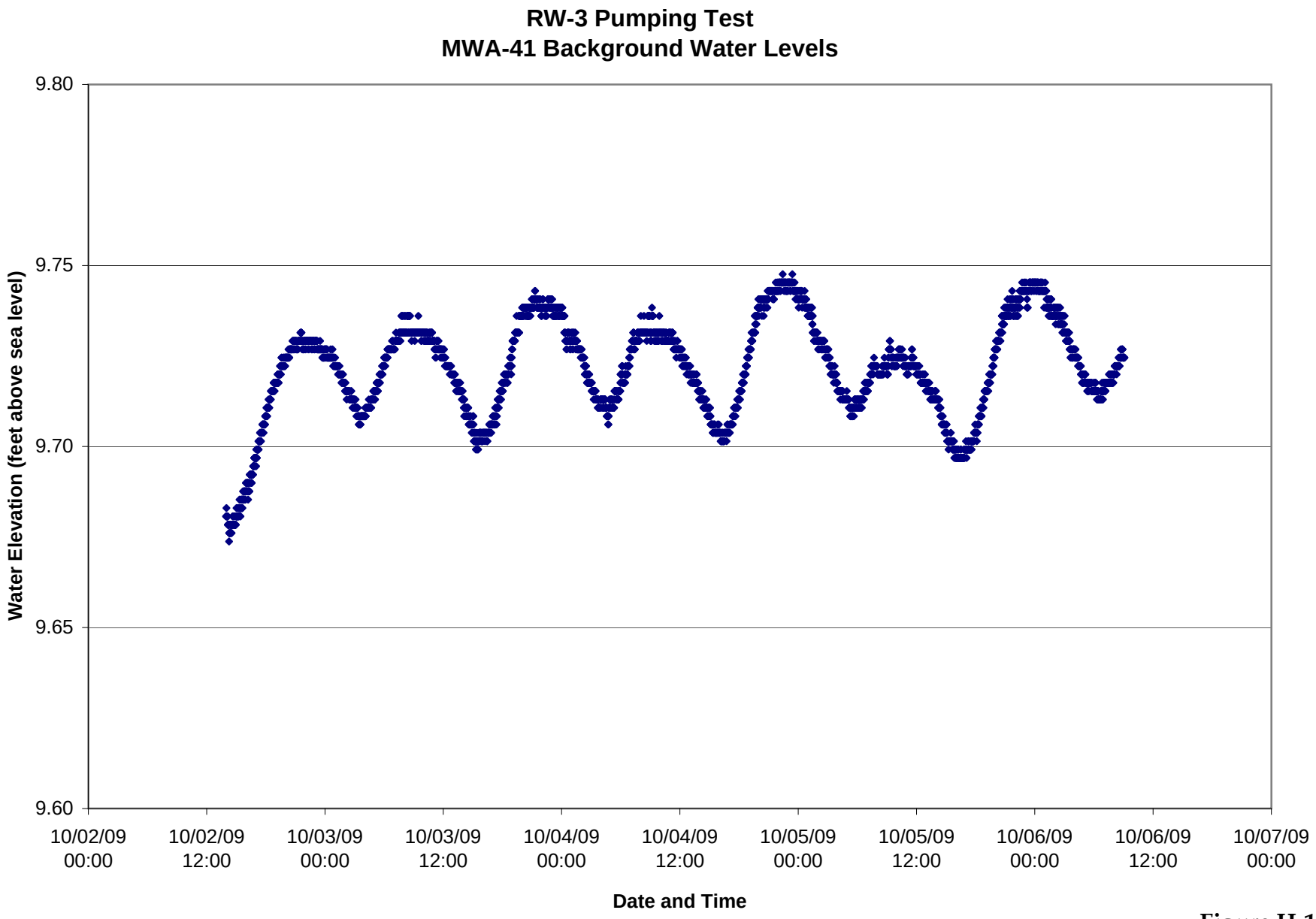
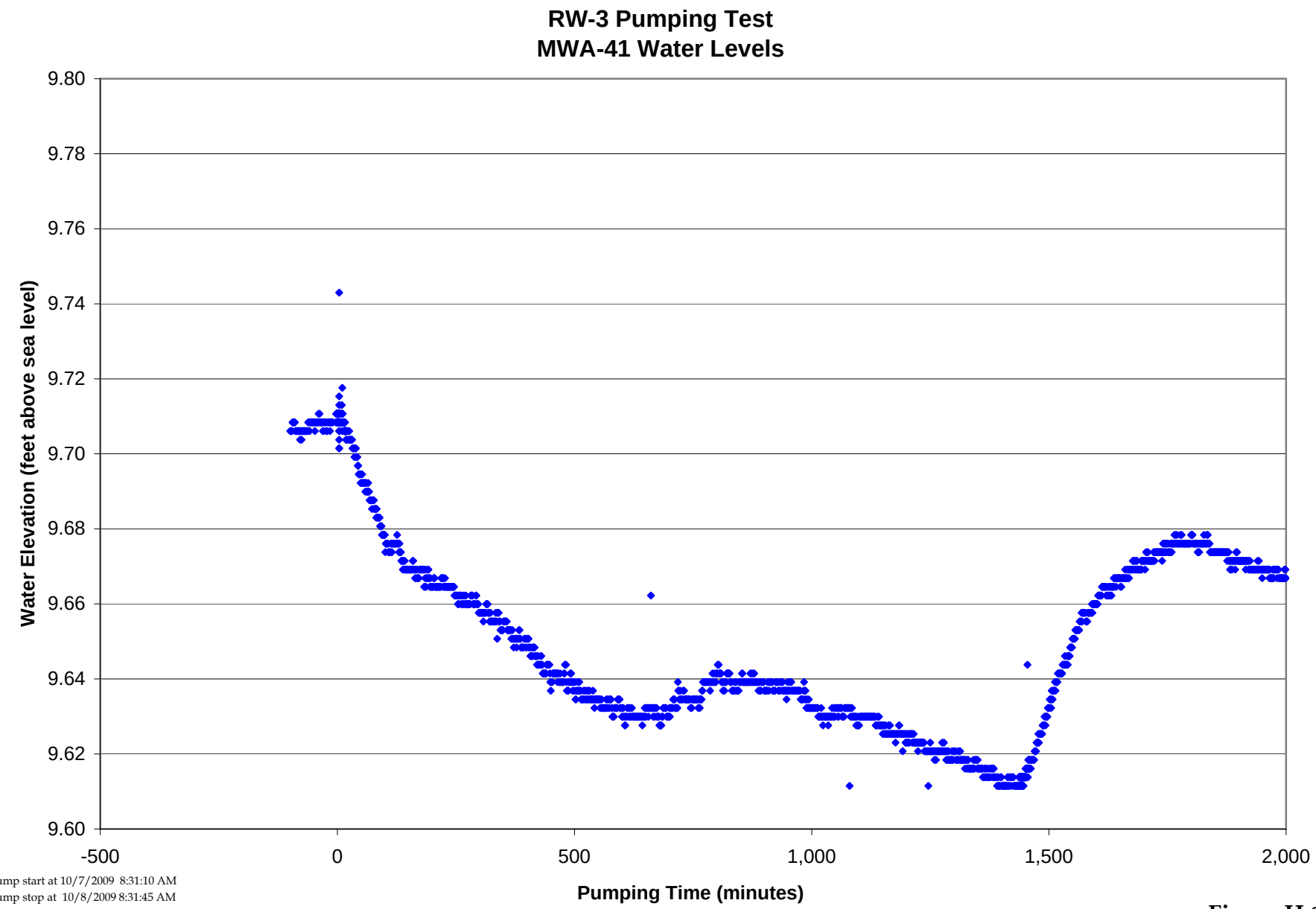


Figure H-18
Attachment H: Groundwater Level Data Plots
Groundwater Source Control Measure Pre-Design Investigation



Pump start at 10/7/2009 8:31:10 AM
Pump stop at 10/8/2009 8:31:45 AM

Figure H-19
Attachment H: Groundwater Level Data Plots
Groundwater Source Control Measure Pre-Design Investigation

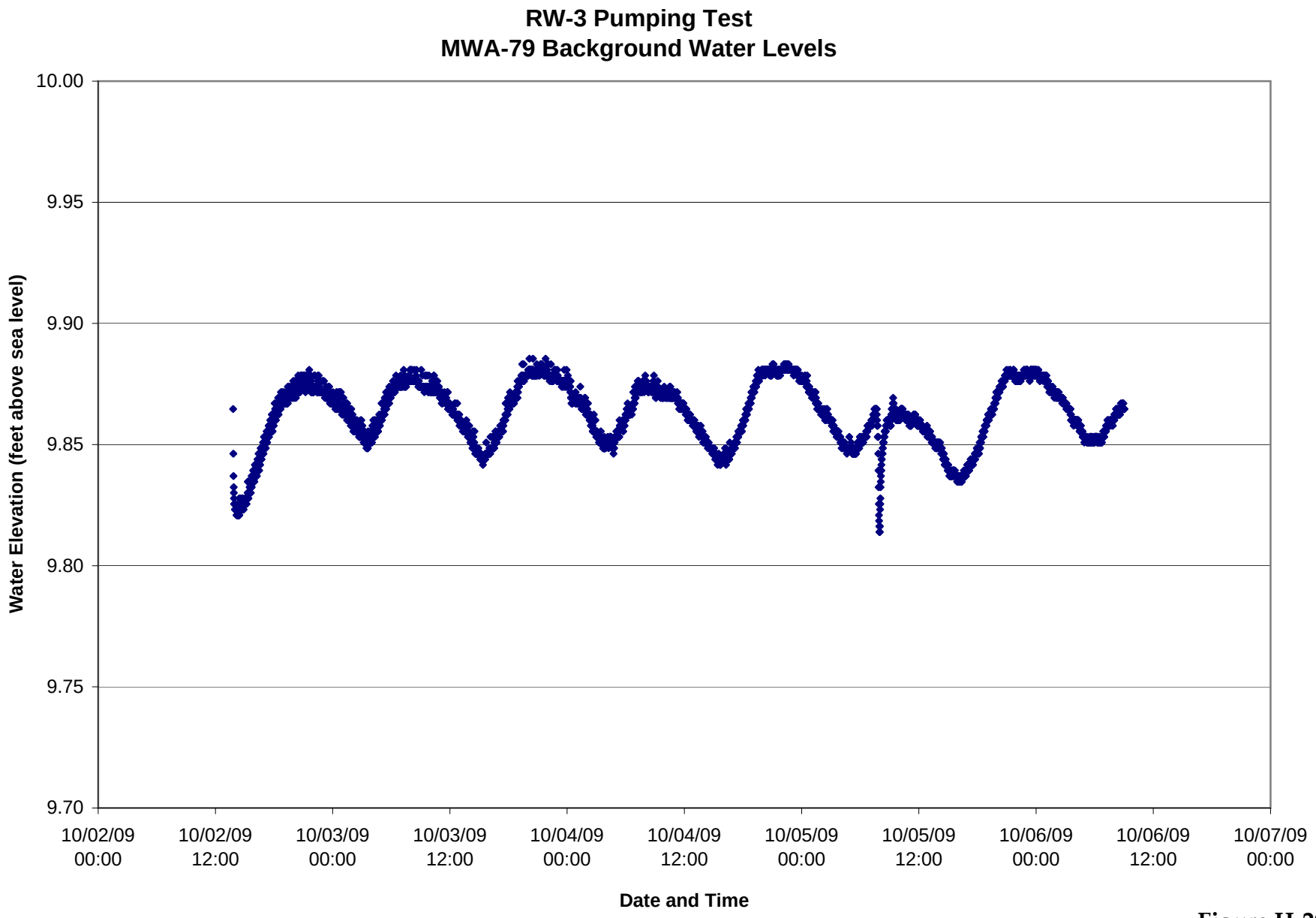
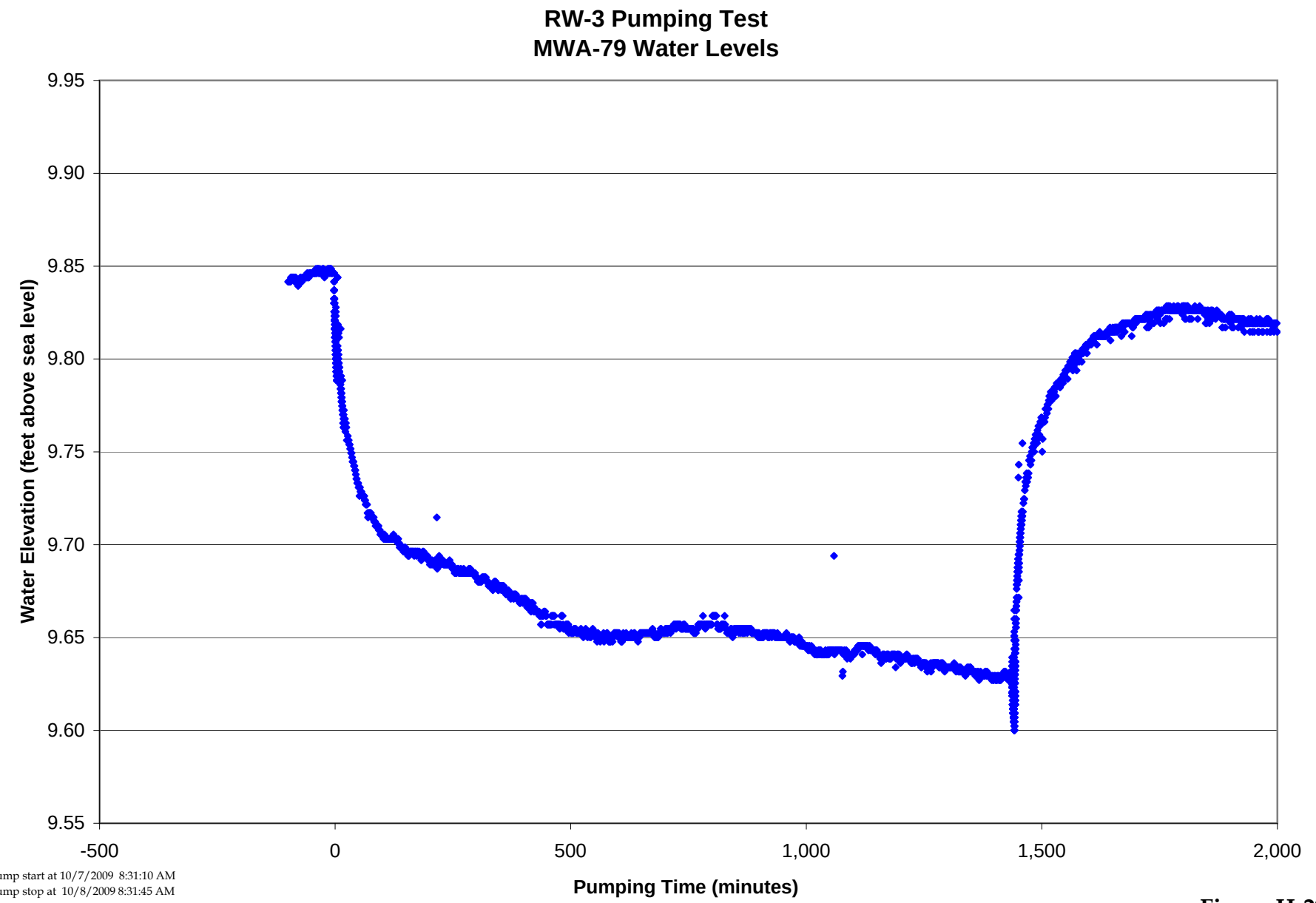


Figure H-20
Attachment H: Groundwater Level Data Plots
Groundwater Source Control Measure Pre-Design Investigation



Pump start at 10/7/2009 8:31:10 AM
Pump stop at 10/8/2009 8:31:45 AM

Figure H-21
Attachment H: Groundwater Level Data Plots
Groundwater Source Control Measure Pre-Design Investigation

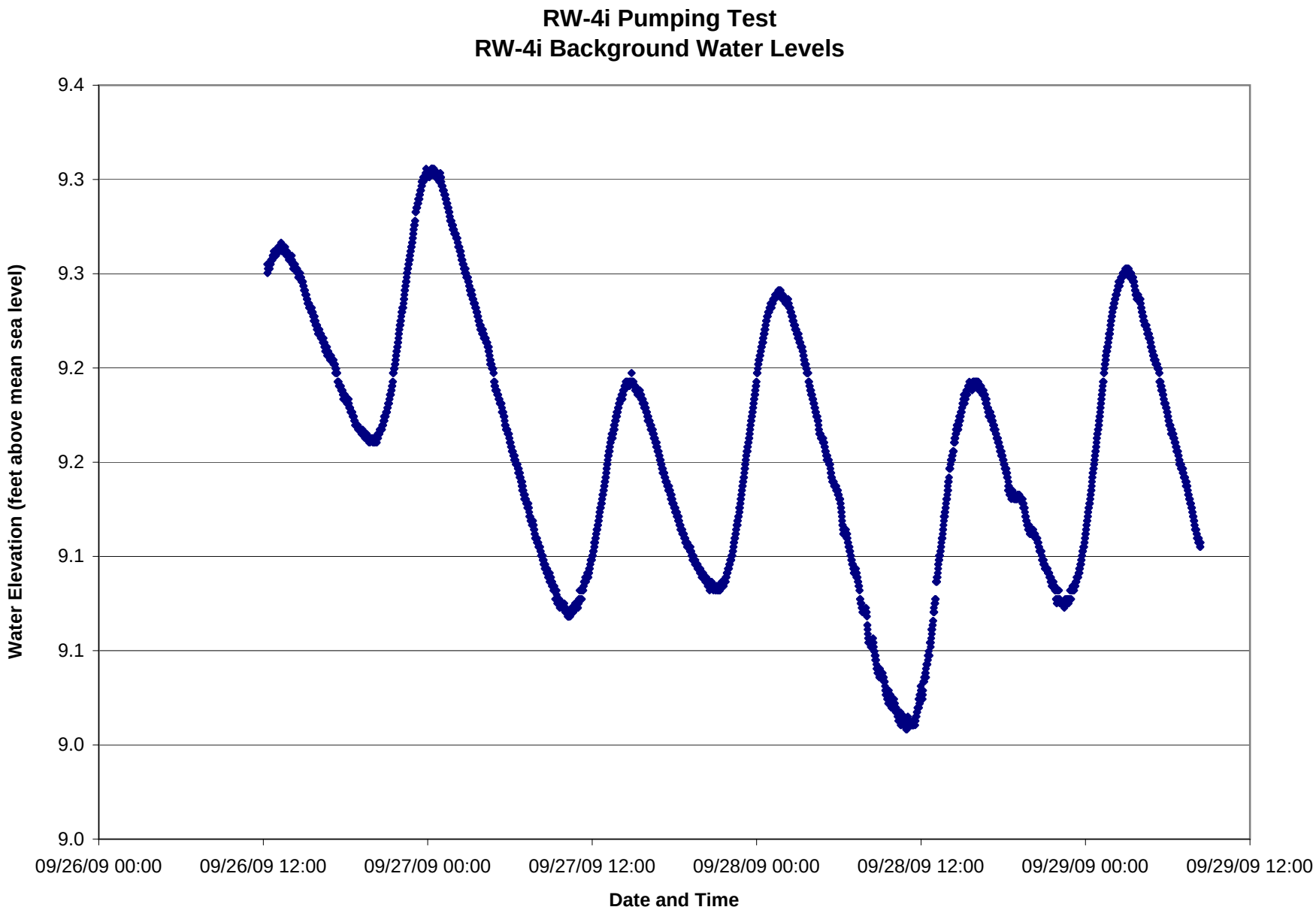
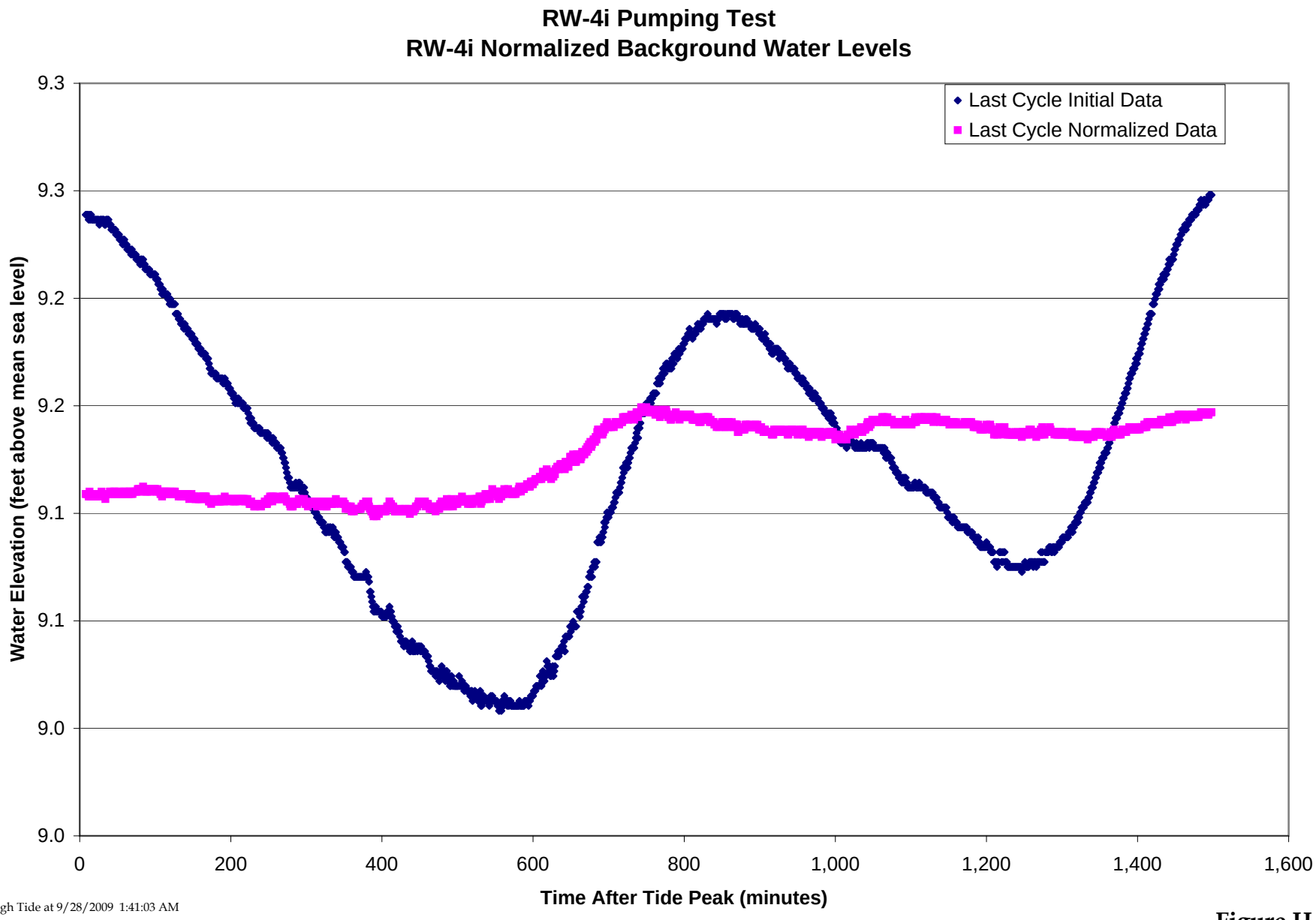
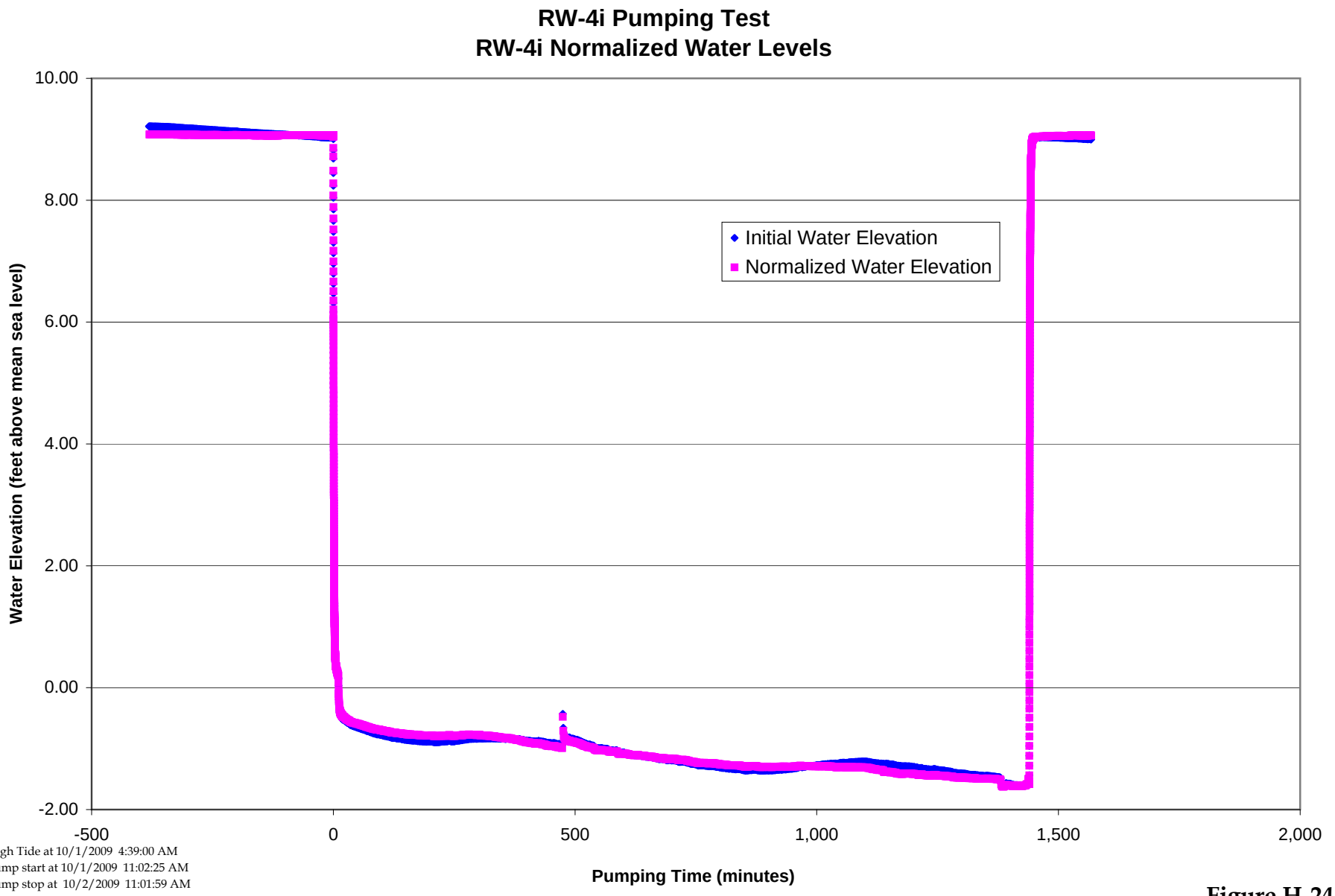


Figure H-22
Attachment H: Groundwater Level Data Plots
Groundwater Source Control Measure Pre-Design Investigation



High Tide at 9/28/2009 1:41:03 AM

Figure H-23
Attachment H: Groundwater Level Data Plots
Groundwater Source Control Measure Pre-Design Investigation



High Tide at 10/1/2009 4:39:00 AM
Pump start at 10/1/2009 11:02:25 AM
Pump stop at 10/2/2009 11:01:59 AM

Figure H-24
Attachment H: Groundwater Level Data Plots
Groundwater Source Control Measure Pre-Design Investigation

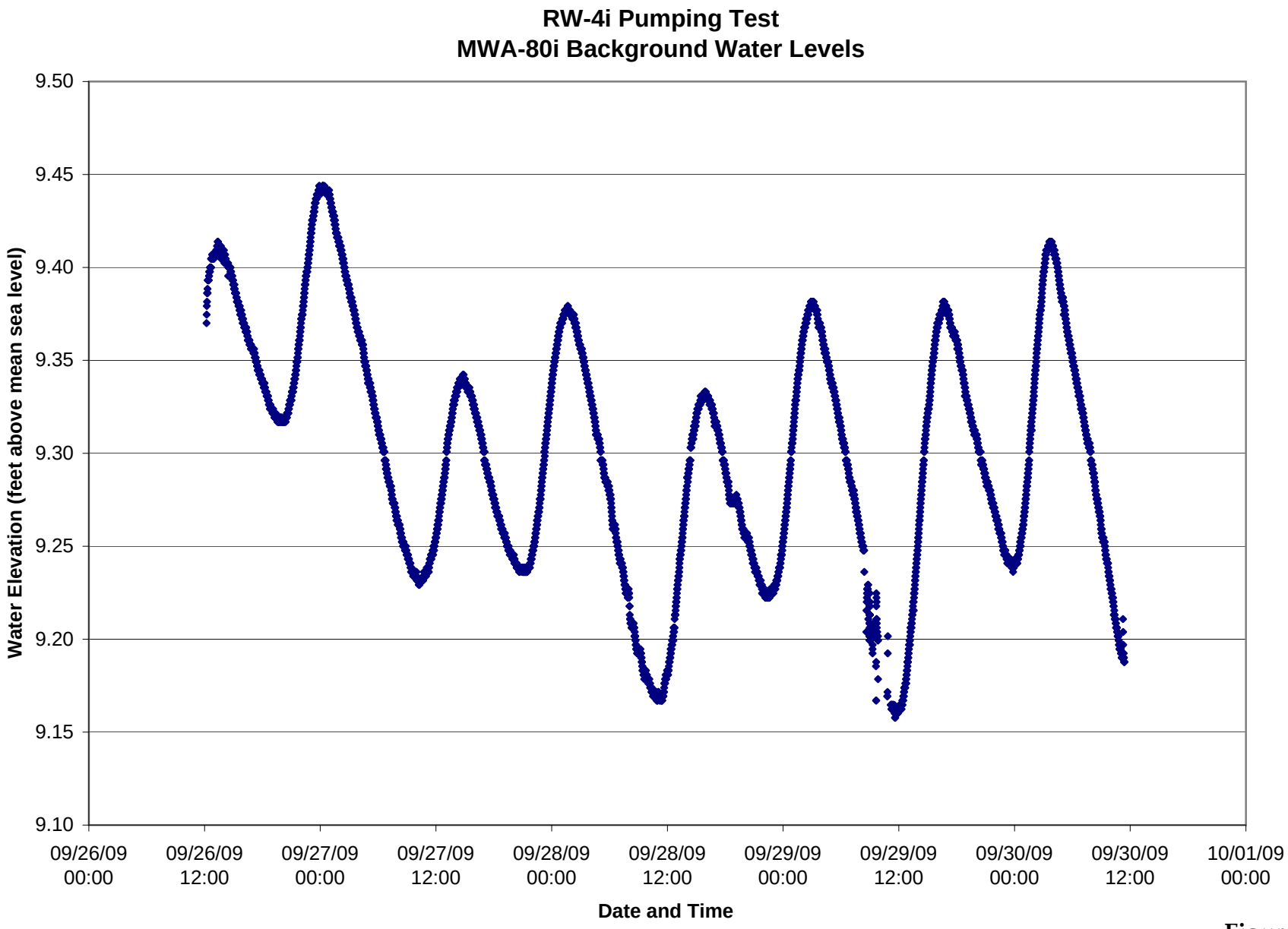


Figure H-25
Attachment H: Groundwater Level Data Plots
Groundwater Source Control Measure Pre-Design Investigation

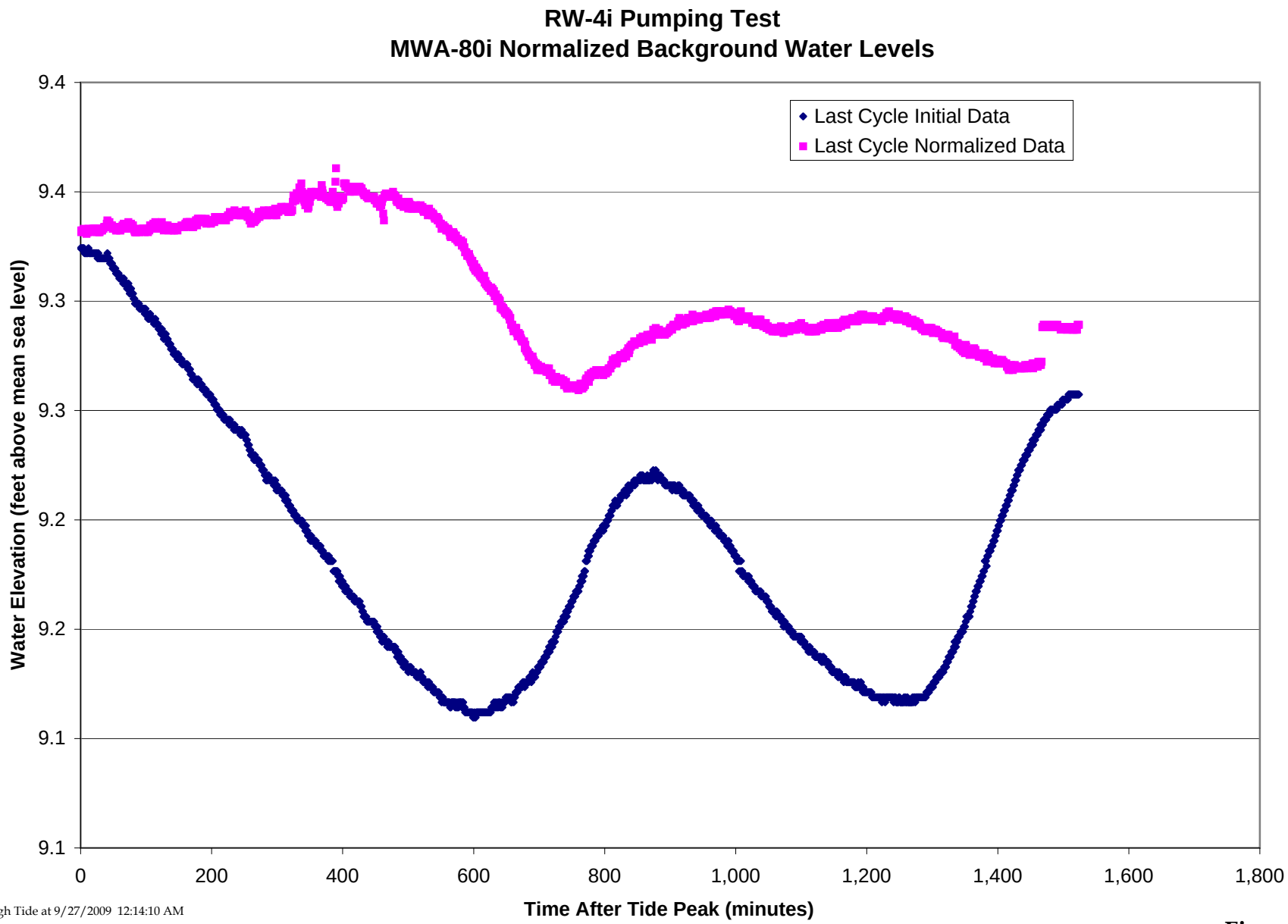
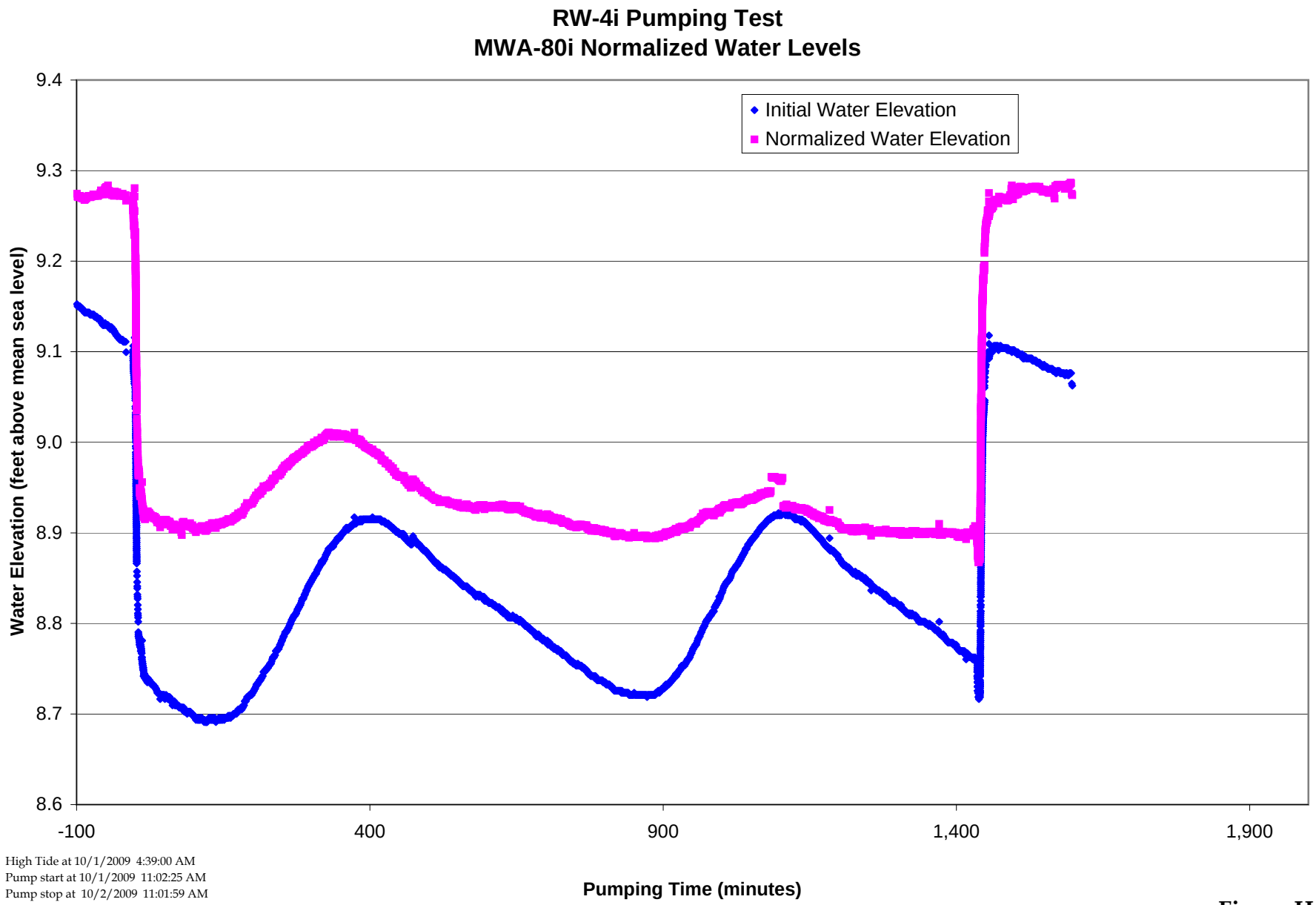


Figure H-26
Attachment H: Groundwater Level Data Plots
Groundwater Source Control Measure Pre-Design Investigation



High Tide at 10/1/2009 4:39:00 AM
Pump start at 10/1/2009 11:02:25 AM
Pump stop at 10/2/2009 11:01:59 AM

Figure H-27
Attachment H: Groundwater Level Data Plots
Groundwater Source Control Measure Pre-Design Investigation

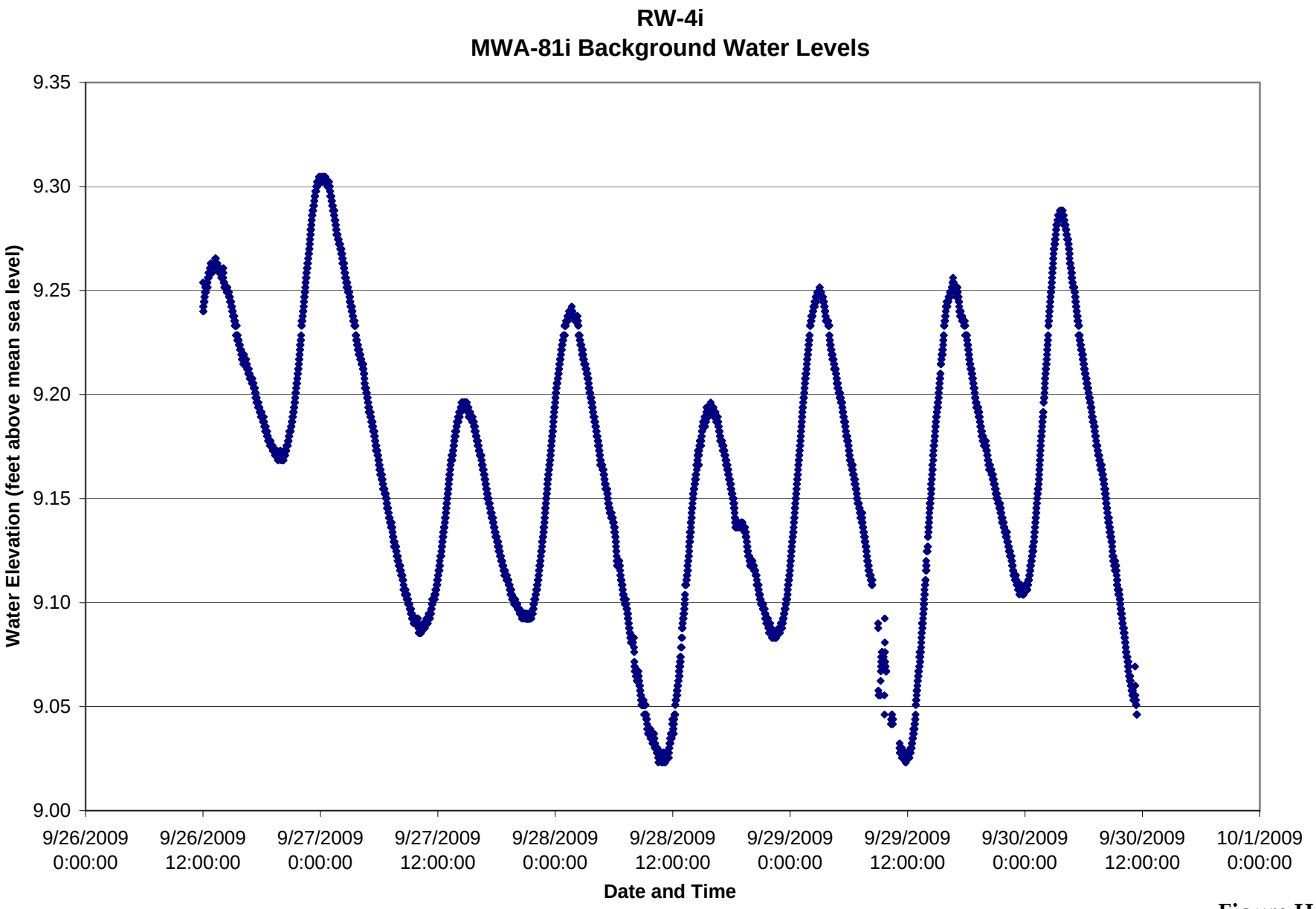


Figure H-28
Attachment H: Groundwater Level Data Plots
Groundwater Source Control Measure Pre-Design Investigation

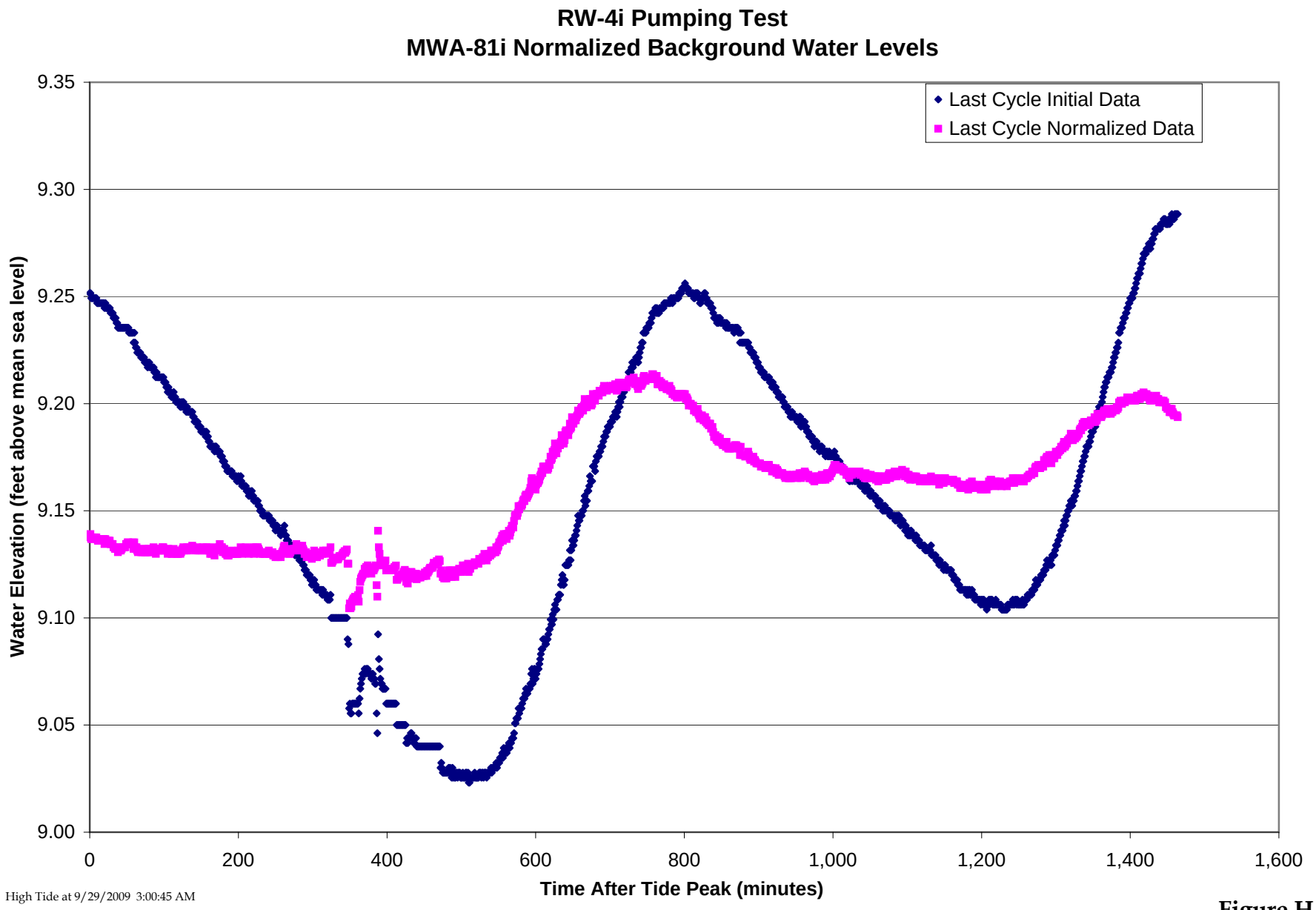
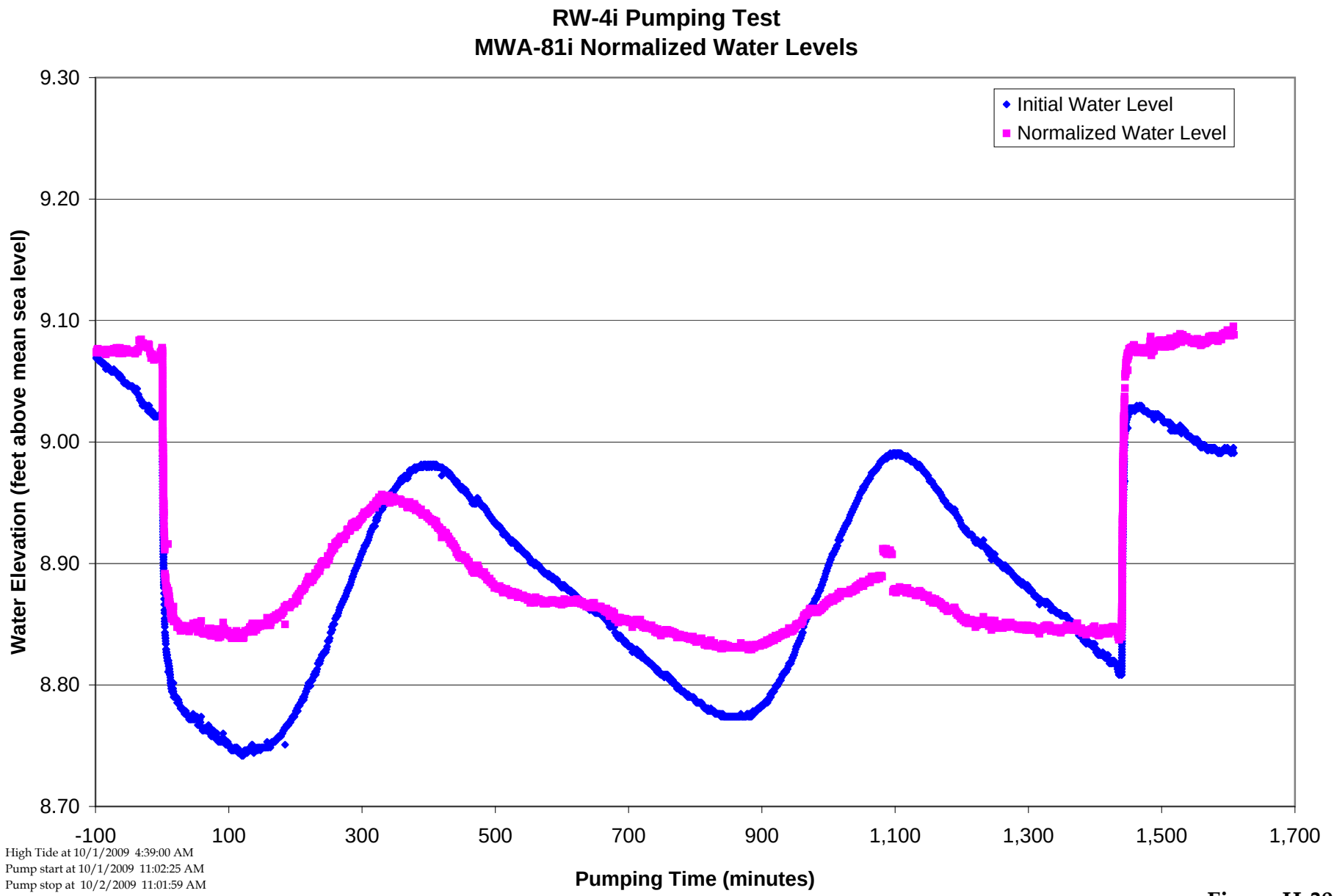


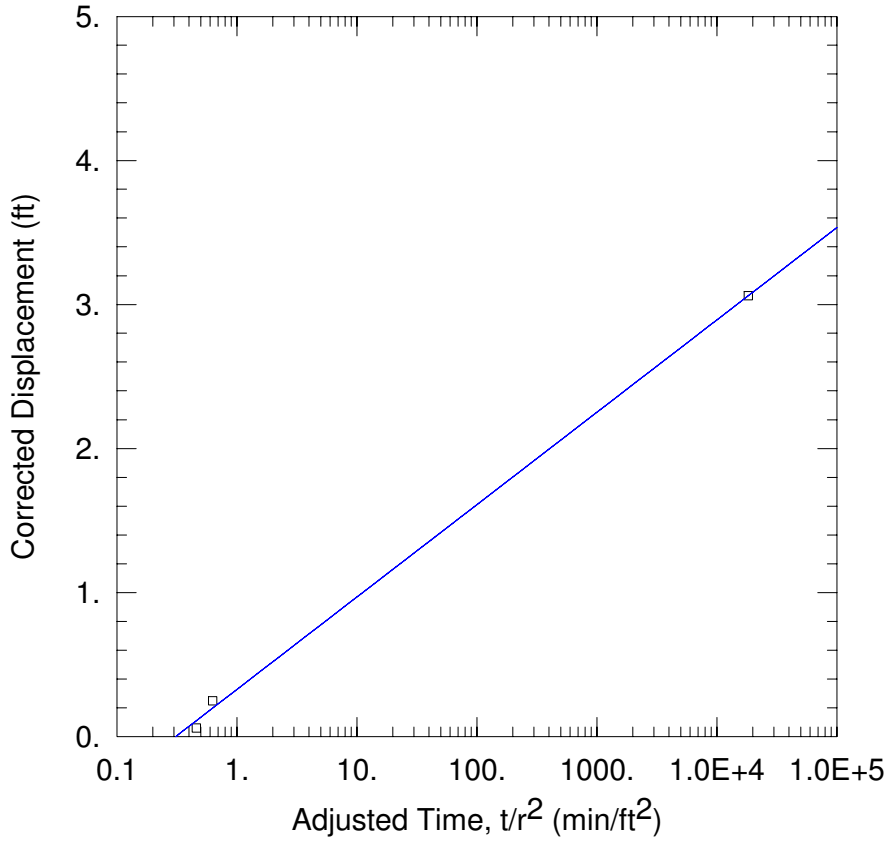
Figure H-29
Attachment H: Groundwater Level Data Plots
Groundwater Source Control Measure Pre-Design Investigation



High Tide at 10/1/2009 4:39:00 AM
Pump start at 10/1/2009 11:02:25 AM
Pump stop at 10/2/2009 11:01:59 AM

Figure H-30
Attachment H: Groundwater Level Data Plots
Groundwater Source ControlMeasure Pre-Design Investigation

Attachment I
AQTESOLV Output Files



RW-1

Data Set: C:\...\RW1 Distance Drawdown.aqt
Date: 03/25/10 Time: 14:32:28

PROJECT INFORMATION

Company: ERM
Client: Arkema
Project: 0058955
Location: Portland, OR
Test Well: RW-1
Test Date: 10/14/2009

SOLUTION

Aquifer Model: Unconfined
Solution Method: Cooper-Jacob

T = 356.8 ft^2/day
S = 0.1727

AQUIFER DATA

Saturated Thickness: 7.75 ft

Anisotropy Ratio (Kz/Kr): 0.4356

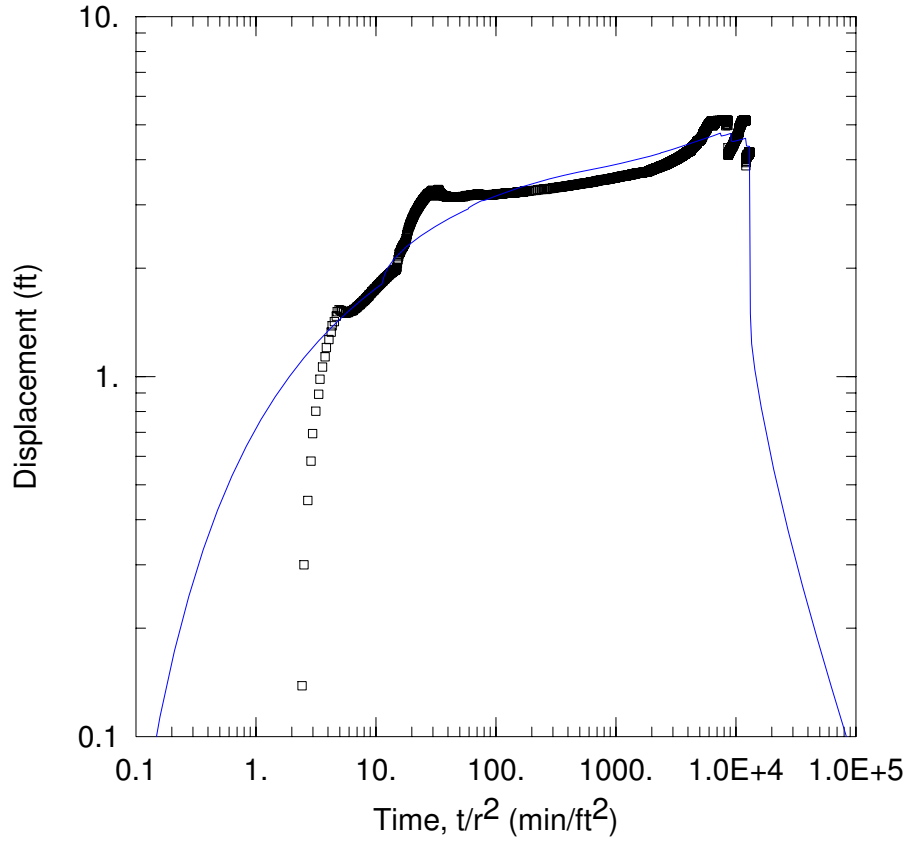
WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
RW1	0	0

Observation Wells

Well Name	X (ft)	Y (ft)
MWA-60	56.71	0
MWA-2	66.43	0
New Well	0.167	0



RW-1

Data Set: C:\...\RW1 Neuman.aqt
Date: 03/25/10 Time: 14:30:49

PROJECT INFORMATION

Company: ERM
Client: Arkema
Project: 0058955
Location: Portland, OR
Test Well: RW-1
Test Date: 10/14/2009

SOLUTION

Aquifer Model: Unconfined
Solution Method: Neuman

T = 193.3 ft^2/day
S = 0.08512
Sy = 1.
ß = 0.0008042

AQUIFER DATA

Saturated Thickness: 7.75 ft

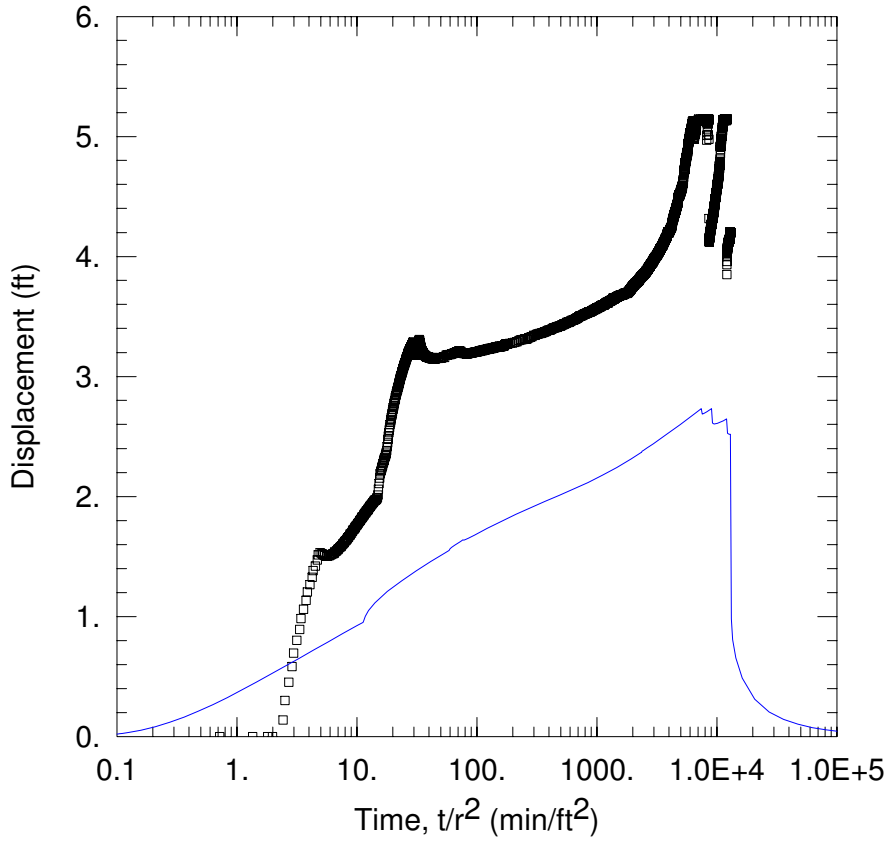
WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
RW1	0	0

Observation Wells

Well Name	X (ft)	Y (ft)
▫ RW-1	0.167	0



RW-1

Data Set: C:\...\RW1 Neuman (efficiency).aqt
Date: 05/04/10 Time: 15:56:23

PROJECT INFORMATION

Company: ERM
Client: Arkema
Project: 0058955
Location: Portland, OR
Test Well: RW-1
Test Date: 10/14/2009

SOLUTION

Aquifer Model: Unconfined
Solution Method: Neuman

T = 356.8 ft^2/day
S = 0.1727
Sy 1.
ß = 0.001

AQUIFER DATA

Saturated Thickness: 7.75 ft

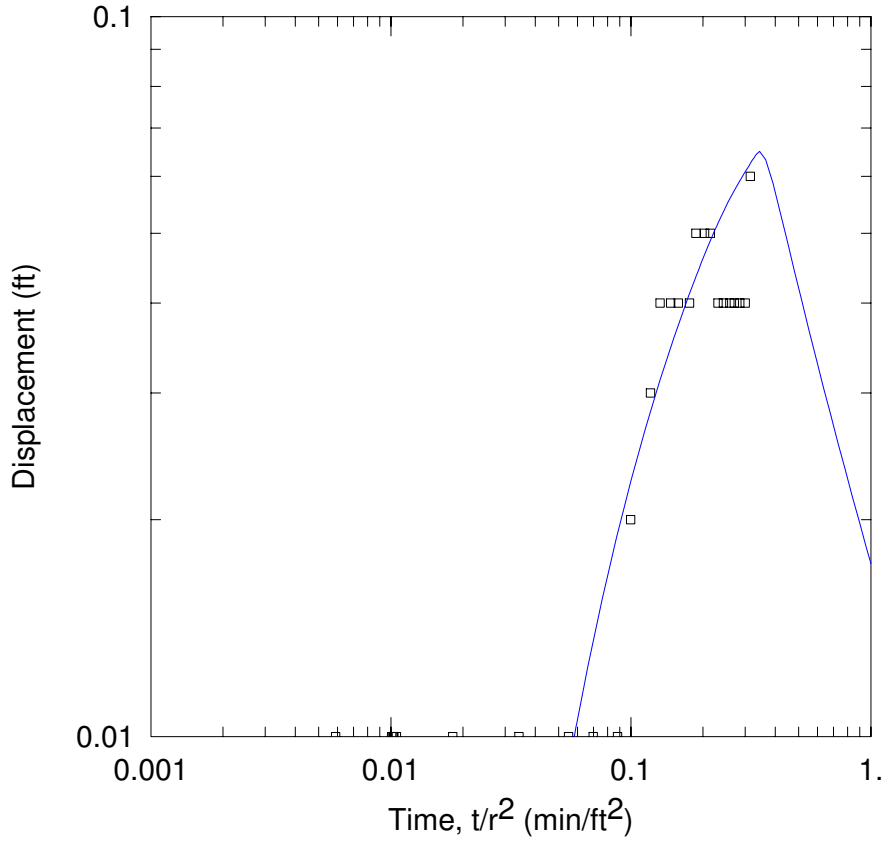
WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
RW1	0	0

Observation Wells

Well Name	X (ft)	Y (ft)
▫ RW-1	0.167	0



RW-1

Data Set: C:\...\RW1 MWA2 Neuman.aqt
Date: 03/25/10 Time: 14:30:09

PROJECT INFORMATION

Company: ERM
Client: Arkema
Project: 0058955
Location: Portland, OR
Test Well: RW-1
Test Date: 10/14/2009

SOLUTION

Aquifer Model: Unconfined
Solution Method: Neuman

T = 2076.2 ft^2/day
S = 0.3759
Sy = 1.713
ß = 0.004738

AQUIFER DATA

Saturated Thickness: 7.75 ft

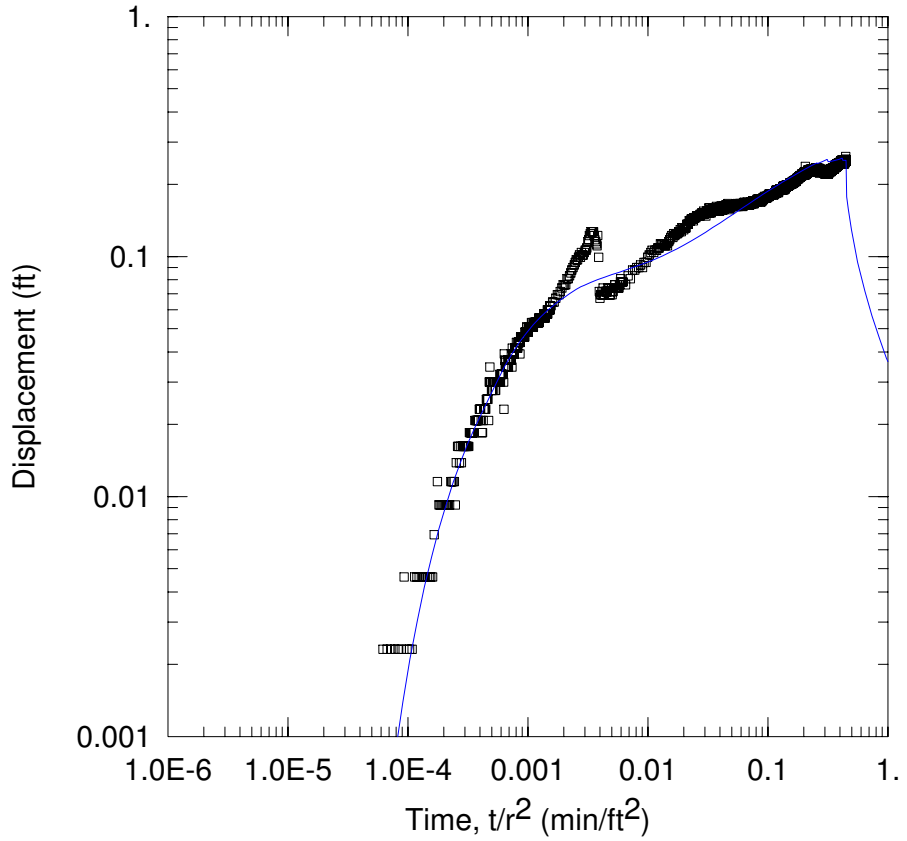
WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
RW1	0	0

Observation Wells

Well Name	X (ft)	Y (ft)
▫ MWA-2	66.428	0



RW-1

Data Set: C:\...\RW1 MWA60 Neuman.aqt
Date: 03/25/10 Time: 14:31:24

PROJECT INFORMATION

Company: ERM
Client: Arkema
Project: 0058955
Location: Portland, OR
Test Well: RW-1
Test Date: 10/14/2009

SOLUTION

Aquifer Model: Unconfined
Solution Method: Neuman

T = 1839. ft^2/day
S = 0.001103
Sy = 0.01583
ß = 0.1608

AQUIFER DATA

Saturated Thickness: 7.75 ft

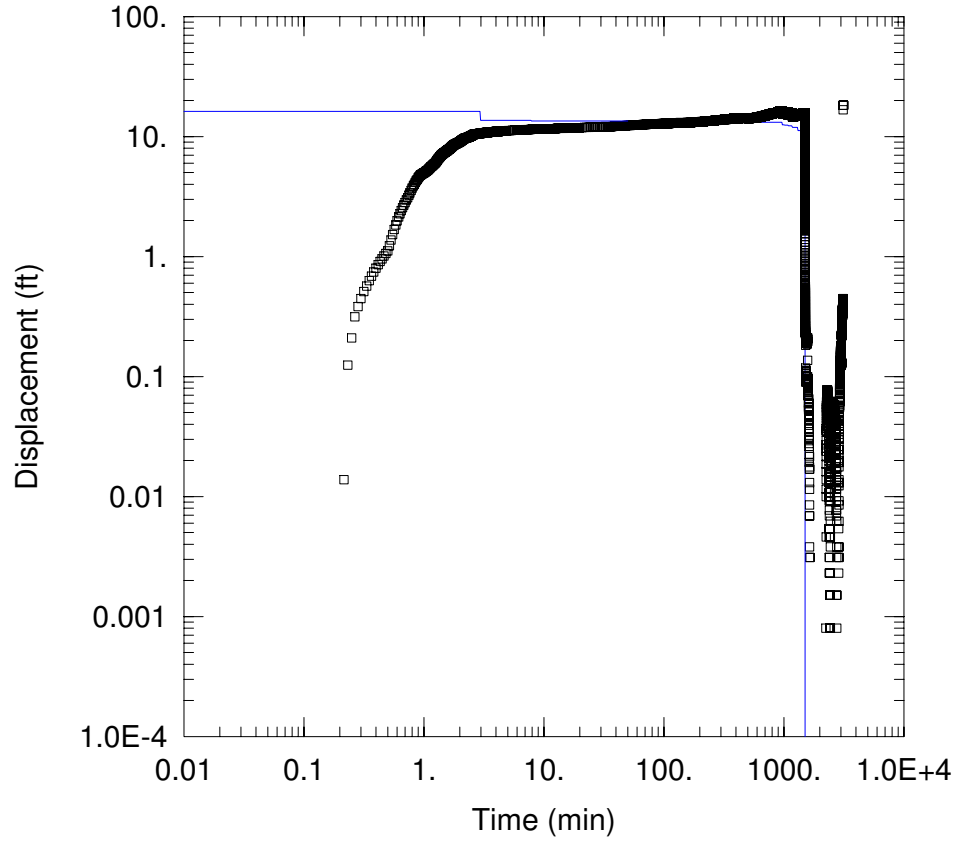
WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
RW1	70.01	15.21

Observation Wells

Well Name	X (ft)	Y (ft)
▫ MWA-60	14.4	26.3



RW-2I

Data Set: C:\...\RW-2i.aqt
Date: 03/24/10 Time: 11:09:58

PROJECT INFORMATION

Company: ERM
Client: Arkema, Inc.
Project: 0058055
Location: Portland, OR
Test Well: RW-2i
Test Date: 10/21/2009

SOLUTION

Aquifer Model: Leaky
Solution Method: Hantush

T = 105.3 ft^2/day
S = 4.382E-18
r/B' = 0.0002798
ß' = 2.031E-10
r/B" = 0.0004
ß" = 0.000465

AQUIFER DATA

Saturated Thickness: 5. ft
Aquitard Thickness (b'): 1. ft
Anisotropy Ratio (Kz/Kr): 0.1
Aquitard Thickness (b"): 1. ft

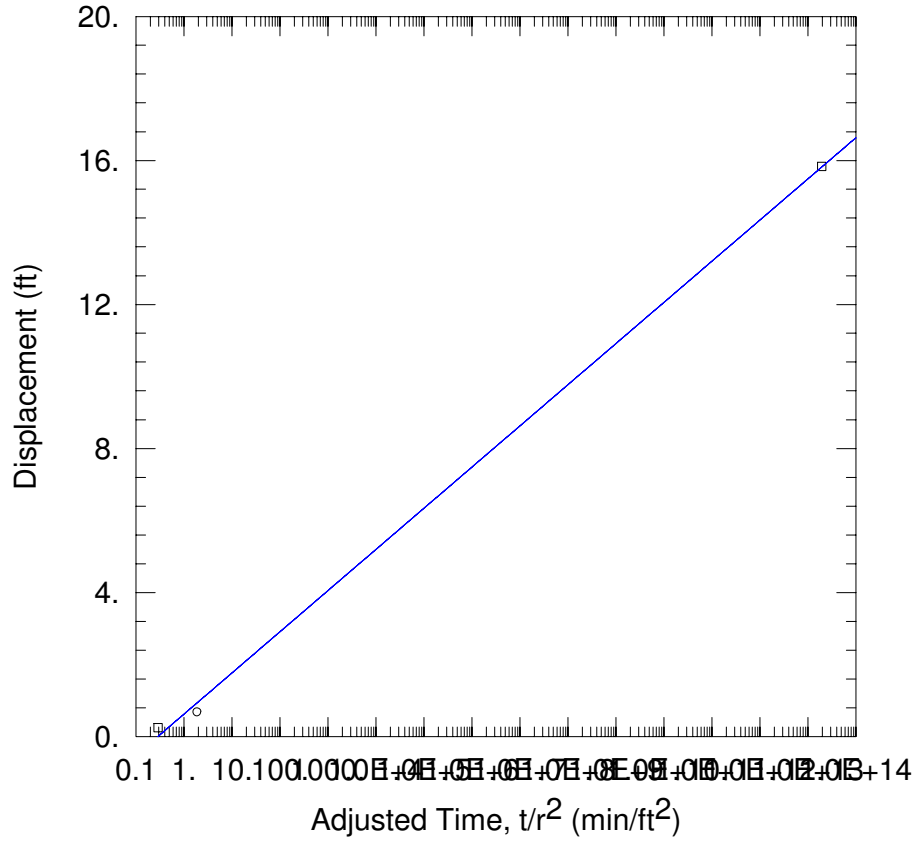
WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
RW-2i	0	0

Observation Wells

Well Name	X (ft)	Y (ft)
▫ RW-2i	0	0



RW-2I

Data Set: C:\...\RW-2i distance-drawdown.aqt
Date: 03/24/10 Time: 11:00:22

PROJECT INFORMATION

Company: ERM
Client: Arkema, Inc.
Project: 0058055
Location: Portland, OR
Test Well: RW-2i
Test Date: 10/21/2009

SOLUTION

Aquifer Model: Confined
Solution Method: Cooper-Jacob

T = 153.3 ft^2/day
S = 0.06894

AQUIFER DATA

Saturated Thickness: 5. ft

Anisotropy Ratio (Kz/Kr): 0.1

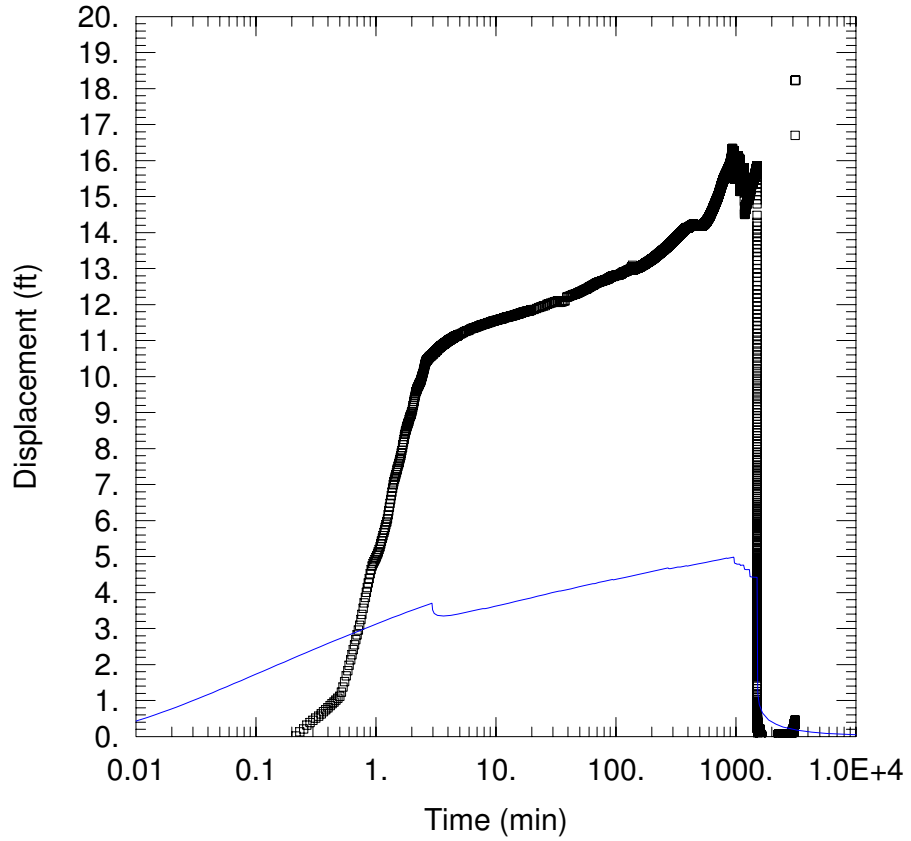
WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
RW-2i	0	0

Observation Wells

Well Name	X (ft)	Y (ft)
▫ RW-2i	0	0
○ MWA-78iCor	32.17	0
▫ MWA-8i	82.42	0



RW-2I

Data Set: C:\...\RW-2i (efficiency).aqt
Date: 05/04/10 Time: 15:52:27

PROJECT INFORMATION

Company: ERM
Client: Arkema, Inc.
Project: 0058055
Location: Portland, OR
Test Well: RW-2i
Test Date: 10/21/2009

SOLUTION

Aquifer Model: Leaky
Solution Method: Hantush

T = 153.3 ft^2/day
S = 0.06894
r/B' = 8.76E-5
ß' = 0.01789
r/B" 0.0004
ß" = 0.000465

AQUIFER DATA

Saturated Thickness: 5. ft
Aquitard Thickness (b'): 1. ft

Anisotropy Ratio (Kz/Kr): 0.1
Aquitard Thickness (b"): 1. ft

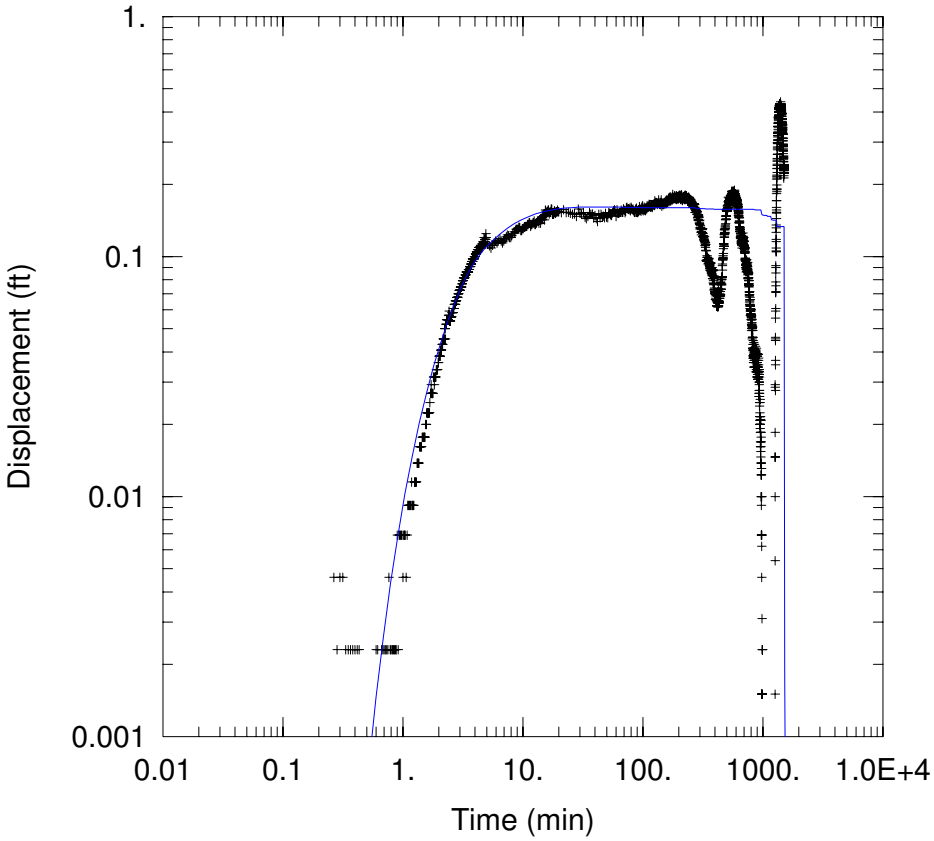
WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
RW-2i	0	0

Observation Wells

Well Name	X (ft)	Y (ft)
▫ RW-2i	0.167	0



RW-2I

Data Set: C:\...\RW-2i(8i)Hantush.aqt
Date: 03/24/10 Time: 11:18:38

PROJECT INFORMATION

Company: ERM
Client: Arkema, Inc.
Project: 0058055
Location: Portland, OR
Test Well: RW-2i
Test Date: 10/21/2009

SOLUTION

Aquifer Model: Leaky
Solution Method: Hantush

T = 0.2906 ft^2/min
S = 0.0003718
r/B' = 1.098
ß' = 6.863E-5
r/B" = 0.
ß" = 0.

AQUIFER DATA

Saturated Thickness: 5. ft
Aquitard Thickness (b'): 1. ft

Anisotropy Ratio (Kz/Kr): 0.1
Aquitard Thickness (b"): 1. ft

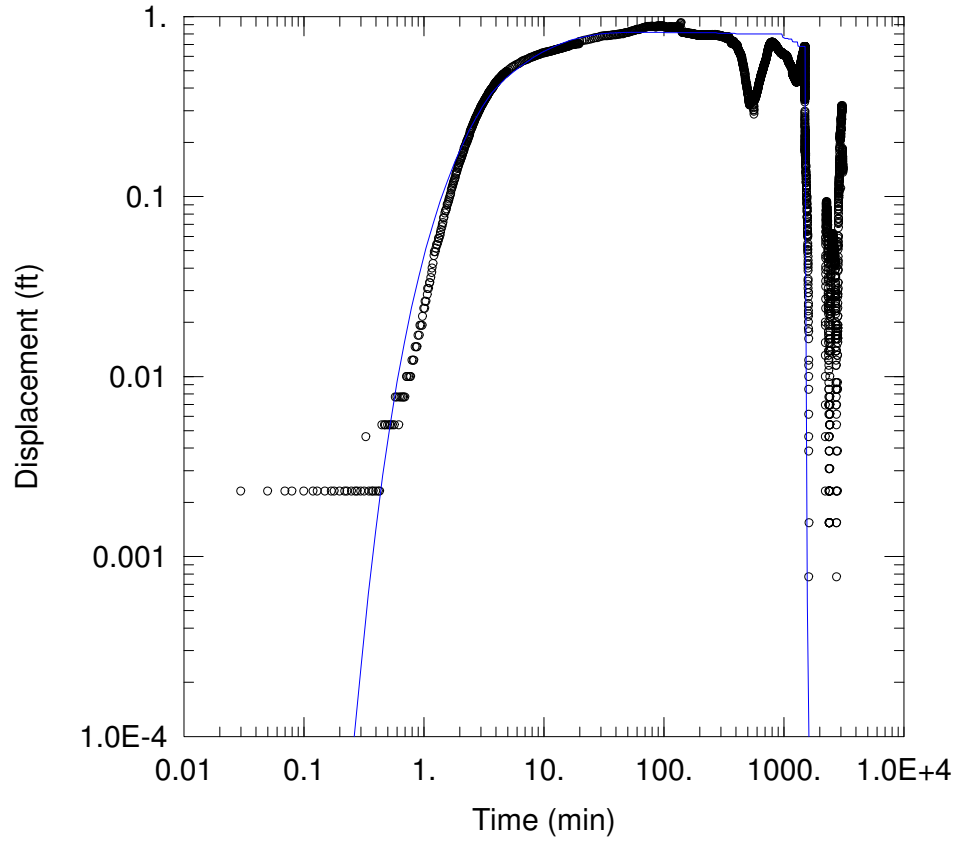
WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
RW-2i	0	0

Observation Wells

Well Name	X (ft)	Y (ft)
+ MWA-8i	82.42	0



RW-2I

Data Set: C:\...\RW-2i(78i)Hantush.aqt
Date: 03/24/10 Time: 11:14:36

PROJECT INFORMATION

Company: ERM
Client: Arkema, Inc.
Project: 0058055
Location: Portland, OR
Test Well: RW-2i
Test Date: 10/21/2009

SOLUTION

Aquifer Model: Leaky
Solution Method: Hantush

T = 0.09793 ft^2/min
S = 0.0006897
r/B' = 0.7295
ß' = 2.099E-5
r/B" = 0.
ß" = 0.

AQUIFER DATA

Saturated Thickness: 5. ft
Aquitard Thickness (b'): 1. ft

Anisotropy Ratio (Kz/Kr): 0.1
Aquitard Thickness (b"): 1. ft

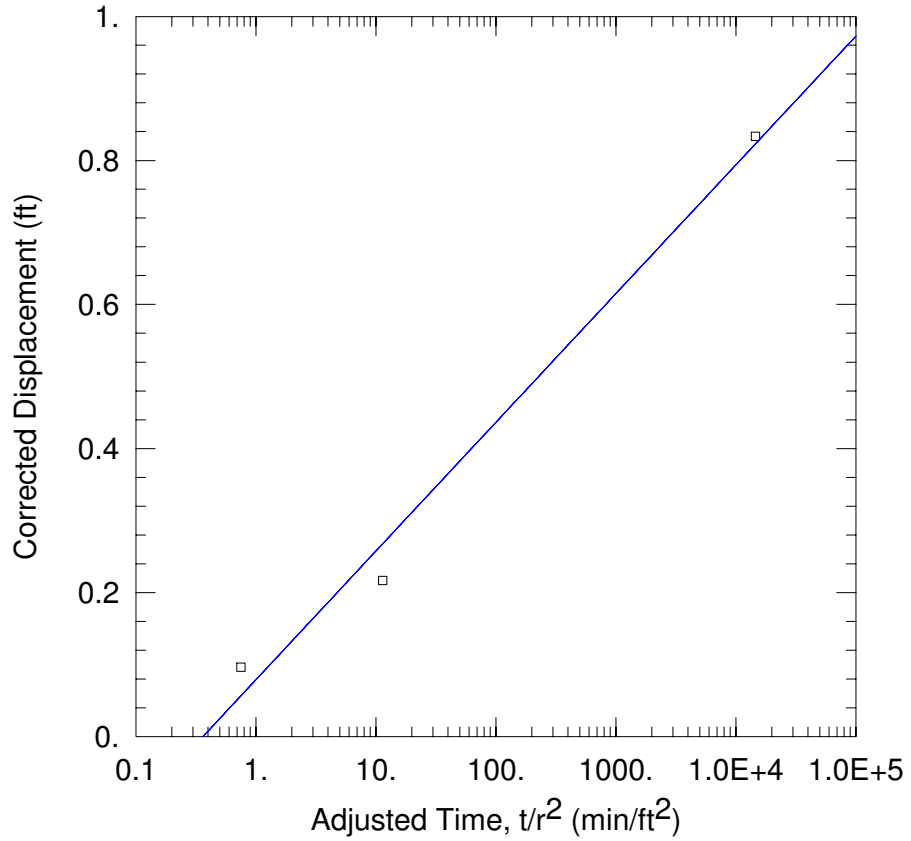
WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
RW-2i	0	0

Observation Wells

Well Name	X (ft)	Y (ft)
◦ MWA-78iCor	32.17	0



RW-3

Data Set: C:\...\RW-3 Distance-drawdown.aqt
Date: 03/25/10 Time: 14:33:39

PROJECT INFORMATION

Company: ERM
Client: Arkema, Inc.
Project: 0058055
Location: Portland, OR
Test Well: RW-3
Test Date: 10/21/2009

SOLUTION

Aquifer Model: Unconfined
Solution Method: Cooper-Jacob

T = 881.9 ft^2/day
S = 0.4992

AQUIFER DATA

Saturated Thickness: 5.35 ft

Anisotropy Ratio (Kz/Kr): 0.1

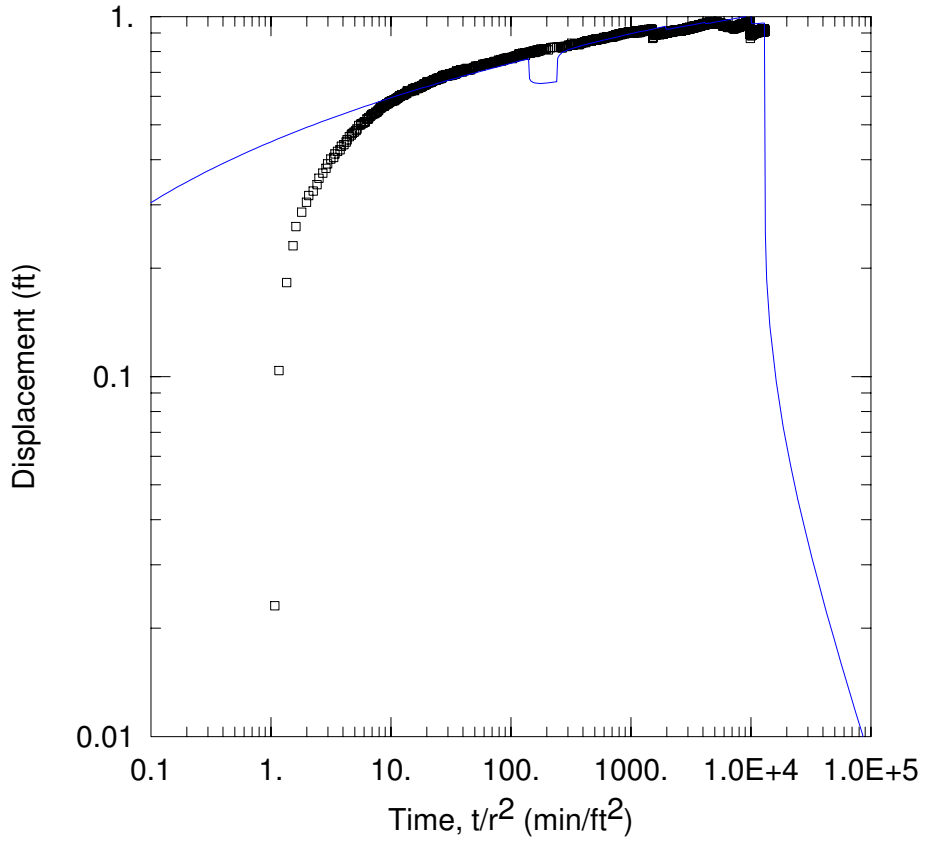
WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
RW-3	0	0

Observation Wells

Well Name	X (ft)	Y (ft)
▫ MWA-41	46.4	0
▫ MWA-79	11.89	0
▫ RW-3	0.167	0



RW-3

Data Set: C:\...\RW-3 Neuman.aqt
Date: 03/25/10 Time: 14:28:20

PROJECT INFORMATION

Company: ERM
Client: Arkema, Inc.
Project: 0058055
Location: Portland, OR
Test Well: RW-3
Test Date: 10/21/2009

SOLUTION

Aquifer Model: Unconfined
Solution Method: Neuman

T = 1185.4 ft^2/day
S = 0.001417
Sy = 0.00022
ß = 0.0003144

AQUIFER DATA

Saturated Thickness: 5.35 ft

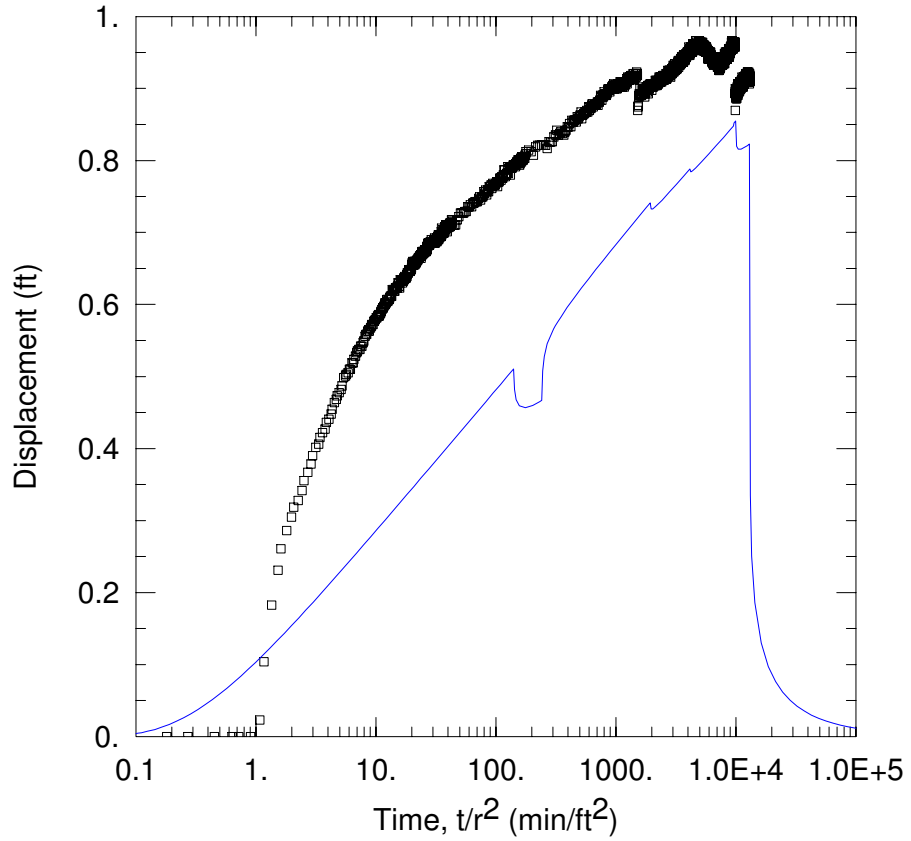
WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
RW-3	0	0

Observation Wells

Well Name	X (ft)	Y (ft)
▫ RW-3	0.167	0



RW-3

Data Set: C:\...\RW-3 Neuman (efficiency).aqt
Date: 05/04/10 Time: 15:47:27

PROJECT INFORMATION

Company: ERM
Client: Arkema, Inc.
Project: 0058055
Location: Portland, OR
Test Well: RW-3
Test Date: 10/21/2009

SOLUTION

Aquifer Model: Unconfined
Solution Method: Neuman

T = 881.9 ft^2/day
S = 0.4992
Sy = 0.00022
ß = 0.001

AQUIFER DATA

Saturated Thickness: 5.35 ft

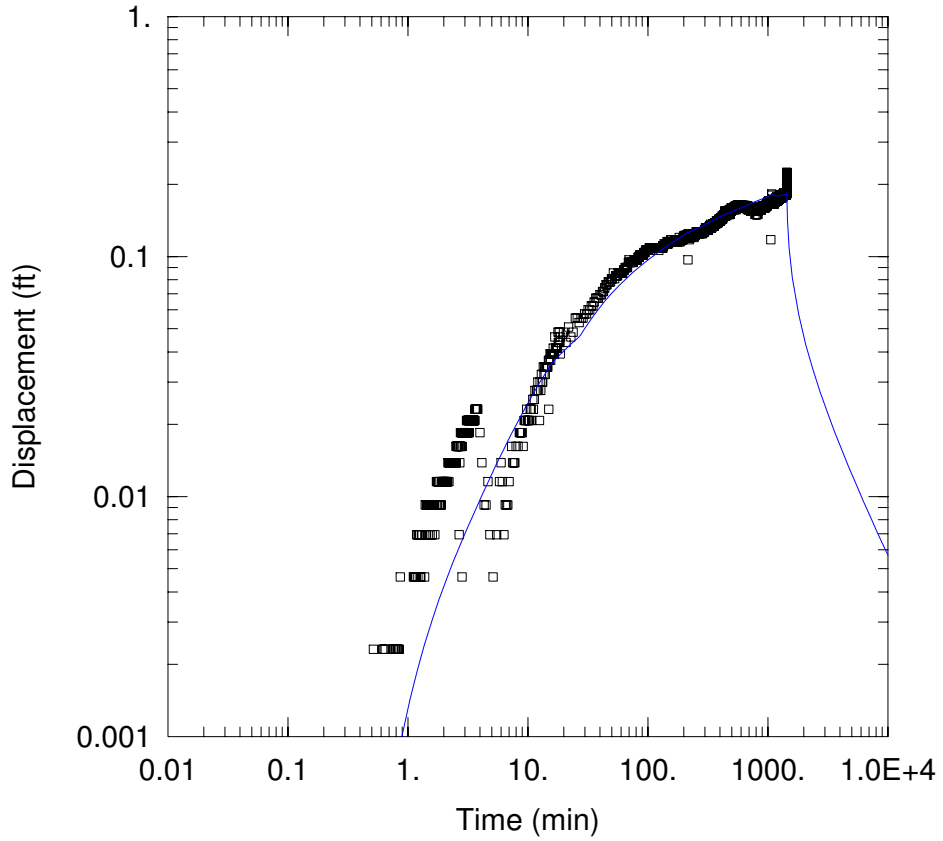
WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
RW-3	0	0

Observation Wells

Well Name	X (ft)	Y (ft)
▫ RW-3	0.167	0



RW-3

Data Set: C:\...\RW-3 MWA-41 Neuman.aqt
Date: 03/25/10 Time: 14:29:31

PROJECT INFORMATION

Company: ERM
Client: Arkema, Inc.
Project: 0058055
Location: Portland, OR
Test Well: RW-3
Test Date: 10/21/2009

SOLUTION

Aquifer Model: Unconfined
Solution Method: Neuman

T = 1984.8 ft^2/day
S = 0.004557
Sy = 0.007307
ß = 2.201

AQUIFER DATA

Saturated Thickness: 5.35 ft

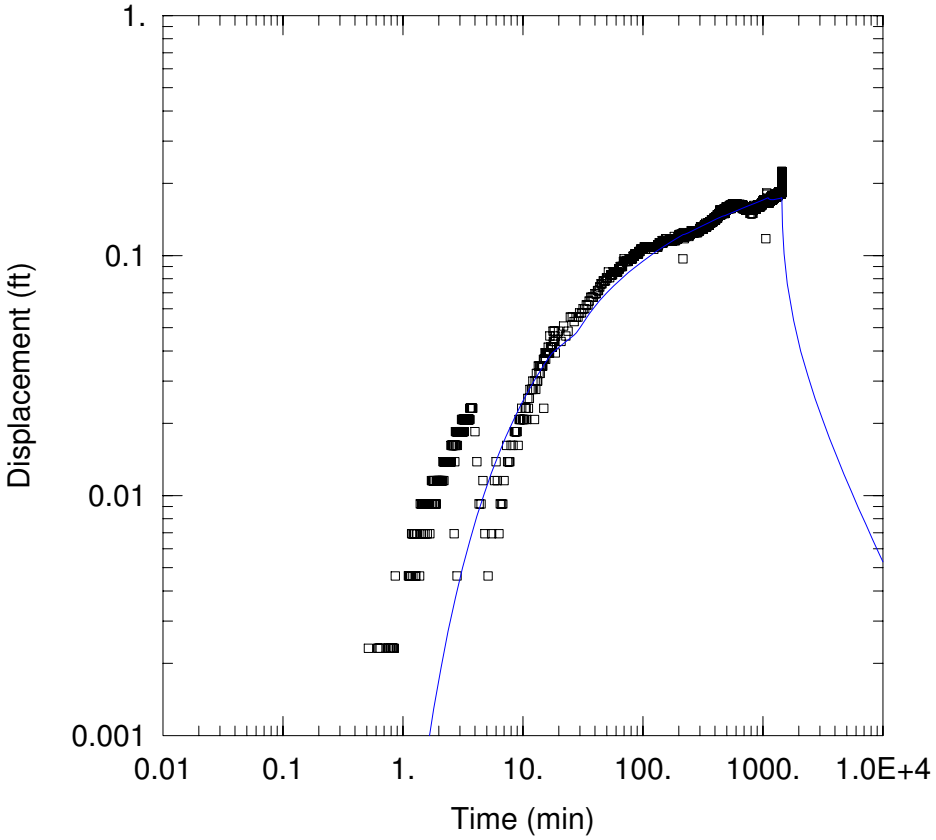
WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
RW-3	0	0

Observation Wells

Well Name	X (ft)	Y (ft)
▫ MWA-41	46.4	0



RW-3

Data Set: C:\...\RW-3 MWA-79 Neuman.aqt
Date: 03/25/10 Time: 14:28:53

PROJECT INFORMATION

Company: ERM
Client: Arkema, Inc.
Project: 0058055
Location: Portland, OR
Test Well: RW-3
Test Date: 10/21/2009

SOLUTION

Aquifer Model: Unconfined
Solution Method: Neuman

T = 2133.6 ft^2/day
S = 0.1649
Sy = 0.003787
ß = 0.7861

AQUIFER DATA

Saturated Thickness: 5.35 ft

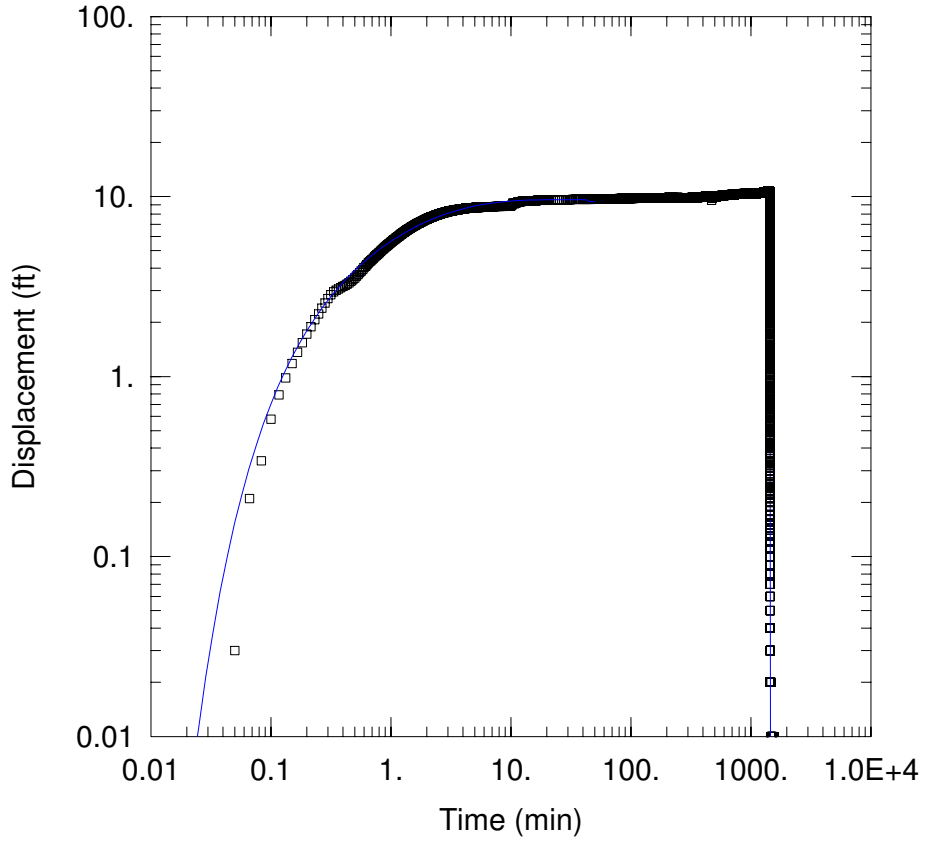
WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
RW-3	0	0

Observation Wells

Well Name	X (ft)	Y (ft)
▫ MWA-79	11.89	0



RW-4I

Data Set: C:\...\RW-4i.aqt
Date: 04/29/10 Time: 12:06:16

PROJECT INFORMATION

Company: ERM
Client: Arkema, Inc.
Project: 0058055
Location: Portland, OR
Test Well: RW-2i
Test Date: 10/21/2009

SOLUTION

Aquifer Model: Leaky
Solution Method: Hantush

T = 24.92 ft^2/day
S = 0.2544
1/B' = 1.708 ft^{-1}
ß'/r = 2.704E-5 ft^{-1}
1/B" = 0.0825 ft^{-1}
ß"/r = 0.0028 ft^{-1}

AQUIFER DATA

Saturated Thickness: 7.5 ft
Aquitard Thickness (b'): 1. ft
Anisotropy Ratio (Kz/Kr): 0.1
Aquitard Thickness (b"): 1. ft

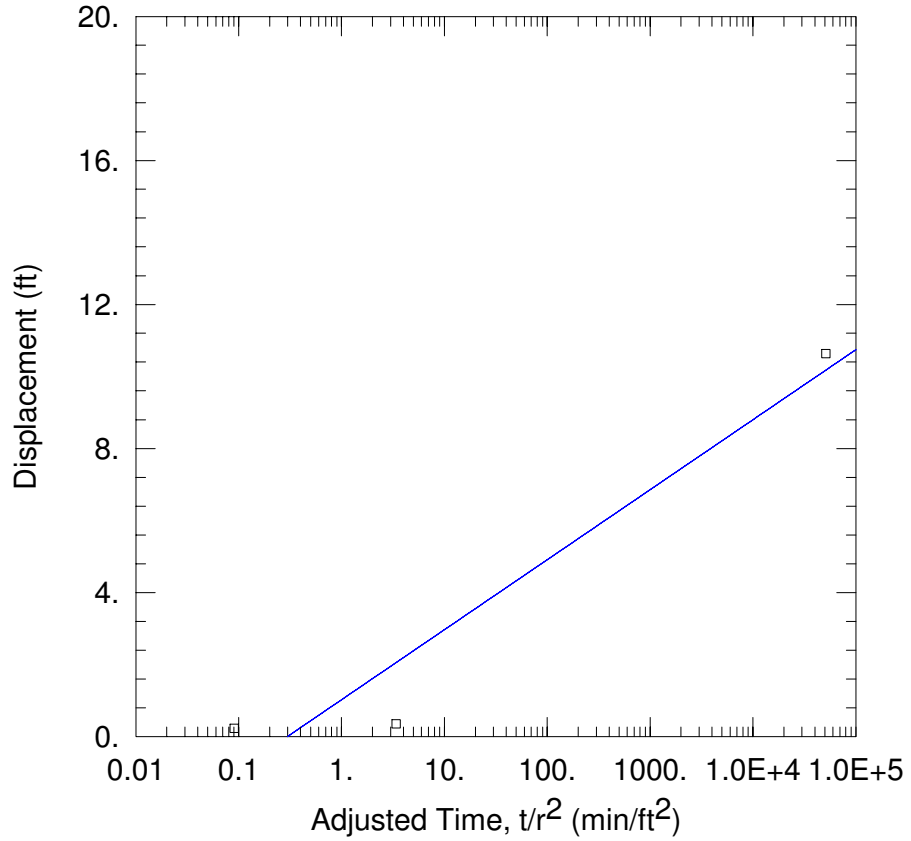
WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
RW-4i	28.93	53.65

Observation Wells

Well Name	X (ft)	Y (ft)
▫ RW-4i	29.097	53.65



RW-4I (DISTANCE-DRAWDOWN)

Data Set: C:\...\RW-4i_distance-drawdown.aqt
Date: 04/29/10 Time: 12:07:10

PROJECT INFORMATION

Company: ERM
Client: Arkema, Inc.
Project: 0058055
Location: Portland, OR
Test Well: RW-2i
Test Date: 10/21/2009

SOLUTION

Aquifer Model: Confined
Solution Method: Cooper-Jacob

T = 104.3 ft^2/day
S = 0.04856

AQUIFER DATA

Saturated Thickness: 7.5 ft

Anisotropy Ratio (Kz/Kr): 0.1

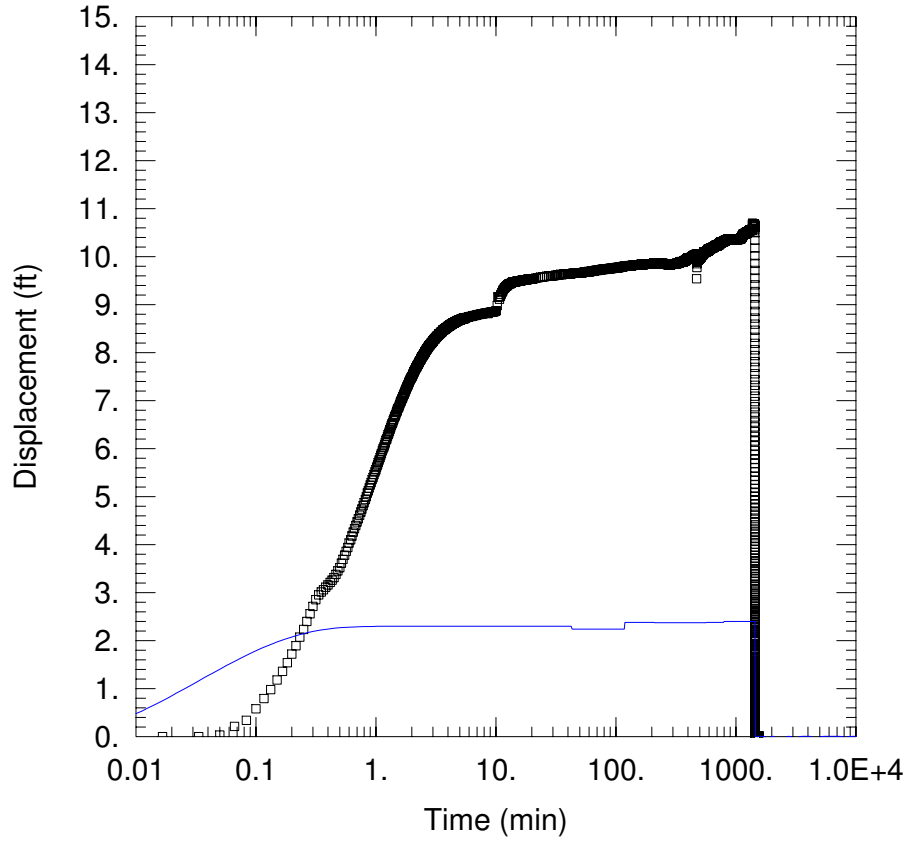
WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
RW-4i	28.93	53.65

Observation Wells

Well Name	X (ft)	Y (ft)
▫ RW-4i	29.097	53.65
▫ MWA-80i	20.65	34.89
▫ MWA-81i	145.87	8.82



RW-4I

Data Set: C:\...\RW-4i(efficiency).aqt
Date: 05/04/10 Time: 15:40:20

PROJECT INFORMATION

Company: ERM
Client: Arkema, Inc.
Project: 0058055
Location: Portland, OR
Test Well: RW-2i
Test Date: 10/21/2009

SOLUTION

Aquifer Model: Leaky
Solution Method: Hantush

T = 104.3 ft^2/day
S = 0.04856
1/B' = 1.708 ft^{-1}
ß'/r = 2.704E-5 ft^{-1}
1/B" = 0.0825 ft^{-1}
ß"/r = 0.0028 ft^{-1}

AQUIFER DATA

Saturated Thickness: 7.5 ft
Aquitard Thickness (b'): 1. ft

Anisotropy Ratio (Kz/Kr): 0.1
Aquitard Thickness (b"): 1. ft

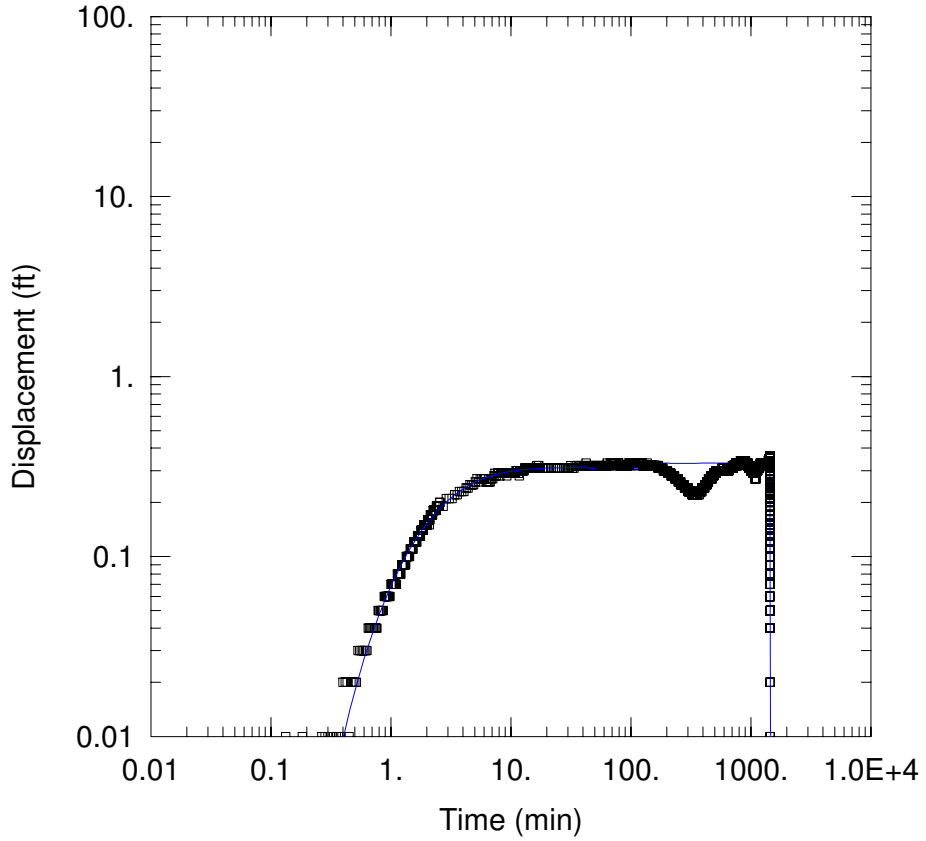
WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
RW-4i	28.93	53.65

Observation Wells

Well Name	X (ft)	Y (ft)
▫ RW-4i	29.097	53.65



RW-4I (MWA-80I)

Data Set: C:\...\RW-4i_MW-80i.aqt
Date: 04/29/10 Time: 11:22:44

PROJECT INFORMATION

Company: ERM
Client: Arkema, Inc.
Project: 0058055
Location: Portland, OR
Test Well: RW-2i
Test Date: 10/21/2009

SOLUTION

Aquifer Model: Leaky
Solution Method: Hantush

T = 179.8 ft^2/day
S = 0.001032
1/B' = 0.05592 ft^{-1}
ß'/r = 0.01196 ft^{-1}
1/B" = 0.002395 ft^{-1}
ß"/r = 0.002784 ft^{-1}

AQUIFER DATA

Saturated Thickness: 5. ft
Aquitard Thickness (b'): 1. ft
Anisotropy Ratio (Kz/Kr): 0.1
Aquitard Thickness (b"): 1. ft

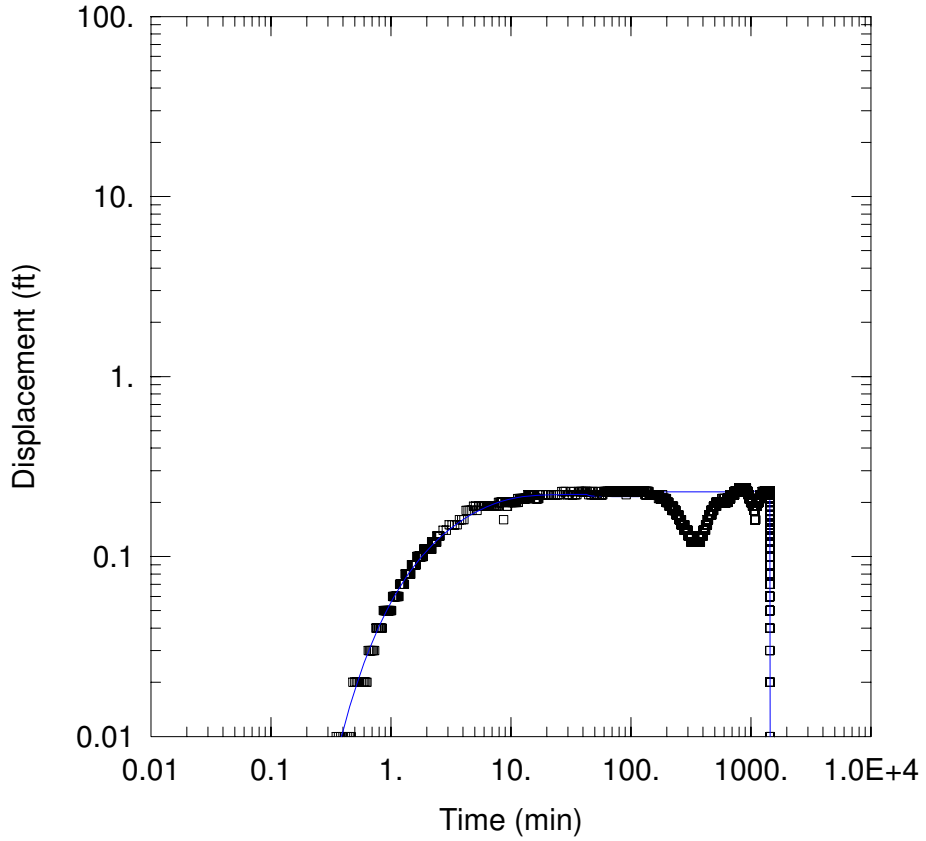
WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
RW-4i	28.93	53.65

Observation Wells

Well Name	X (ft)	Y (ft)
▫ MWA-80i	20.65	34.89



RW-4I (MWA-81I)

Data Set: C:\...\RW-4i_MW-81i.aqt
Date: 05/03/10 Time: 13:35:24

PROJECT INFORMATION

Company: ERM
Client: Arkema, Inc.
Project: 0058055
Location: Portland, OR
Test Well: RW-2i
Test Date: 10/21/2009

SOLUTION

Aquifer Model: Leaky
Solution Method: Hantush

T = 212.6 ft^2/day
S = 2.763E-5
1/B' = 0.008538 ft^{-1}
ß'/r = 1.372E-6 ft^{-1}
1/B" = 0.005895 ft^{-1}
ß"/r = 0.002784 ft^{-1}

AQUIFER DATA

Saturated Thickness: 7.5 ft
Aquitard Thickness (b'): 1. ft

Anisotropy Ratio (Kz/Kr): 0.1
Aquitard Thickness (b"): 1. ft

WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
RW-4i	28.93	53.65

Observation Wells

Well Name	X (ft)	Y (ft)
▫ MWA-81i	145.87	8.82

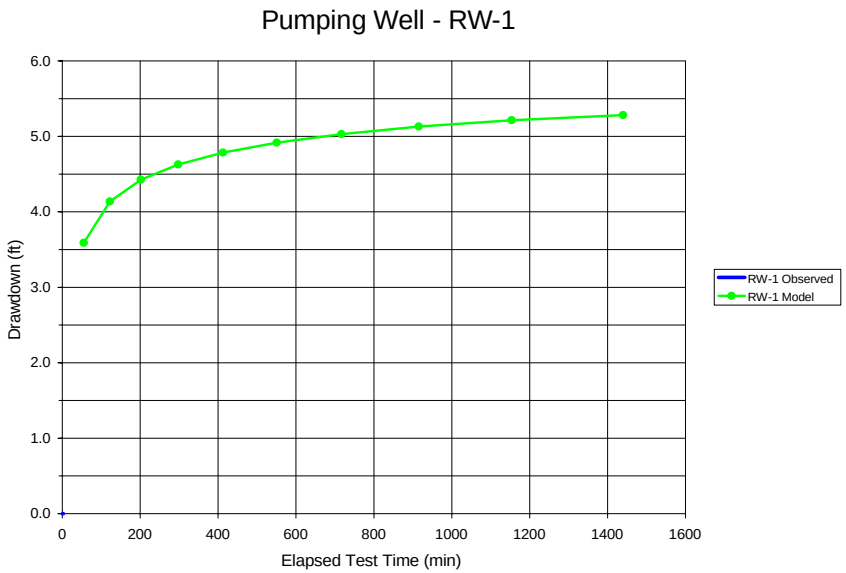
Attachment J
Groundwater Model Pumping Test Simulations

Project No. 0104709

Drawn By: T. Cota

Date: 01/19/10

GIS File:



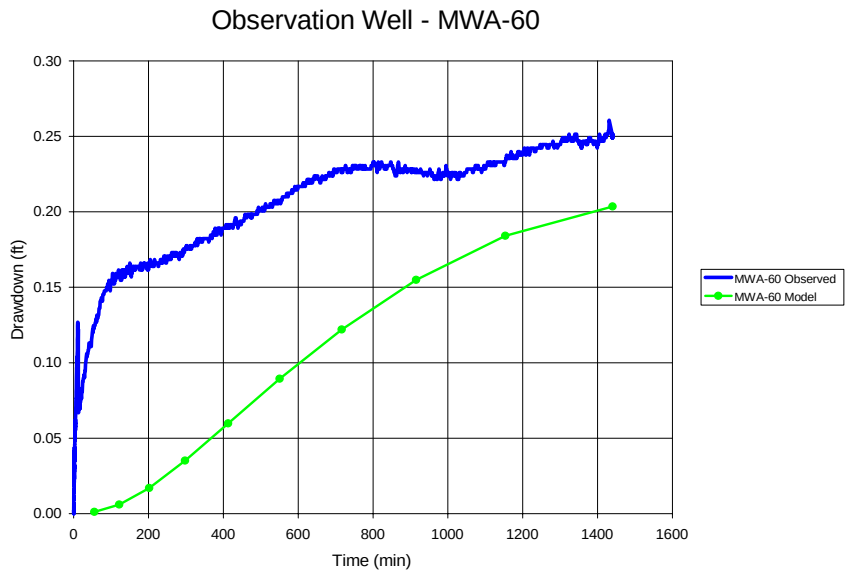


Figure J-1

Comparison of Model Drawdown Solution and Observed Drawdown RW-1 Pumping Test Arkema, Inc. Portland, Oregon

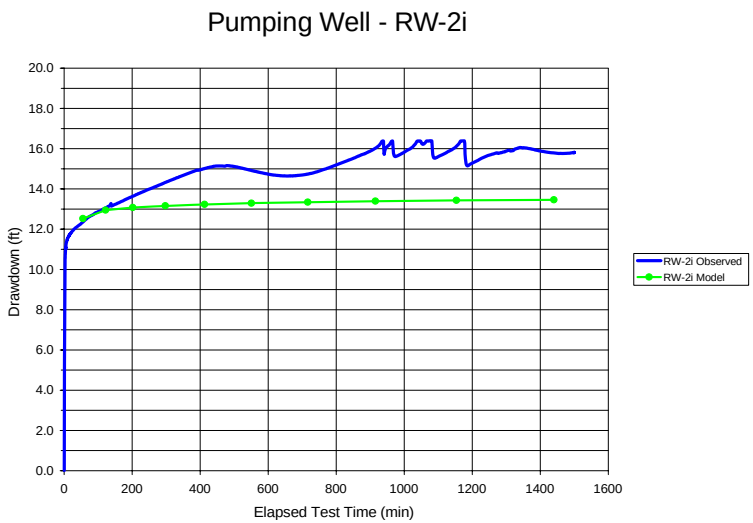
ERM 01/10

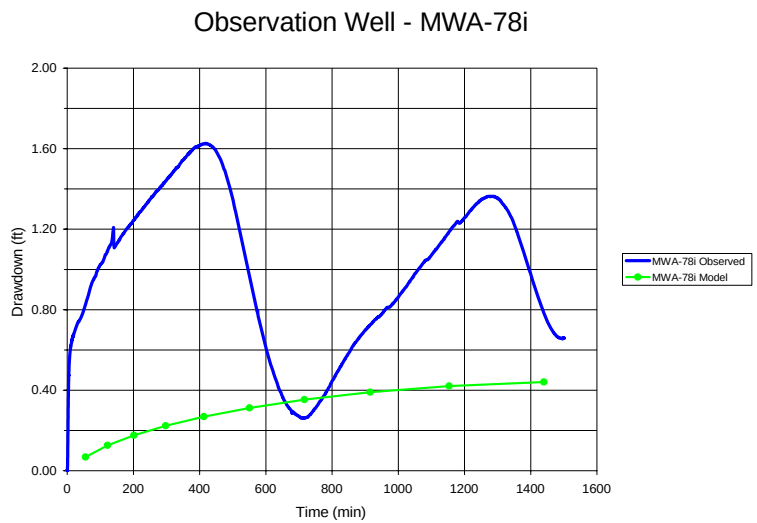
Project No. 0104709

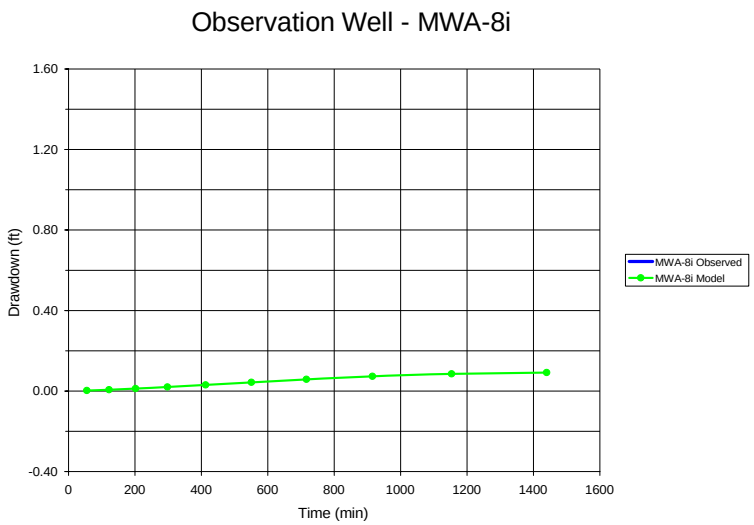
Drawn By: T. Cota

Date: 01/19/10

GIS File:







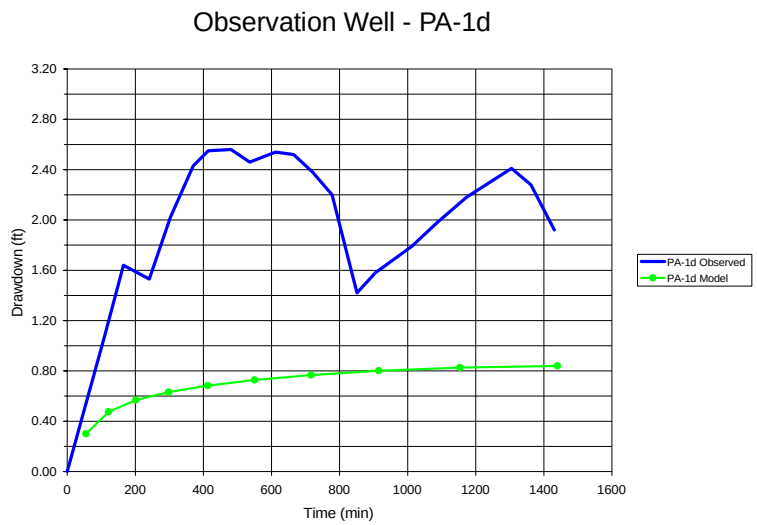


Figure J-2

Comparison of Model Drawdown Solution and Observed Drawdown RW-2i Pumping Test Arkema, Inc. Portland, Oregon

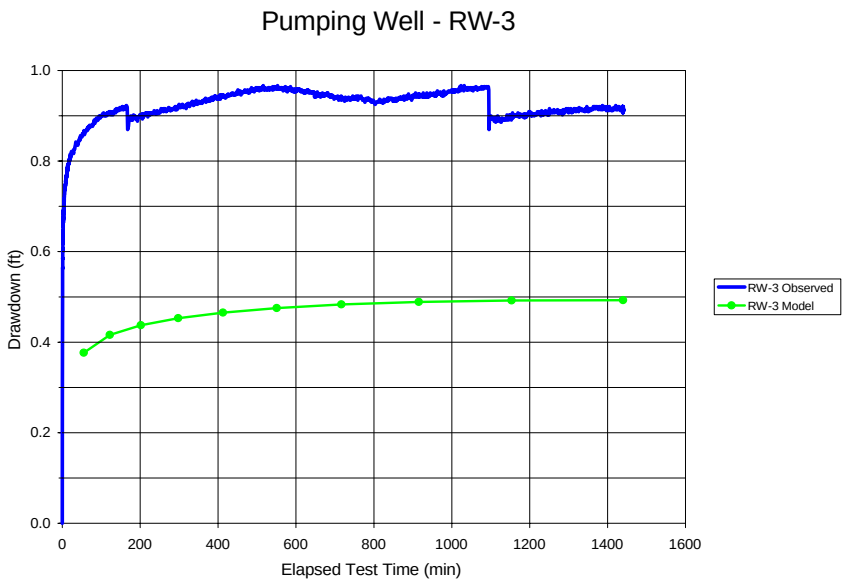
ERM 01/10

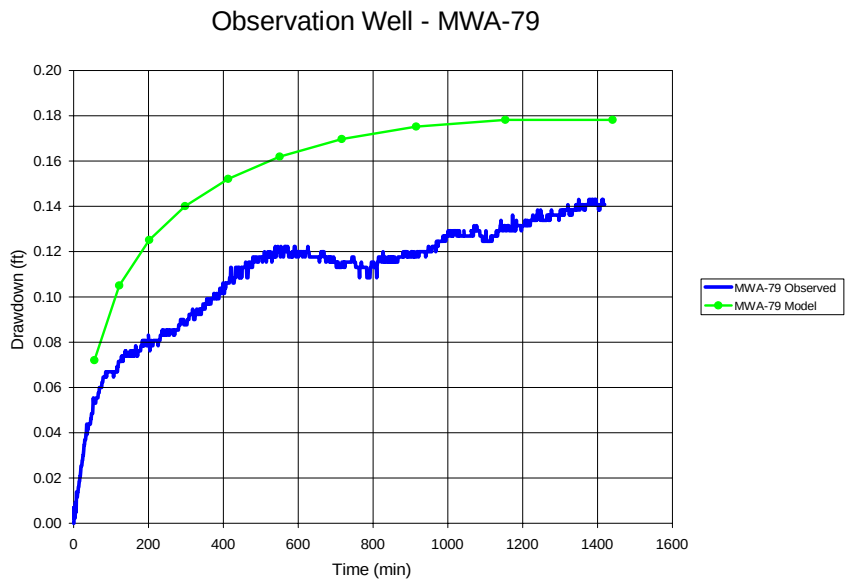
Project No. 0104709

Drawn By: T. Cota

Date: 01/19/10

GIS File:





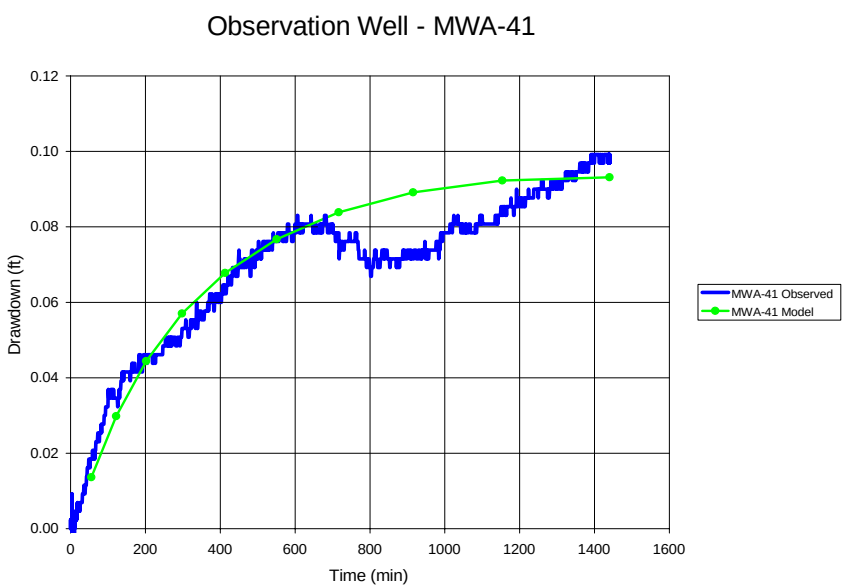


Figure J-3

Comparison of Model Drawdown Solution and Observed Drawdown RW-3 Pumping Test Arkema, Inc. Portland, Oregon

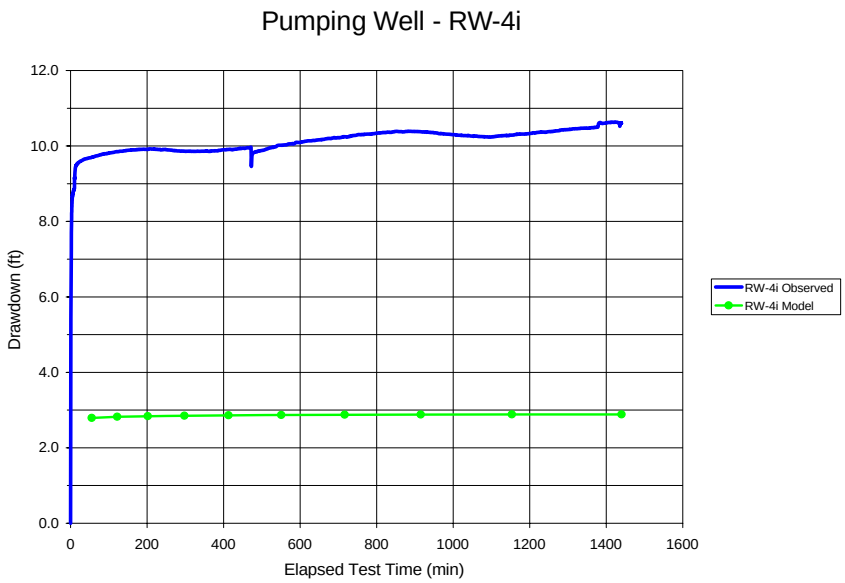
ERM 01/10

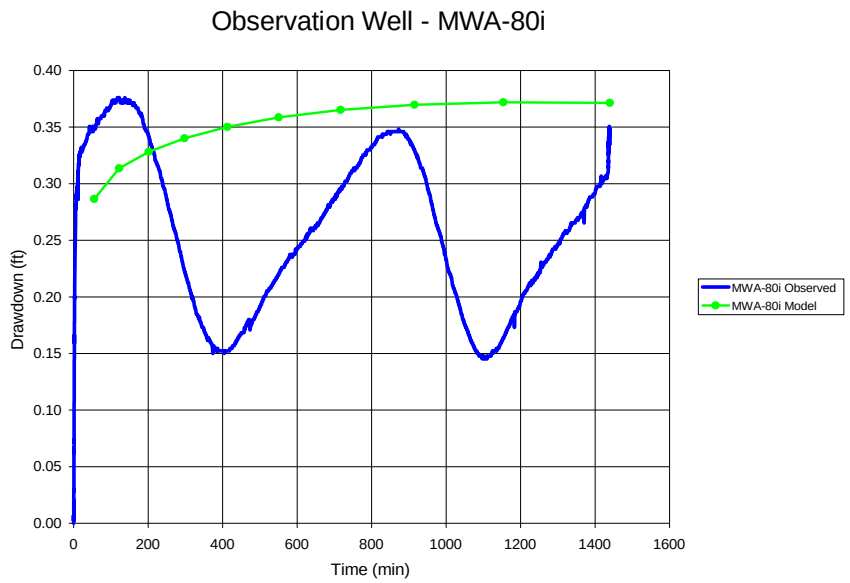
Project No. 0104709

Drawn By: T. Cota

Date: 01/19/10

GIS File:





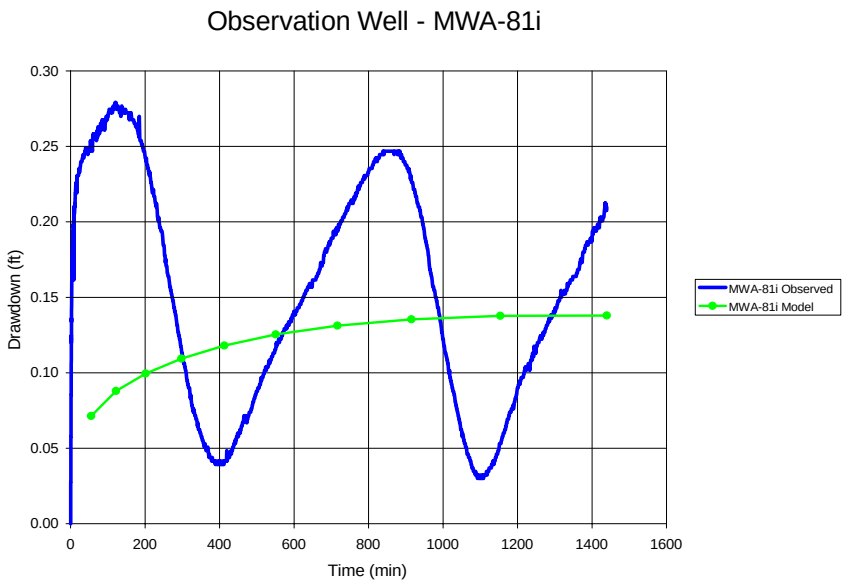


Figure J-4

Comparison of Model Drawdown Solution and Observed Drawdown RW-4i Pumping Test Arkema, Inc. Portland, Oregon

ERM 01/10

Attachment K
Groundwater Model Steady State Calibration

MODSTATS Version 1.5 - GROUND WATER MODEL CALIBRATION SUMMARY
ERM - Rocky Mountain
Ground Water Modeling
Denver, Colorado

Simulation: ARK016
Comments: Steady-State Calibrated Model
Flow Conditions: Steady-State Flow

Calibration Target	Layer Number	Target Head	Model Head	Model Residual
MWA-2	1	12.86	12.87	-0.01
MWA-3	1	13.00	13.16	-0.16
MWA-4	1	13.08	13.36	-0.28
MWA-5	1	12.72	13.65	-0.93
MWA-6r	1	13.11	13.99	-0.88
MWA-15r	1	13.26	15.03	-1.77
MWA-17si	1	12.97	13.22	-0.25
MWA-18	1	12.99	14.12	-1.13
MWA-19	1	12.68	13.34	-0.66
MWA-20	1	13.40	15.85	-2.45
MWA-22	1	16.44	15.97	0.47
MWA-23	1	27.63	23.86	3.77
MWA-24	1	15.48	16.76	-1.28
MWA-25	1	14.21	16.55	-2.34
MWA-26	1	14.65	17.18	-2.53
MWA-27	1	13.79	15.75	-1.96
MWA-29	1	12.99	13.48	-0.49
MWA-30	1	13.13	13.43	-0.30
MWA-33	1	18.82	20.79	-1.97
MWA-35	1	14.46	16.56	-2.10
MWA-36	1	14.41	16.61	-2.20
MWA-37	1	14.38	16.63	-2.25
MWA-38	1	14.93	17.24	-2.31
MWA-39	1	27.82	22.45	5.37
MWA-40	1	19.45	18.88	0.57
MWA-41	1	13.87	16.79	-2.92
MWA-42	1	13.31	15.90	-2.59
MWA-43	1	13.26	14.83	-1.57
MWA-44	1	13.12	14.27	-1.15
MWA-45	1	13.35	15.43	-2.08
MWA-46	1	12.74	13.23	-0.49
MWA-47	1	13.04	13.22	-0.18
MWA-60	1	12.97	13.73	-0.76
MWA-61	1	12.88	12.87	0.01
MWA-62	1	13.87	14.37	-0.50
MWA-63	1	14.41	14.09	0.32
MWA-67si	1	12.86	12.87	-0.01
MWA-68si	1	12.93	12.98	-0.05
MWA-69	1	12.67	13.00	-0.33
NMP-1D	1	12.58	14.61	-2.03
NMP-2D	1	13.00	14.40	-1.40
NMP-3D	1	13.22	14.19	-0.97
NMP-4D	1	13.03	14.45	-1.42
NMP-5D	1	12.93	14.42	-1.49
NMP-6D	1	13.17	14.26	-1.09
PMP-1	1	13.41	14.89	-1.48
PMP-2	1	13.51	14.76	-1.25
PMP-3	1	13.55	14.61	-1.06
PMP-4	1	13.08	14.05	-0.97
PMP-5	1	13.03	13.74	-0.71
PMP-6	1	13.08	13.74	-0.66
PT-1	1	22.47	20.73	1.74
PT-2	1	14.13	16.50	-2.37

PT-3	1	12.95	13.56	-0.61
AL2-17	1	32.55	34.31	-1.76
AL5-19	1	30.20	32.98	-2.78
BTB-4B-25	1	31.40	32.58	-1.18
MW-03-S(27)	1	25.91	26.13	-0.22
MW-06-S(31)	1	26.32	26.30	0.02
MW-07-S(41)	1	25.30	25.36	-0.06
RP-01-31	1	13.84	14.57	-0.73
RP-03-30R	1	23.65	24.53	-0.88
RP-04-16	1	25.56	29.04	-3.48
RP-05-16	1	30.24	34.10	-3.86
RP-06-30	1	22.24	21.12	1.12
RP-08-23	1	25.91	24.66	1.25
RP-10-30	1	28.41	26.34	2.07
RP-15-25	1	33.79	30.03	3.76
RP-16-25	1	29.24	29.43	-0.19
RP-17-25	1	32.50	31.58	0.92
RP-18-30	1	30.44	28.62	1.82
RP-19-25	1	29.50	30.43	-0.93
RP-24-30	1	13.13	12.59	0.54
W-03-S(17)	1	29.92	29.25	0.67
W-08-26	1	30.30	29.52	0.78
W-09(38)	1	28.65	29.01	-0.36
W-11-S(21)	1	31.71	29.96	1.75
W-12-S(20)	1	30.94	31.76	-0.82
W-15-S(14)	1	31.45	30.52	0.93
W-19-S(25)	1	14.33	15.29	-0.96
MW-1	1	26.27	24.95	1.32
MW-11	1	23.81	23.10	0.71
BTB-4B-55	2	25.86	26.97	-1.11
AL2-32	2	30.56	28.46	2.10
AL5-35	2	28.88	28.15	0.73
MW-01-26	2	41.81	36.07	5.74
MW-02-26	2	37.84	35.10	2.74
MW-03-27	2	37.29	33.86	3.43
MW-04-27	2	34.35	32.37	1.98
MW-04-47	2	34.74	32.43	2.31
MW-05-24	2	32.01	30.38	1.63
MW-05-34	2	31.81	30.26	1.55
MW-09-23	2	36.06	33.64	2.42
MW-10-24	2	35.97	34.24	1.73
MW-11-24	2	35.98	34.92	1.06
MW-12-27	2	38.69	36.68	2.01
RP-02-31	2	13.74	14.85	-1.11
RP-09-35	2	14.77	17.32	-2.55
RP-16-40	2	29.34	29.24	0.10
W-03-I(41)	2	27.31	22.30	5.01
W-04-I(49)	2	25.66	23.76	1.90
W-06-S(27)	2	31.15	29.76	1.39
W-08(54)	2	28.93	27.21	1.72
MWA-7(i)	3	28.75	23.35	5.40
MWA-8i	3	13.59	12.89	0.70
MWA-9i	3	12.05	13.21	-1.16
MWA-10i	3	13.08	13.39	-0.31
MWA-16i	3	13.12	14.37	-1.25
MWA-32i	3	13.00	13.42	-0.42
MWA-34i	3	13.32	13.35	-0.03
MWA-48i	3	13.51	16.60	-3.09
MWA-49i	3	12.87	13.10	-0.23
MWA-50i	3	13.21	13.64	-0.43
MWA-51i	3	13.31	14.14	-0.83
MWA-52i	3	13.43	15.71	-2.28
MWA-53i	3	12.95	13.50	-0.55
MWA-54i	3	13.32	15.91	-2.59
MWA-55i	3	13.27	15.80	-2.52
MWA-64i	3	13.02	12.89	0.13
MWA-66i	3	13.13	13.02	0.11

MWA-70i	3	15.62	20.95	-5.33
MW-01-41	3	38.10	36.00	2.10
MW-02-46	3	37.89	35.33	2.56
MW-03-49	3	37.36	33.76	3.60
MW-03-I(60)	3	19.98	20.18	-0.20
MW-09-42	3	35.83	33.63	2.20
MW-10-44	3	35.95	34.20	1.75
MW-11-37	3	36.01	34.93	1.08
MW-12-41	3	38.69	37.08	1.61
RP-02-49	3	13.60	14.31	-0.71
RP-08-80	3	16.05	17.72	-1.67
RP-09-47	3	14.76	17.38	-2.62
RP-10-60	3	15.80	19.64	-3.84
RP-18-70	3	18.87	20.44	-1.57
RP-24-60	3	12.68	12.61	0.07
W-10(71)	3	19.07	18.23	0.84
W-11-I(60)	3	18.04	20.31	-2.27
W-12-I(58)	3	23.73	22.58	1.15
W-15-I(38)	3	31.50	28.27	3.23
W-16-31	3	29.18	25.16	4.02
MWA-11i	4	13.69	15.64	-1.95
MWA-14i	4	13.89	13.71	0.18
RPW-02(38)	4	38.37	36.32	2.05
RP-04-48	4	28.38	28.45	-0.07
RP-19-90	4	18.09	20.70	-2.61
MWA-12i(d)	4	25.30	23.26	2.04
MWA-13d	4	12.99	13.18	-0.19
MWA-28i(d)	4	14.60	16.66	-2.06
MWA-31i(d)	4	11.51	13.54	-2.03
MWA-56d	4	12.82	13.50	-0.68
MWA-57d	4	13.22	15.71	-2.49
MWA-58d	4	11.87	13.27	-1.40
MWA-59d	4	10.99	14.01	-3.02
AL2-46	4	29.65	28.41	1.24
AL6-96	4	25.87	26.03	-0.16
BTB-4A-84	4	26.94	26.66	0.28
MW-01-56	4	38.02	35.84	2.18
MW-02-62	4	38.38	35.64	2.74
MW-03-68	4	37.45	33.68	3.77
MW-03-81	4	20.21	20.43	-0.22
MW-04-63	4	35.06	32.43	2.63
MW-05-52	4	29.85	30.46	-0.61
MW-09-58	4	35.36	33.64	1.72
MW-10-57	4	36.18	34.18	2.00
MW-11-56	4	36.38	34.96	1.42
MW-12-59	4	38.79	37.08	1.71
RP-01-51	4	13.82	14.60	-0.78
RP-03-52R	4	22.64	24.40	-1.76
RP-04-41	4	28.48	28.45	0.03
RP-05-47	4	30.53	30.15	0.38
RP-06-87	4	15.59	17.25	-1.66
RP-15-53	4	28.73	28.11	0.62
RP-17-95	4	24.76	25.09	-0.33
RP-24-73	4	12.65	12.65	0.00
RPW-03(53)	4	36.17	34.36	1.81
W-03-D(89)	4	23.17	22.02	1.15
W-04-89	4	27.45	23.79	3.66
W-06-D(49)	4	32.95	29.84	3.11
W-09-116	4	24.37	24.47	-0.10
W-09-86	4	23.69	24.49	-0.80
W-11-D(91)	4	17.82	20.29	-2.47
W-12-D(100)	4	23.61	22.51	1.10
W-15-D(62)	4	31.00	28.26	2.74
W-16-D(85)	4	27.52	25.05	2.47
W-16-I(50)	4	27.60	25.07	2.53
W-19-I(49)	4	14.28	15.30	-1.02
AL5-62	5	28.73	28.07	0.66

RP-10-97	5	17.12	19.75	-2.63
RP-15-65	5	28.62	28.13	0.49
RP-17-119	5	24.19	25.13	-0.94
RP-24-85	5	12.62	12.71	-0.09
MW-03-137	5	20.16	20.39	-0.23
RP-04-56	5	28.38	28.41	-0.03
RP-05-65	5	29.77	30.20	-0.43
RP-06-105	5	15.50	17.03	-1.53
RP-06-95	5	15.50	16.99	-1.49
RP-18-111	5	19.73	20.45	-0.72
MWA-21b	6	12.05	13.27	-1.22
BST2W-61	6	29.51	28.41	1.10
BST5W-74	6	28.45	28.12	0.33
MW-01-76	6	33.38	35.78	-2.40
MW-05-70	6	29.67	30.22	-0.55
MW-09-80	6	35.71	33.59	2.12
MW-11-79	6	36.82	34.84	1.98
MW-12-79	6	38.58	36.85	1.73
RP-01-65	6	13.85	14.65	-0.80
RP-02-66	6	13.56	14.81	-1.25
RP-08-107	6	16.26	17.72	-1.46
RP-09-64	6	14.14	17.46	-3.32
RP-10-130	6	17.12	19.79	-2.67
RP-17-145	6	23.69	25.17	-1.48
RP-18-125	6	20.84	20.45	0.39
RP-19-129	6	19.58	20.71	-1.13
W-06-B(67)	6	29.58	29.73	-0.15
W-08-74	6	28.34	27.08	1.26
W-11-B(122)	6	18.53	20.23	-1.70
W-19-D(68)	6	14.46	15.21	-0.75

```
----------- Calibration Statistics for Entire Model -----------
Number of Targets:         217

Minimum Residual:         -5.33
Maximum Residual:          5.74

Residual Mean:            -0.07
Absolute Residual Mean:    1.49

Sum of Squared Residuals:  763.29
Root Mean Squared Error:   1.88
Residual Standard Dev.:    1.87

Range In Target Head:      30.82
Residual Std. Dev./Range:  0.061


------------- Calibration Statistics for Layer  1  ------------
Number of Targets:         82

Minimum Residual:         -3.86
Maximum Residual:          5.37

Residual Mean:            -0.57
Absolute Residual Mean:    1.30

Sum of Squared Residuals:  226.42
Root Mean Squared Error:   1.66
Residual Standard Dev.:    1.56

Range In Target Head:      21.21
Residual Std. Dev./Range:  0.074


------------- Calibration Statistics for Layer  2  ------------
```

```
Number of Targets:         21

Minimum Residual:         -2.55
Maximum Residual:          5.74

Residual Mean:             1.66
Absolute Residual Mean:    2.11

Sum of Squared Residuals:  128.14
Root Mean Squared Error:   2.47
Residual Standard Dev.:    1.83

Range In Target Head:      28.07
Residual Std. Dev./Range:  0.065


------------- Calibration Statistics for Layer  3  ------------
Number of Targets:         37

Minimum Residual:         -5.33
Maximum Residual:          5.40

Residual Mean:            -0.09
Absolute Residual Mean:    1.74

Sum of Squared Residuals:  187.17
Root Mean Squared Error:   2.25
Residual Standard Dev.:    2.25

Range In Target Head:      26.64
Residual Std. Dev./Range:  0.084


------------- Calibration Statistics for Layer  4  ------------
Number of Targets:         46

Minimum Residual:         -3.02
Maximum Residual:          3.77

Residual Mean:             0.37
Absolute Residual Mean:    1.52

Sum of Squared Residuals:  156.35
Root Mean Squared Error:   1.84
Residual Standard Dev.:    1.81

Range In Target Head:      27.80
Residual Std. Dev./Range:  0.065


------------- Calibration Statistics for Layer  5  ------------
Number of Targets:         11

Minimum Residual:         -2.63
Maximum Residual:          0.66

Residual Mean:            -0.63
Absolute Residual Mean:    0.84

Sum of Squared Residuals:  13.81
Root Mean Squared Error:   1.12
Residual Standard Dev.:    0.93

Range In Target Head:      17.15
Residual Std. Dev./Range:  0.054
```

```
------------- Calibration Statistics for Layer  6  ------------
Number of Targets:         20

Minimum Residual:         -3.32
Maximum Residual:          2.12

Residual Mean:            -0.50
Absolute Residual Mean:    1.39

Sum of Squared Residuals:  51.41
Root Mean Squared Error:   1.60
Residual Standard Dev.:    1.52

Range In Target Head:      26.53
Residual Std. Dev./Range:  0.057
```

Appendix C
Initial Slope Stability Analysis Results

Memorandum

Environmental Resources Management

200 Harry S Truman Pkwy
Suite 400
Annapolis, Maryland 21401
(410) 266-0006
(410) 266-8912 (fax)

To: Brendan Robinson, P.E./Erik Ipsen, P.E., ERM

From: Stephen Lindsay, P.E./Darren Quillen, ERM

Date: 7 May 2010

Subject: Groundwater Barrier Wall Design Geotechnical Engineering Analysis

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INTRODUCTION

A geotechnical engineering analysis of the groundwater barrier wall (GWBW) was performed as part of the preliminary design. The purpose of this analysis was to confirm and refine the findings of the geotechnical engineering analysis performed as part of the Groundwater Source Control Measure Focused Feasibility Study (FFS). The analysis performed as part of the FFS considered several GWBW depths, alignments, and construction techniques, whereas this updated analysis focused on a GWBW installed to the interface with the basaltic bedrock (i.e. a depth varying from 50 to 85 feet) using conventional slurry wall construction. Similar to the FFS analysis, the objective of this updated analysis was to identify the minimum practical offset of the GWBW from the existing top of bank of the Willamette River and to confirm adequate riverbank stability during and following completion of construction of the GWBW.

BACKGROUND

The analysis performed as part of the FFS was primarily based on empirical relationships between Standard Penetration Test (SPT) data (i.e. blow counts) and strength, as well as limited geotechnical laboratory data, including particle size analysis, soil classification, moisture content, and Atterberg limits. In addition to this data, this updated analysis is based on additional geotechnical laboratory data obtained from testing soil samples collected during installation of several observation/recovery wells in August and September 2009, including MWA-80i, MWA-81i, RW-1, RW-2i, and RW-4i. The testing performed on these samples consisted of standard index properties and shear strength. Strength data was obtained on material from both the Intermediate and Deep Zones; however, data on the fill material remains limited to SPT data and field soil classification. Geotechnical laboratory data on the fill material will be obtained as part of the subsurface debris investigation activities. This information will be

used to confirm and refine the findings of this preliminary design geotechnical engineering analysis and finalize the GWBW alignment.

Based upon the geotechnical laboratory and field data available at the time of this analysis, a nominal cross-section of the subsurface conditions anticipated along the GWBW alignment was generated. In descending order, this cross-section consisted of the following distinct materials:

- A layer of fine sand and silt fill material extending to an approximate depth of 25 feet below ground surface (bgs) (comparable to the upper portion of the zone designated in the FFS as the Shallow Zone);
- A layer of fine to coarse sand extending to an approximate depth of 42 feet bgs (comparable to the lower portion of the zone designated in the FFS as the Shallow Zone and the entire Intermediate Zone);
- A layer of silt and silty sand extending to an approximate depth of 60 feet bgs (comparable to the upper region of the zone designated in the FFS as the Deep Zone); and
- A layer of fine sand and silt extending from a depth of 60 feet bgs to the top of the basaltic bedrock (comparable to the lower region of the zone designated in the FFS as the Deep Zone).

Each of these zones of subsurface materials was assigned index properties, including unit weight (moist and saturated), and strength, based on the geotechnical data available and experience with similar materials. The index properties incorporated in the analyses are presented in the table below.

Material Description	Unit Weight (lb/ft^3)	Saturated Unit Weight (lb/ft^3)	Cohesion Intercept (lb/ft^2)	Internal Friction Angle (°)	Soil Type
Fill (fine sand/silt)	110	125	55	30	1
Sand	115	125	0	39	2
Silt	105	120	1,571	0	3
Fine Sand/Silt	110	125	0	31	4

ANALYSES

The GWBW scenarios modeled included:

- A surcharge load representing the GWBW trenching machine located a certain distance upgradient of the top of the bank to identify the GWBW offset in locations where a clearance trench is not expected to be required; and
- A clearance trench through the fill material to a depth of approximately 25 feet bgs.

Both normal and rapid draw-down conditions were considered for both GWBW scenarios. It is noted that a specific scenario that included the GWBW was not modeled since the GWBW itself would be located upgradient of the critical failure surface and would, therefore, not affect stability.

ERM used the slope stability program STABL2.2, which considers both rotational and sliding block failures, to configure and perform multiple stability analyses for each scenario based on soil parameters and the corresponding geometry. The results of the various scenarios, which are presented graphically (attached), create an envelope of adequate soil stability. Multiple analyses were conducted to identify the minimum factor of safety acceptable while allowing the closest approach of the GWBW to the top of riverbank.

RESULTS

Before modeling the two scenarios described above, the general stability of the riverbank with no construction loads and normal groundwater conditions was evaluated. The initial strength parameters used for the fill material were based on SPT blow counts and field soil classification. These strength parameters resulted in a factor of safety less than 1.0 for riverbank stability. It has been observed that the riverbank is generally stable; therefore, revised strength parameters were selected for the fill material assuming the riverbank is on the verge of failure (i.e. factor of safety equal to 1.0). These parameters, presented in the table above, were used to evaluate the two scenarios for normal groundwater conditions.

For the first scenario, it was determined that the GWBW could be located approximately 16 feet upgradient of the top of riverbank with no resulting

decrease in the factor of safety (i.e. factor of safety equal to 1.0). Model output for this scenario is presented as Attachment 1 and 2 (normal groundwater and rapid-drawdown conditions, respectively).

The second scenario evaluated the stability of a clearance trench constructed for the purpose of removing large debris and other obstructions that could impact GWBW installation. The clearance trench would be excavated through the fill material to a depth of approximately 25 feet bgs. Using the assumed soil parameters, it was determined that the clearance trench could be constructed using two horizontal to one vertical (2:1) side slopes and located at a distance of closest approach of approximately 10 feet upgradient of the top of riverbank. Therefore, in locations where a clearance trench is required, the GWBW would be located approximately 60 feet upgradient of the riverbank top of bank. The minimum factor of safety deemed acceptable was 1.5, an established industry standard. Model output for this scenario is presented as Attachment 3.

It is noted that the index properties for the fill material were based on SPT blow counts and field soil classification. Conservative assumptions with respect to the performance of this material in trench excavations were made. Investigative trenching completed subsequent to this geotechnical engineering analysis as part of the subsurface debris investigation suggests that the fill material is capable of supporting trench side slopes from 0:1 (i.e. vertical side slopes) to 1:1. This geotechnical engineering analysis will be confirmed and refined upon receipt of the geotechnical laboratory results for the fill material.

Attachment 1
Existing Riverbank with Static Load, Normal Groundwater Condition

** PCSTABL6 **

by
Purdue University

1

--Slope Stability Analysis--
Simplified Janbu, Simplified Bishop
or Spencer`s Method of Slices

Run Date:
Time of Run:
Run By:
Input Data Filename: run.in
Output Filename: result.out
Unit: ENGLISH
Plotted Output Filename: result.plt

PROBLEM DESCRIPTION Arkema Portland OR - Riverbank Normal

BOUNDARY COORDINATES

5 Top Boundaries
8 Total Boundaries

Boundary No.	X-Left (ft)	Y-Left (ft)	X-Right (ft)	Y-Right (ft)	Soil Type Below Bnd
1	0.00	46.00	100.00	50.00	2
2	100.00	50.00	166.00	59.90	2
3	166.00	59.90	200.00	65.00	1
4	200.00	65.00	220.00	85.00	1

5	220.00	85.00	320.00	86.00	1
6	166.00	59.90	320.00	59.90	2
7	0.00	44.00	320.00	44.00	3
8	0.00	26.00	320.00	26.00	4

1

ISOTROPIC SOIL PARAMETERS

4 Type(s) of Soil

Soil Type No.	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Param.	Pressure Constant (psf)	Piez. Surface No.
1	110.0	125.0	55.0	30.0	0.00	0.0	1
2	115.0	125.0	0.0	31.0	0.00	0.0	1
3	105.0	120.0	1571.0	0.0	0.00	0.0	1
4	110.0	125.0	0.0	31.0	0.00	0.0	1

1

1 PIEZOMETRIC SURFACE(S) HAVE BEEN SPECIFIED

Unit Weight of Water = 62.40

Piezometric Surface No. 1 Specified by 4 Coordinate Points

Point No.	X-Water (ft)	Y-Water (ft)
1	0.00	59.90
2	166.00	59.90
3	174.00	61.10
4	320.00	61.10

1

BOUNDARY LOAD(S)

2 Load(s) Specified

Load No.	X-Left (ft)	X-Right (ft)	Intensity (psf)	Deflection (deg)
1	227.50	230.50	1667.0	0.0
2	241.50	244.50	1667.0	0.0

NOTE - Intensity Is Specified As A Uniformly Distributed
Force Acting On A Horizontally Projected Surface.

1

A Critical Failure Surface Searching Method, Using A Random
Technique For Generating Circular Surfaces, Has Been Specified.

250 Trial Surfaces Have Been Generated.

50 Surfaces Initiate From Each Of 5 Points Equally Spaced
Along The Ground Surface Between X = 195.00 ft.
and X = 210.00 ft.

Each Surface Terminates Between X = 215.00 ft.
and X = 230.00 ft.

Unless Further Limitations Were Imposed, The Minimum Elevation
At Which A Surface Extends Is Y = 0.00 ft.

4.00 ft. Line Segments Define Each Trial Failure Surface.

1

Following Are Displayed The Ten Most Critical Of The Trial
Failure Surfaces Examined. They Are Ordered - Most Critical
First.

* * Safety Factors Are Calculated By The Modified Bishop Method * *

Failure Surface Specified By 9 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	202.50	67.50
2	206.18	69.06
3	209.70	70.97
4	213.03	73.19
5	216.13	75.72
6	218.97	78.53
7	221.55	81.59
8	223.82	84.88
9	223.91	85.04

Circle Center At X = 187.7 ; Y = 107.4 and Radius, 42.5

*** 1.020 ***

Individual data on the 9 slices

Slice No.	Width (ft)	Water Force Weight (lbs)	Water Force Top (lbs)	Water Force Bot (lbs)	Earthquake Force Norm (lbs)	Earthquake Force Tan (lbs)	Surcharge Hor (lbs)	Surcharge Ver (lbs)	Load
1	3.7	429.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	3.5	1132.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	3.3	1566.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	3.1	1746.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	2.8	1701.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	1.0	603.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	1.5	738.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	2.3	448.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	0.1	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Failure Surface Specified By 9 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	202.50	67.50
2	206.33	68.66
3	209.98	70.29
4	213.41	72.36
5	216.54	74.84
6	219.35	77.69
7	221.78	80.86
8	223.79	84.32
9	224.10	85.04

Circle Center At X = 195.1 ; Y = 98.7 and Radius, 32.1

*** 1.025 ***

1

Failure Surface Specified By 8 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	202.50	67.50
2	206.33	68.66
3	209.93	70.41
4	213.20	72.70
5	216.07	75.49
6	218.46	78.70
7	220.32	82.24
8	221.25	85.01

Circle Center At X = 197.2 ; Y = 91.9 and Radius, 25.0

*** 1.028 ***

Failure Surface Specified By 9 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	202.50	67.50
2	206.38	68.48
3	210.06	70.06
4	213.45	72.18
5	216.47	74.80
6	219.05	77.85
7	221.13	81.27
8	222.66	84.97
9	222.67	85.03

Circle Center At X = 198.1 ; Y = 92.9 and Radius, 25.8

*** 1.031 ***

1

Failure Surface Specified By 9 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	202.50	67.50
2	206.38	68.49
3	210.08	70.01
4	213.54	72.02
5	216.69	74.48
6	219.48	77.35
7	221.84	80.57
8	223.75	84.09
9	224.10	85.04

Circle Center At X = 197.2 ; Y = 96.2 and Radius, 29.1

*** 1.037 ***

Failure Surface Specified By 8 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	202.50	67.50
2	206.34	68.63
3	209.93	70.39
4	213.17	72.74
5	215.96	75.60
6	218.24	78.89

7	219.92	82.52
8	220.59	85.01

Circle Center At X = 197.9 ; Y = 90.3 and Radius, 23.3

*** 1.041 ***

1

Failure Surface Specified By 12 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	195.00	64.25
2	199.00	64.29
3	202.97	64.77
4	206.87	65.68
5	210.64	67.01
6	214.24	68.74
7	217.63	70.86
8	220.77	73.34
9	223.62	76.15
10	226.15	79.25
11	228.32	82.61
12	229.56	85.10

Circle Center At X = 196.7 ; Y = 100.6 and Radius, 36.3

*** 1.044 ***

Failure Surface Specified By 12 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	195.00	64.25
2	199.00	64.23
3	202.98	64.65
4	206.88	65.51
5	210.67	66.79
6	214.29	68.49
7	217.71	70.58
8	220.87	73.03
9	223.74	75.82
10	226.28	78.90
11	228.47	82.25
12	229.90	85.10

Circle Center At X = 197.2 ; Y = 100.2 and Radius, 36.0

*** 1.044 ***

1

Failure Surface Specified By 9 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	202.50	67.50
2	206.35	68.60
3	210.08	70.04
4	213.66	71.82
5	217.06	73.93
6	220.26	76.33
7	223.22	79.02
8	225.92	81.97
9	228.28	85.08

Circle Center At X = 192.5 ; Y = 109.9 and Radius, 43.5

*** 1.045 ***

Failure Surface Specified By 12 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	195.00	64.25
2	199.00	64.26
3	202.98	64.71
4	206.88	65.59
5	210.66	66.90
6	214.27	68.62
7	217.67	70.73
8	220.81	73.20
9	223.66	76.01
10	226.19	79.11
11	228.36	82.47
12	229.67	85.10

Circle Center At X = 197.0 ; Y = 100.2 and Radius, 36.0

*** 1.046 ***

1

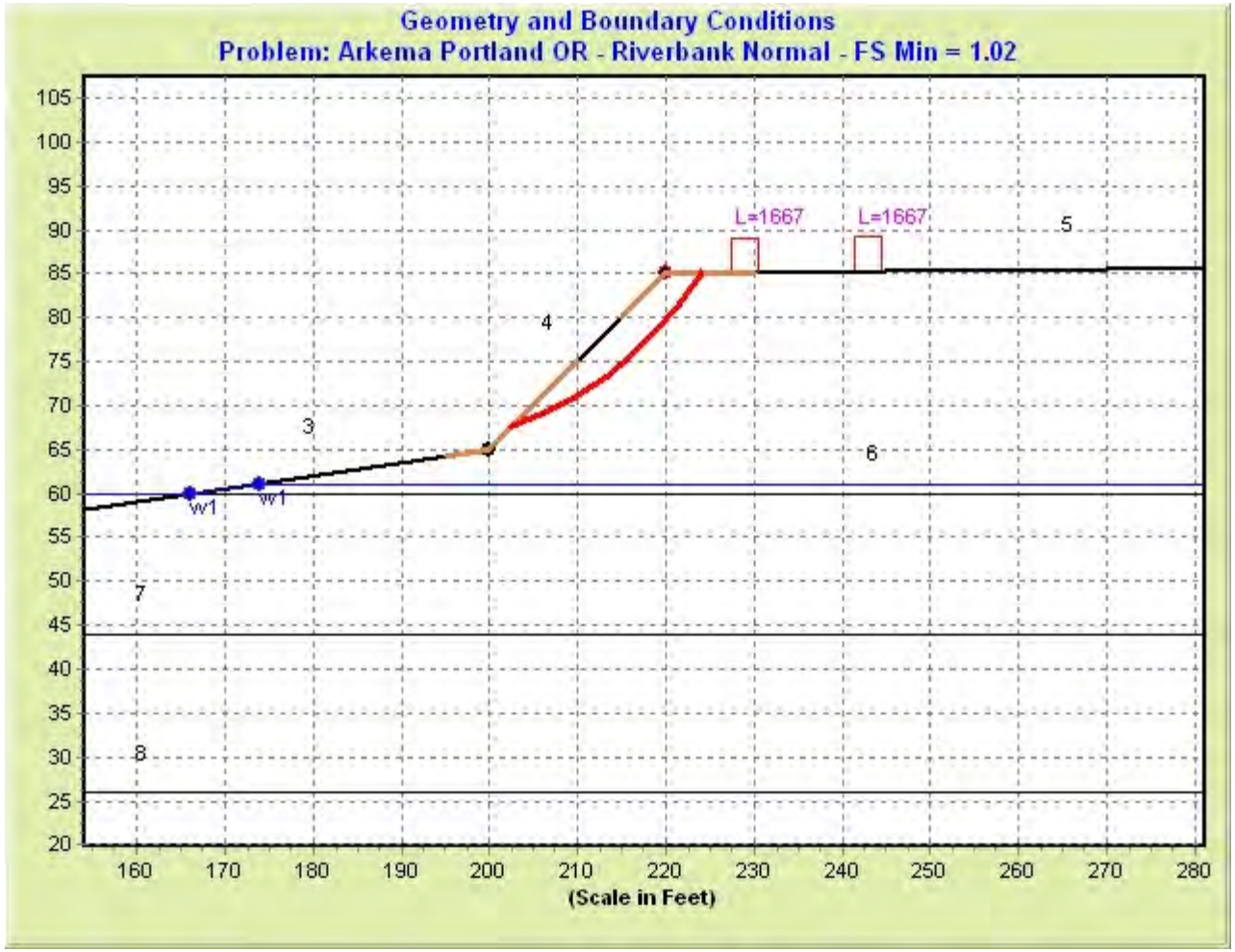
Y A X I S F T

0.00 40.00 80.00 120.00 160.00 200.00

```
X      0.00 +------*--+**--W----+---------+---------+---------+
            -
            -
            -
            -
            -
       40.00 +
            -
            -
            -
            -
            -
A      80.00 +
            -
            -
            -          *
            -
            -
X     120.00 +
            -
            -
            -
            -
            -
I     160.00 +
            -          *
            -          W
            -
            -
            -          7
S     200.00 +          .*1
            -          .711
            -          .711.
            -          ..721*
            -           .771/1
            -              1/
       240.00 +                /2
            -              2/
            -
            -
```



```
            -
            -
F     280.00 +
            -
            -
            -
            -
            -
T     320.00 +     *  *  *    *
```


Geometry and Boundary Conditions
Problem: Arkema Portland OR - Riverbank Normal - FS Min = 1.02
L=1667
L=1667
5
4
3
6
7
8
w1
w1
105
100
95
90
85
80
75
70
65
60
55
50
45
40
35
30
25
20
160
170
180
190
200
210
220
230
240
250
260
270
280
(Scale in Feet)

** PCSTABL6 **

by
Purdue University

1

--Slope Stability Analysis--
Simplified Janbu, Simplified Bishop
or Spencer`s Method of Slices

Run Date:
Time of Run:
Run By:
Input Data Filename: run.in
Output Filename: result.out
Unit: ENGLISH
Plotted Output Filename: result.plt

PROBLEM DESCRIPTION Arkema Portland OR - Riverbank Normal

BOUNDARY COORDINATES

5 Top Boundaries
8 Total Boundaries

Boundary No.	X-Left (ft)	Y-Left (ft)	X-Right (ft)	Y-Right (ft)	Soil Type Below Bnd
1	0.00	46.00	100.00	50.00	2
2	100.00	50.00	166.00	59.90	2
3	166.00	59.90	200.00	65.00	1
4	200.00	65.00	220.00	85.00	1

5	220.00	85.00	320.00	86.00	1
6	166.00	59.90	320.00	59.90	2
7	0.00	44.00	320.00	44.00	3
8	0.00	26.00	320.00	26.00	4

1

ISOTROPIC SOIL PARAMETERS

4 Type(s) of Soil

Soil Type No.	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Param.	Pressure Constant (psf)	Piez. Surface No.
1	110.0	125.0	55.0	30.0	0.00	0.0	1
2	115.0	125.0	0.0	31.0	0.00	0.0	1
3	105.0	120.0	1571.0	0.0	0.00	0.0	1
4	110.0	125.0	0.0	31.0	0.00	0.0	1

1

1 PIEZOMETRIC SURFACE(S) HAVE BEEN SPECIFIED

Unit Weight of Water = 62.40

Piezometric Surface No. 1 Specified by 4 Coordinate Points

Point No.	X-Water (ft)	Y-Water (ft)
1	0.00	59.90
2	166.00	59.90
3	174.00	61.10
4	320.00	61.10

1

BOUNDARY LOAD(S)

2 Load(s) Specified

Load No.	X-Left (ft)	X-Right (ft)	Intensity (psf)	Deflection (deg)
1	227.50	230.50	1667.0	0.0
2	241.50	244.50	1667.0	0.0

NOTE - Intensity Is Specified As A Uniformly Distributed
Force Acting On A Horizontally Projected Surface.

1

A Critical Failure Surface Searching Method, Using A Random Technique For Generating Sliding Block Surfaces, Has Been Specified.

100 Trial Surfaces Have Been Generated.

2 Boxes Specified For Generation Of Central Block Base

Length Of Line Segments For Active And Passive Portions Of Sliding Block Is 5.0

Box No.	X-Left (ft)	Y-Left (ft)	X-Right (ft)	Y-Right (ft)	Height
1	208.00	69.50	212.00	73.50	3.50
2	215.00	75.00	219.00	79.00	6.50

1

Following Are Displayed The Ten Most Critical Of The Trial Failure Surfaces Examined. They Are Ordered - Most Critical First.

* * Safety Factors Are Calculated By The Modified Janbu Method * *

Failure Surface Specified By 6 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	205.19	70.19
2	208.47	69.76
3	216.90	75.37
4	219.67	79.53
5	222.18	83.85
6	222.97	85.03

*** 1.017 ***

Individual data on the 6 slices

Slice No.	Width (ft)	Weight (lbs)	Water Force Top (lbs)	Water Force Bot (lbs)	Earthquake Force Norm (lbs)	Earthquake Force Tan (lbs)	Earthquake Force Hor (lbs)	Surcharge Load Ver (lbs)
1	3.3	668.6	0.0	0.0	0.0	0.0	0.0	0.0
2	8.4	4746.2	0.0	0.0	0.0	0.0	0.0	0.0
3	2.8	1776.1	0.0	0.0	0.0	0.0	0.0	0.0
4	0.3	184.0	0.0	0.0	0.0	0.0	0.0	0.0

5	2.2	727.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	0.8	50.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Failure Surface Specified By 6 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	206.21	71.21
2	208.30	70.42
3	217.43	75.39
4	220.28	79.50
5	223.69	83.15
6	225.01	85.05

*** 1.079 ***

1

Failure Surface Specified By 6 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	206.63	71.63
2	209.35	70.92
3	216.15	76.05
4	218.60	80.40
5	221.51	84.47
6	222.07	85.02

*** 1.085 ***

Failure Surface Specified By 5 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	205.62	70.62
2	209.05	70.13
3	218.45	80.20
4	220.90	84.56
5	221.29	85.01

*** 1.096 ***

1

Failure Surface Specified By 6 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	205.91	70.91
2	208.35	69.63
3	218.18	75.89
4	221.65	79.49
5	223.66	84.07
6	224.64	85.05

*** 1.116 ***

Failure Surface Specified By 6 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	208.18	73.18
2	209.42	72.52
3	216.92	76.79
4	220.14	80.62
5	223.55	84.27
6	224.15	85.04

*** 1.119 ***

1

Failure Surface Specified By 6 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	207.86	72.86
2	209.32	72.24
3	215.68	74.70
4	219.18	78.28
5	220.87	82.99
6	221.74	85.02

*** 1.121 ***

Failure Surface Specified By 5 Coordinate Points

Point	X-Surf	Y-Surf

No.	(ft)	(ft)
1	209.63	74.63
2	211.23	74.23
3	217.90	78.45
4	220.56	82.68
5	221.42	85.01

*** 1.151 ***

1

Failure Surface Specified By 6 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	207.39	72.39
2	208.83	71.86
3	217.71	75.62
4	220.96	79.41
5	224.21	83.21
6	224.28	85.04

*** 1.155 ***

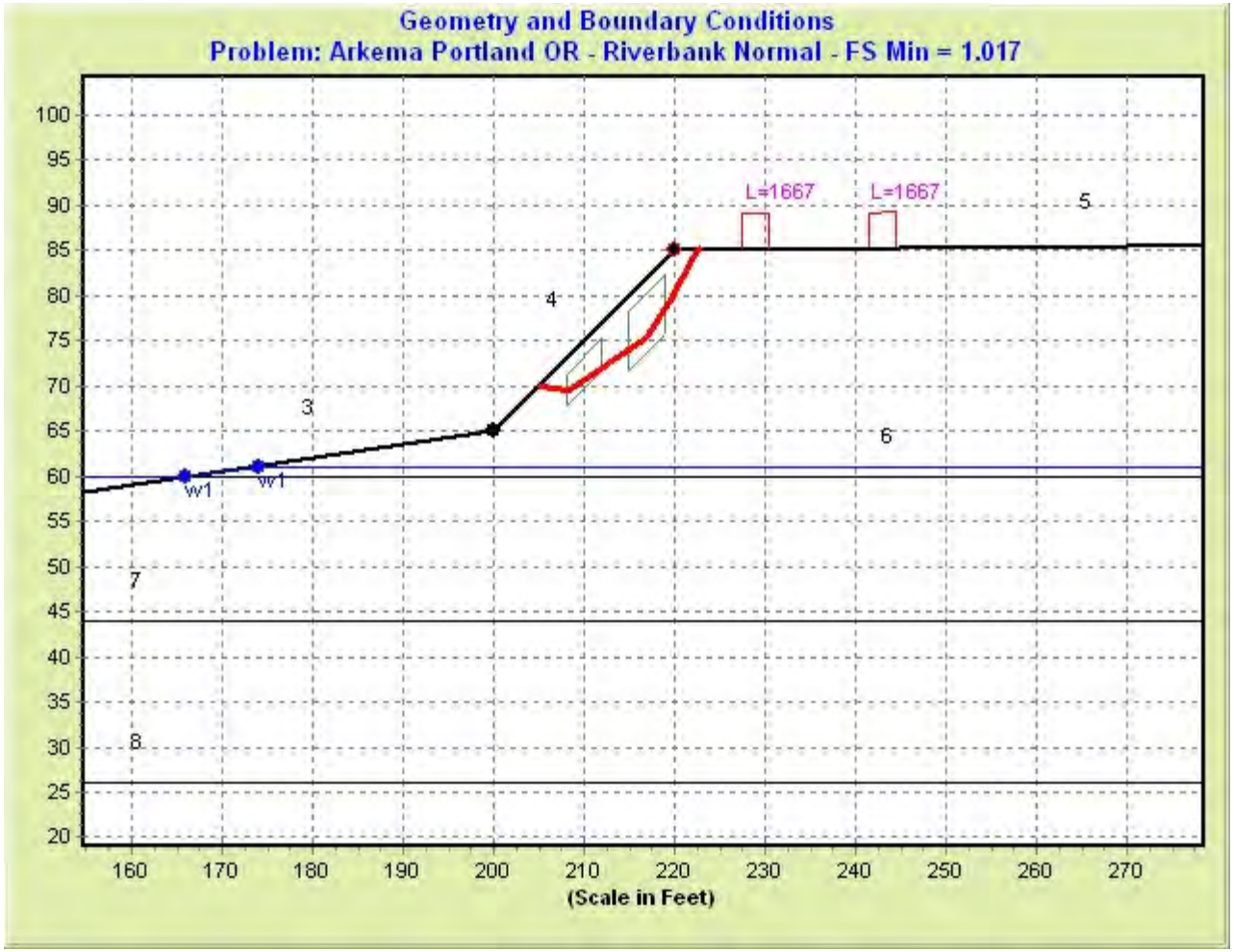
Failure Surface Specified By 5 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	206.47	71.47

```
        2      208.23      70.28
        3      218.56      79.74
        4      221.84      83.51
        5      222.71      85.03


         ***    1.164   ***



1

            Y          A    X    I    S          F    T


            0.00     40.00     80.00    120.00    160.00    200.00

      X     0.00 +------*--+**--W----+---------+---------+---------+
            -
            -
            -
            -
            -
         40.00 +
            -
            -
            -
            -
            -
      A     80.00 +
            -
            -
            -          *
            -
            -
      X    120.00 +
            -
            -
            -
            -
            -
```



```
      I   160.00 +
            -          *
            -          W
            -
            -
            -
      S    200.00 +            *
            -            118
            -             .3.
            -            .11*
            -              2/1
            -              1/
         240.00 +                 /2
            -              2/
            -
            -
            -
            -
      F    280.00 +
            -
            -
            -
            -
            -
      T    320.00 +     *  *  *     *
```


Geometry and Boundary Conditions
Problem: Arkema Portland OR - Riverbank Normal - FS Min = 1.017
L=1667
L=1667
5
4
3
6
w1
w1
7
8
100
95
90
85
80
75
70
65
60
55
50
45
40
35
30
25
20
160
170
180
190
200
210
220
230
240
250
260
270
(Scale in Feet)

Attachment 2
Existing Riverbank with Static Load, Rapid Draw-down Condition

** PCSTABL6 **

by
Purdue University

1

--Slope Stability Analysis--
Simplified Janbu, Simplified Bishop
or Spencer`s Method of Slices

Run Date:
Time of Run:
Run By:
Input Data Filename: run.in
Output Filename: result.out
Unit: ENGLISH
Plotted Output Filename: result.plt

PROBLEM DESCRIPTION Arkema Portland OR - Riverbank Rapid Dra
wdown

BOUNDARY COORDINATES

5 Top Boundaries
12 Total Boundaries

Boundary No.	X-Left (ft)	Y-Left (ft)	X-Right (ft)	Y-Right (ft)	Soil Type Below Bnd
1	0.00	46.00	100.00	50.00	2
2	100.00	50.00	166.00	59.90	2
3	166.00	59.90	200.00	65.00	1
4	200.00	65.00	220.00	85.00	1

5	220.00	85.00	320.00	86.00	1
6	166.00	59.90	179.50	59.90	5
7	179.50	59.90	201.00	63.13	5
8	201.00	63.13	221.00	83.13	5
9	221.00	83.13	320.00	84.12	5
10	166.00	59.90	320.00	59.90	2
11	0.00	44.00	320.00	44.00	3
12	0.00	26.00	320.00	26.00	4

1

ISOTROPIC SOIL PARAMETERS

5 Type(s) of Soil

Soil Type No.	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Param.	Pressure Constant (psf)	Piez. Surface No.
1	110.0	125.0	90.0	30.0	0.00	0.0	2
2	115.0	125.0	0.0	31.0	0.00	0.0	1
3	105.0	120.0	1571.0	0.0	0.00	0.0	1
4	110.0	125.0	0.0	31.0	0.00	0.0	1
5	110.0	125.0	90.0	30.0	0.00	0.0	1

1

2 PIEZOMETRIC SURFACE(S) HAVE BEEN SPECIFIED

Unit Weight of Water = 62.40

Piezometric Surface No. 1 Specified by 4 Coordinate Points

Point No.	X-Water (ft)	Y-Water (ft)

1	0.00	59.90
2	166.00	59.90
3	174.00	61.10
4	320.00	61.10

Piezometric Surface No. 2 Specified by 4 Coordinate Points

Point No.	X-Water (ft)	Y-Water (ft)
1	166.00	59.90
2	200.00	65.00
3	220.00	85.00
4	320.00	86.00

1

BOUNDARY LOAD(S)

2 Load(s) Specified

Load No.	X-Left (ft)	X-Right (ft)	Intensity (psf)	Deflection (deg)
1	224.50	227.50	1667.0	0.0
2	238.50	241.50	1667.0	0.0

NOTE - Intensity Is Specified As A Uniformly Distributed
Force Acting On A Horizontally Projected Surface.

1

A Critical Failure Surface Searching Method, Using A Random
Technique For Generating Circular Surfaces, Has Been Specified.

250 Trial Surfaces Have Been Generated.

50 Surfaces Initiate From Each Of 5 Points Equally Spaced
Along The Ground Surface Between X = 195.00 ft.
and X = 210.00 ft.

Each Surface Terminates Between X = 215.00 ft.
and X = 230.00 ft.

Unless Further Limitations Were Imposed, The Minimum Elevation
At Which A Surface Extends Is Y = 0.00 ft.

4.00 ft. Line Segments Define Each Trial Failure Surface.

1

Following Are Displayed The Ten Most Critical Of The Trial
Failure Surfaces Examined. They Are Ordered - Most Critical
First.

* * Safety Factors Are Calculated By The Modified Bishop Method * *

Failure Surface Specified By 9 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	202.50	67.50
2	206.35	68.58
3	210.07	70.05

4	213.61	71.92
5	216.93	74.15
6	219.99	76.72
7	222.77	79.60
8	225.22	82.77
9	226.64	85.07

Circle Center At X = 194.3 ; Y = 104.2 and Radius, 37.6

*** 0.996 ***

Individual data on the 13 slices

Slice No.	Width (ft)	Weight (lbs)	Water Force (lbs)	Water Force Top (lbs)	Water Force Bot (lbs)	Earthquake Force Norm (lbs)	Earthquake Force Tan (lbs)	Surcharge Hor (lbs)	Surcharge Ver (lbs)	Load
1	3.9	648.8	0.0	260.0	0.0	0.0	0.0	0.0	0.0	
2	0.2	52.5	0.0	21.8	0.0	0.0	0.0	0.0	0.0	
3	3.6	1646.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
4	3.5	2352.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
5	3.3	2694.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
6	3.1	2744.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
7	0.0	7.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
8	1.0	888.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
9	1.8	1279.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
10	1.7	871.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
11	0.7	236.7	0.0	0.0	0.0	0.0	0.0	0.0	1194.9	
12	0.3	65.0	0.0	0.0	0.0	0.0	0.0	0.0	421.0	
13	1.2	137.2	0.0	130.4	0.0	0.0	0.0	0.0	1946.6	

Failure Surface Specified By 9 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)

1	202.50	67.50
2	206.35	68.60
3	210.08	70.04
4	213.66	71.82
5	217.06	73.93
6	220.26	76.33
7	223.22	79.02
8	225.92	81.97
9	228.28	85.08

Circle Center At X = 192.5 ; Y = 109.9 and Radius, 43.5

*** 1.006 ***

1

Failure Surface Specified By 9 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	202.50	67.50
2	206.07	69.31
3	209.55	71.28
4	212.94	73.40
5	216.23	75.67
6	219.42	78.09
7	222.50	80.64
8	225.46	83.34
9	227.20	85.07

Circle Center At X = 163.8 ; Y = 148.1 and Radius, 89.4

*** 1.006 ***

Failure Surface Specified By 8 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	202.50	67.50
2	205.80	69.76
3	208.99	72.17
4	212.05	74.75
5	214.99	77.46
6	217.78	80.33
7	220.44	83.32
8	221.80	85.02

Circle Center At X = 158.9 ; Y = 134.9 and Radius, 80.3

*** 1.020 ***

1

Failure Surface Specified By 8 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	206.25	71.25
2	210.12	72.25
3	213.84	73.73
4	217.34	75.67
5	220.57	78.03
6	223.48	80.77
7	226.02	83.86
8	226.78	85.07

Circle Center At X = 200.4 ; Y = 102.1 and Radius, 31.5

*** 1.034 ***

Failure Surface Specified By 12 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	195.00	64.25
2	198.99	64.48
3	202.94	65.14
4	206.79	66.22
5	210.50	67.71
6	214.03	69.59
7	217.34	71.84
8	220.39	74.43
9	223.14	77.34
10	225.56	80.52
11	227.63	83.94
12	228.16	85.08

Circle Center At X = 194.9 ; Y = 101.2 and Radius, 37.0

*** 1.037 ***

1

Failure Surface Specified By 12 Coordinate Points

Point	X-Surf	Y-Surf

No.	(ft)	(ft)
1	195.00	64.25
2	199.00	64.27
3	202.97	64.77
4	206.85	65.76
5	210.57	67.21
6	214.09	69.11
7	217.36	71.42
8	220.31	74.12
9	222.92	77.15
10	225.13	80.48
11	226.92	84.06
12	227.28	85.07

Circle Center At X = 196.9 ; Y = 96.7 and Radius, 32.5

*** 1.046 ***

Failure Surface Specified By 11 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	198.75	64.81
2	202.74	65.05
3	206.67	65.79
4	210.48	67.03
5	214.09	68.75
6	217.45	70.92
7	220.50	73.50
8	223.20	76.46
9	225.50	79.73
10	227.35	83.27
11	228.02	85.08

Circle Center At X = 198.9 ; Y = 95.9 and Radius, 31.1

*** 1.048 ***

1

Failure Surface Specified By 12 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	195.00	64.25
2	199.00	64.12
3	202.98	64.49
4	206.89	65.34
5	210.66	66.68
6	214.24	68.47
7	217.57	70.68
8	220.60	73.30
9	223.28	76.26
10	225.58	79.54
11	227.45	83.07
12	228.21	85.08

Circle Center At X = 198.1 ; Y = 96.3 and Radius, 32.1

*** 1.075 ***

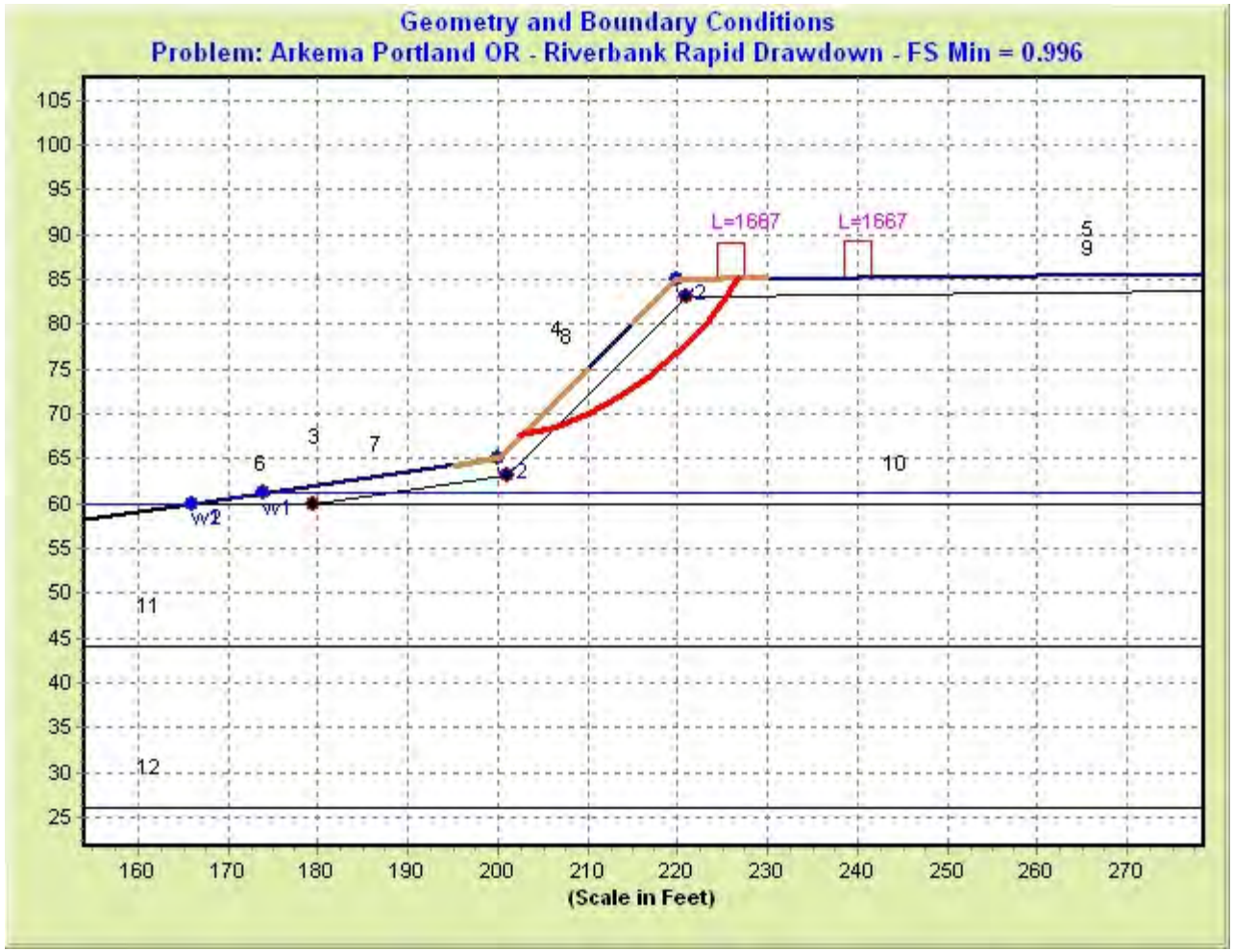
Failure Surface Specified By 10 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)

```
  1      202.50      67.50
  2      206.49      67.79
  3      210.40      68.64
  4      214.14      70.05
  5      217.65      71.97
  6      220.85      74.38
  7      223.67      77.21
  8      226.05      80.42
  9      227.96      83.94
 10       228.38      85.08

Circle Center At X =  202.5 ; Y =   95.3  and Radius,   27.8


    ***    1.079   ***



1

          Y          A    X    I    S          F    T


          0.00     40.00     80.00    120.00    160.00    200.00

X      0.00 +------*--+**--W----+---------+---------+---------+
          -
          -
          -
          -
          -
      40.00 +
          -
          -
          -
          -
          -
A      80.00 +
          -
          -
```



```
          -          *
          -
          -
X    120.00 +
          -
          -
          -
          -
          -
I    160.00 +
          -          *
          -          W
          -          *
          -
          -           6
S    200.00 +            .*1
          -          .713
          -           .613.
          -           ..211*
          -             .0211/1
          -
      240.00 +                 2/2
          -
          -
          -
          -
          -
F    280.00 +
          -
          -
          -
          -
          -
T     320.00 +     *  *  *    **
```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Problem: Arkema Portland OR - Riverbank Rapid Drawdown - FS Min = 0.996
L=1667
L=1667
5
9
4
8
3
7
6
2
2
10
w2
w1
11
12
105
100
95
90
85
80
75
70
65
60
55
50
45
40
35
30
25
160
170
180
190
200
210
220
230
240
250
260
270
(Scale in Feet)

** PCSTABL6 **

by
Purdue University

1

--Slope Stability Analysis--
Simplified Janbu, Simplified Bishop
or Spencer`s Method of Slices

Run Date:
Time of Run:
Run By:
Input Data Filename: run.in
Output Filename: result.out
Unit: ENGLISH
Plotted Output Filename: result.plt

PROBLEM DESCRIPTION Arkema Portland OR - Riverbank Rapid Dra
wdown

BOUNDARY COORDINATES

5 Top Boundaries
12 Total Boundaries

Boundary No.	X-Left (ft)	Y-Left (ft)	X-Right (ft)	Y-Right (ft)	Soil Type Below Bnd
1	0.00	46.00	100.00	50.00	2
2	100.00	50.00	166.00	59.90	2
3	166.00	59.90	200.00	65.00	1
4	200.00	65.00	220.00	85.00	1

5	220.00	85.00	320.00	86.00	1
6	166.00	59.90	179.50	59.90	5
7	179.50	59.90	201.00	63.13	5
8	201.00	63.13	221.00	83.13	5
9	221.00	83.13	320.00	84.12	5
10	166.00	59.90	320.00	59.90	2
11	0.00	44.00	320.00	44.00	3
12	0.00	26.00	320.00	26.00	4

1

ISOTROPIC SOIL PARAMETERS

5 Type(s) of Soil

Soil Type No.	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Param.	Pressure Constant (psf)	Piez. Surface No.
1	110.0	125.0	90.0	30.0	0.00	0.0	2
2	115.0	125.0	0.0	31.0	0.00	0.0	1
3	105.0	120.0	1571.0	0.0	0.00	0.0	1
4	110.0	125.0	0.0	31.0	0.00	0.0	1
5	110.0	125.0	90.0	30.0	0.00	0.0	1

1

2 PIEZOMETRIC SURFACE(S) HAVE BEEN SPECIFIED

Unit Weight of Water = 62.40

Piezometric Surface No. 1 Specified by 4 Coordinate Points

Point No.	X-Water (ft)	Y-Water (ft)

1	0.00	59.90
2	166.00	59.90
3	174.00	61.10
4	320.00	61.10

Piezometric Surface No. 2 Specified by 4 Coordinate Points

Point No.	X-Water (ft)	Y-Water (ft)
1	166.00	59.90
2	200.00	65.00
3	220.00	85.00
4	320.00	86.00

1

BOUNDARY LOAD(S)

2 Load(s) Specified

Load No.	X-Left (ft)	X-Right (ft)	Intensity (psf)	Deflection (deg)
1	224.50	227.50	1667.0	0.0
2	238.50	241.50	1667.0	0.0

NOTE - Intensity Is Specified As A Uniformly Distributed
Force Acting On A Horizontally Projected Surface.

1

A Critical Failure Surface Searching Method, Using A Random
Technique For Generating Sliding Block Surfaces, Has Been

Specified.

100 Trial Surfaces Have Been Generated.

2 Boxes Specified For Generation Of Central Block Base

Length Of Line Segments For Active And Passive Portions Of
Sliding Block Is 5.0

Box No.	X-Left (ft)	Y-Left (ft)	X-Right (ft)	Y-Right (ft)	Height (ft)
1	208.00	69.50	212.00	73.50	3.50
2	215.00	75.00	219.00	79.00	6.50

1

Following Are Displayed The Ten Most Critical Of The Trial
Failure Surfaces Examined. They Are Ordered - Most Critical
First.

* * Safety Factors Are Calculated By The Modified Janbu Method * *

Failure Surface Specified By 5 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	207.14	72.14
2	209.00	71.72
3	218.14	80.15
4	220.37	84.62
5	220.60	85.01

*** 1.002 ***

Individual data on the 7 slices

Slice No.	Width (ft)	Water Weight (lbs)	Water Force Top (lbs)	Water Force Bot (lbs)	Earthquake Force Norm (lbs)	Earthquake Force Tan (lbs)	Surcharge Hor (lbs)	Surcharge Ver (lbs)	Load
1	1.9	258.1	0.0	102.2	0.0	0.0	0.0	0.0	0.0
2	7.5	2353.2	0.0	1235.8	0.0	0.0	0.0	0.0	0.0
3	1.6	571.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	0.1	43.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	1.7	419.1	0.0	363.4	0.0	0.0	0.0	0.0	0.0
6	0.4	34.3	0.0	38.5	0.0	0.0	0.0	0.0	0.0
7	0.2	5.6	0.0	5.3	0.0	0.0	0.0	0.0	0.0

Failure Surface Specified By 5 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	206.50	71.50
2	208.63	71.20
3	218.18	81.34
4	221.69	84.90
5	221.70	85.02

*** 1.051 ***

1

Failure Surface Specified By 6 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	207.19	72.19
2	208.57	70.83
3	218.01	76.15
4	221.47	79.76
5	224.93	83.37
6	226.62	85.07

*** 1.094 ***

Failure Surface Specified By 6 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	206.21	71.21
2	208.30	70.42
3	217.43	75.39
4	220.28	79.50
5	223.69	83.15
6	225.01	85.05

*** 1.102 ***

1

Failure Surface Specified By 4 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	206.61	71.61
2	209.99	71.53
3	218.21	81.00
4	221.11	85.01

*** 1.108 ***

Failure Surface Specified By 5 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	206.76	71.76
2	208.42	71.43
3	216.19	78.07
4	218.38	82.57
5	219.27	84.27

*** 1.109 ***

1

Failure Surface Specified By 6 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	205.19	70.19
2	208.47	69.76

3	216.90	75.37
4	219.67	79.53
5	222.18	83.85
6	222.97	85.03

*** 1.135 ***

Failure Surface Specified By 5 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	208.86	73.86
2	209.86	73.05
3	218.57	80.31
4	221.37	84.45
5	221.70	85.02

*** 1.143 ***

1

Failure Surface Specified By 6 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	206.63	71.63
2	209.35	70.92
3	216.15	76.05
4	218.60	80.40
5	221.51	84.47

```
6      222.07      85.02

***    1.180   ***
```

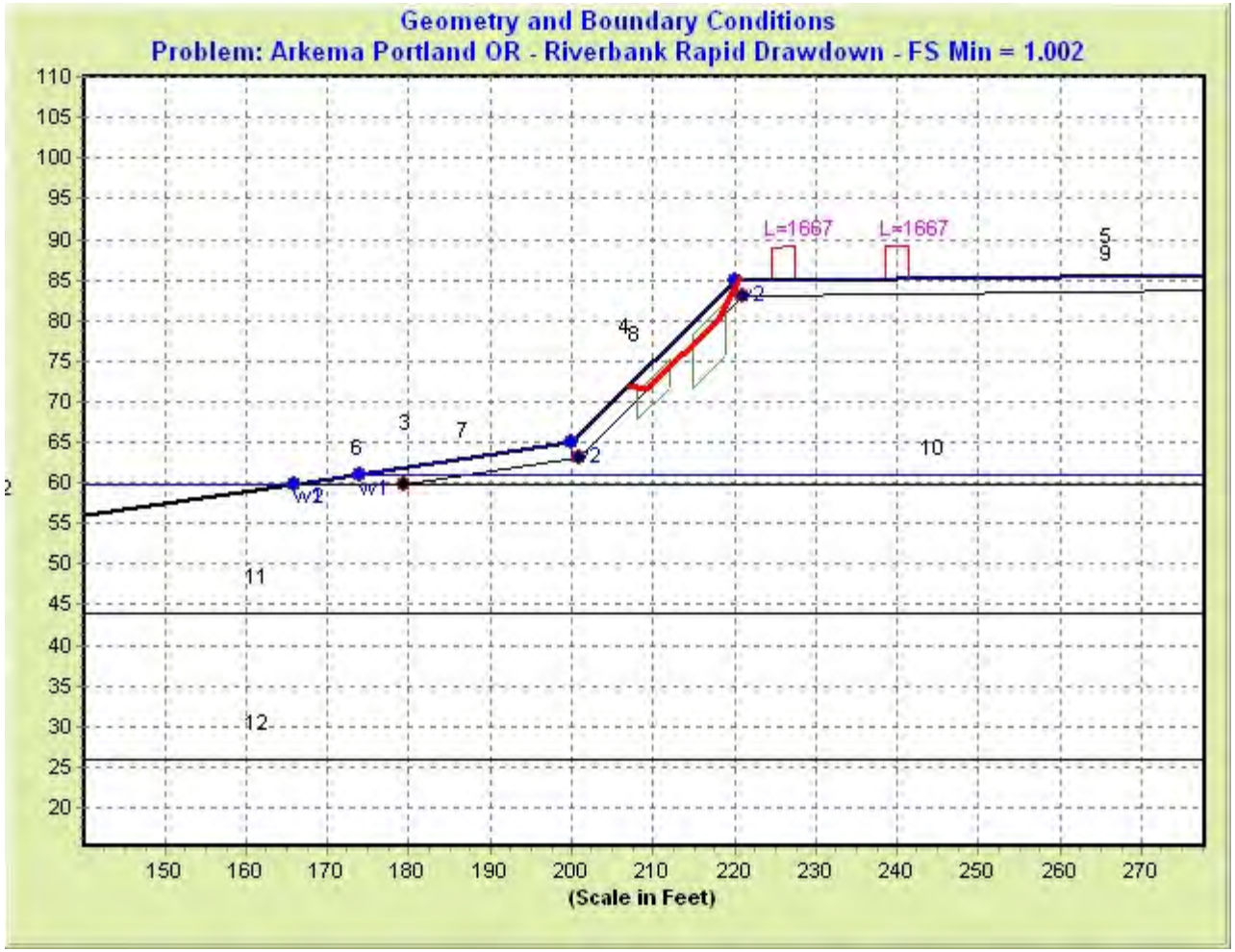
Failure Surface Specified By 5 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	206.71	71.71
2	208.18	70.23
3	216.85	79.32
4	220.28	82.95
5	222.34	85.02

```
***    1.186   ***

1

        Y          A    X    I    S          F    T

        0.00     40.00     80.00    120.00    160.00    200.00

X     0.00 +------*--+**--W----+---------+---------+---------+
        -
        -
        -
        -
        -
     40.00 +
        -
        -
```



```
        -
        -
        -
A     80.00 +
        -
        -
        -          *
        -
        -
X    120.00 +
        -
        -
        -
        -
        -
I    160.00 +
        -          *
        -          W
        -          *
        -
        -
S    200.00 +            *
        -            71.
        -              .96
        -              .31*
        -                31/1
        -
     240.00 +                2/2
        -
        -
        -
        -
        -
F    280.00 +
        -
        -
        -
        -
        -
T    320.00 +     *  *  *    **
```


Geometry and Boundary Conditions
Problem: Arkema Portland OR - Riverbank Rapid Drawdown - FS Min = 1.002
L=1667
L=1667
5
9
4
8
3
7
6
2
2
10
w2
w1
11
12
(Scale in Feet)

Attachment 3
Clearance Trench Excavation

** PCSTABL6 **

by
Purdue University

1

--Slope Stability Analysis--
Simplified Janbu, Simplified Bishop
or Spencer`s Method of Slices

Run Date:
Time of Run:
Run By:
Input Data Filename: run.in
Output Filename: result.out
Unit: ENGLISH
Plotted Output Filename: result.plt

PROBLEM DESCRIPTION Arkema Portland OR - Clearance Trench 2
to 1

BOUNDARY COORDINATES

9 Top Boundaries
13 Total Boundaries

Boundary No.	X-Left (ft)	Y-Left (ft)	X-Right (ft)	Y-Right (ft)	Soil Type Below Bnd
1	0.00	46.00	100.00	50.00	2
2	100.00	50.00	166.00	59.90	2
3	166.00	59.90	200.00	65.00	1
4	200.00	65.00	220.00	85.00	1

5	220.00	85.00	230.00	85.00	1
6	230.00	85.00	280.20	59.90	1
7	280.20	59.90	282.20	59.90	2
8	282.20	59.90	332.40	85.00	1
9	332.40	85.00	342.40	85.00	1
10	166.00	59.90	280.20	59.90	2
11	282.20	59.90	342.20	59.90	2
12	0.00	44.00	342.40	44.00	3
13	0.00	26.00	342.40	26.00	4

1

ISOTROPIC SOIL PARAMETERS

4 Type(s) of Soil

Soil Type No.	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Param.	Pressure Constant (psf)	Piez. Surface No.
1	110.0	125.0	55.0	30.0	0.00	0.0	1
2	115.0	125.0	0.0	39.0	0.00	0.0	1
3	105.0	120.0	1571.0	0.0	0.00	0.0	1
4	110.0	125.0	0.0	31.0	0.00	0.0	1

1

1 PIEZOMETRIC SURFACE(S) HAVE BEEN SPECIFIED

Unit Weight of Water = 62.40

Piezometric Surface No. 1 Specified by 4 Coordinate Points

Point No.	X-Water (ft)	Y-Water (ft)

1	0.00	59.90
2	166.00	59.90
3	174.00	61.10
4	320.00	61.10

1

A Critical Failure Surface Searching Method, Using A Random
Technique For Generating Circular Surfaces, Has Been Specified.

250 Trial Surfaces Have Been Generated.

50 Surfaces Initiate From Each Of 5 Points Equally Spaced
Along The Ground Surface Between X = 280.00 ft.
and X = 300.00 ft.

Each Surface Terminates Between X = 305.00 ft.
and X = 340.00 ft.

Unless Further Limitations Were Imposed, The Minimum Elevation
At Which A Surface Extends Is Y = 0.00 ft.

4.00 ft. Line Segments Define Each Trial Failure Surface.

1

Following Are Displayed The Ten Most Critical Of The Trial
Failure Surfaces Examined. They Are Ordered - Most Critical
First.

* * Safety Factors Are Calculated By The Modified Bishop Method * *

Failure Surface Specified By 16 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	285.00	61.30
2	289.00	61.27
3	292.99	61.49
4	296.97	61.96
5	300.90	62.69
6	304.78	63.66
7	308.59	64.87
8	312.32	66.33
9	315.94	68.01
10	319.46	69.93
11	322.84	72.06
12	326.08	74.40
13	329.17	76.95
14	332.09	79.68
15	334.83	82.59
16	336.83	85.00

Circle Center At X = 287.5 ; Y = 124.3 and Radius, 63.0

*** 1.573 ***

Individual data on the 16 slices

Slice No.	Width (ft)	Water Weight (lbs)	Water Force Top (lbs)	Water Force Bot (lbs)	Earthquake Force Norm (lbs)	Earthquake Force Tan (lbs)	Earthquake Force Hor (lbs)	Earthquake Force Ver (lbs)	Surcharge Load
1	4.0	447.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	4.0	1283.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

3	4.0	1994.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	3.9	2571.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	3.9	3008.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	3.8	3302.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	3.7	3454.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	3.6	3468.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	3.5	3353.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	3.4	3119.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11	3.2	2781.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12	3.1	2356.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13	2.9	1864.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14	0.3	172.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
15	2.4	990.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
16	2.0	264.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Failure Surface Specified By 16 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	285.00	61.30
2	289.00	61.21
3	292.99	61.41
4	296.96	61.91
5	300.89	62.69
6	304.74	63.77
7	308.50	65.12
8	312.16	66.75
9	315.68	68.64
10	319.06	70.79
11	322.26	73.18
12	325.29	75.79
13	328.11	78.63
14	330.72	81.66
15	333.09	84.88
16	333.17	85.00

Circle Center At X = 288.3 ; Y = 115.5 and Radius, 54.3

*** 1.578 ***

1

Failure Surface Specified By 17 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	285.00	61.30
2	289.00	61.41
3	292.99	61.74
4	296.95	62.29
5	300.87	63.06
6	304.75	64.05
7	308.56	65.25
8	312.31	66.65
9	315.97	68.27
10	319.53	70.08
11	322.99	72.09
12	326.33	74.29
13	329.55	76.67
14	332.63	79.23
15	335.56	81.95
16	338.33	84.83
17	338.48	85.00

Circle Center At X = 285.0 ; Y = 133.4 and Radius, 72.1

*** 1.579 ***

Failure Surface Specified By 17 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	285.00	61.30
2	288.99	61.63
3	292.95	62.14
4	296.89	62.84
5	300.80	63.72
6	304.65	64.78
7	308.46	66.01
8	312.20	67.42
9	315.87	69.01
10	319.47	70.76
11	322.98	72.68
12	326.40	74.76
13	329.71	76.99
14	332.92	79.38
15	336.02	81.91
16	339.00	84.58
17	339.42	85.00

Circle Center At X = 279.9 ; Y = 147.3 and Radius, 86.2

*** 1.585 ***

1

Failure Surface Specified By 17 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	285.00	61.30
2	289.00	61.40
3	292.99	61.72
4	296.95	62.25
5	300.88	62.99

6	304.77	63.94
7	308.59	65.11
8	312.35	66.48
9	316.03	68.05
10	319.62	69.81
11	323.11	71.77
12	326.49	73.91
13	329.74	76.24
14	332.87	78.73
15	335.86	81.39
16	338.70	84.21
17	339.41	85.00

Circle Center At X = 285.2 ; Y = 135.3 and Radius, 74.0

*** 1.589 ***

Failure Surface Specified By 17 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	285.00	61.30
2	289.00	61.31
3	292.99	61.54
4	296.97	62.00
5	300.91	62.68
6	304.81	63.58
7	308.65	64.70
8	312.42	66.04
9	316.11	67.58
10	319.70	69.33
11	323.20	71.28
12	326.57	73.43
13	329.82	75.76
14	332.94	78.27

15	335.91	80.95
16	338.72	83.79
17	339.79	85.00

Circle Center At X = 286.8 ; Y = 132.3 and Radius, 71.0

*** 1.599 ***

1

Failure Surface Specified By 17 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	285.00	61.30
2	288.97	60.84
3	292.97	60.70
4	296.97	60.86
5	300.94	61.33
6	304.86	62.12
7	308.71	63.20
8	312.47	64.58
9	316.10	66.25
10	319.60	68.20
11	322.93	70.41
12	326.08	72.88
13	329.03	75.58
14	331.76	78.50
15	334.25	81.63
16	336.49	84.94
17	336.53	85.00

Circle Center At X = 292.9 ; Y = 112.1 and Radius, 51.4

*** 1.614 ***

Failure Surface Specified By 14 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	285.00	61.30
2	288.97	61.82
3	292.90	62.56
4	296.78	63.53
5	300.60	64.71
6	304.35	66.11
7	308.01	67.72
8	311.58	69.53
9	315.03	71.54
10	318.37	73.74
11	321.58	76.13
12	324.65	78.70
13	327.56	81.44
14	329.64	83.62

Circle Center At X = 277.9 ; Y = 131.4 and Radius, 70.4

*** 1.620 ***

1

Failure Surface Specified By 15 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	290.00	63.80

2	293.99	63.50
3	297.99	63.49
4	301.98	63.78
5	305.94	64.36
6	309.84	65.24
7	313.66	66.41
8	317.39	67.86
9	321.00	69.58
10	324.48	71.56
11	327.79	73.80
12	330.93	76.28
13	333.88	78.98
14	336.62	81.90
15	339.13	85.00

Circle Center At X = 296.1 ; Y = 117.2 and Radius, 53.8

*** 1.656 ***

Failure Surface Specified By 14 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	290.00	63.80
2	293.98	63.37
3	297.98	63.34
4	301.96	63.71
5	305.88	64.48
6	309.71	65.64
7	313.40	67.18
8	316.92	69.09
9	320.23	71.33
10	323.30	73.90
11	326.10	76.76
12	328.59	79.89

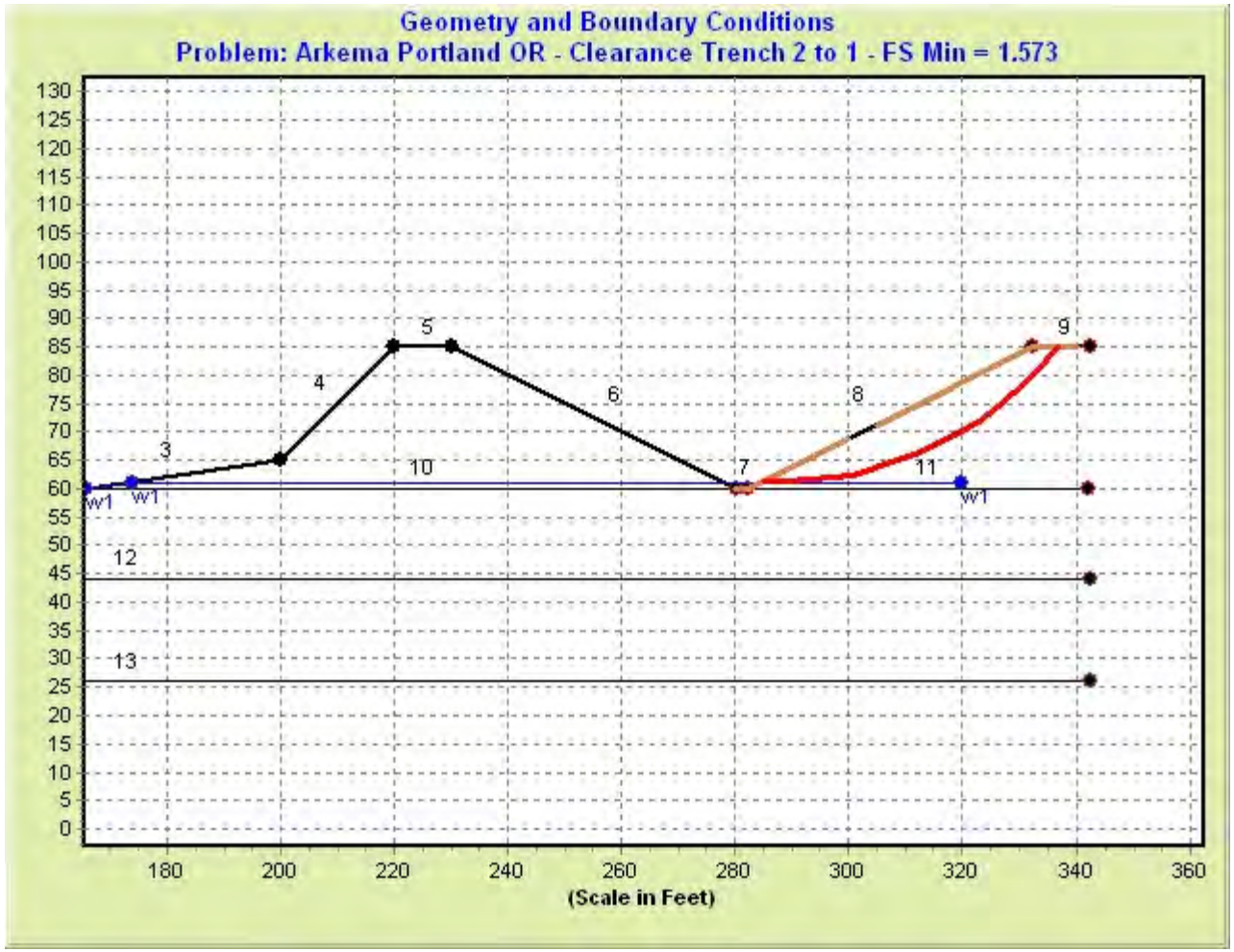
13	330.76	83.25
14	331.39	84.50

Circle Center At X = 296.3 ; Y = 103.0 and Radius, 39.7

*** 1.659 ***

```
1

        Y        A   X   I   S        F   T

        0.00    42.80   85.60   128.40   171.20   214.00

X     0.00 +-----*---**--W-----+---------+---------+---------+
           -
           -
           -
           -
           -
     42.80 +
           -
           -
           -
           -
           -
A     85.60 +
           -
           -        *
           -
           -
           -
X    128.40 +
           -
           -
           -
           -
           -          *
```

```
I   171.20 +          W
        -
        -
        -
        -          *
        -
S   214.00 +
        -              *
        -              *
        -
        -
        -
    256.80 +
        -
        -
        -          *
        -         .*.
        -        ..14
F   299.60 +         ..11.
        -        ...18.
        -        ...118.
        -         .W.118.
        -          ...1128
        -           ...51*
T   342.40 +   *  *  *  ..*
```


Geometry and Boundary Conditions
Problem: Arkema Portland OR - Clearance Trench 2 to 1 - FS Min = 1.573
130
125
120
115
110
105
100
95
90
85
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
180
200
220
240
260
280
300
320
340
360
(Scale in Feet)
3
4
5
6
7
8
9
10
11
12
13
w1
w1
w1

** PCSTABL6 **

by
Purdue University

1

--Slope Stability Analysis--
Simplified Janbu, Simplified Bishop
or Spencer`s Method of Slices

Run Date:
Time of Run:
Run By:
Input Data Filename: run.in
Output Filename: result.out
Unit: ENGLISH
Plotted Output Filename: result.plt

PROBLEM DESCRIPTION Arkema Portland OR - Clearance Trench 2
to 1

BOUNDARY COORDINATES

9 Top Boundaries
13 Total Boundaries

Boundary No.	X-Left (ft)	Y-Left (ft)	X-Right (ft)	Y-Right (ft)	Soil Type Below Bnd
1	0.00	46.00	100.00	50.00	2
2	100.00	50.00	166.00	59.90	2
3	166.00	59.90	200.00	65.00	1
4	200.00	65.00	220.00	85.00	1

5	220.00	85.00	230.00	85.00	1
6	230.00	85.00	280.20	59.90	1
7	280.20	59.90	282.20	59.90	2
8	282.20	59.90	332.40	85.00	1
9	332.40	85.00	342.40	85.00	1
10	166.00	59.90	280.20	59.90	2
11	282.20	59.90	342.20	59.90	2
12	0.00	44.00	342.40	44.00	3
13	0.00	26.00	342.40	26.00	4

1

ISOTROPIC SOIL PARAMETERS

4 Type(s) of Soil

Soil Type No.	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Param.	Pressure Constant (psf)	Piez. Surface No.
1	110.0	125.0	55.0	30.0	0.00	0.0	1
2	115.0	125.0	0.0	39.0	0.00	0.0	1
3	105.0	120.0	1571.0	0.0	0.00	0.0	1
4	110.0	125.0	0.0	31.0	0.00	0.0	1

1

1 PIEZOMETRIC SURFACE(S) HAVE BEEN SPECIFIED

Unit Weight of Water = 62.40

Piezometric Surface No. 1 Specified by 4 Coordinate Points

Point No.	X-Water (ft)	Y-Water (ft)

1	0.00	59.90
2	166.00	59.90
3	174.00	61.10
4	320.00	61.10

1

A Critical Failure Surface Searching Method, Using A Random Technique For Generating Sliding Block Surfaces, Has Been Specified.

100 Trial Surfaces Have Been Generated.

3 Boxes Specified For Generation Of Central Block Base

Length Of Line Segments For Active And Passive Portions Of Sliding Block Is 5.0

Box No.	X-Left (ft)	Y-Left (ft)	X-Right (ft)	Y-Right (ft)	Height
1	280.00	57.00	285.00	57.00	3.00
2	290.00	58.00	300.00	63.00	7.50
3	320.00	75.00	330.00	80.00	4.00

1

Following Are Displayed The Ten Most Critical Of The Trial Failure Surfaces Examined. They Are Ordered - Most Critical First.

* * Safety Factors Are Calculated By The Modified Janbu Method * *

Failure Surface Specified By 6 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	280.07	59.96
2	281.77	58.37
3	294.80	60.25
4	326.16	77.41
5	329.22	81.36
6	329.73	83.67

*** 1.505 ***

Individual data on the 10 slices

Slice No.	Width (ft)	Water Weight (lbs)	Water Force Top (lbs)	Water Force Bot (lbs)	Earthquake Force Norm (lbs)	Earthquake Force Tan (lbs)	Earthquake Force Hor (lbs)	Earthquake Force Ver (lbs)	Surcharge Load (lbs)
1	0.1	0.1	5.6	6.9	0.0	0.0	0.0	0.0	0.0
2	0.1	0.3	5.0	6.3	0.0	0.0	0.0	0.0	0.0
3	1.6	156.2	117.9	268.4	0.0	0.0	0.0	0.0	0.0
4	0.4	79.8	31.9	72.5	0.0	0.0	0.0	0.0	0.0
5	10.2	3949.6	0.0	1238.4	0.0	0.0	0.0	0.0	0.0
6	2.4	1519.9	0.0	157.7	0.0	0.0	0.0	0.0	0.0
7	1.5	1015.2	0.0	46.5	0.0	0.0	0.0	0.0	0.0
8	29.8	16966.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	3.1	1096.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	0.5	57.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Failure Surface Specified By 6 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)

1	281.70	59.90
2	284.42	57.94
3	296.38	58.72
4	326.87	77.52
5	330.39	81.08
6	331.10	84.35

*** 1.511 ***

1

Failure Surface Specified By 6 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	280.90	59.90
2	284.00	58.11
3	294.17	60.19
4	323.65	77.07
5	327.00	80.78
6	329.90	83.75

*** 1.513 ***

Failure Surface Specified By 7 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	278.02	60.99

2	278.52	60.49
3	282.49	57.44
4	296.25	59.99
5	328.36	78.39
6	331.83	81.99
7	333.97	85.00

*** 1.514 ***

1

Failure Surface Specified By 6 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	282.27	59.94
2	284.72	58.30
3	299.98	60.24
4	322.38	75.00
5	325.70	78.74
6	326.62	82.11

*** 1.517 ***

Failure Surface Specified By 6 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	281.61	59.90
2	284.11	57.41

3	296.76	58.10
4	329.24	80.10
5	332.66	83.75
6	333.74	85.00

*** 1.531 ***

1

Failure Surface Specified By 5 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	280.64	59.90
2	283.69	58.04
3	299.37	61.99
4	320.83	75.94
5	321.99	79.79

*** 1.534 ***

Failure Surface Specified By 6 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	281.07	59.90
2	283.47	57.57
3	297.86	58.61
4	325.13	77.53
5	328.63	81.11

6	329.81	83.70

*** 1.536 ***

1

Failure Surface Specified By 6 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	279.56	60.22
2	283.09	57.65
3	293.43	60.78
4	326.70	78.06
5	329.23	82.37
6	330.68	84.14

*** 1.547 ***

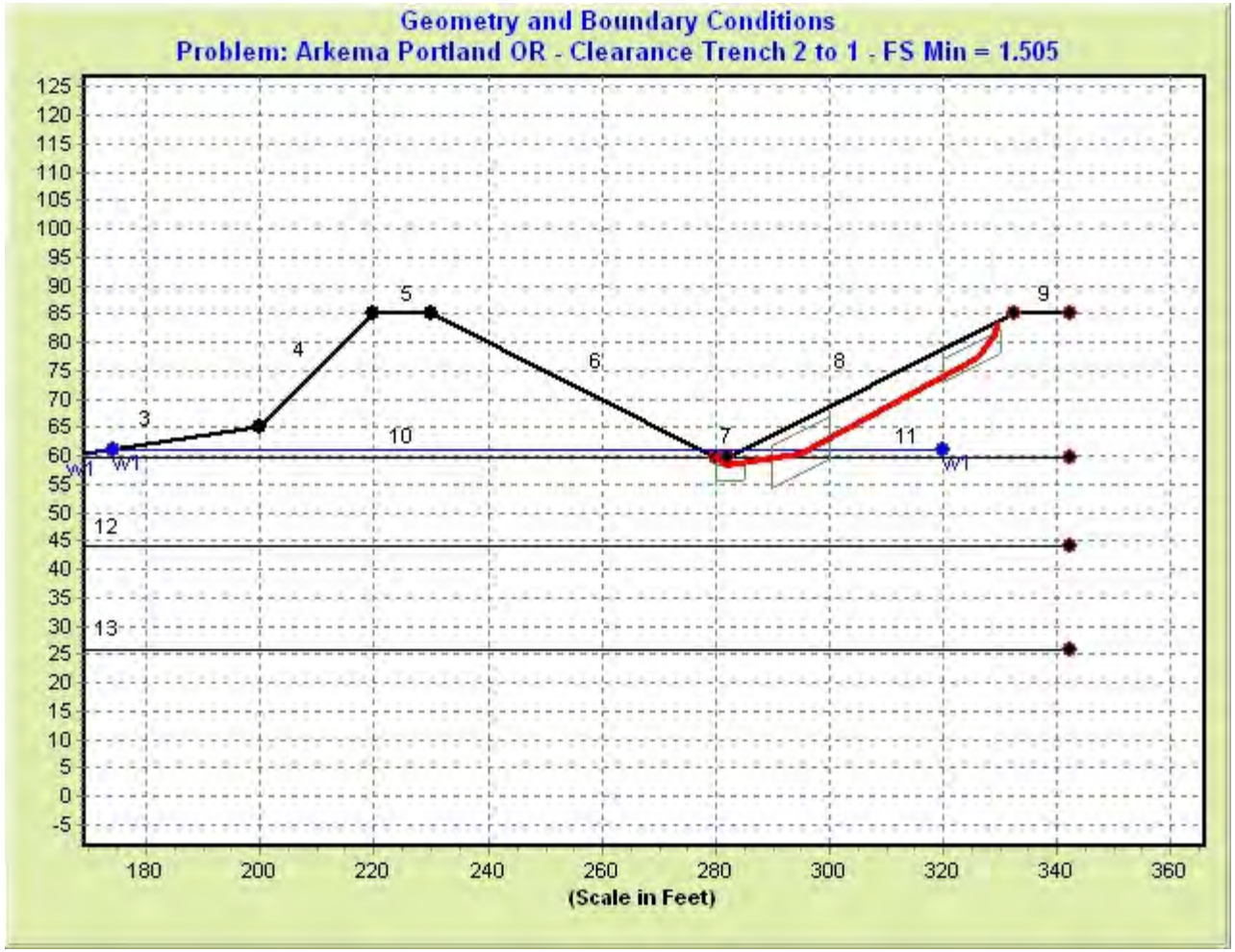
Failure Surface Specified By 6 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	281.41	59.90
2	284.82	56.90
3	294.82	57.39
4	327.49	78.49
5	329.15	83.21
6	329.42	83.51

```
        ***    1.548   ***


1
            Y          A    X    I    S          F    T

            0.00     42.80     85.60    128.40    171.20    214.00
      X     0.00 +-----*---**--W-----+---------+---------+---------+
            -
            -
            -
            -
            -
        42.80 +
            -
            -
            -
            -
            -
      A     85.60 +
            -
            -         *
            -
            -
            -
      X    128.40 +
            -
            -
            -
            -
            -          *
      I    171.20 +           W
            -
            -
            -
            -           *
```



```
            -
      S    214.00 +                 .
            -              ..*
            -             ...*
            -             .....
            -             ....
            -            ....
        256.80 +            ....
            -           ...
            -          ...
            -          .*.
            -          4*
            -          01.
      F    299.60 +           2.
            -
            -
            -           W  .37
            -              111
            -               4*
      T    342.40 +    *   *   *    *
```


Geometry and Boundary Conditions
Problem: Arkema Portland OR - Clearance Trench 2 to 1 - FS Min = 1.505
125
120
115
110
105
100
95
90
85
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
-5
180
200
220
240
260
280
300
320
340
360
(Scale in Feet)
3
4
5
6
7
8
9
10
11
12
13
w1
w1
w1