Prepared for:

Kevin Kiernan, Division Director
Victor O. Okereke, Engineering Services Manager

King County

Department of Natural Resources and Parks
Solid Waste Division
King Street Center
201 South Jackson Street, Suite 701
Seattle, Washington 98104-3855
206-296-6542

Prepared by:

Aspect Consulting, LLC

In Association with:
Anchor QEA, LLC
Herrera Environmental Consultants
BHC Consultants

For comments or questions contact:

Jamey Barker
King County Project Representative
201 South Jackson Street, Suite 701
Seattle, Washington 98104-3855
(206) 296-4417
jamey.barker@kingcounty.gov

John J. Strunk, LHG
Aspect Consulting, LLC
350 Madison Avenue North
Bainbridge Island, Washington 98110
(206) 780-7719
jstrunk@aspectconsulting.com

Aspect CONSULTING

ENVIRONMENTAL REVIEW, INVESTIGATION AND EVALUATION TECHNICAL MEMORANDUM - VASHON ISLAND CLOSED LANDFILL

ENVIRONMENTAL INVESTIGATIONS, MONITORING AND REMEDIATION SERVICES

Prepared for: King County Solid Waste Division

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Aspect Consulting, LLC

Erick W. Miller, LHG
Sr. Associate Hydrogeologist
emiller@aspectconsulting.com

John J. Strunk, LHG
Sr. Associate Geologist
jstrunk@aspectconsulting.com

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ES-1 Executive Summary

This technical memorandum summarizes our monitoring system evaluation at the Vashon Island Closed Landfill (VLF) and provides recommended tasks to further refine groundwater flow paths, identify source areas, and update groundwater, landfill gas, leachate, and surface water monitoring systems.

Based on our review of the previous reports, our recommended list of tasks to refine groundwater flow paths, identify sources, and update a compliance monitoring system is as follows:

1. **Hydrodgeologic Conceptual Model Update:** The current hydrogeologic model will be evaluated and refined as appropriate in order to identify the contaminant source areas, groundwater flow paths and fate and transport mechanisms. The following work elements are proposed to update the hydrogeologic conceptual model:

   1.1. Update Site Hydrostratigraphic Model – Four new cross sections through the site will be developed to confirm current stratigraphic interpretations and improve understanding of the Cc2 flow path at the south end of the facility. The sections will incorporate additional subsurface information obtained from new monitoring wells (discussed below), incorporate off-site wells, include detailed stratigraphic information, at-time-drilling (ATD) water level information, and key water quality parameters.

   1.2. Refine Groundwater Flowpaths – Comparison of geochemical data along currently interpreted flow paths at the site suggests monitored natural attenuation (MNA) may be an appropriate remedial strategy. Recommended tasks are presented below to further define the interconnection and flow between hydrostratigraphic units and to evaluate MNA within the Cc2 unit. In addition, flow paths in the Regional Aquifer are currently interpreted as having a radial flow pattern with the high point driven by well MW-27; however, our data review suggests that water levels in MW-27 could be perched above the Regional Aquifer. The following work elements are recommended to address these issues and better define groundwater flow paths:

      1.2.1. Update potentiometric maps by incorporating water level measurements from off-site wells and for new wells installed in this investigation. The need for an additional Regional Aquifer well will be evaluated based on the outcome of this analysis. If a new Regional Aquifer well is installed, it will be completed as a paired well with MW-27 to evaluate if the water level in MW-27 is perched above the Regional Aquifer.

      1.2.2. Conduct pump and/or slug testing on select wells to estimate hydraulic conductivity values for use in computing groundwater flow velocities. The wells proposed for testing are based on hydrogeologic completion unit and geographic distribution. A subset of wells that have been previously tested are also selected to confirm prior hydraulic conductivity estimates.

1.2.3. Investigate the groundwater gradients and flow paths through measurements in both on-site and off-site wells to improve the understanding of flow and interconnection between hydrogeologic units. Evaluate timing and magnitude of water level changes using existing water level data. Based on results of this analysis, make recommendations for installing pressure transducers in October 2012 and performing automated water level monitoring in select wells at south end of facility during the wet season.

1.2.4. MNA may be appropriate as a remediation strategy at the site as halogenated volatile organic compounds (HVOC) concentrations in individual monitoring wells have been decreasing over time, and HVOC concentrations also decrease between wells and seeps along the same flow path. Work elements to evaluate MNA include analytical testing for select parameters in leachate, MW-5D, MW-21, MW-2 and MW-20 and seeps as well as statistical analysis of recent concentration trends. Following review of results from the expanded geochemical sampling, additional lines of evidence will be considered, including molecular diagnostic tools.

1.2.5. Development of a water balance for the Cc2 unit to improve understanding of the site hydrogeologic conceptual model.

2. **Source Investigations:** Previous work (Berryman and Henigar, 2006) has identified potential landfill gas (LFG) pathways in the 1988 closure area and West Perimeter Road area in the north portion of the landfill and in the South Slope Area. The South Slope Area will be evaluated as a potential source of leachate. The following work elements are recommended to better identify potential sources of leachate and LFG:

   2.1. Installation of a new monitoring well (MW-33) completed in the Cc2 unit on the downgradient (west edge) of the South Slope Area.

   2.2. Leachate source sampling.

   2.3. Differentiation of historic and on-going impacts through sampling of chemical and isotopic tracers.

   2.4. Evaluation of the LFG system collection points will be made through a series of monitoring events at the blower facility, extraction wells, and collection points including, trench risers.

   2.5. Evaluation of potential gas migration pathways by sampling LFG below a gas collection gravel layer installed beneath the liner and over older refuse. Gas samples collected from beneath the liner will be compared with samples collected from within the unlined portion of the landfill. These data will be used to evaluate the gas migration pathways by characterizing LFG generated in the northern and southern areas of the facility.

2.6. The need for an additional Cc2 well will be evaluated based on geochemical analysis and observations of the Cc2 unit during drilling of MW-27.

3. **Groundwater monitoring system improvements**: Our review of site well logs indicated potential monitoring well construction issues. Recommended activities to address monitoring well infrastructure are as follows:

   3.1. Based on video survey results develop recommendation for decommissioning and replacement based on results of video survey for MW-5D.

   3.2. Perform video camera survey to verify monitoring well MW-1 integrity. Based on video results, evaluate the replacement of the protective casing or well decommissioning.

   3.3. Provide access improvements to the springs and seeps.

   3.4. Perform an evaluation of Point of Compliance wells.

   3.5. Evaluate assessment monitoring statistical methods.

   3.6. Develop sampling protocol for West Hillslope.

4. **Surface Water Monitoring System Improvements**: A recommendation is provided to confirm that the surface water run-on monitored at station SW-B is restricted to the off-site contribution and samples are collected prior to mixing with on-site water. A preliminary evaluation of potential surface water improvements is also provided including upgrades to the south siltation pond, northwest landfill drainage improvements, and asphalt ditch maintenance.

5. **Leachate Monitoring**

   5.1. The leachate lagoon was constructed prior to adoption of WAC Chapters 173-351 and 173-304. No leak detection or double liner was required. The quality of leachate contained in the lagoon has improved. A review of water quality in the lagoon is recommended to evaluate whether the potential for water quality impacts from the lagoon justify in investing in a double liner with leak detection.

   5.2. An additional leachate sample point is recommended to identify the characteristics of the leachate collected from lined and unlined areas of the landfill and to reduce VOC losses during sampling.

6. **Landfill Gas Monitoring/Source Investigations**

   6.1. Collect LFG monitoring data at collection or extraction well control points to assess the range of operating conditions and assess the current gas system control strategy.

   6.2. Sample LFG near the southern area of the landfill to evaluate the effectiveness of the LFG control system and determine if LFG concentrations vary within various trench systems and between lined and unlined areas of the landfill.

   6.3. Review the existing LFG operation strategy in regards to the existing extraction and collection system efficiency and effectiveness.

1 Introduction

1.1 Purpose and Scope

This technical memorandum summarizes our monitoring system evaluation and presents a work plan for updating the existing groundwater, surface water and landfill gas monitoring systems at the Vashon Island Closed Landfill (VLF). This technical memorandum addresses Task 300.2 of Contract No E00102E08 with Aspect Consulting, LLC. The focus of this technical memorandum is to summarize the evaluation of the site hydrogeologic conceptual model, potential contaminant sources, the site monitoring systems, identify data gaps and provide a work plan to collect information to address data gaps. This technical memorandum also provides preliminary evaluation of environmental control systems, particularly as they relate to monitoring and identification of potential contaminant sources. Environmental control systems will be comprehensively addressed under Task 310 of this contract. Previous Task 300 deliverables, including design related questions, design criteria, and site visit are consolidated in this technical memorandum. The site, as referenced in this memorandum, refers to the landfill property.

Section 1 of the technical memorandum first presents design criteria which develops the investigation objectives. Section 2 discusses the current hydrogeologic model, proposed work elements to update the model, and work elements for determining age and source of impacted groundwater. Subsequent report sections (Section 3 through Section 6) describe and present work elements to improve the groundwater, surface water, leachate lagoon and landfill gas (LFG) monitoring systems.

A site visit was performed under Task 300.1.4 and the letter report documenting the site visit is included in Appendix A with site photos. Appendix B presents field methods for accomplishing the work elements. A cost estimate for the work and schedule are presented in Appendix C. Appendix D provides a summary of groundwater quality in the Cc2 unit and a preliminary source evaluation on impacts observed at MW-5D and the West Hillslope seeps. Appendix E contains previously constructed hydrostratigraphic cross sections developed by Berryman and Henigar.

The project location is presented on Figure 1, and the site layout is shown on Figure 2.

1.2 Design Criteria

Design criteria for the hydrogeologic conceptual model and site monitoring systems include:

- Compliance with Criteria for Municipal Solid Waste Landfills (Chapter 173-351 Washington Administration Code [WAC]);
- Adequate characterization of groundwater, surface water, leachate, and LFG to evaluate the need for improving engineering control measures; and,
- Maximize efficiency and cost effectiveness of post closure monitoring activities.

In summary, the objective of the work proposed herein is to ensure site compliance, develop an effective and cost efficient monitoring system, and to provide the data and analysis necessary to evaluate the need for improvements to site engineering controls.

2 Hydrogeologic Conceptual Model Update

2.1 Current Site Model

2.1.1 Site Stratigraphic Model

The current hydrogeologic conceptual model for the site is developed in Berryman & Henigar, et.al. (2000, 2004, and 2006) and King County (DNRP, 2011) and summarized below. The site stratigraphic model breaks the subsurface into seven primary units, designated A through G, based on interpreted geologic origin. Monitoring wells installed at the VLF and their assigned completion units are presented on Figure 4. The principal hydrostratigraphic units for the current site model are summarized below from shallowest to deepest. Five hydrostratigraphic cross sections are presented in the 2004 Hydrogeologic Report Update (Berryman and Henigar, et al., 2004) and are included in Appendix E for reference.

Unit A consists of relatively impermeable Vashon Till that mantles the landfill property area east of the West Side Highway. The till ranges in thickness from 15 to 50 feet except where it has been eroded or removed by landfill-related activities. Groundwater has not been identified in Unit A and no monitoring wells are completed in this unit.

Underlying the till is an advance outwash sand designated as Unit B that is typically about 40 to 50 feet thick. Groundwater has been identified at one location (piezometer P-1B) in the Unit B soil where a thin (2.5-foot) saturated zone was identified perched on fine-grained underlying Unit C soils. The approximate location of piezometer P-1B is shown on Figure 4. This piezometer has been decommissioned.

Unit C consists of an approximate 100- to 120-foot thick, fine-grained lacustrine unit (indicated by Cf for Unit C fine grained) with incised channel deposits (indicated by Cc for Unit C coarse grained). The fine- grained Unit C soils comprise an aquitard consisting of glaciolacustrine silts and clays and Pre-Vashon Till. Three water-bearing channel deposits incised into the Cf unit have been identified and designated as Cc1, Cc2, and Cc3, from shallowest to deepest. The thickness and extent of these units at the facility have been extensively evaluated (Berryman & Henigar, et al., 2006).

Unit D is comprised of fluvial deposits exhibiting a wide range in texture consistent with varying energy in a fluvial environment. Thickness of Unit D ranges from about 25 to 65 feet. Textures range from sandy gravel channel deposits to fine-grained overbank deposits and the unit exhibits a corresponding range of hydraulic properties.

An approximate 40-foot-thick lacustrine unit (Unit E) underlies Unit D and is thought to be continuous beneath the site. Unit F consists of Pre-Vashon fluvial deposits also widely varying in texture similar to Unit D. Thickness of Unit F ranges from 30 to over 90 feet. The oldest and deepest unit at the site is, dark gray, varved clay that is thought to be regionally extensive (Unit G) and over 50 feet thick.

2.1.2 Groundwater Occurrence and Flow

Other than the aforementioned single occurrence of groundwater within the Unit B soils, the Cc1 unit is the shallowest water-bearing unit identified on the site. This unit is recharged by precipitation and potentially through unlined stormwater ponds, wetlands northeast of the site, and Judd Creek (Berryman & Henigar, et al., 2006). Where till is absent beneath an unlined stormwater pond such as the south siltation pond (see Appendix E, Cross Section E-E'), recharge would be greater than if till were present. Groundwater flow in the Cc1 unit is interpreted to be a function of recharge locations and the geometry of the incised lacustrine unit that restricts flow within the higher permeability channels. Groundwater flow in the Cc1 unit is interpreted to be in a westerly direction. Within the Cc2 unit, groundwater flow has been shown to flow in a southwesterly direction with discharge occurring at the West Hill Slope springs (King County DNRP, 2011).

The Regional Aquifer is considered to be comprised of the Cc3, Unit D, and Unit F soils. Groundwater in the Cc3 unit at MW-27 is interpreted to be hydraulically continuous with groundwater in Unit D. The Unit E aquitard that separates, Units D and F has likely been removed by erosion beneath some portions of the site (see MW-25 and MW-26, Appendix E, Cross Section C-C') (Berryman & Henigar, et al., 2006). Flow in the Regional Aquifer is thought to be complex and controlled by local recharge to the unit and varying hydraulic conductivity. Most recent groundwater flow interpretations for this unit show a radial pattern extending from a potentiometric high at monitoring well MW-27 (Berryman & Henigar, et al., 2006).

The landfill Regional Aquifer has been evaluated in the context of previous Vashon Island regional aquifer classification systems (Berryman and Henigar, 2006). Hydrostratigraphic classifications have been developed by Carr, 1983 as part of a water resource study for King County and by the Vashon-Maury Island Groundwater Advisory Committee (GWAC, 1998). These regional classification systems were found to be generalized and the hydrostratigraphic classification at the landfill were found to generally correlate, but not in any detail. The landfill Regional Aquifer was found to be generally correlative with Unit II of Carr (1983) and Zone 2 of the Vashon GWAC (1998). An evaluation of private water supply wells sampled in 2002 indicated that three wells (85 acres, Smith/Shiratori, and Paquette) may be installed in the Regional Aquifer (Figure 3) (Berryman and Henigar, 2006).

2.1.3 Groundwater Quality

VOCs, predominantly vinyl chloride and cis-1,2-dichloroethene (cis-1,2-DCE), have been detected in the downgradient monitoring wells screened in the Cc2 sand unit, as well as in seeps on the western hillslope which discharge from the Cc2 unit. Water quality in the Cc2 unit is further described in Appendix D.

VOCs were historically elevated in several monitoring wells in the Cc1 sand unit, however, water levels have declined in this unit, limiting sample collection. Where sufficient water is present for sampling, there have not been systematic detections of VOCs in the Cc1 sand unit over the last decade (with the possible exception of vinyl chloride in MW-4).

Sporadic detections of individual VOCs (most commonly toluene) have occurred in the Cc3 sand unit and in the Regional Aquifer (Unit D), however, there have not been systematic detections of VOCs in these units.

2.2 Review/Update Site Hydrostratigraphic Model

The site hydrostratigraphic model is critical for evaluating and identifying contaminant source areas and contaminant fate and transport. The site hydrostratigraphic model will be evaluated by developing four cross sections through the site to ensure interpretations are consistent with geologic logs and to identify areas of uncertainty. Where practical, these sections will tie in stratigraphic control from off-site wells. Any updates to the site stratigraphic model will be supported by additional subsurface information obtained during drilling described in Section 2.4.

Two cross sections will be developed in an east–west direction. In addition to allowing evaluation of the site hydrostratigraphic model, the cross sections will assist in evaluating impacts in the Cc2 at the south end of the facility and the relationship of vertical gradients between the Cc3 unit and the Regional Aquifer. One of these cross sections will be parallel to the groundwater flow direction in the Cc2 unit and will pass through MW-13 (and adjacent wells), MW-20, MW-5D and extend out to the springs. The second east-west cross section will extend through P-1, MW-27, MW14 and MW-4 and to the springs.

A third cross section will be developed in a north –south direction along the alignment of existing section A-A' to allow a direct comparison of interpretation revisions. The fourth cross section will be done on a regional scale and will incorporate off-site wells to better understand the relationship of site stratigraphy to off-site wells. The orientation of this cross section will be determined after off-site wells are located as described below in Task 2.3.1.

The cross sections will include the stratigraphic detail from information presented on the well log. Unique descriptors such as "wood" will be included to facilitate interpretation and correlation of units. The cross sections will also present ATD water level measurements to refine understanding of hydraulic connection and flow between units. Select water quality parameters of chloride, alkalinity and total VOCs will also be presented on the cross sections. The upper portion of the cross sections will have an expanded scale, as necessary, to show as-built information of the facility engineering closure elements including underliner and overliner, leachate lines, stormwater ponds, and former and existing leachate lagoons,

2.3 Refine Groundwater Flowpath Analysis

2.3.1 Evaluate Regional Groundwater Flow

Water level measurements in off-site wells provide a cost-effective means to improve the understanding of regional groundwater flow directions and gradients. Under this task, existing off-site water level data will be used to investigate and refine the radial flow pattern currently defined for the Regional Aquifer.

A domestic well survey was performed in 2002 that included collecting water quality samples from off-site wells and obtaining static water level measurements in four wells. The locations of the off-site wells that were monitored in 2002 are presented on Figure 3. The number of well logs in Ecology's well log database within approximately a half mile from the landfill is presented on Figure 3. Prior to initiating this work, a meeting will be held with KCSWD and KCWLRD to discuss King County's available off-site well data.

The well completion zones from these off-site well logs will be interpreted and placed in the context of the site's stratigraphic model. Water levels from the off-site wells, either from the well log or the 2002 monitoring, will be assigned to the appropriate hydrostratigraphic unit and evaluated with on-site water levels to develop an improved understanding of the regional groundwater flow directions. A sensitivity analysis of the groundwater flow direction will be evaluated through seasonal water level changes. If seasonal/annual variability in water levels results in significantly different interpretations of gradient changes, then water level measurements in off-site wells will be measured. Water level measurements in off-site wells will entail evaluating legal and physical access to the wells and obtaining water level measurements. Methodology for off-site well water level measurements is presented in Appendix B. The domestic well survey update, if necessary, will include coordination with King County Water and Land Resources Division, who we understand has previously evaluated some of the off-site wells in the landfill vicinity.

If no additional off-site wells are available, then the need for additional Regional Aquifer wells will be considered.

2.3.2 Aquifer Hydraulic Conductivity Testing

Groundwater flow velocities are a key component of contaminant transport evaluations. Groundwater flow velocities using current hydraulic conductivity estimates provide very slow groundwater velocities for the Cc2 unit (a mean value of about 0.002 ft/day which is inconsistent with facility impacts affecting the springs, i.e. the travel time is on the order of 500 years and the earliest waste placement was about 100 years ago). In this work element, short-term pump tests and/or slug (rising and falling head) tests will be performed to obtain hydraulic conductivity data for use in computing groundwater flow velocities required under WAC Chapter 173-351- 410 and for use in any future engineering control evaluations.

A subset of wells representative of each groundwater unit or aquifer have been identified for hydraulic conductivity testing. Table 1 presents wells that were previously tested and those that are proposed for hydraulic conductivity testing. The wells selected are based on completion unit and geographic distribution. A subset of wells that have been previously tested were also selected to confirm prior hydraulic conductivity estimates. Wells where turbidity exceeds 50 NTUs and or significant sediment has accumulated in the well will be redeveloped prior to hydraulic conductivity testing.

Hydraulic conductivity test methods are presented in Appendix B.

2.3.3 *Groundwater Gradient Investigation*

This task will investigate groundwater gradients and flow paths through measurement and integration of off-site and on-site water level data. This task addresses flow and the interconnection between the Cc1, Cc2, and Regional Aquifers.

2.3.3.1 Regional Aquifer Flow Evaluation

Within the Regional Aquifer, current interpretations of groundwater flow indicate a radial pattern, although this interpretation may be influenced by vertical gradients. Water levels in monitoring well MW-27 create a potentiometric high in the Regional Aquifer groundwater elevation contour maps, resulting in a radial pattern of horizontal flow away from this well. The well screen elevation in MW-27 is about 25 feet higher than nearby Regional well MW-19, which is also completed in the Regional Aquifer and 40 ft higher than MW-12. A relatively steep horizontal gradient between MW-27 and other Regional wells (e.g., 0.09 between MW-27 and MW-19 under static conditions) suggest MW-27 is perched above the Regional Aquifer or is receiving a relatively constant source of recharge that maintains the gradient. In other words, if water were recharging the Regional Aquifer through windows in the Cf aquitard in the vicinity of MW-27, a mound could develop resulting in a localized, steeper hydraulic gradient.

A water level in the overdrilled section of the MW-27 borehole, at depth 227 feet or about 25 feet below the final screened interval, indicates a water level about 20 ft lower than that of the completed well and a downward vertical gradient of about 1.6 consistent with unsaturated flow between the screen interval and the deeper zone. The high vertical gradient does not suggest a continuous saturated zone between the Regional Aquifer and the CC3 unit at MW-27. This analysis assumes that the water level obtained during drilling which was noted as "very slowly rising" was close to static conditions. In conclusion, the relatively high horizontal and vertical gradients suggest MW-27 is monitoring a zone above the Regional Aquifer and combining water levels in MW-27 with water levels in other Regional Aquifer wells may not reflect flow within the Regional Aquifer.

Alternative groundwater flow patterns will be evaluated by integrating water levels in off-site Regional Aquifer wells and omitting MW-27. Deeper water levels identified in the overdrilled MW-27 borehole will be considered in the analysis. The analysis will include an evaluation of whether an additional groundwater well is needed based on the interpreted groundwater flow patterns and known areas of impact to the Cc2 unit. This evaluation will also consider coverage provided by off-site wells and potentially by a new Regional Aquifer monitoring well. This new monitoring well, if installed would be paired with MW-27, as discussed in Section 2.3.3.2.

Monitoring well MW-28 is completed within silty sands and silty gravels interpreted by Berryman and Henigar (2004) as being within Unit D of the Regional Aquifer. The bottom 2 feet of the well screen penetrates the top of a 28 feet thick section of Unit E silt. Thus, water accumulating on the silt would be monitored by this well; however, the well has historically been dry. The silt at MW-28 is at a higher elevation than other Regional Aquifer wells (see Appendix E, Section C-C') and the unsaturated condition indicates that groundwater flows around this elevated region of the Unit E aquitard. A map showing the saturated thickness of the Regional Aquifer and its relative permeability (based on lithologic descriptions and slug tests) will be developed to aid in interpretation of Regional Aquifer groundwater flow.

2.3.3.2 Vertical Gradient Evaluation

Water quality data at the VLF indicate complex flow paths between shallower to deeper units. For example, alkalinity has exhibited a steady increase in monitoring well MW-19, completed in the Regional Aquifer since about 2001. Shallower, paired well MW-9 is completed in the overlying Cc2 unit, but has lower alkalinity concentrations and shows a more subtle upward trend, indicating the higher alkalinity in MW-19 is occurring from some pathway other than vertical leakage. The interconnection of the Cc1, Cc2, and Regional Aquifer will be investigated under this task.

Hydraulic connection between water-bearing units will be first evaluated through existing water level data. Water level data will be plotted and the timing, magnitude and spatial distribution of water level responses will be used to evaluate preferential flow paths and interconnection between units. Based on this analysis, a determination to instrument select monitoring wells with pressure transducers will be made. If instrumented, the transducer would be utilized to obtain a near-continuous record of water level changes for a minimum 6-month period from October to March. Potential wells selected for monitoring are indicated on Figure 4. Monitoring will focus on the South Area of the VLF where water quality impacts have occurred and potentially include:

- MW-19 (Regional) and MW-9 (Cc2);
- MW-4 (Cc1) and MW-14 (Cc3);
- MW-2 (Cc2/Cf), MW-3 (Cc1) and MW-12 (Regional);
- MW-7 (Regional) and MW-24 (Cf);
- MW-20;
- MW-27;
- MW-5S and MW-5D; and
- Proposed well MW-33.

Because the upper Cc1 and Cc2 units are perched above the Regional Aquifer (i.e., unsaturated soils are present above the Regional Aquifer), the water level changes should reflect recharge to these units and not a pressure response. The timing, magnitude, and spatial distribution of water level changes will be evaluated to identify preferential flow paths and interconnection between wells.

In addition to the transducer water level data, vertical gradients at the VLF may be further evaluated through the installation of a new monitoring well described in Section 2.3.3.1. The new Regional Aquifer monitoring well will be considered for installation if necessary to define flow paths in the Regional Aquifer. Should this well be installed, it will be considered for completion as a multiport well. The proposed well will be paired with MW-27 to define vertical gradients between the deeper portion of the Regional Aquifer and the CC3 unit monitored at MW-27. The collocated wells (MW-27 and new Regional Aquifer well) would be useful for defining vertical hydraulic and chemical gradients. Defining these gradients and establishing vertically distributed monitoring points within the Regional Aquifer and overlying perched zones will further the understanding of groundwater flow in the Regional Aquifer and be useful for defining upgradient and downgradient compliance points within this aquifer.

The new Regional Aquifer monitoring well would be installed using sonic drilling methods, to better define lithologies, hydraulic communication between Cc3 and the Regional Aquifer and horizontal flow paths. Previous monitoring wells at the site were drilled using air rotary methods and predominantly sampled via the cuttings discharge which provides highly disturbed samples. Sonic drilling methods provide a relatively undisturbed core sample throughout the drilling depth and typically do not require the addition of water allowing for detection of perched zone and discrete fine-grained aquitard horizons. Drilling the well using sonic methods will permit detailed logging of the soil and groundwater conditions and improve understanding of site hydrostratigraphy. The well will be drilled using sonic drilling methods and will be completed as a multilevel monitoring well. Installation methods for the monitoring well are presented in Appendix B. Installing the well as a multiport completion would be useful for defining vertical hydraulic and chemical gradients. Installation of a multiport monitoring well will require a variance from Ecology. Drilling the well using sonic methods will permit detailed logging of the soil and groundwater conditions and improve understanding of site hydrostratigraphy.

A variance will be sought from Ecology to allow installation of a multiport well such as a Solinst Multilevel Groundwater Monitoring system. If allowed, the system would be installed with 4 ports used to monitor the Regional Aquifer at the following depth intervals:

- Approximately 230 feet in a water-bearing zone indicated on the well log for the overdrilled section of MW-27;
- At about 220 feet in a water-bearing zone, indicated on the overdrilled section of MW-27;
- About 190 feet at about the same zone as MW-27 screen interval; and
- Approximately 135 feet in a perched zone noted during drilling of MW-27.

The deeper multilevel ports will be fitted with dedicated pressure transducers for obtaining water level data. Water levels will be obtained manually in the shallower ports. The deeper ports will be fitted with dedicated sampling pumps.

If Ecology will not permit the multilevel installation, then a single dedicated monitoring well would be installed to monitor the Regional Aquifer zone beneath the MW-27 completion interval.

2.3.4 Monitored Natural Attenuation Evaluation

Halogenated volatile organic compounds (HVOCs), predominantly vinyl chloride (VC) and cis-1,2-dichloroethene (cis-1,2-DCE), have been detected in the downgradient monitoring wells screened in the Cc2 sand unit, as well as in seeps on the western hillslope which discharge from the Cc2 unit. Monitored natural attenuation may be appropriate as a remediation strategy at the site as HVOC concentrations in individual monitoring wells have been decreasing over time, and HVOC concentrations also decrease between wells and seeps along the same flow path.

The available data (Appendix D) supports natural attenuation of chlorinated solvents along the flow-path in the Cc2 unit, and time trends suggest that concentrations will continue to decline. The slow decline in concentrations of vinyl chloride is consistent with degradation of chlorinated solvents under anaerobic conditions.

2.3.4.1 Landfill Geochemical Conditions

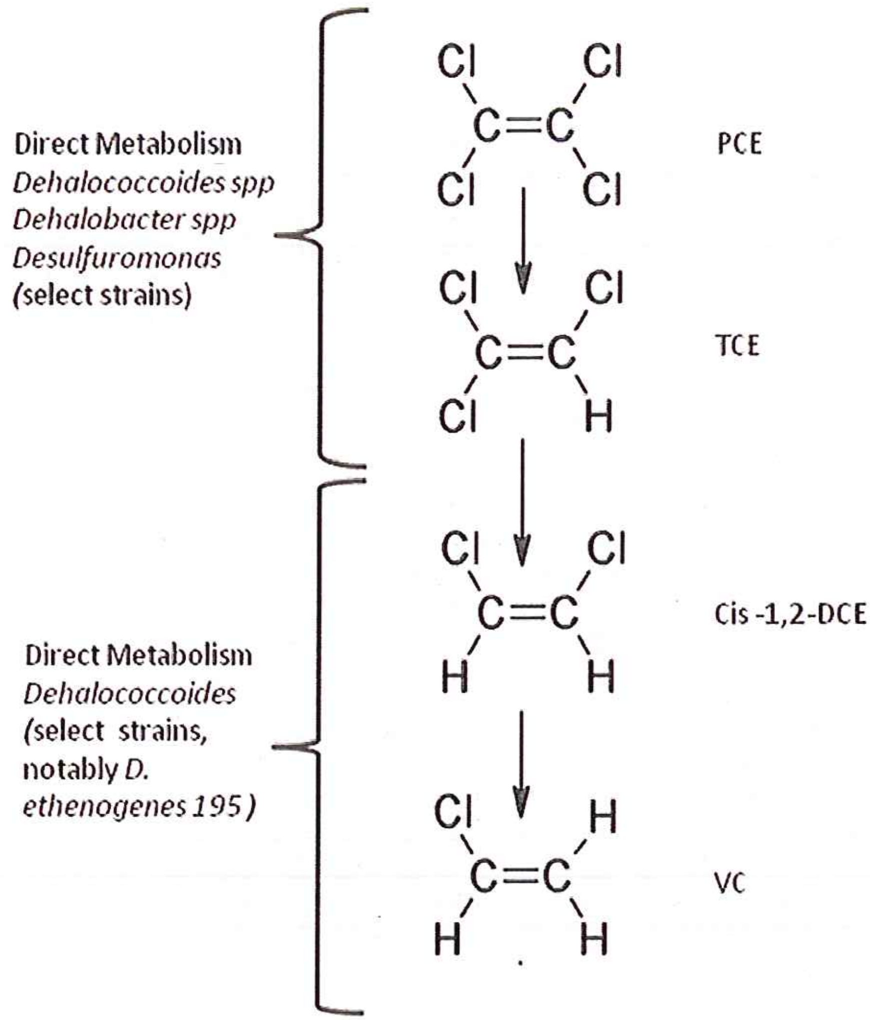
Landfill leachate is generated when water comes into contact with refuse. The quantity of leachate generated at the VLF is limited at this time as the bulk of the refuse area was lined and capped during landfill closure. Leachate that infiltrates or is in contact with groundwater introduces a complex mixture of organic and inorganic contaminants to groundwater and typically leads to development of characteristic geochemical conditions and gradients within the groundwater aquifer system. Decomposition of the buried solid waste mass creates a dissolved organic carbon (DOC) source that supports microbial communities present in the groundwater system. Geochemical redox zonation develops in the groundwater system adjacent to, and surrounding, the source of elevated DOC. The organic compounds in landfill leachate provide an energy source (electron donor) for microbial metabolism. The consumption of organic matter requires a terminal electron acceptor. Electron acceptors are used in a specific sequence, which is related to the energy associated with each terminal electron accepting process (TEAP). The most energetically favorable TEAP is aerobic respiration. Once oxygen is depleted, it is replaced in turn by nitrate reduction, manganese oxide reduction, iron oxide reduction, sulfate reduction and finally methanogenesis, in which carbonate is the electron acceptor.

As a result of these processes, anaerobic groundwater conditions are developed near the source of elevated DOC as the microbial community consumes the organic carbon and electron acceptors. The DOC concentrations decrease moving away from the source, creating a sequence of redox zones starting from methanogenic and sulfate-reducing conditions closest to the landfill and progressing to nitrate-reducing and aerobic conditions at the fringes of the impacted groundwater (Bjerg et al., 2011). Methanogenic conditions are typically limited to strictly anaerobic conditions near the landfill core.

2.3.4.2 Biodegradation Halogenated Volatile Organic Compounds

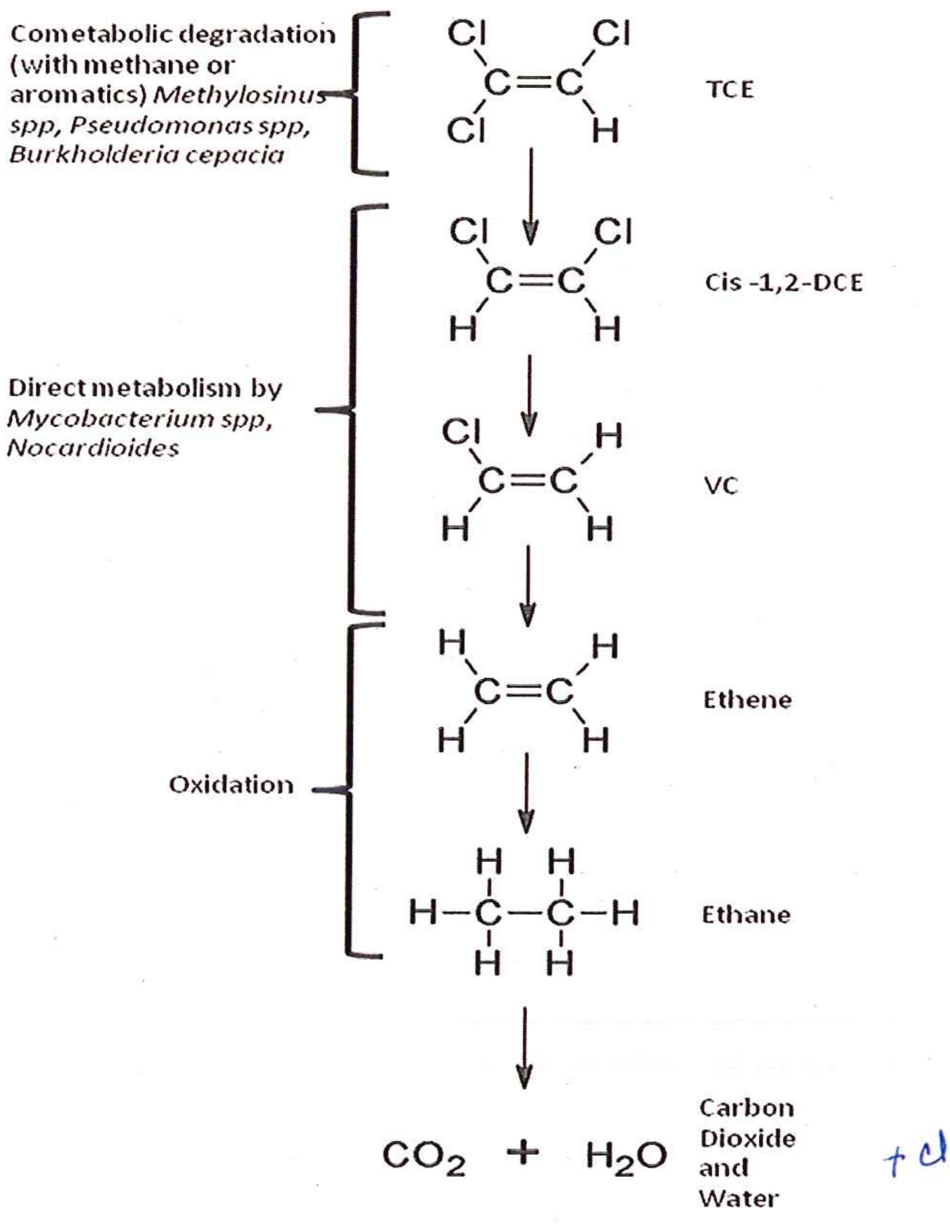
HVOCs can be degraded in the environment under both aerobic and anaerobic conditions. Under anaerobic conditions, HVOCs also act as terminal electron acceptors (TEAs), with their sequence of utilization depending on the chlorine number of the molecule. Reductive dechlorination of higher chlorinated HVOC parent compounds such as PCE and TCE into daughter products such as cis-1,2-DCE and VC is favorable under the anaerobic conditions typical of landfill environments. Degradation of the lower chlorinated HVOC daughter compounds generally occurs at slower rates under anaerobic conditions, so that compounds such as cis-1,2-DCE and VC may be detected in groundwater further downgradient from the source. However, biodegradation of these compounds can be achieved under aerobic conditions.

Under anaerobic conditions, PCE is biotransformed via reductive dechlorination sequentially to TCE, cis-1,2-DCE, VC, and ultimately ethene. Small amounts of trans-1,2-DCE and 1,1-DCE may also be formed (and subsequently degraded) in this breakdown sequence. Reported anaerobic biodegradation half-lives for breakdown of cis-1,2-DCE range from a few months to a year (Barbee, 1994) and much longer for VC, which can persist under anaerobic conditions (estimated half-life of 12 years; Butler 1994). While many microorganisms are capable of utilizing PCE and TCE as a primary substrate for reductive dechlorination, including many species of *Dehalococcoides* and *Dehalobacter*, and select species of *Desulfuromonas,* only a few microorganisms are known to be capable of reductive dechlorination of cis-1,2-DCE and VC, most notably *Dehalococcoides ethenogenes 195*.



Reductive dechlorination pathway of HVOCs under anaerobic conditions (after Vogel et al, 1987; ITRC, 2011; Holliger et al, 1999; University of Minnesota Biocatalysis/Biodegradation Database).

Under aerobic conditions, TCE can be dechlorinated cometabolically by microorganisms utilizing methane or aromatic hydrocarbons such as toluene. The less chlorinated daughter HVOCs can also be completely dechlorinated to ethene. Degradation of cis-1,2-DCE and VC is typically more rapid under aerobic conditions, with a median reported half-life of 8 days for VC (Suarez and Rifai, 1999). Ethene is then oxidized to ethane and ultimately mineralized to carbon dioxide and water.



Biodegradation pathway of HVOCs under aerobic conditions. (after Bradley and Chapelle, 1998; Chu et al, 2004; Coleman et al, 2002).

Groundwater conditions observed at the VLF are consistent with HVOC degradation under anaerobic conditions, with elevated iron concentrations (indicative of iron-reducing conditions), and detections of cis-1,2-DCE and VC in some Cc2 wells (especially MW-5D). Cis-1,2-DCE and VC detections in the downgradient wells and seeps could also result from anaerobic degradation within the landfill followed by transport of daughter products in LFG as discussed in Section 6. PCE was detected in landfill gas during the 2003 VOC sampling event. TCE, cis-1,2-DCE, and VC have been detected in groundwater in the Cc2 unit downgradient from the landfill. Conditions that support reductive dechlorination will be evaluated for the VLF.

2.3.4.3 Natural Attenuation

Natural attenuation comprises all the naturally occurring processes that can reduce the concentration, mass, mobility, or toxicity of a contaminant in groundwater. These processes can be destructive or non-destructive and include: dilution/dispersion, volatilization, sorption, chemical stabilization, and biodegradation/biotransformation. For HVOCs, biodegradation and biotransformation are the primary natural attenuation processes that convert and eventually break down contaminants to less toxic and harmful compounds.

Practical application of natural attenuation as a remediation strategy includes establishing and confirming multiple lines of evidence to demonstrate contaminant mass removal. The primary and secondary lines of evidence (EPA, 1998) that will be evaluated include:

Decreasing Contaminant Trends – Contaminant concentration time series plots will be evaluated for evidence of decreasing or stable trends over time. This is a primary line of evidence that natural attenuation is occurring at the Site. See Appendix D for a preliminary evaluation of trends.

Geochemical Redox Indicators – Geochemical parameters that document groundwater redox conditions conducive to degradation and transformation of HVOCs provide a secondary line of evidence that natural attenuation is occurring. Oxidation-reduction potential (ORP) and pH provide basic information on geochemical conditions. Specific geochemical indicators of groundwater redox zonation and TEAP distribution include:

- Aerobic: dissolved oxygen;
- Nitrate reducing: nitrate, nitrite, and ammonium;
- Manganese reduction: dissolved manganese;
- Iron reduction: dissolved ferrous iron;
- Sulfate reduction: sulfate and sulfide;
- Methanogenesis: alkalinity and methane

In addition to these indicators, ethene and ethane are specific indicators of complete HVOC degradation.

Molecular Diagnostic Tools – In addition to decreasing contaminant trends and geochemical parameters, more recently developed molecular biological tools can potentially provide definitive lines of evidence for biodegradation of HVOCs. These tools include:

- compound specific isotope analysis (CSIA) of carbon in HVOCs to document that individual HVOCs are undergoing degradation;
- quantitative polymerase chain reaction (qPCR) analysis for identification and quantification of organisms known to degrade HVOCs; and
- phospholipid fatty acids (PLFA) to confirm the presence of an active microbial community capable of biodegradation HVOCs.

2.3.4.4 Evaluation of Site Geochemical Conditions and Natural Attenuation

The purpose of this task is to evaluate the geochemical conditions within the Cc2 sand unit and develop lines of evidence to document ongoing biodegradation and assess the intrinsic capacity of the aquifer for HVOC degradation. This evaluation supports analysis of engineering controls in assessing whether monitored natural attenuation is an appropriate approach for limiting HVOC occurrence downgradient of the site.

As part of the natural attenuation evaluation, a statistical evaluation of recent concentration trends with time will be developed for HVOCs in each well. Trends will be classified as either increasing, decreasing, stable, or uncertain.

The following groundwater geochemical data will also be evaluated:

- Field parameters: temperature, pH, conductivity, dissolved oxygen, ORP, and turbidity
- Alkalinity
- Nitrate
- Nitrite
- Ammonium
- Manganese
- Ferrous iron (measured in the field) and dissolved iron
- Sulfate
- Sulfide
- Methane
- Ethene
- Ethane

In addition to HVOCs, parameters listed above which are not currently included in the existing VLF monitoring data set will be added during the next quarterly sampling event. Sampling for these additional parameters will be conducted in Cc2 wells (MW-5D, MW-21, MW-2, and MW-20) and the seeps at the southern end of the landfill. Leachate samples will also be collected and analyzed for HVOCs, leachate parameters, and geochemical redox indicators.

Pending review of the results of the expanded geochemical sampling, additional lines of evidence will be considered as appropriate. If sufficiently high HVOC (PCE, TCE, cis-1,2-DCE, and/or VC) concentrations are detected for CSIA, sampling of leachate, wells MW-5D and MW-21, and seeps SW-2 and SW-4 would be performed for stable carbon isotope ratios (13C/12C) in these compounds. Depending on HVOC compound distributions and inferred redox conditions in leachate and specific wells and seep locations, additional sampling for qPCR may also be proposed during a subsequent sampling event.

2.3.5 Develop Site Water Balance

The West Hillslope investigation indicates that the springs located along the West Hillslope discharge from the Cc2 unit. These springs, as well as Cc2 monitoring wells, at the south end of the VLF have shown landfill related groundwater quality impacts. A water balance of the Cc2 unit should be developed to evaluate the need for improving current controls and assist in site monitoring. A water balance would address whether most discharge from Cc2 is occurring at the springs or is moving downward in the Regional Aquifer.

The water balance will compare recharge estimates for the Cc1 and Cc2 units for the purpose of determining potential for downward migration to the Regional Aquifer. The analysis will also provide insight into the site flow paths and the potential for windows between the Cc1 and Cc2 units. Because recharge can only be estimated indirectly, there will be uncertainty in the analysis, but multiple methods will be employed to reduce uncertainty.

Cc1 recharge will be estimated using a conventional water budget approach and from water level fluctuations measured in monitoring wells. The water budget approach uses the basic equation:

Recharge = Precipitation – Runoff-ET+/- changes in storage

The Water Level Fluctuation Method computes recharge based on observed water level changes. The method requires measured water level changes in the Cc1 aquifer and estimated values of aquifer specific yield. More closely spaced water level measurements provide better estimates for refining the water budget. Water level data collection described in Section 2.3.1 will be utilized as well as long-term water level data.

Recharge to the Cc2 unit will be computed based on spring discharge estimates. The springs have monthly discharge measurements from the period November 2006 to October 2010. Estimating total annual discharge will require synthesizing discharge data based on correlation to precipitation. Test correlations will be developed between monthly discharge measurements and precipitation (e.g., antecedent 2-week period or antecedent 1-month period) to determine the best correlation. This analysis will assume the contributing area to the springs is equivalent to the surface water divide for purposes of converting the discharge to inches of recharge water. An alternative analysis will be performed assuming the contributing area to the Cc2 unit is the mapped lateral extent of the unit.

Recharge to the Cc2 unit estimated from spring discharge will be compared to recharge occurring to the Cc1 unit to evaluate if the majority of the discharge to the Cc1 occurs to the springs or if a considerable differential exists that could indicate significant downward movement to the Regional Aquifer. The estimates of downward migration will be compared to downward flow estimates based on the hydraulic properties (determined in Section 2.3.2) of the units and on vertical gradients (determined in Section 2.3.3.2).

Obtaining flow records from Pump Station No. 2 would also be useful to assist in developing the site water balance. Pump Station No. 2 flow records could be compared to leachate pump records at Pump Station No. 1. Because wastewater flows from the Transfer Station are not monitored, Pump Station No. 2 flows could be subtracted from Pump Station No. 1 flows to identify the relative contribution of Pump Station No. 2 flow to total wastewater flow.

2.3.6 *Update Groundwater Flow Path Model*

The groundwater flow path model will be updated based on the Regional Aquifer groundwater flow investigation, automated water level data, new monitoring well data, if installed, and water balance results. Age-dating of groundwater described in Section 2.4.3 will be integrated into the analysis to provide an independent line of evidence for the site flow model.

2.4 Source Related Investigations

In an investigation of LFG as a potential contaminant source, Berryman & Henigar (February, 2006) conclude that leachate may have been a dominant factor influencing groundwater quality historically, current leachate influences are minimal, and LFG is the dominant factor controlling water quality impacts in recent years.

A subsequent analysis by Berryman & Henigar, and Udaloy Environmental Services (March, 2006) indicated that the north end of the facility (1988 closure area and West Perimeter Road) was a possible current LFG pathway. The south slope area was also described as a potential LFG migration pathway. Leachate generation in the North Area was considered to be small, while the South Area was considered as a potential current source of leachate. Section 2.4.1 describes work elements to evaluate the South Area as leachate source.

Review of previous studies indicates that both LFG and leachate could potentially be affecting water quality at the VLF, as discussed below.

2.4.1 *Leachate*

The following sections focuses on leachate from the unlined refuse in the South Area of VLF and characterization from within the existing leachate collection system.

2.4.1.1 South Area Refuse on Unit B Soils

An evaluation of historical and current contaminant transport pathways indicates that the unlined south slope area (South Area) could potentially be generating leachate. The unlined South Area was stabilized with a geotextile and covered with a native soil cover and has been documented as an area where till is absent and refuse is present on Unit B soils. The South Area also coincides with the area mapped as having direct contact between the Cc1 and Cc2 units. Refuse within the South Area appears to have been historically placed in a former ravine. The conceptual model of contaminant flow paths (Berryman & Henigar, et al., 2006) concludes this is the most likely pathway for potential contaminant migration. A new monitoring well (proposed well MW-33) will be installed on the east side of the leachate lagoon, adjacent to this area to evaluate the potential for deeper subsurface LFG and leachate migration from the former ravine. The well will target the Cc2 aquifer as a completion zone. The proposed location for the monitoring well is presented on Figure 4.

The well is located within the mapped extent of refuse and could potentially encounter refuse during drilling. As such, the well should be drilled with a dual casing to minimize potential for contaminant drag down. The drilling method is presented in Appendix B. The well will be constructed with an unsaturated screen above the water table to permit collection of LFG samples as well as groundwater samples. The well will target the Cc2 aquifer as a completion zone.

During drilling of Regional Aquifer monitoring well, we will monitor water levels and specific conductance. These data along with the geochemical and landfill gas analysis will be used to assess the need for an additional well in the Cc2 unit. A new Cc2 well could be used to define vertical and hydraulic gradients between the Cc2 and Cc3 unit, if paired with a Cc3 well such as MW-27. Alternatively, a new Cc2 well installed at the southwest corner of the refuse mass in the Cc2 would assist in bounding the northern extent of impacts to the Cc2 unit and assist in differentiating between impacts occurring from the main refuse mass and the South Slope Area.

2.4.1.2 Leachate Source Sampling

Leachate from VLF and transfer station is collected and conveyed to the leachate detention lagoon located southwest of the closed landfill. All leachate, condensate, and sanitary flows generated on-site flow to this detention lagoon through a leachate conveyance structure identified as "Leachate Box" and designated LVB. Periodically, leachate is removed from the leachate detention lagoon by pumping to a tanker truck that discharges to King County's Sanitary Sewer system. Currently, leachate samples are collected at the LVB located upstream of the leachate detention pond and from the tanker truck prior to discharging to King County's sanitary sewer system.

The LVB structure collects flows from the landfill, transfer station, sanitary facilities associated with the transfer station and the water discharged from Pump Station No. 2. Pump Station No. 2 receives subsurface flow from underdrains and leachate collectors draining water from some unlined portions of the landfill. The samples are collected from a small plastic container that collects the flows from the influent leachate collection piping. The LVB structure and Pump Station No. 2 are shown in Appendix A, Photos 1-4 and 1-5, respectively.

However, this setup allows the influent leachate to cascade into the LVB structure providing a chance for VOCs in the leachate to be released to the atmosphere, thus, not presenting an accurate representation of the leachate being collected from unlined refuse areas. In addition, when Pump Station No. 2 discharges to the LVB structure, the structure becomes flooded and the sampling container is filled with a mix of fluids, including the sanitary flows from the transfer station.

The samples collected at LVB are representative of the flow to the leachate detention lagoon. However, due to the mixing in the structure, it is not possible to isolate what is coming from the three different sources with the current sampling methodology. Adding a sampling point that provides a more representative sample of the leachate collected at Pump Station No. 2 from unlined areas would be beneficial for characterizing the leachate. A better representation of the concentrations of constituents in the leachate will permit better assessment of whether leachate is impacting off-site sources such as the west slope springs. A potential location for an additional sampling point is Pump Station No. 2, which receives only flows from unlined portions of the VLF. Leachate sample locations are presented on Figure 5.

It is also important to note that samples collected in open containers below outfall pipes are likely to lose VOCs during sample collection. In order to ensure VOC concentrations are representative of leachate, it will be important to collect separate samples from Pump Station No. 2 flow and from the lined refuse area, as well as modifying the sampling procedure such that sample bottles are not open to air during sample collection. An airtight attachment should be placed over the pipe that fits to a sampling tube that is used to fill the bottle with minimal aeration or exposure to the atmosphere. A sampling methodology will be developed to provide a more representative sample of the VOC content of the leachate.

Sampling from the tanker truck is a permit requirement for discharge to the sanitary sewer system and should be continued.

2.4.2 Landfill Gas

Landfill gas (LFG) is a potential source of groundwater contaminants at VLF. LFG investigation components related to source identification are described in Section 6.

2.4.3 Investigate Historic/On-going Impacts

The primary objective of this task is to differentiate historical from on-going impacts. The chemical and isotope tracer methods described below to achieve this objective will also provide data to assist in differentiating between leachate and landfill gas sources within the Cc2 unit and seeps. The impacts observed at MW-5D and the seeps could be due to a current or historic leachate or landfill gas release. A preliminary evaluation of source indications provided by analysis of existing data is presented in Appendix D.

Additional sampling is recommended in order to assess the relative contribution of leachate and/or LFG to HVOCs in downgradient wells and seeps. Leachate VOC samples have historically been collected in a manner that is not ideal for obtaining VOC concentrations representative of leachate conditions, and VOC concentrations in LFG have only been measured during a single sampling event. As discussed in Section 6, a new round of LFG VOC sampling is proposed using a modified sampling procedure in order to collect representative gas samples as well as collection of representative samples of VOCs in leachate. While previous investigations (Berryman & Henigar and Udaloy Environmental Services, 2004) focused on differentiating between leachate and LFG impacts, the sampling proposed in Section 6 will be used to investigate the various parts of the LFG system to determine potential areas of fugitive LFG.

2.4.3.1 Sampling for Chemical and Isotope Tracers

Several potentially useful chemical and isotopic tracers are also available that could help identify contaminant sources and pathways more conclusively. Analysis for selected chemical and isotopic tracers in landfill leachate, LFG, upgradient and downgradient wells, and seeps would allow for estimating the groundwater travel times and the relative age of water quality impacts between sampling locations as well as for distinction between leachate and LFG impacts, These tracers include:

- Radiocarbon (^{14}C)
- Tritium (^{3}H), in combination with helium-3 (^{3}He)
- Atmospheric chlorofluorocarbons (CFCs)
- Sulfur hexafluoride (SF_6)
- Stable isotope ratios of hydrogen (D/H) and oxygen ($^{18}O/^{16}O$) in water
- Stable isotope ratio of carbon ($^{13}C/^{12}C$) in dissolved organic carbon (DOC), dissolved inorganic carbon (DIC), and methane
- Stable isotope ratio of sulfur ($^{34}S/^{32}S$) in sulfate

Multiple tracers are typically analyzed to provide a more comprehensive evaluation. A preliminary evaluation based on limited site-specific data collection is often necessary to determine which tracer(s) will be most useful.

The potential relevance of these tracers is discussed in more detail below.

- The introduction of large quantities of very recent biogenic carbon in the landfill generates an elevated radiocarbon signature in organic and inorganic carbon compounds in the leachate and landfill gas derived from decomposition of organic matter. This elevated radiocarbon signature may be a sensitive indicator of leachate or LFG impacts if it is distinguishable from background radiocarbon levels, which decrease with the age of the groundwater (e.g., Kerfoot et al., 2003).
- Tritium is useful for identifying young groundwater (<60 years old) and, when measured in conjunction with helium-3, estimating the groundwater age. Comparison of tritium levels between upgradient and downgradient sampling points could be useful in elucidating flow paths and timescales within the Cc2 unit. However, tritium may also be elevated above ambient levels in landfill leachate and LFG (Mutch et al., 2007). Measurement of tritium and helium-3 in wells and seeps could still be useful in estimating groundwater age and travel times. Additionally, if tritium levels are found to be elevated in the landfill leachate, measurements in downgradient wells and seeps may provide a means to distinguish between leachate and landfill gas as a source of HVOCS (Kerfoot et al., 2003).

- CFCs derived from the atmosphere are also used for determining groundwater ages of young waters recharged since the 1940s. However, the usefulness of CFCs for this purpose at the Site may be limited if the landfill is a source of these compounds, in which case CFCs could be more useful as a tracer of landfill impacts.
- Sulfur hexafluoride may be more useful for determining groundwater age than CFCs, as the landfill is less likely to be a source of sulfur hexafluoride, which is predominantly an industrial refrigerant. Sulfur hexafluoride in the water should therefore reflect atmospheric levels when recharge occurred. The range of applicability is from the mid-1970s to present. Thus, if downgradient HVOC impacts are from leachate, sulfur hexafluoride dating could distinguish between pre-closure versus post-closure releases and inform evaluations of the effectiveness of engineering controls in place since landfill closure in 1999.
- Stable isotope ratios of oxygen and hydrogen in water provide information of water sources. Enriched hydrogen isotope ratios may also be an indicator of landfill impacts (Hackley et al., 1996).
- Stable carbon isotopes of dissolved organic carbon (DOC), dissolved inorganic carbon (DIC), and methane in HVOC-impacted groundwater could be compared to background groundwater, leachate, and LFG to determine whether HVOC impacts are associated with leachate (similar $^{13}C/^{12}C$ in DOC and DIC but not methane) versus LFG (similar $^{13}C/^{12}C$ in methane and DIC but not DOC) (Mohammadzadeh and Clark, 2011; North et al., 2004).
- Stable isotopic analysis of sulfate/sulfur could be used to assess leachate impacts downgradient, as $^{34}S/^{32}S$ should be enriched in groundwater impacted by leachate compared to sulfate in upgradient wells (Fritz et al., 1994).

Representative sampling of VOCs in leachate and LFG will be supplemented with chemical and isotope tracer data to provide a comprehensive data set for understanding sources and pathways of HVOC impacts in Cc2 groundwater and seeps, including evaluating historic versus recent or ongoing leachate release versus LFG transport. An initial assessment phase will include collecting data for the tracers discussed above from leachate, LFG , MW-20, MW-5D, and seep SW-3. This initial evaluation would determine a list of selected tracers that are most useful. Additional subsequent sampling for this subset of tracers will be carried out for wells MW-2, MW-21, MW-33 (new Cc2 well) and seep SW-2.

3 Groundwater Monitoring

This section describes improvements to monitoring wells, evaluation of compliance wells, and statistical methods. These work elements are proposed to improve monitoring efficiency and quality.

3.1 Infrastructure Upgrades

Upgrades to the monitoring well infrastructure identified from the site visit and a review of well logs are described below.

The well completion log for monitoring well MW-5S indicates no well seal other than in the upper 3 feet. The well was installed in 1986 and would not meet current monitoring well standards. Monitoring well MW-5S is a part of a multi-completion well and is completed with MW-5D and a shallow gas probe in the same 8-inch borehole. We understand from the site visit that MW-5D has accumulated sediment and experiences iron staining. We also understand that a downhole video survey of this well has been conducted. At a minimum, the down-hole video survey should be reviewed and the well redeveloped. Decommissioning and replacement will be evaluated based on results of the video survey.

Monitoring well MW-1 has a loose monument and should be evaluated to determine if the well should be repaired or decommissioned. A down-hole video survey should be performed to verify well integrity and evaluate if this well should be decommissioned.

Access improvements to sampling points west of the Westside Highway should be considered based on observations during the site visit. Access improvements to the sampling points could be considered to reduce the potential for injury to people collecting samples and reduce time and effort needed for sample collection. However, it is necessary (for public safety) to minimize the visibility of a trail at this location. Maintenance or modifications of the weirs will be required to maintain their ability to provide volatilization of VOC constituents. A site job shed with tools and equipment for repairs would be beneficial, as the existing site is littered with construction materials and tools. Design of the access trail modifications could conform to the minimum requirements of the National Park Service Trail Standards.

Future sampling protocol for the West Hillslope will be developed. The condition of seepage samplers and weirs will be evaluated and upgraded as appropriate. During the West Hillslope investigation (King County., 2011) seepage samplers were installed at six seep locations (stations SW-S1 through SW-S6). The samplers were temporary and designed for the duration of the study. The functionality of these seepage samplers will be evaluated through pumping and/or bailing to check for screen plugging and turbidity. Seepage samplers will be replaced and/or redeveloped as necessary based on this evaluation. A likely option for replacement will be use of pre-pack well screens at these locations. Weir locations will also be evaluated for leakage and sediment infill. Leaking weirs will be removed and reinstalled. Where the v-notch of the weir is submerged by sediment infill , the sediment will be removed to create a pool upstream of the weir and a free falling nappe. Sampling protocol for the seep samplers, weirs, and West Hillslope monitoring wells will be developed.

3.2 Evaluate Point Of Compliance Wells

The groundwater monitoring network and point of compliance (POC) wells will be reevaluated under this task. Under WAC Chapter 173-351-450, alternate groundwater monitoring programs may be proposed following the second year of groundwater monitoring. The monitoring network was last evaluated in 2004 and should be reevaluated based on more recent analytical data and the studies being performed as part of this work plan. The evaluation will entail identifying an appropriate subset of wells/springs for detection monitoring, including sampling frequency and analytical testing scheme.

3.3 Evaluate Assessment Monitoring Statistical Methods

The current monitoring program will be evaluated for compliance with assessment monitoring under WAC Chapter 173-351-440. An August 30, 2010 letter from Ecology indicates that there were several Upper Prediction Limit (UPL) exceedances, using the interwell comparison and that the interwell exceedances may be triggered by sources other than the VLF. The calculation of the UPL and interwell versus intrawell comparisons will be considered in the assessment monitoring evaluation.

4 Surface Water Monitoring

Surface water quality monitoring is conducted at two locations on-site as well as at springs and weirs located several hundred feet west of the Westside Highway SW. Section 4.1 describes surface water quality monitoring on-site. A preliminary overview of potential improvements to the surface water infrastructure is presented in Section 4.2. These modifications will be addressed under Task 310.

4.1 Surface Water Monitoring On-Site

Surface water monitoring at the VLF is conducted at two locations on-site. The monitoring points are located near the discharge from the Borrow Area Stormwater Pond (SW-D) and at the headwaters of the unnamed tributary downstream from the outfall from the south detention pond (SW-B) just within the County's property line (Figure 4). All surface water flows collected on-site can be monitored at these two locations.

Sampling at SW-D is intended to provide water quality data for surface water run-on from off-site prior to this stormwater being mixed with other surface water generated on-site. The samples taken at SW-B are representative of the water quality of all combined surface water runoff from the VLF. Surface water quality monitoring is scheduled to be conducted quarterly; however, flows at the monitoring locations vary seasonally and during dry summer months there is not always sufficient flow to perform sampling.

A site visit was conducted to observe the surface water monitoring system and document any deficiencies or differences from the documented system. During the site visit, both surface water monitoring locations were observed as were other stormwater collection and conveyance facilities on-site. Both monitoring locations were clearly marked and access was unobstructed.

Sampling location SW-B is within a stormwater manhole where surface water run-on from off-site is combined with flow from the Borrow Area Stormwater Pond. During the site visit, the manhole lid was not opened and the specific location where samples are collected within the manhole was not reviewed. At this location, water samples should be collected only from the off-site contribution prior to mixing with any water from the Borrow Area Stormwater Pond.

At this time, no routine stormwater quality sampling is conducted from different locations within the site. If any surface water quality issues are detected in the future at SW-B, water quality sampling and analysis at different locations within the site might be appropriate to determine where the issues originate.

4.2 Preliminary Review of Potential Surface Water Modifications

4.2.1 Stormwater Collection, Conveyance, and Treatment System Modifications

Stormwater collection, conveyance, and treatment systems on-site were also evaluated. The following stormwater system components were identified for improvement.

4.2.2 South Siltation Pond

The South Siltation Pond is located on the north side of the access road that serves the South Detention Pond located at the southern extent of the VLF property. It was initially installed as an unlined sediment control pond for use during VLF operations. Because the landfill is now closed, the pond is no longer required to function in this capacity. Public health concerns have been raised due to continuous standing water present in the South Siltation Pond. The primary health concern is proliferation of mosquitoes. Since this facility is no longer needed to provide sediment control and is a potential health hazard, modifications to allow the pond to function as a detention pond with no permanent standing water should be considered.

4.2.3 Northwest Landfill Drainage Improvements

Storm runoff at the northwest corner of the VLF property is collected in grass lined drainage ditches that slope to the south end of the landfill. These grass lined ditches are located directly above unlined portions of the landfill. During the site visit to the landfill, it was observed that settlement in the northwest area of the VLF created the potential for ponding in these ditches. Ponding in the grass lined ditches increases the potential for infiltration of stormwater into the unlined refuse. It is recommended that maintenance of these ditches be performed to improve and maintain flow.

4.2.4 Asphalt Ditch Maintenance

The entire east perimeter, south perimeter, and a portion of the west perimeter of the landfill are served with an asphalt lined ditch to convey surface water runoff to the South Siltation and Detention Ponds. During on-site investigations, it was observed that vegetation and debris in the channel of the asphalt lined ditches was significant enough to create ponding. The ditches should be cleaned of vegetation and debris to prevent water ponding.

5 Leachate Monitoring

Work elements to address monitoring of the leachate system and leachate lagoon are discussed below.

5.1 Leachate Lagoon Monitoring/Modifications

The leachate lagoon was constructed before WAC Chapters 173-351 and 173-304 were adopted. At that time, no leak detection layer or double liner was required and none was constructed. Ecology and Health have noted that leakage from the lagoon is possible. Since the landfill was closed, water quality conditions in the lagoon have improved. Recent water quality data from the lagoon will be reviewed to evaluate whether the potential for leakage to negatively impact groundwater quality still justifies investing in a double liner with leak detection layer. Collection of additional water quality data from the leachate pond may be recommended following review of any existing data.

If the water quality review indicates that there is a potential for the leachate pond to impact groundwater, then a leak detection system and a groundwater monitoring alternative will be evaluated. A double liner leak detection system could take advantage of the dead storage at the bottom of the lagoon.

5.2 Leachate Sampling Improvements

As discussed in Section 2.4.1.2, the addition of a leachate sampling point at Pump Station No. 2 and sampling from the leachate pipes at LVB would increase the ability of the County to identify the characteristics of the leachate collected from lined and unlined areas of the landfill and reduce the potential for VOCs to be removed from the leachate before laboratory analysis. The two new proposed locations are presented on Figure 5. Specific sampling methodology, frequency, and analytical test methods will be developed for these locations.

6 Landfill Gas Monitoring/Source Investigations

This section describes investigations to evaluate the landfill gas (LFG) to groundwater pathway at the facility. Data collected during this investigation will also be used to evaluate collection system efficiency and effectiveness.

6.1 Testing/Additional Monitoring

6.1.1 Comprehensive Collection/Extraction Point Monitoring

To assess and evaluate the operation and maintenance of the LFG control system, a comprehensive understanding of the collection system is necessary. During the site visit, many of the lateral and extraction well control valves were either closed or partially open. The current operational strategy is to operate the lateral and extraction well control valves to evacuate LFG matched as closely as possible to the LFG generation rate, by maintaining a slight negative pressure.

Determining the available vacuum, corresponding flow rates, and associated gas concentration range at each collection trench or extraction well control point will be important to determine the range of operating conditions. In turn, the system control strategy can then be assessed.

The LFG system collection points will be evaluated by performing a series of monitoring events at the blower facility, extraction wells, and collection points including, trench risers EF-1, EF-2, and EF-3 each located within 6-inch perforated collection lines. EF-1 and EF-2 are located along the western landfill boundary, and EF-3 is located at the southern boundary.

The monitoring will be performed to determine the maximum vacuum and flow rate at each extraction and collection point in which oxygen concentrations do not exceed 2 percent and the lowest vacuum and flow rate in which the well or trench does not have positive pressure. Two percent is the typical operation value used by King County and is set at a level to prevent internal combustion of landfill material. This will be accomplished by increasing vacuum in steps (to develop a range) and document flow rates and LFG concentrations at all extraction points to verify operating parameters with regards to current operating strategy.

6.1.2 Additional Testing of Gas to Groundwater Pathway

Previous testing of VOCs in LFG had concluded that LFG is the dominant factor controlling groundwater quality (Berryman & Henigar, 2006). The previous investigation focused on assessing LFG in monitoring wells and gas probes. This investigation focuses on identifying specific LFG pathways.

A portion of the landfill was constructed over older refuse and a gas collection gravel layer installed beneath the liner. Potential gas migration pathways will be evaluated by sampling LFG below the liner at EF-1 and comparing it with samples collected from EF-3, located within the unlined portion of the landfill (Figure 6). These data would determine if there is a difference between VOCs generated from the northern and southern portions of the landfill and also determine variability within each trench system.

Three samples will be collected from each location, including an initial sample with no purging, a second sample after purging approximately half the gas in the system and a third sample of gas drawn into the system during purging. A VOC sample also would be collected from the unsaturated portion of the screen in the proposed new monitoring well MW-33. The VOC samples would be analyzed, according to EPA method TO-15.

6.2 Review Current Operating Strategies

Following collection of one round of data from all LFG extraction points, the current operating strategy for LFG control will be reviewed with regard to the existing extraction and collection system efficiency and effectiveness.

The condition and effectiveness of the collection and extraction systems should be assessed to assist in identifying modifications in operating strategy and or recommendations for new infrastructure or abandonment of non-functioning facilities. Monitoring LFG concentrations (O_2, CO_2, and CH_4) and flow will be considered to confirm appropriate valve position (open, partially open, closed) at each extraction point to confirm if extraction matching production rate is adequate for control or if increased active vacuum extraction is beneficial.

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Limitations

Work for this project was performed and this report prepared in accordance with generally accepted professional practices for the nature and conditions of work completed in the same or similar localities, at the time the work was performed. It is intended for the exclusive use of King County Solid Waste Division for specific application to the referenced property. This report does not represent a legal opinion. No other warranty, expressed or implied, is made.

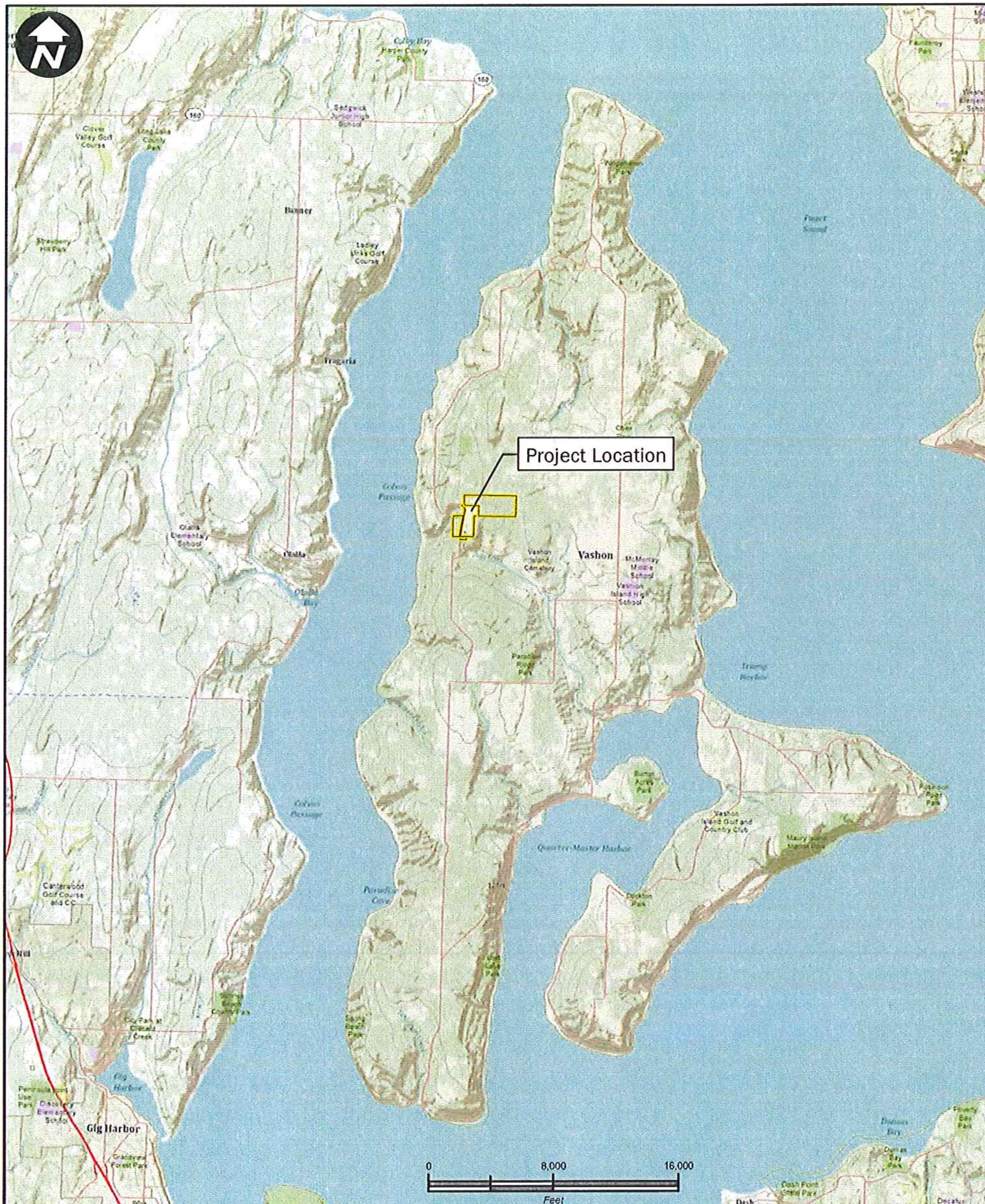
Table 1 - Hydraulic Conductivity Testing: Proposed and Previously Tested Wells

Environmental Review, Investigation and Evaluation Technical Memorandum
(090057 Vashon Island Landfill, King County, WA)

Well[1] Number	Unit(s)[1] Screened	Screen Top (fbgs)	Screen bottom (fbgs)	Static DTW[3] (fbgs) (fbgs)	Well Dia. (inches)	Screen Slot (inches)	Prior Testing Type[2]	Prior Test Result[5] K in ft/min	Well Completion Zone
MW-1*	Cc1	118	128	127.52	3	0.010	Bailer	3.3E-04	Screen in fine to medium sand (SM-SP)
MW-3	Cc1	35	40.15	42.12	3	0.010	Bailer	6.1E-03	Upper 4' of screen in sand (SP) and lower 1' of screen in silt (ML)
MW-4	Cc1	100	110	105.65	3	0.010	Bailer	3.0E-04	Upper 3' of screen in sand (SP) and lower 7' of screen in silt (ML)
MW-5S	Cc1	74	84	dry[4]	2	0.020	Infiltration	5.7E-03	Screen in sand (SP); lower 0.5' of in silt
MW-13	Cc1	108	113	101.32	2	0.020	none		Entire 5' screen completed in a 6' sand (SM-SP) layer between silt (ML) layers
MW-2	Cc2	79	84	74.6	3	0.010	none		Screen in Silt (ML)
MW-24	Cc1	80.5	90.5	89.31	2	0.020	none		Upper 7' of screen in silty sand (SM) and lower 3' of screen in silt (ML)
MW-5D	Cc2	115	126	117.6	2	0.020	Infiltration	3.7E-06	Upper 9' of screen in silty sand (SM) and lower 2' of screen in clayey silt (CH)
MW-9	Cc2	167	177	166.5	2	0.010	Slug Test (RH)	3.2E-02	Upper 2' of screen in gravel (GP) and lower 8' of screen in gravelly sand (SW)
MW-10	Cc1	143	153	145.27	2	0.010	Slug Test (RH)	4.0E-03	Screen in sand (SP-SM)
MW-20	Cc2	127.7	132	123.98	2	0.020	none		Upper 3.8' of screen in sand (SM-SP) and lower 0.5' of screen in silt (ML)
MW-21	Cc2	100.6	110	107.15	2	0.020	none		Entire 9.4' screen in and (SP); silt (ML) layer directly below screen
MW-14	Cc3	161	171	141.91	2	0.020	Slug Test (FH & RH)	2.5E-03	Upper 9' of screen in sand (SP-SM) and lower 1' in silt (ML)
MW-8	Cc3	168	178	177.01	2	0.010	Slug Test (RH)	1.6E-02	Screen in sand (SM)
MW-7	R	220	230	192.43	2	0.010	Slug Test (FH & RH)	6.3E-03	Screen in sand (SP-SM)
MW-12	R	170.5	180.5	142.97	2	0.020	Slug Test (FH & RH)	4.3E-03	Screen in sand (SP-SM)
MW-19	R	259.5	269.5	245.35	2	0.020	Slug Test (FH & RH)	7.2E-03	Screen in sand (SP-SM)
MW-25	R	248.5	262.6	244.02	4	0.040	none		Screen in silty gravel (GP-GM)
MW-26	R	246.1	260.2	246.94	4	0.040	none		Upper 7' of screen in gravel (GW) and lower 7.1' of screen in silty gravel (GC)

Notes:
Gray highlighted rows indicate wells that are proposed to be tested.
fbgs = feet below surveyed ground surface elevation relative to site datum.
K=Hydraulic Conductivity
ft/min=feet per minute
1. Unit Designations (Berryman & Henigar, 2006).
2. FH=falling head slug test, RH=rising head test
3. Static depth to water (DTW) measurements made October 31, 2008 by KCSWD personnel.
4. The water level in Cc1 was below the total depth of MW-5S when measured (10/31/08), so this well will only be tested if the water level is sufficiently high enough during time of testing.
5. Bouwer and Rice method was used for the slug test analysis. For wells with both falling and rising head test results available an average is listed here.
*Well has loose monument.

King County



Project Location Map

DRAFT

Environmental Review, Investigation & Evaluation Technical Memorandum
Vashon Island Landfill, King County, Washington

King County

DATE	OCT 2011
DESIGNED BY	SCC
DRAWN BY	SCC
REVISED BY	-
PROJECT NO.	090057
FIGURE NO.	1

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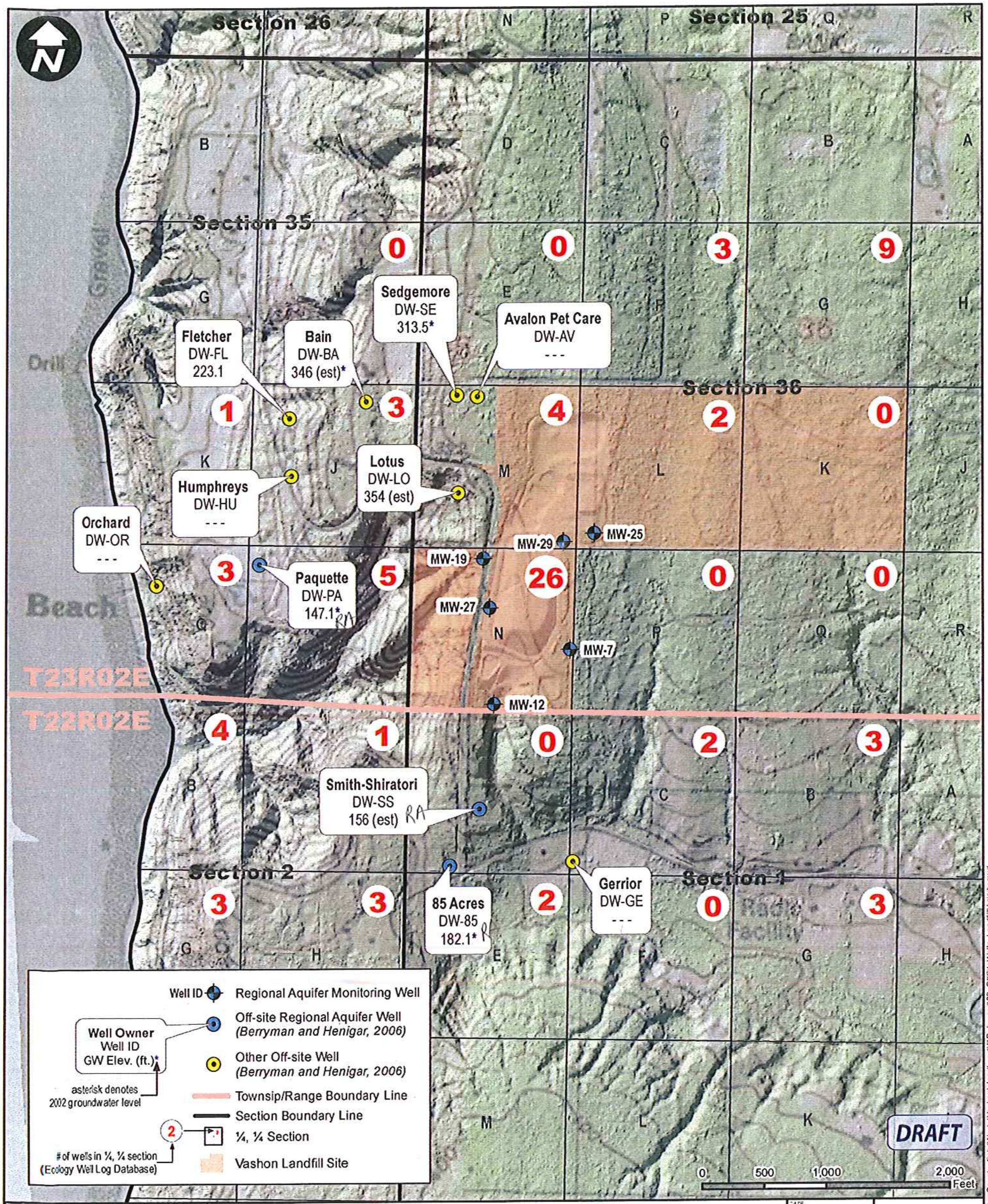
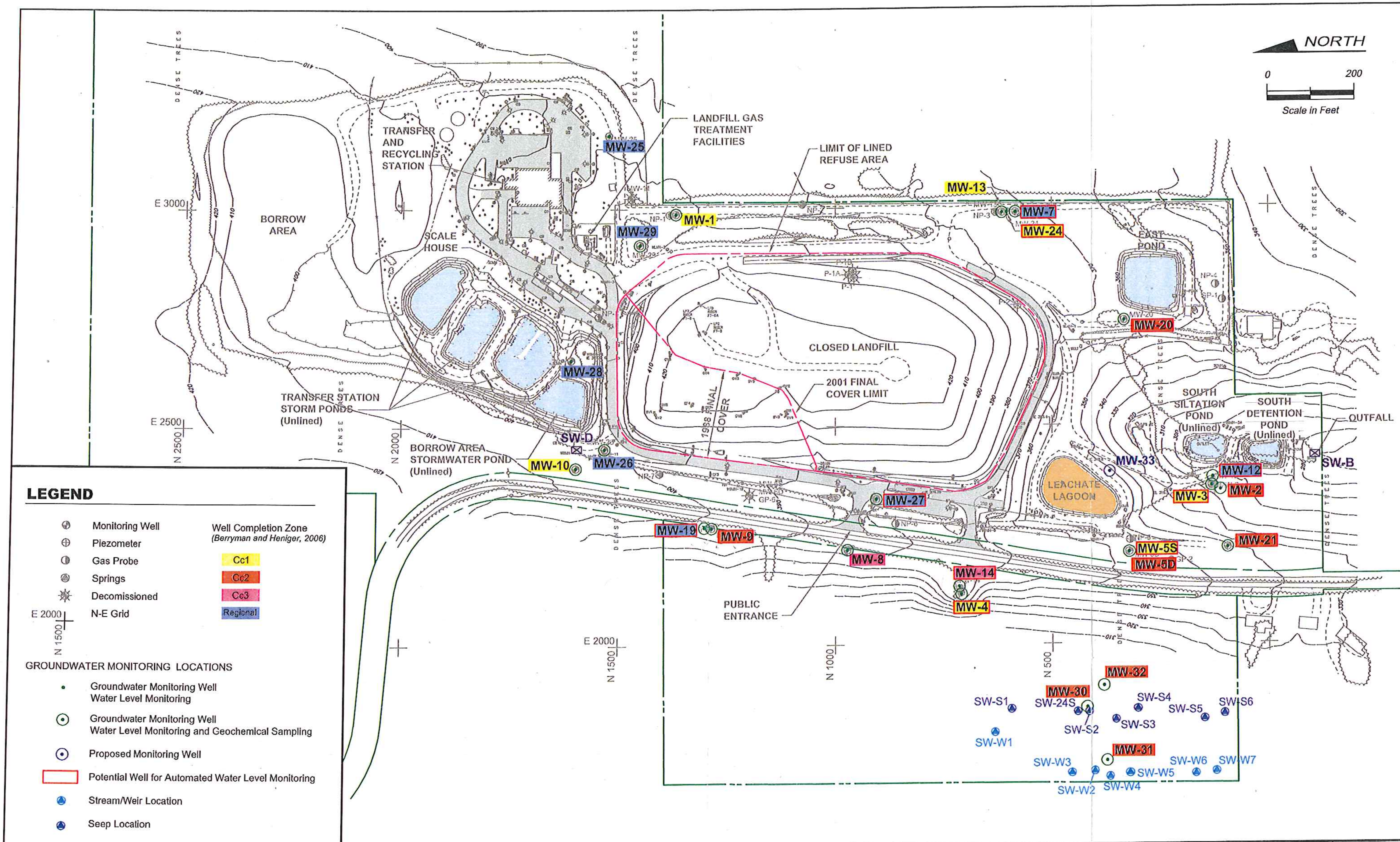


King County

Off-site Wells in Landfill Vicinity

Vashon Island Landfill, King County, Washington

DATE	Oct 2011	PROJECT NO.	090057
DESIGNED BY	EWM		
DRAWN BY	PPW	FIGURE NO.	3
REVISED BY	- - -		



PHOTOGRAMMETRY BY: (3D)I TECHNOLOGIES, INC. 04-26-04
SEEP AND SPRING COORDINATES FROM KCSWD (MARCH, 2011)

DRAFT

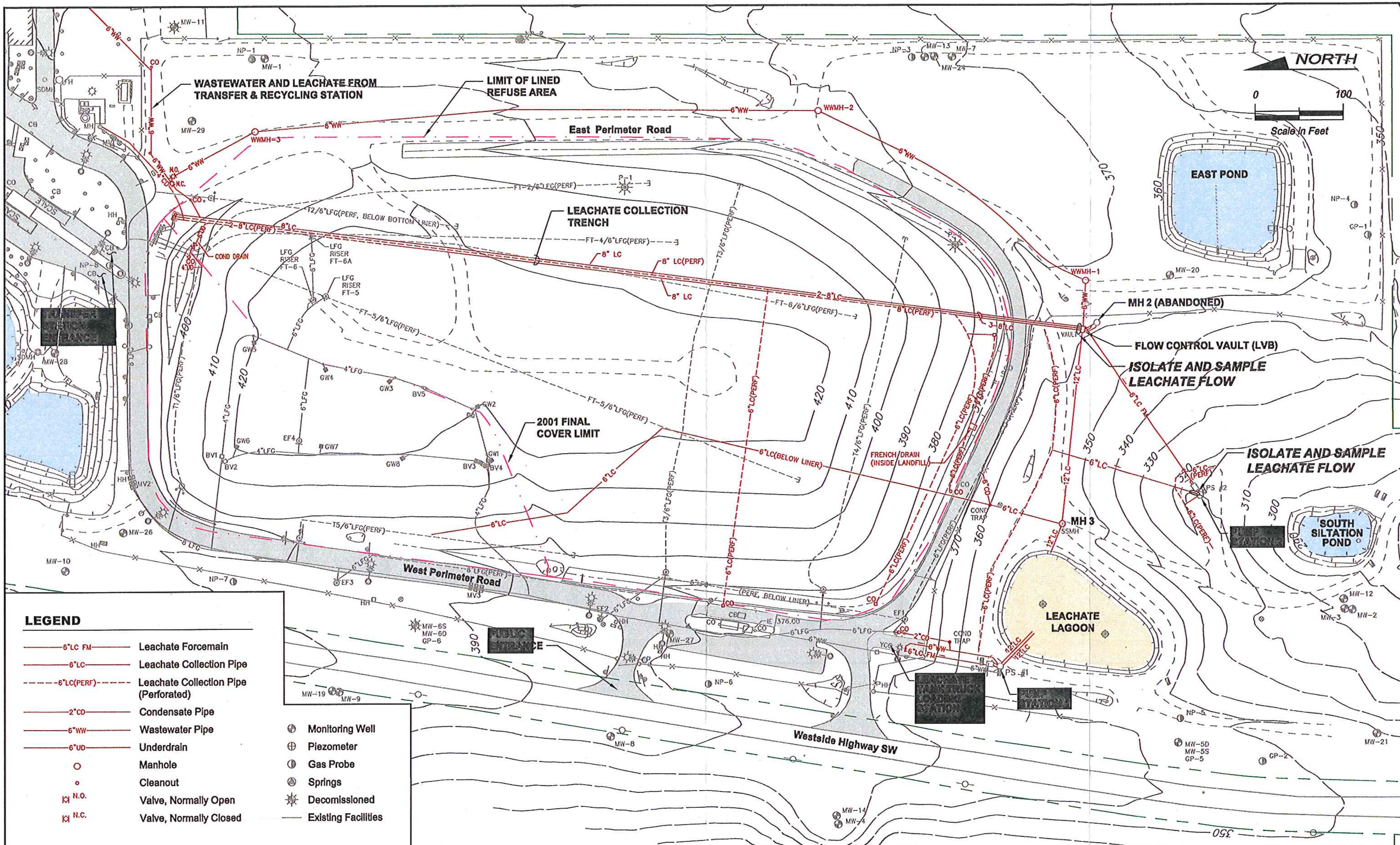
King County

Groundwater and Surface Water Monitoring Locations

Environmental Review, Investigation & Evaluation Technical Memorandum
Vashon Island Landfill, King County, Washington

DATE: OCT 2011	PROJECT NO. 090057
DESIGNED BY: EWM	
DRAWN BY: SCC/PMB	FIGURE NO. 4
REVISED BY: EWM (Feb 2012)	

CAD Path: Q:\King County\090057 Vashon Island Closed Landfill\2012-02 Enviro Review Tech Memo\090057-04.dwg Figure 4 (11x17) || Coordinate System: NAD 1983 State Plane Washington North FIPS 4601 Feet || Date Saved: Feb 29, 2012 4:31pm || User: pbaker



Photogrammetry By: (3D)i Technologies, Inc. 04-26-04

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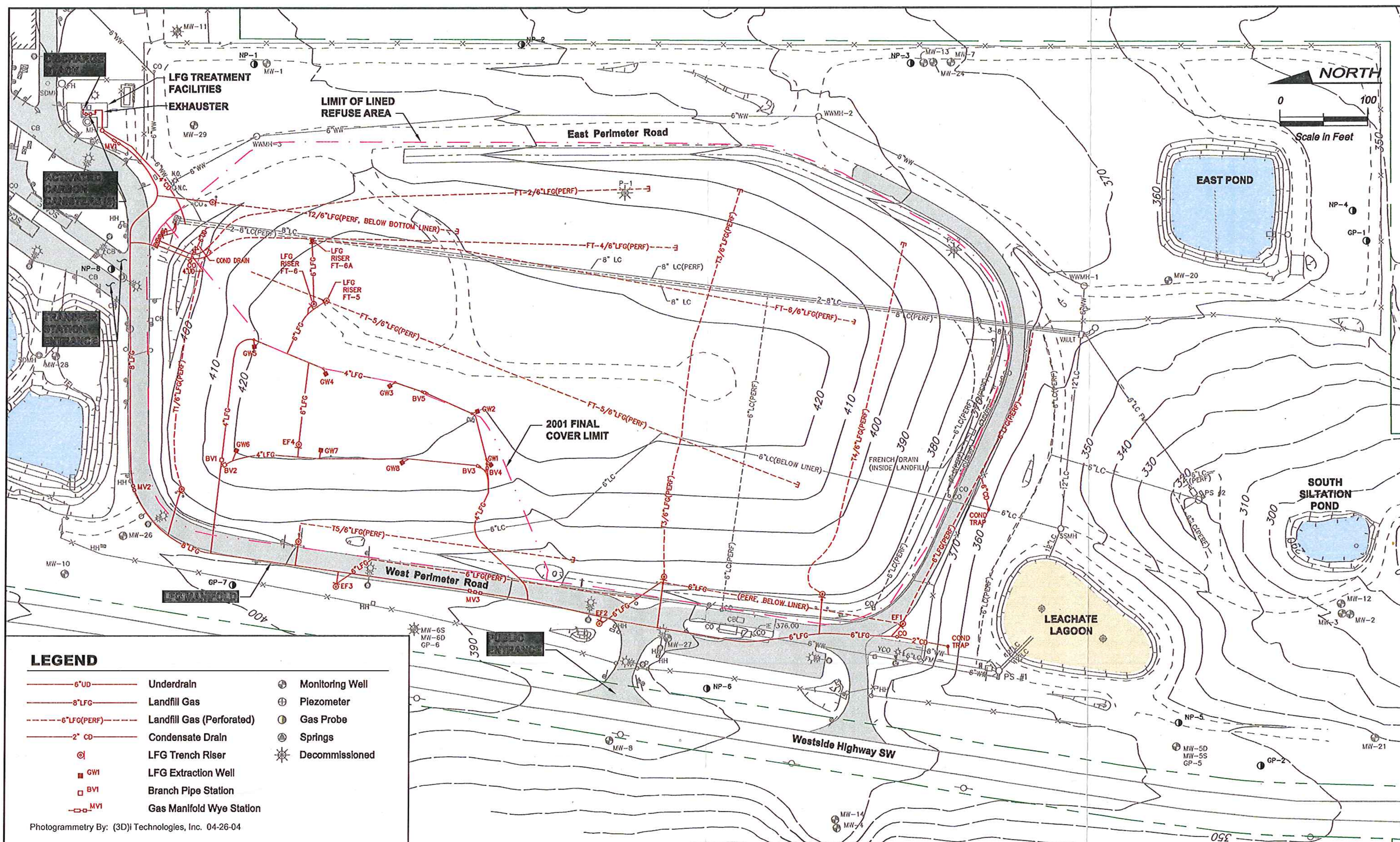
King County

Leachate Control System and Proposed Sampling Locations

Environmental Review, Investigation & Evaluation Technical Memorandum
Vashon Island Landfill, King County, Washington

DATE	OCT 2011
DESIGNED BY	EWM
DRAWN BY	SCC
REVISED BY	JJS
PROJECT NO.	090057
FIGURE NO.	5



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King County

Landfill Gas Control and Landfill Gas Monitoring System

Environmental Review, Investigation & Evaluation Technical Memorandum
Vashon Island Landfill, King County, Washington

DATE	OCT 2011
DESIGNED BY	EWM
DRAWN BY	SCC
REVISED BY	JJS
PROJECT NO.	090057
FIGURE NO.	6

APPENDIX A

Site Visit Memorandum

Aspect CONSULTING

King County
Department of
Natural Resources and Parks
Solid Waste Division

September 7, 2011

Mr. Jamey Barker, PE
King County Solid Waste Division
King Street Center
201 South Jackson Street, Suite 222
Seattle, Washington 98104-3855

Re: Contract Number: E00102E08 – Phase 1
D.300.1.4.2 – Vashon Island Landfill Site Visit
Site Visit Report and Photo Log
Project No. 090057-300-05

Dear Mr. Barker:

This letter report presents a summary and observations of the Vashon Island Landfill Site Visit conducted on June 10, 2011. The Site Visit provided for a field inspection to aid in our understanding of the environmental monitoring and control systems and obtain information to address high priority issues and questions related to the facility. This letter report includes a list of attendees, a photo record, a summary of the site visit objectives and outcome, and other findings. This letter report addresses Task 300.1.4 of Aspect's contract with King County.

Site Visit Attendees

The following King County staff and members of the consultant team attended the meeting:

Aspect Team	King County Solid Waste Division (KCSWD)
John Strunk – Aspect Consulting, LLC Erick Miller – Aspect Consulting, LLC	Jamey Barker Dan Swope Matt McCollum Wally Grant
Mike Spillane – Herrera Environmental Consultants, Inc. Bruce Carpenter – Herrera Environmental Consultants, Inc.	
Bard Horton – BHC Consultants, LLC Noah Allen – BHC Consultants, LLC	
Dimitrios Vlassopoulos – Anchor QEA, LLC Jessica Goin – Anchor QEA, LLC	

Photo Log

During the Site Visit, groundwater monitoring, landfill gas, leachate, and stormwater facilities were observed and referenced against existing site plans and documentation. Photographs of site features were taken and select photos are presented on Figures 1 through 4.

125 feet beneath the base of the pond. Monitoring well MW-10 is completed in the CC1 unit and overlain by an approximate 20-foot thick silt unit. Because of the depths of these wells and the intervening aquitards, any recharge affect from the Borrow Area stormwater pond on these wells is likely indirect.

5. *Evaluate areas for stormwater ponding.*
Limited ponding of water was observed in the asphalt lined drainage ditches near the south end of the landfill. This ponding was a result of sediment, debris, and plant growth within the ditch channel. Regular clearing of the asphalt ditch of obstructions will minimize potential ponding. No other ponding within drainage ditches was observed. However, the grade of the grass lined drainage ditches located on the east and west sides of the access road provided locations for potential ponding during storm events. Additionally, the storm piping from the Borrow Area pond provides a potential pathway for stormwater to enter the unlined refuse at the northwest corner of the landfill because the water could flow through the pipe bedding.

6. *Inspect area around Borrow Area stormwater pond and other stormwater ponds regarding potential for water infiltration into refuse or utility trenches.*
Standing water in the Borrow Area pond has the potential to infiltrate into the unlined refuse located in the northwest corner of the landfill. The effluent stormwater pipe trench from the Borrow Area pond could provide a conduit for infiltration of stormwater into the unlined refuse. No other ponds appear to pose a significant risk for infiltration into refuse.

7. *Observe the leachate lagoon and connections.*
The leachate lagoon, connections, and truck loading facility were observed. No evidence of defects was observed. Per correspondence with the Department of Ecology, monitoring of the leachate lagoon liner should be continued.

8. *Observe Pump Station No. 2.*
Observations were made of Pump Station No. 2 and the flow control vault. Photos of these facilities showing the inlet and discharge piping to the flow control vault are presented on Figure 1.

9. *Observe structures with failing lining systems.*
Leachate Pump Station No. 2 was observed to have bulges in its lining system. King County is in the process of repairing Pump Station No. 2 and correcting this issue. The County intends to fill the bottom 18 feet of Pump Station No. 2 with a controlled density fill (CDF) material which will effectively seal the area surrounding the liner bulge.

10. *Observe groundwater monitoring wells completed around the landfill.*
Monitoring wells were located and identified.

11. *Observe field relations between south landfill area where refuse directly overlies Unit B soils and the groundwater monitoring network.*
This relationship was observed. Mapped extent of refuse extends beneath the leachate lagoon and down slope to within about 30 feet of the South Siltation Pond.

21. *Identify operating parameters of LFG blower and carbon canister system.* Current blower is 7.5 HP. Wally Grant indicated he would provide the current operating parameters and current system concentration and flow rate data.

22. *Locate and document monitoring and above ground access points within the LFG collection and conveyance system.* The LFG extraction points including risers from the trench laterals, condensate traps, and extraction wells were observed to be operational, although some of the extraction wells were closed. Monitoring results and operational records of the extraction system have been requested from King County.

23. *Inspect LFG well locations and observe seals.* The LFG well locations, including GP-1 and GP-2, nested probes NP-1 through NP-8, and monitoring wells MW-5, MW-13, and MW24 were observed and are operational. See *Groundwater/Monitoring Network* for additional information regarding MW-5.

Other Observations

General Observations

The landfill property appears to be clean and well-maintained. The landfill consists of a large covered refuse mound surrounded by a perimeter road. The site generally slopes to the south, and the area to the south of the refuse mound is a steep slope. At the north end of the site is an active refuse transfer station and the stormwater collection ponds for the transfer station. The West Hillslope area is across Westside Highway to the west of the landfill. The leachate lagoon is just south of the refuse mound. Leachate is pumped out of the lagoon as needed and taken off-site for treatment.

Leachate System

The leachate flow control vault and leachate sampling point LVB (Figure 1, photo 1-4) have five influent pipes and a single effluent pipe. Three influent pipes are directly from the closed landfill, one is the discharge from PS-2, and the fifth is the discharge from the operating transfer station and on-site sanitary sewer (Figure 1, photo 1-4). No substantial flows were observed during the Site Visit. According to King County Operations staff, there is minimal leachate flow through the structure. Leachate collects in the flow control box and then drains into the leachate lagoon via manhole MH-3. Leachate is currently hauled off-island for disposal at regional treatment facilities, but discussions with King County personnel indicate leachate disposal will be occurring at the Vashon POTW on-island in the near future.

Samples are taken from the two influent pipes at the top left (North) of Figure 1, photo 1-4 (with slide gate valves). The pipes on the bottom (South) of the picture are blocked with blind flanges. A downturned elbow on the right of the photo discharges flows from PS-2. Flows from the transfer station enter from a pipe on the right of the photo (East).

Pump Station No. 2 was turned on during the Site Visit and discharge into the flow control vault was verified. Flow from the flow control vault enters manhole MH-3 (Figure 1. Photo 1-6). Inspection of MH-3 indicated movement of the leachate toward the leachate lagoon confirming these connections. No water was observed entering MH-3 from the 6-inch leachate collector located below the liner.

The pond is no longer required for water quality purposes, as there is little vehicle activity or construction activity at the south end of the landfill.

The South Storm Water Detention Pond (Figure 3, photo 3-7) is the southernmost pond on County property. The pond was installed to detain stormwater flows prior to discharge to unnamed tributary of Judd Creek to the south. No outflow from the South Storm Water Detention Pond was being generated at the time of the Site Visit (Figure 3, photo 3-5).

The East Pond (Figure 3, photos 3-4 and 3-6) is lined and provides water quality treatment and detention. No issues requiring modification were observed.

Drainage ditches on either side of the transfer station access road (Figure 3, photo 3-10) present a potential for stormwater to infiltrate into unlined refuse located beneath the ditches. The limits of the unlined refuse extend west of the access road, approximately to the perimeter fence.

Vegetation within the asphalt drainage ditch is prevalent at the south end of the closed landfill, located between the landfill and the perimeter road. The vegetation and other debris causes some ponding of surface water within the asphalt lined ditch (Figure 1, photo 1-8). The majority of the vegetation grows from sediment collected in the ditch, but some vegetation grows through cracks in the asphalt along the ditch. Vegetation and sediment should be removed to minimize ponding.

Cover

The observed portions of the cover appeared in good condition without any areas of surface water ponding or nuisance vegetation.

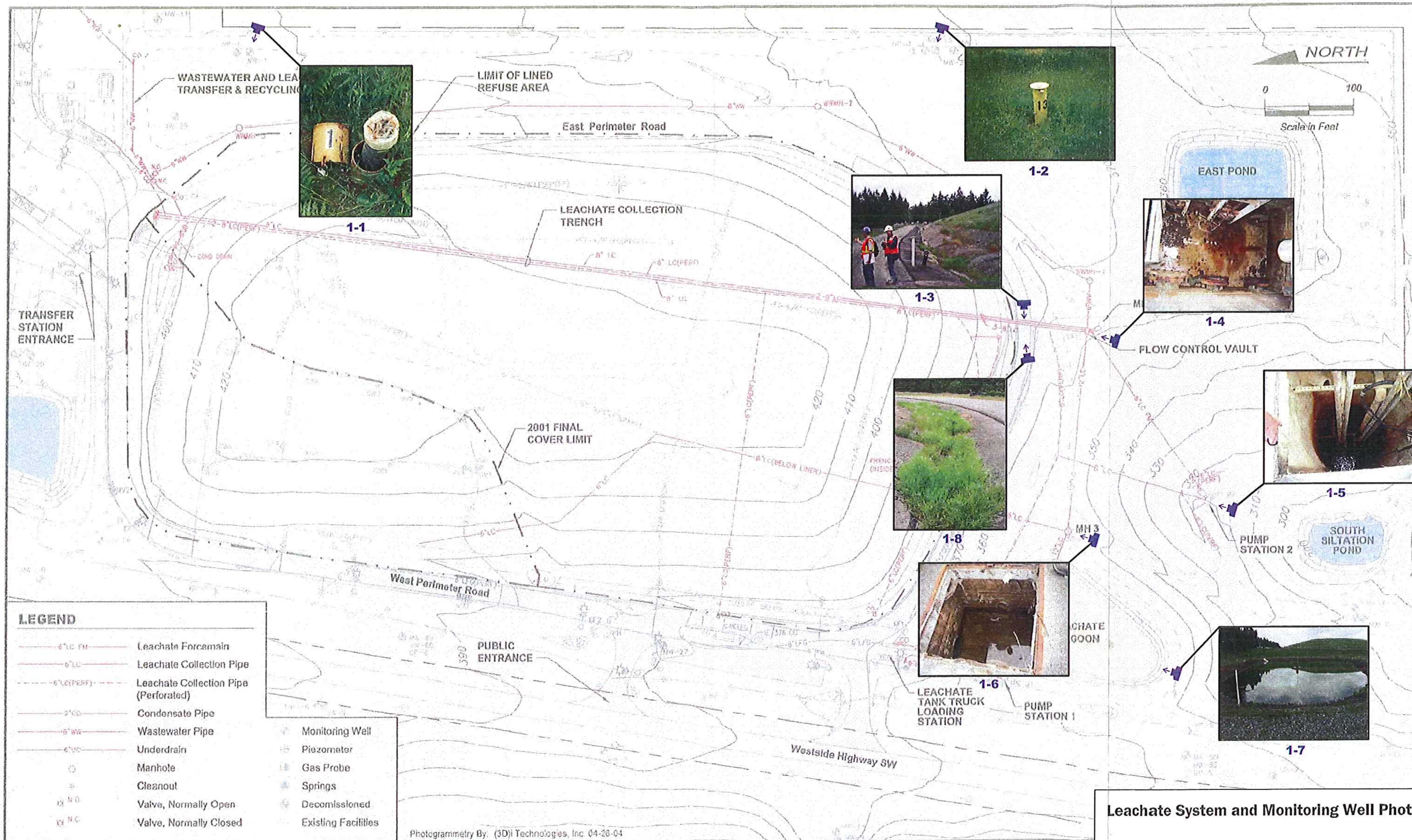
Groundwater Monitoring Network

Select monitoring well and gas probes were visually examined. It was noted by King County that MW-5D has experienced iron and siltation issues with about 1-foot of silt historically measured in the bottom of the well. A camera survey may be necessary to further evaluate the condition of this well. Well MW-1 has a loose monument and casing and may be a candidate for well decommissioning.

West Hillslope Monitoring Network

Across Westside Highway from the Vashon Island landfill is a steep slope, known as the West Hillslope area. Several seeps and small streams were sampled in this area. Samples in the West Hillslope area have been collected at wells, seeps, and weirs. Historically, there have been three sets of sampling points at weirs 1, 2, and 3. As part of the Hillslope investigation, several seep sampling locations were added upstream of the original sampling weirs, additional seeps were sampled, and monitoring wells were installed. Hillslope seeps, wells, and weirs were visited.

Continued water quality sampling at the springs and weirs will likely be required. It will be necessary to maintain the weirs and spring sampling points in good condition. Some sediment infilling was noted behind the weirs that could affect their operation (for example, Figure 4, photo 4-1). Additionally, access improvements to the sampling points for people and equipment could be considered.



Legend

1-6
Photograph direction and number

Leachate System and Monitoring Well Photos

June 10, 2011
Vashon Island Closed Landfill
Vashon Island, Washington

Aspect CONSULTING

JULY-2011	BY: EWM/PMB	FIGURE NO. 1
PROJECT NO. 090057	REV BY:	

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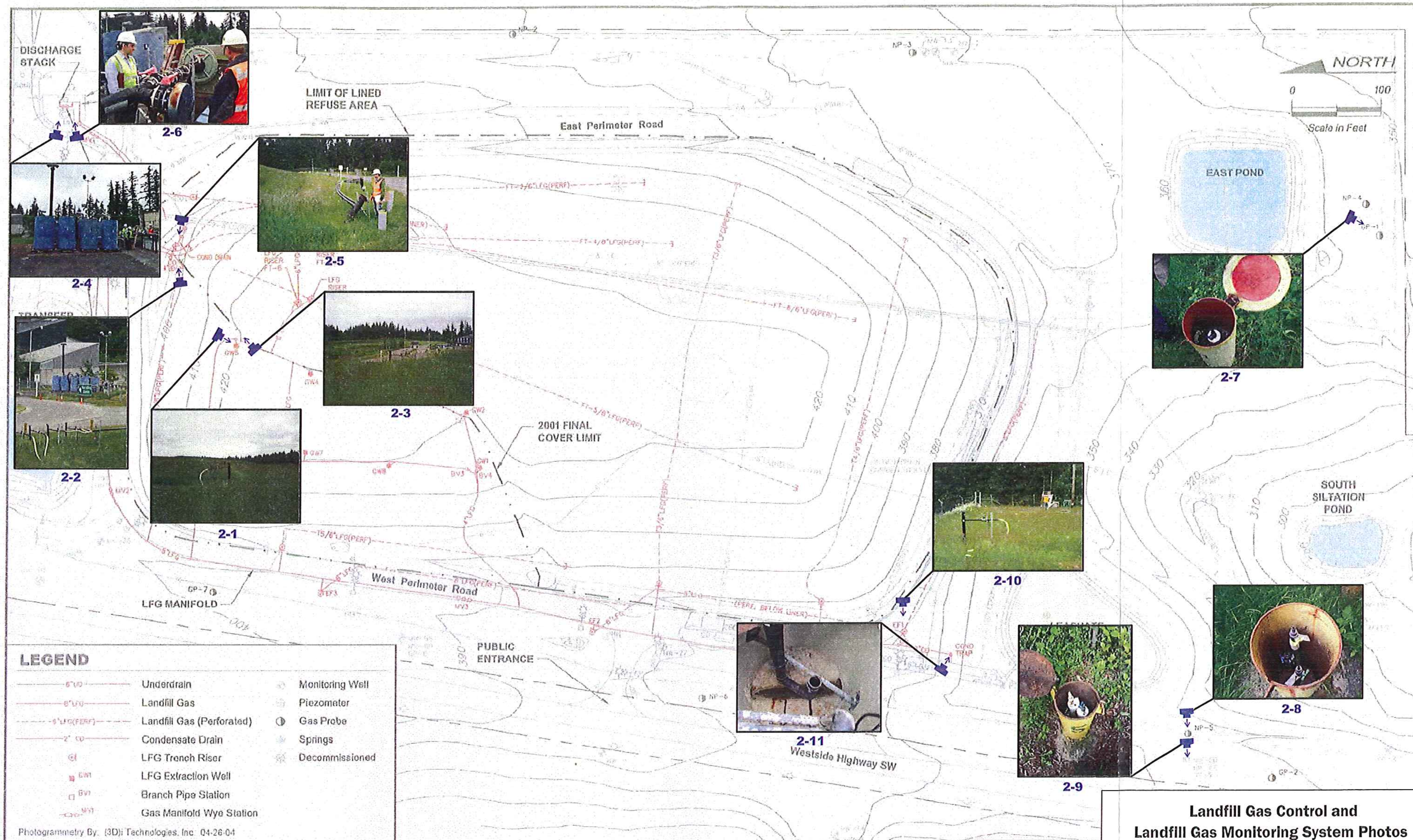

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Photograph direction and number 2-9

Landfill Gas Control and Landfill Gas Monitoring System Photos

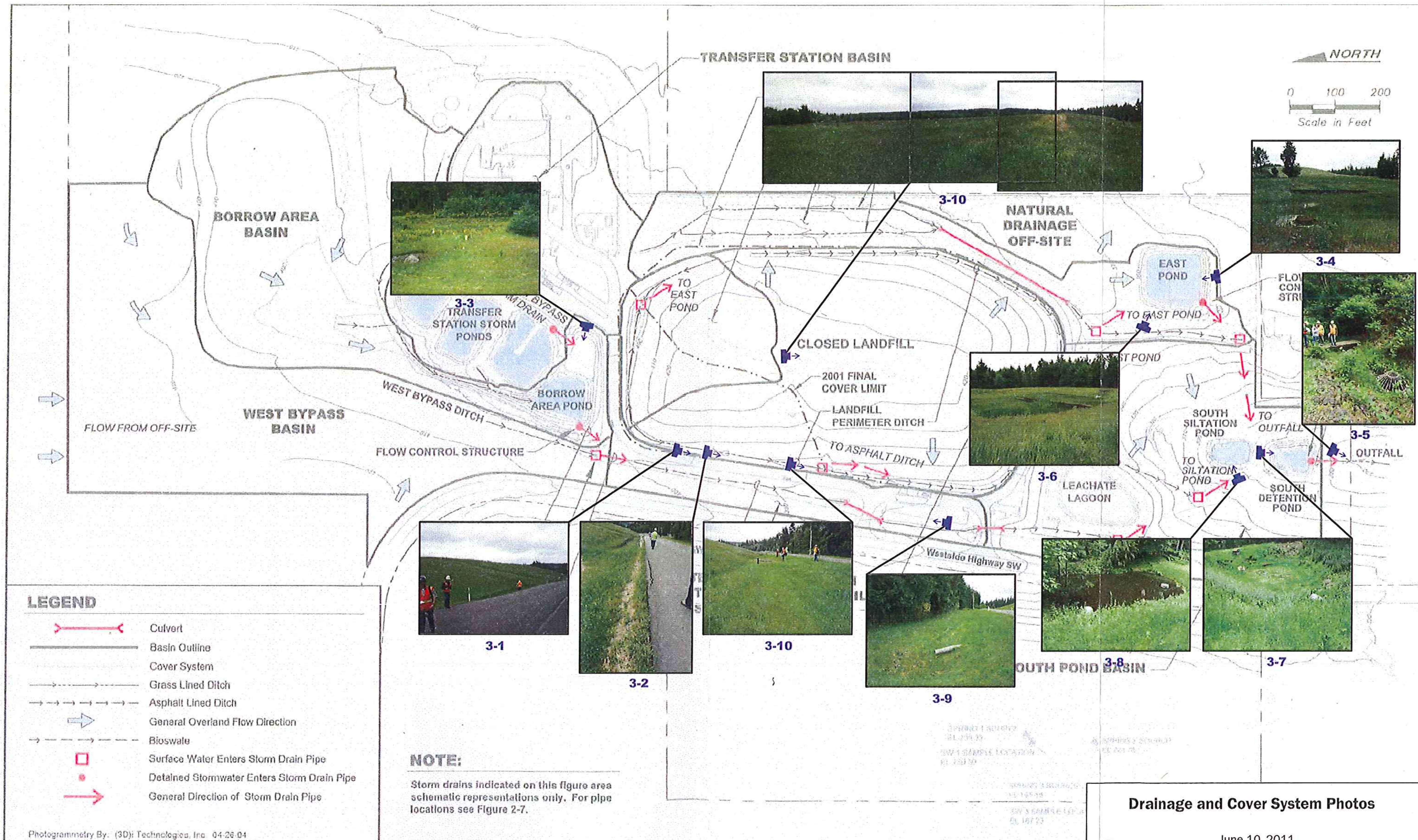
June 10, 2011

Vashon Island Closed Landfill

Vashon Island, Washington

Aspect CONSULTING	JULY-2011 PROJECT NO. 090057	BY: EWM/PMB REV BY:	FIGURE NO. 2

Q:\King County\090057 Vashon Island Closed Landfill\2011-07\090057-02.dwg



Legend

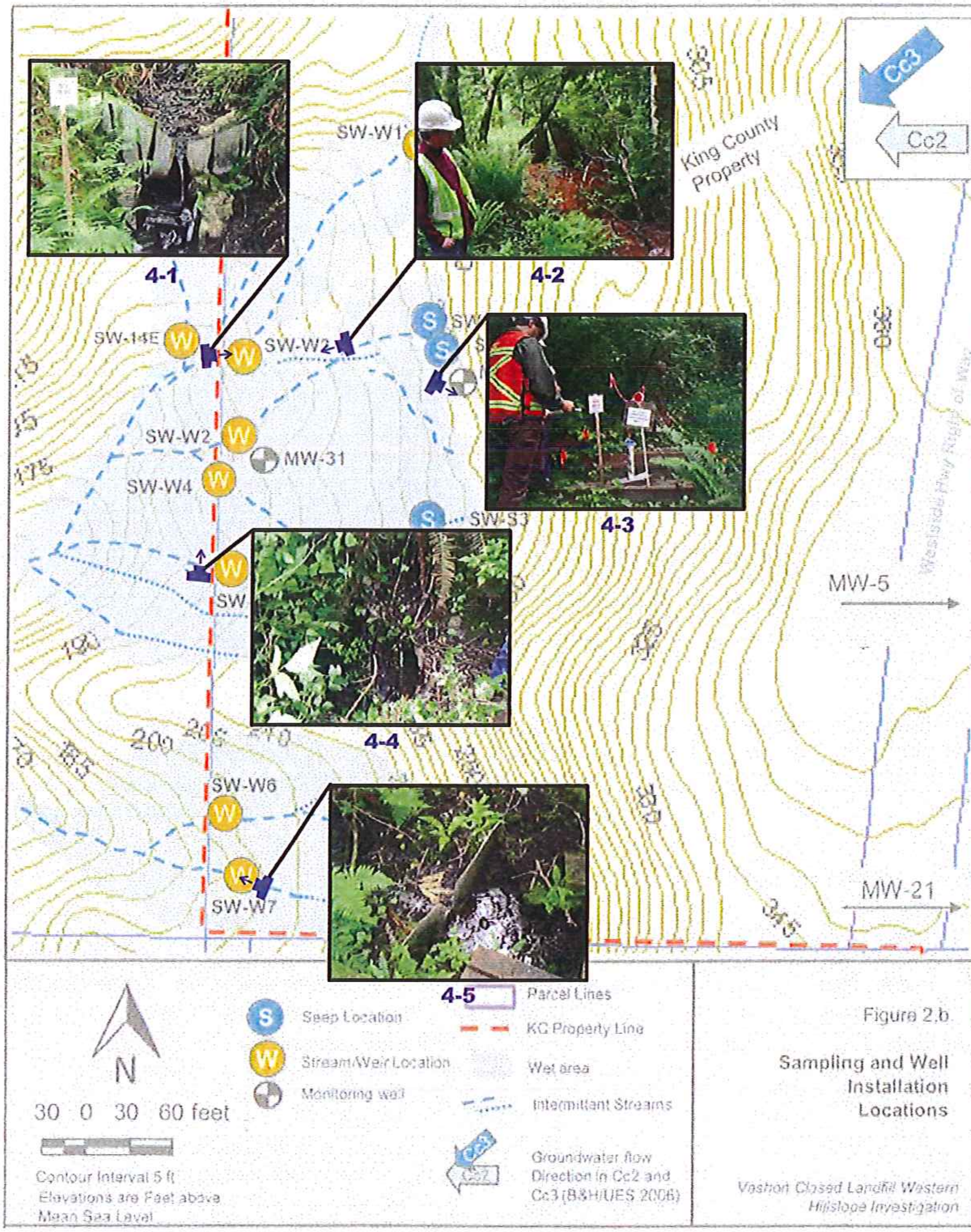
Photograph direction and number 3-9

Drainage and Cover System Photos

June 10, 2011
Vashon Island Closed Landfill
Vashon Island, Washington

Aspect Consulting	JULY-2011 PROJECT NO. 090057	BY: EWM/PMB REV BY:	FIGURE NO. 3

Q:\King County\090057 Vashon Island Closed Landfill\2011-07\090057-03.dwg



Legend

Photograph direction and number 4-5

West Hill Slope Area Photos

June 10, 2011
Vashon Island Closed Landfill
Vashon Island, Washington

Aspect Consulting	JULY-2011	BY: EWM/PMB	FIGURE NO.
	PROJECT NO. 090057	REV BY: -	4

CAD Path: Q:\090057 Vashon Island\2011-07\090057-04.dwg

APPENDIX B

Field Procedures

B. Field Procedures

The following sections describe the detailed procedures and guidelines for completion of field tasks associated with this investigation at the Vashon Island Closed Landfill (VLF). Forms to be used in the field are provided in this appendix following the text.

B.1 Field Preparation

Prior to each exploration phase, an Aspect Consulting, LLC representative will meet with the King County Solid Waste Division (KCSWD) personnel at the Landfill to discuss the work, including possible access constraints, investigation derived waste soil cuttings and purge water management, storage areas, and other drilling and sampling logistics. During the meeting, Aspect Consulting will field-stake the exploration locations with KCSWD personnel. Aspect Consulting will assist KCSWD in identifying measures KCSWD needs to take to provide physical access to the well sites prior to the scheduled drilling date. Prior to drilling, KCSWD will be responsible for clearing utilities at the proposed borehole locations.

All drilling activities will be directed by a hydrogeologist or geologist from Aspect Consulting. A Boring Log (Form 1) will be kept during drilling, as well as a Daily Report (Form 2) of all relevant site activities. Aspect Consulting will contract directly with the drilling contractor to provide all drilling services for this project.

B.2 Monitoring Well Installations

Two monitoring wells are proposed as part of this investigation. Proposed monitoring well MW-33 will target the Cc2 aquifer and be located south of the South Area covered refuse area adjacent to the leachate lagoon access road. Proposed well MW-34, if determined necessary, will be completed in the Regional Aquifer. Both wells will be drilled using sonic drilling methods.

B.2.1 Sonic Drilling Method

Sonic drilling is a method of advancing a dual-cased drill stem that allows for collection of a complete core of the subsurface materials. The drill bit and casing are advanced into the formation with a high-frequency vibration that is transmitted to the drill bit as percussive action in gravel and cobbles and shearing action in silts and clays. The drilling method consists of advancing an inner core or sample barrel into the formation, then advancing an outer casing to the depth of the tip of the sample barrel to keep the borehole open during sample retrieval (or well installation). The sample barrel is then retrieved

B.2.4 Proposed Monitoring Well MW-33 Completion

Proposed monitoring well MW-33 will be completed with the screen interval completed in the Cc2 aquifer unit as a 4-inch-diameter Schedule 40 PVC well. The screen will be 0.020-inch slot machine slotted, PVC screen with a 10x20 Colorado Silica Sand filter pack.

All well construction materials will be new. Sand pack will extend from the total depth of the boring to approximately 3 feet above the well screen. Over drilled portion of the well boring in excess of approximately 3 feet will be backfilled with bentonite chips. For over-drill sections less than 3 feet, the borehole will be allowed to collapse or will be backfilled with pea gravel, unless a distinct aquitard is penetrated, in which case the boring will be backfilled with bentonite chips. An approximate 3-foot bentonite pellet seal will be placed over the Colorado Silica Sand. The remainder of the annular space above the bentonite chips will be backfilled with either bentonite pellets or high-solids bentonite grout to about 8 feet below ground surface, at the discretion of the on-site geologist. If highly permeable material is encountered, a bentonite chip seal will be extended to prevent high-solids bentonite grout from short circuiting through the formation and influencing the well screen. If a bentonite slurry is used it will be installed using a tremie pipe. Bentonite chips may be used in lieu of the bentonite grout or bentonite slurry. In this case, hydrated bentonite chips will be placed to fill the annular space around the monitoring well casing to within approximately 2 to 3 feet below ground surface. During placement of the chips, they will be continuously sounded to ensure bridging is not occurring. Water used for hydrating chips or for mixing bentonite grout shall be from a potable source.

Bentonite chips will be used from 8 feet below ground surface to about 2 feet below ground surface. The remaining 2 feet of annular space will be backfilled with cement. An 8-inch-diameter steel protective casing and three bollards will be installed following KCSWD standards.

B.2.5 Proposed Monitoring Well MW-34

Monitoring well MW-34 is contingent on review of Regional groundwater flow patterns. The well will be drilled to an approximate depth of 230 feet with the screen interval installed in the Regional Aquifer. The well will be drilled using sonic methods and may be installed as multi-port well using a Solinst CMT multi-level groundwater monitoring system, if permitted by Ecology. If phone conversations indicate that a multi-level well would be accepted by Ecology, a detailed letter describing the multi-level monitoring installation will be submitted as part of the variance request to Ecology.

The well would be installed with four ports as described in the main body of the text. The multilevel system consists of 1.7-inch diameter polyethylene tubing segmented into seven channels.

Field Procedures

Prior to slug testing, the wells will be pumped using the dedicated QED sample pumps and the turbidity and total depth monitored to evaluate if sediment has accumulated in the well. Any wells where the turbidity exceeds 50 NTUs will be redeveloped following the procedures described in Section B.4.

The slug tests produce a change in water level within a well and measure the rate of return to the static water level (SWL). This rate of water level change in the well is used to compute the hydraulic conductivity of the water bearing zone. There are two common ways to induce a change in water level for slug tests: 1) using a slug bar – a solid cylinder of known volume – into a well to displace water; and 2) using a pneumatic slug test device. The pneumatic device does not work well with partially saturated screening interval, which is anticipated (see Table 1), so a slug bar will be used on these wells. To test the results for dependency of hydraulic head, two slug bars of different lengths (different displacement volumes) will be used at each well. The slug bars will both be an inch (or less) in diameter to allow passage of the transducer cable in the smallest diameter wells (2 inch diameter). To test for repeatability, two slug tests will be performed with each bar. Two-inch diameter slugs may be utilized in 4-inch wells.

The water level in the well will be measured using a vented pressure transducer (5 or 15psi range) and collected electronically on a data logger set to a nearly continuous time interval (1 second or less). Manually collected water level measurements, taken periodically throughout the test with a water level indicator, will be used to confirm results collected from the pressure transducer. Prior to the testing the pressure transducer will be installed in the well at a depth twice the length of the longer slug bar below the initial SWL to avoid contact with the slug bars. Once the transducer is in place and the data logger is programmed, the slug bar will be lowered on a line until it is just above water – as evidenced by change in monitored pressure reading when bottom of slug bar enters water or by a level indicator lowered with the slug. The rope will then be marked at the top of casing and at one and one half the length of the slug bar above top of casing.

Falling Head Test

The slug bar will be dropped into the groundwater so it is fully submerged (lowered to the second mark on the rope). This insertion should be done quickly, and with care taken not to disturb the pressure transducer. Water in the well will rapidly rise, then slowly fall to meet the initial SWL over time. The pressure will be monitored to confirm initial displacement was relatively instantaneous compared to the response. When the pressure indicates that water levels have recovered 80% (for low-K formations) to 95% (for high-K formations) of the initial displacement, the test is concluded at which time the water level will be confirmed manually.

Rising Head Test

At the completion of the each falling head test the slug bar is fully submerged and the water level has returned to near static conditions. At this time the slug bar will be raised completely out of water. This will be done quickly, and without disturbing the pressure transducer. Water in the well will rapidly fall and then rise to meet the initial SWL over time. The pressure will be monitored to confirm initial displacement was relatively

Samples will be collected in pre-cleaned sample jars obtained from Laucks Testing Laboratories. Sample numbering will follow KCSWD procedures. KCSWD COC forms will be used for all samples (Form 4).

Sample collection for chemical and isotopic tracers requires special care to avoid contact with the atmosphere and other sources of error. Samples for tracer and isotope analysis will be collected using appropriate sampling protocols.

B.7 Sampling Quality Assurance Procedures

The following sections discuss proper sample preservation, containers, handling, and documentation applicable to sample collection.

B.7.1 Sample Containers, Preservation, and Holding Times

The analytical laboratory will supply Aspect Consulting with clean sample containers that will include appropriate preservative. The samples collected for chemical analysis will be stored only in these containers. The objective of the sample preservation is to prevent or hinder the loss or degradation of the chemicals in the samples during transit and storage.

B.7.2 Sample Handling

Samples are to be collected and handled in such a manner as to minimize the possibility of sample contamination occurring or samples being lost. All samples are to be kept chilled at a maximum temperature of 4 degrees Celsius from the time of collection until time of analysis by the laboratory. Field personnel will keep samples cold using blue ice and coolers, in which samples are to be stored until delivery to the analytical laboratory.

B.7.3 Quality Assurance/Quality Control Samples

Collection and analyses of trip blanks, rinsate blanks and field duplicates are used as quality control checks of any possible contamination introduced in transit to the laboratory.

A trip blank shall consist of a reagent grade water sample prepared by the laboratory and handled/transported in the same manner as if it was obtained as a sample collected from a sample location. The primary purpose of a trip blank is to check for contamination introduced during shipment of the samples. The trip blank will be prepared by the laboratory and accompany samples collected at the site.

A rinsate blank will be collected to evaluate decontamination procedures only if non-dedicated sampling equipment is used. One rinsate blank per day of sampling will be collected.

B.8 Water Level Monitoring Program

Water levels will be monitored in wells at the south end of the facility as shown in Figure 4. Wells will be equipped with transducers (Schlumberger Divers). Transducers and suspension cables will be decontaminated prior to installation. A site visit will be made prior to installation to perform a reconnaissance of the well caps and determine best method of installation. Well caps may be modified by drilling a hole and installing an eyebolt from which the transducer is suspended. Alternatively, new well caps may be purchased. The transducers are about 1-inch in diameter and will be installed with the QED well wizard pumps in place. If retrieval of the transducer for download purposes is problematic as a result of the pumps, then the pumps may be removed and stored in clean plastic bags. A barometric sensor will be installed at the time of transducer installation for removing barometric pressure influences on the closed loop transducers. Barometric pressure corrections are applied when the water level data is processed. Trandsucers will be ideally installed during the rising limb of the hydrograph (i.e., sometime between the 4th and 1st quarter of the year) and left in place for a minimum of 3 months. Monthly retrieval and downloads of the transducers will be performed and manual water level measurements taken during these downloads.

B.9 Off-site Well Measurements

Water levels may be measured in off-site wells depending on existing available data and access considerations. Aspect staff in coordination with KC personnel will request well owners' verbal authorization via telephone or site visit for access to collect two rounds of water level measurements. After obtaining preliminary permission and prior to measurement, the suitability of the wellhead installations for reliable measurement of static water level will be evaluated.

The measuring point at the casing top will be identified, photographed, and recorded in the field. The distance from the measuring point to ground surface will be determined and recorded. If the measuring point is not accessible for surveying, a suitable reference point for surveying will be marked and the vertical and horizontal offsets from the measuring point will be recorded to an accuracy of 0.01 feet.

B.11 Landfill Gas VOC Sampling Procedures

Samples for VOCs will be collected from the proposed 4-inch monitoring well MW-33 and from LFG trench risers EF-1 and EF-3. The samples will be analyzed according to EPA method TO-15.

B.11.1 Sampling Events

The ideal condition for sampling is low barometric pressure and sampling will occur following at least 12 hours of falling barometric pressure, with a drop from peak of 0.25 inches mercury.

B.11.2 Preparation of the Proposed Well and Trench Risers for Sampling

The proposed 4-inch groundwater monitoring well MW-33 and trench risers will be retrofitted to enable gas sampling. The well cap for the monitoring well will be fitted with a positive sealing cap equipped with a male quick connect fitting, approximately two weeks prior to gas sampling. This will allow time for soil gas to equilibrate in the closed well. Sample pump tubing will be disconnected from the caps and will be left in the well.

B.11.3 Sampling Procedure for Field Analyses

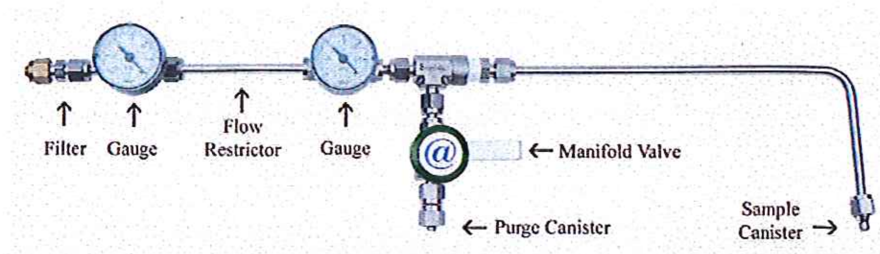
Groundwater Monitoring Well

The existing pump and tubing from the proposed groundwater monitoring well will be removed and placed in a clean plastic bag. The well casing will be fitted with a slip cap equipped with a laboratory stop cock. Gas sampling procedure will otherwise follow that described above for gas probes. We expect to use the vacuum pump to purge the well. Pumps will be replaced following collection of the gas samples.

Procedure for Collection of Laboratory Samples for VOC Analysis

The following procedure will be used for collection of samples for VOC analysis from trench risers EF-1 and EF-3.

1. Calculate the volumes in the EF-1 and EF-2 trench systems.
2. Calibrate the GEM-2000.
3. Check the vacuum in the 1-liter Summa canister. Vacuum should be between 28 and 29 inches, but not less than 25 inches. If vacuum is less than 25 inches, the canister should be replaced with a canister meeting this specification.
4. Connect the Teflon tubing from the riser pipe to the flow controller on the 1-liter Summa Canister. Purge rate will be approximately 100 ml/min and regulated by the flow controller.



3. Connect to well with quick connect fitting and purge well. Well purge will be at approximately 100 ml/min and regulated by the flow controller. Purging at sampling rates between 100 to 200 m/min will minimize stripping of VOCs and ambient air intrusion (California Regional Water Quality Control Board, 2003)
4. Connect the quick connect fitting on ¼-inch Teflon tube and begin purging with the GEM-2000.
5. Record methane, carbon dioxide, and oxygen concentrations, LEL, and barometric pressure measured by the GEM-2000. Continue purging and record parameters at minimum 20 second intervals until parameters are stabilized. Stabilization is defined as 3 readings over a 1 minute period that are within 10% of one another.
6. If the well fails to stabilize after 3 casing volumes, move onto sample collection step 8.
7. Turn off GEM-2000.
8. Record Summa canister vacuum. Vacuum must be above 25 inches. If not repeat the above listed procedure.
9. Open Summa canister valve and collect sample. Stop sampling when the Summa canister vacuum reaches 5 inches.
10. Record the final canister vacuum on the chain of custody.

Analytical Testing

Gas samples will be run for volatile compounds using EPA method TO-15 by Air Toxics Limited in Folsom, California.

Monitoring and influence testing will be performed, in the following sequence:

- Take normal pressure readings at EF-1, EF2, and EF-3. Note operating parameters.
- Isolate EF-1 by turning off for 5 days.
- Collect initial reads at EF-1, bar holes temporary probes, and Condensate Trap,
- Begin influence testing at EF-1. Open the valve at EF-1 slightly and monitor pressure and gas concentrations for a week by installing a monitoring port at the condensate trap at the south central end of the VIL see above (Figure B-1). Monitor pressure conditions at a test port installed at the condensate trap, located at the south central end of the landfill and temporary bar holes installed to intercept the gravel collection layer. Also monitor EF-2, and EF-3.
- Based on the initial monitoring results, open the valve further and monitor at weekly intervals until maximum vacuum is applied without introducing oxygen greater than 2 percent.

West Side Collectors EF-2 and 3

Monitoring and influence testing will also be performed in west side collectors EF-2 and EF-3 to determine influence extent of vacuum and if LFG is being collected below the bottom lining system to determine if gravel layer is a preferential pathway in direct contract with the Unit B soils.

- Take normal readings at EF-1, EF2, and EF-3. Note operating parameters.
- Isolate EF 2 by turning off for 5 days.
- Take readings at probes GP-6 and GP-7, and EF, 1, 2, and 3. Begin influence testing at EF-2 by opening the valve at EF-2 slightly and monitor pressure and gas concentrations for a week. Continue to monitor pressure conditions at probes GP-6 and NP-6, EF1, and EF-3.
- Based on the initial monitoring results, open the valve further and monitor at weekly intervals until maximum vacuum is applied without introducing oxygen greater than 2 percent.
- Repeat process for EF-3 and monitor conditions at GP-6, GP-7, EF-1, and EF-2.

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Form 1

BORING LOG

SHEET ____ OF ____

LOCATION OF BORING	PROJECT NO.	BORING NO.
	PROJECT NAME	
SKETCH OF LOCATION	DRILLING METHOD:	
	LOGGED BY:	
	DRILLER:	
	SAMPLING METHOD:	
	HAMMER WEIGHT/SAMPLER DIAMETER	

OBSERVATION WELL INSTALL YES ____ NO ____					START	FINISH
WATER LEVEL					TIME	TIME
TIME						
DATE					DATE	DATE
CASING DEPTH						

DATUM	GRADE ELEV.

SURFACE CONDITION

SIZE (%) GRAVEL	SAND (SIZE RANGE)	FINES	SAMPLE NO. / SAMPLE TYPE	SAMPLE DEPTH	INCHES DRIVEN / INCHES RECV'D	DEPTH IN FEET	PENETRATION RESISTANCE	USCS SUMMARY	DESCRIPTION: Density, moisture, color, minor, MAJOR CONSTITUENT. NON-SOIL SUBSTANCES: Odor, staining, sheen, scrap, slag, etc. DRILL ACTION
						1			
						2			
						3			
						4			
						5			
						6			
						7			
						8			
						9			
						0			
						1			
						2			
						3			
						4			
						5			
						6			
						7			
						8			
						9			
						0			

Form 2

Aspect CONSULTING

DAILY REPORT

350 Madison Avenue North
Bainbridge Island, Washington 98110
(206) 780-9370

401 Second Avenue S, Suite 201
Seattle, Washington 98104
(206) 328-7443

DATE:	PROJECT NO.	WEATHER:
PROJECT NAME:	CLIENT:	
EQUIPMENT USED:	PROJECT LOCATION:	

THE FOLLOWING WAS NOTED:

COPIES TO:	Aspect Consulting PROJECT MANAGER:
	Page 1 of 1 FIELD REP.:

Aspect CONSULTING

Form 3

GROUNDWATER SAMPLING RECORD

WELL NUMBER: ______ Page:____ of ____

Project Name: ______________________ Project Number: ______________________

Date: ______________________

Developed by: ______________________

Measuring Point of Well: ______________________

Screened Interval (ft. TOC) ______________________

Filter Pack Interval (ft. TOC) ______________________

Starting Water Level (ft TOC): ______________

Casing Stickup (ft): ______________

Total Depth (ft TOC): ______________

Casing Diameter (inches): ______________

Casing Volume __________ (ft Water) x __________ (Lpfv)(gpf) = __________ (L)(gal)

Casing volumes: 2" = 0.16 gpf 4" = 0.65 gpf 6" = 1.47 gpf

2" = 0.62 Lpf 4" = 2.46 Lpf 6" = 5.56 Lpf

Sample Intake Depth (ft TOC): __________

PURGING MEASUREMENTS

Time	Cumul. Vol. (gal or L)	Purge Rate (gpm or Lpm)	Water Level (ft)	Temp. (C or F)	Specific Conductance (μS/cm)	Dissolved Oxygen (mg/L)	pH	Eh ORP (mv)	Turbidity (NTU)	Comments

Total Gallons Purged: ______________ Total Casing Volumes Removed: ______________

Ending Water Level (ft TOC): ______________ Ending Total Depth (ft TOC): ______________

SAMPLE INVENTORY

Time	Volume	Bottle Type		Quantity	Filtration	Preservation	Appearance		Remarks
							Color	Turbidity & Sediment	

METHODS

Sampling Equipment and IDs: ______________________

Purging Equipment: ______________ Decon Equipment: ______________

Disposal of Discharged Water: ______________________

Observations/Comments: ______________________

Form 4

Chain of Custody Record

DATE: ______________

King County
Department of
Natural Resources and Parks
Solid Waste Division

Environmental Monitoring Program

No. 7887

Name King County Solid Waste Division
Address 201 South Jackson Street, Suite 701
Seattle, WA 98104-3855

Attention Sendy Jimenez (206) 296-4411
Contract No T02344T

Project Site Test ______________

Project Site Test Reference

Lab No.	Sample ID	Date	Time	GROUNDWATER												SURFACE WATER									LEACHATE/WASTEWATER														S	Number of Containers	Remarks
																												PERMIT													
				CHGW-A Cedar Hills GW Annly	CHGW C. Hills GW Qtly (NP / OS)	CHGW-V C. Hills GW VOAs Only	GW-APP3 Appendix III Add'l Analytes	CFGW Cedar Falls GW Qtly	DUGW Duvall GW Qtly	ENGW Enumclaw GW Qtly	HOGW Hobart GW Qtly	HTGW Houghton GW Qtly	PUGW Puyallup GW Qtly	SPGW South Park GW Qtly	VAGW Vashon GW Qtly	CHSW-A Cedar Hills SW Annly	CHSW-Q Cedar Hills SW Qtly	CHSW-M Cedar Hills SW Mtly	CHSW-P Cedar Hills SW Permit	CFSW Cedar Falls SW Qtly	DUSW Duvall SW Qtly	RESW Renton SW Qtly	SPSW South Park SW Qtly	VASW Vashon SW Qtly	CHLS-A C. Hills Leachate Annly	CHLS-M Cedar Hills Leachate Mtly	CHTW Cedar Hills Truckwash	CHLS-P C. Hills Leachate Permit	ALLS Algona WW Permit	ENLS Enumclaw WW Permit	FALS Factoria WW Permit	FILS First NE WW Permit	HTLS Houghton WW Permit	RELS Renton WW Perm t	VALS-P Vashon Leachate Permit	VALS-A Vashon Leachate Annly	VALS-Q Vashon Leachate Qtly	VALS-M Vashon Leachate Mtly	REDS Renton Soils / Rinsate (R)		
				1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36		

Relinquished By Sampler	Date	Received By	Date
Sampler Signature		Signature	
Sampler Printed Name KCSWD	Time	Printed Name	Time
Company		Company	
Relinquished By	Date	Received By	Date
Signature		Signature	
Printed Name	Time	Printed Name	Time
Company		Company	

Observations/Comments/Special Instructions:

Total # Containers:

Instructions:

1. Complete in ballpoint pen. Draw one line through errors and initial.
2. Receiving lab is to sign in the shaded box.
3. Check off pre-printed Project Site Test Reference to be performed for each sample, or provide specific instruction if not listed.
4. KCSWD personnel are to retain white and canary pages, receiving lab is to keep pink and goldenrod pages.
5. If KCSWD personnel request, please provide a name and telephone number of your contact person.

Name: ______________

Tel: ______________

White and Canary KCSWD Pink and Goldenrod: Receiving Laboratory

Form 5

Aspect CONSULTING
179 Madrone Lane North
Bainbridge Island, Washington 98110
(206) 780-9370

401 Second Avenue S, Suite 201
Seattle, Washington 98104
(206) 328-7443

GAS MONITORING RECORD

Well/ Station	Date	Time	CH4 (%)	CO2 (%)	O2 (%)	Bal (%)	Well Pressure (in. H_2O)	Barometric Pressure (in. Hg)	Comments

APPENDIX C

Cost Estimate and Schedule

Table C-1
Conceptual Cost Estimates

Environmental, Review, Investigation, and Evaluation Technical Memorandum
Vashon Island Landfill, King County, Washington

Task Title	Labor	ODC	Subs	Total
Task 1 - Review Update hydrostrat Model	$14,000	$0	$0	$14,000
Task 2 - Evaluate Regional Groundwater Flow	$4,000	$0	$0	$4,000
Task 3 - Hydraulic Conductivity Testing	$10,000	$1,000	$3,000	$14,000
Task 4 - Groundwater Gradient Investigation	$20,000	$58,000	$13,000	$91,000
Task 5 - MNA Evaluation	$3,000	$8,000	$11,000	$22,000
Task 6 - Water Balance	$15,000	$0	$0	$15,000
Task 7 - Source Investigations-Leachate	$4,000	$39,000	$27,000	$70,000
Task 8 - Groundwater Monitoring	$11,000	$55,000	$11,000	$77,000
Task 9 - Leachate Lagoon Monitoring	$1,000	$0	$4,000	$5,000
Task 10 - LFG Monitoring Source Investigation	$4,000	$0	$67,000	$71,000
Task 11 - Reporting	$38,000	$0	$12,000	$50,000
Task 12 - Project Management	$25,000	$0	$13,000	$38,000
Total Project Budget	**$149,000**	**$161,000**	**$161,000**	**$471,000**

Notes:

Conceptual level costs for planning level review
Costs based on 2011 Rates
Task 8 assumes decommissioning and replacement of MW-1 and 5D totaling $68,000.

APPENDIX D

Cc2 Unit Water Quality Evaluation

D. Preliminary Evaluation of Unit Cc2 Groundwater Quality

Monitored natural attenuation may be appropriate at the site as volatile organic compounds (VOC) concentrations in individual monitoring wells have been decreasing over time, and VOC concentrations also decrease between wells and seeps located downgradient.

MW-5D has exhibited declining VOC concentrations, with peak concentrations detected between 1993 and 1996 (Figure D-1). Vinyl chloride and cis-1,2-dichloroethene (cis-1,2-DCE) concentrations have declined by factors of 6 and 2, respectively, in MW-5D. In addition, many compounds that were measured at detectable levels in the past (benzene, toluene, trichloroethene (TCE), trans-1,2-dichloroethene (trans-1,2- DCE), and 1,1-dichloroethene (1,1-DCE)) have declined to near or below detection limits. Despite decreasing concentration trends, vinyl chloride and cis-1,2-DCE are still detected in MW-5D (average 5.7 and 9.0 micrograms per liter [μg/L], respectively in 2010). Vinyl chloride and cis-1,2-DCE concentrations remained elevated after other VOCs disappeared, and concentrations have been decreasing gradually since 2000 (Figure D-1). Benzene is also frequently detected at trace levels in MW-5D, with an average concentration of 0.45 μg/L in 2010.

There are three other downgradient wells in the Cc2 unit, MW-2, MW-21, and MW-9. MW-2 also showed a peak in vinyl chloride concentration in the early- to mid-1990s, with decreasing concentrations since then, falling below 1 μg/L by 2000 (Figure D-2). Vinyl chloride is still detected in MW-2, with a concentration of 0.244 μg/L during 4th quarter 2010. Monitoring at MW-21 did not begin until 1999, at which time the cis-1,2-DCE concentration was measured at 8.7 μg/L (Figure D-3). Vinyl chloride is consistently detected in MW-21 at a median concentration of 0.5 μg/L, with values ranging from 0.27 to 1 μg/L. Benzene and trans-1,2-DCE were initially detected, but concentrations have declined below the detection limit.

MW-9 has exhibited no detectable VOCs since monitoring began in 1996. MW-9 is located further north than the other Cc2 wells.

VOC concentrations are also attenuated downgradient within the Cc2 unit. Groundwater flow is southwest across the VLF. MW-5D is the closest Cc2 monitoring well to the refuse, located approximately 400 feet to the southwest of the refuse. In 2010, MW-5D had vinyl chloride and cis-1,2-DCE concentrations between 5 to 10 μg/L, and detectable benzene. MW-21, located 250 feet south of MW-5D, had cis-1,2-DCE and vinyl chloride concentrations less than 1 μg/L, and no detectable benzene, in 2010.

The Western Hillslope seeps are also downgradient within the Cc2 unit. Surface water samples have been collected in weirs since 1991, and at the seeps starting in 2007. Low concentrations of vinyl chloride were detected periodically in weir samples, with values up to 0.14 μg/L. VOCs are consistently detected in the seeps, including cis-1,2-DCE, trans-1,2-DCE, chloroethane, and vinyl chloride. Vinyl chloride is consistently detected in seep samples SW-S2, SW-S3, and SW-S4, with average concentrations of 0.88, 0.42, and 2.95µg/L, respectively. Vinyl chloride has been detected in approximately half of the samples collected at SW-S5, with a maximum concentration of 0.2 µg/L. Cis-1,2-DCE is consistently detected in SW-S2 and SW-S3 with average concentrations of 1.1 µg/L and 0.55 µg/L, respectively. Cis-1,2-DCE has also been detected in SW-S4, SW-S5 and SW-S6, with maximum concentrations of 1.16, 0.908, and 0.36 µg/L, respectively. Trans-1,2-DCE and chloroethane have also been detected in SW-S2, with maximum concentrations of 0.43 and 1.21 µg/L, respectively.

In addition to the attenuation of VOCs within the Cc2 unit, attenuation of VOCs and metals is observed between the seeps and weirs in the hillslope area. As discussed above, vinyl chloride and cis-1,2-DCE are consistently detected in the seep samples, however, in the weirs there have only been a small number of detections of vinyl chloride (maximum concentration of 0.14 µg/L with detections in roughly 10% of samples). This indicates that aeration of the stream/spring attenuates VOCs in the surface water.

Additionally, arsenic concentrations are elevated in the sand aquifer unit Cc2 downgradient of the landfill (median concentration of 0.1 mg/L in MW-5D) and in seeps supplied by unit Cc2 on the western hillslope (generally around 0.03 milligrams per liter (mg/L) in SW-S2, which has the highest concentrations), as compared to the upgradient monitoring well (concentrations in MW-20 are less than 0.002 mg/L). Arsenic concentrations correlate with an increase in dissolved iron concentrations (Figure D-4), and arsenic concentrations are higher in MW-5D than in the leachate (median As concentration 0.003 mg/L), which indicate that reducing conditions downgradient may be leading to a release of arsenic from aquifer materials. Reducing conditions lead to the dissolution of iron oxides, releasing adsorbed arsenic. However, arsenic concentrations are lower in the seeps and springs than in MW-5D, indicating attenuation of arsenic further downgradient. Iron oxide precipitates were observed around SW-S2, and dissolved iron concentrations decline from approximately 25 mg/L at SW-S2 to less than 4 mg/L at SW-W2, while arsenic concentrations decrease by an order of magnitude between seep SW-S2 and weir SW-W2. This indicates that a return to oxidizing conditions in the surface water is effective at attenuating arsenic through adsorption to iron oxide precipitates.

D.1.1 Preliminary Source Evaluation at MW-5D and Seeps

Landfill gas (LFG) transport would generate an increase in VOCs and alkalinity, as CO_2 is a major component of landfill gas. Leachate would also introduce VOCs and increase alkalinity, but is also associated with elevated inorganics, notably chloride and sodium.

There is evidence for a historical leachate release to the Cc2 unit, as chloride and VOC concentrations, especially vinyl chloride and cis-1,2-DCE, were elevated in MW-5D in 1993-1996 (Figure D-1). Chloride has returned to background levels in MW-5D, and was not elevated in MW-2 (the other downgradient well operational during the relevant time period). Vinyl chloride concentrations were elevated in MW-2 during the same time span (Figure D-2). Monitoring did not begin at the other Cc2 wells, MW-9 and MW-21, until 1996 and 1999, respectively.

Data collection began in 1991 at SW-W1, SW-W2, and SW-W3. There have been low level detections of vinyl chloride in weir samples from 1991 to the present; however, aeration between the seeps and weirs likely led to a loss of VOCs in those samples. Chloride concentration is elevated at seep sampler SW-S2 (approximately 50 mg/L) as compared to background levels (Figure D-5). The chloride concentration in SW-W2 is approximately 30 mg/L. The chloride concentration in SW-W3 was higher(above 10 mg/L) than background levels (5 mg/L) in 2000; but since 2007, it has decreased to levels similar to background.

The seep monitoring data suggests impacts from LFG and leachate are being detected at different locations. Vinyl chloride is consistently detected in SW-S2, with an average concentration of 0.88 µg/L. In SW-S2, chloride concentrations are elevated (50 mg/L), and vinyl chloride concentrations are not correlated to alkalinity concentrations. In contrast, SW-S4, which also has consistent vinyl chloride detections with an average concentration of 2.95µg/L, has chloride concentrations consistent with background (5 mg/L) and a high correlation between alkalinity and vinyl chloride (Figures D-6 and Figure D-7).

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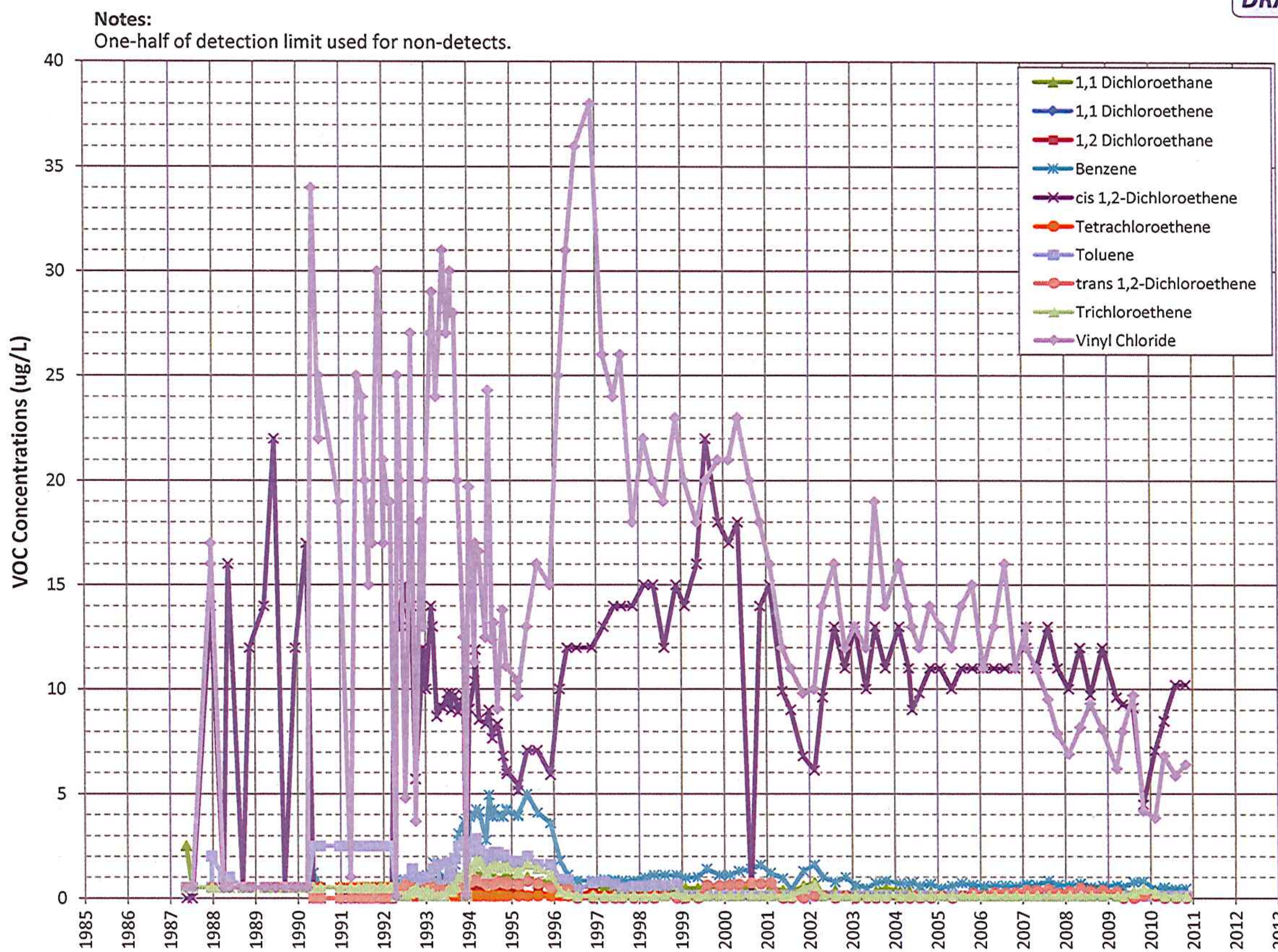

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Figure D-1
VOC Concentrations in MW-5D

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Notes:
One-half of detection limit used for non-detects.

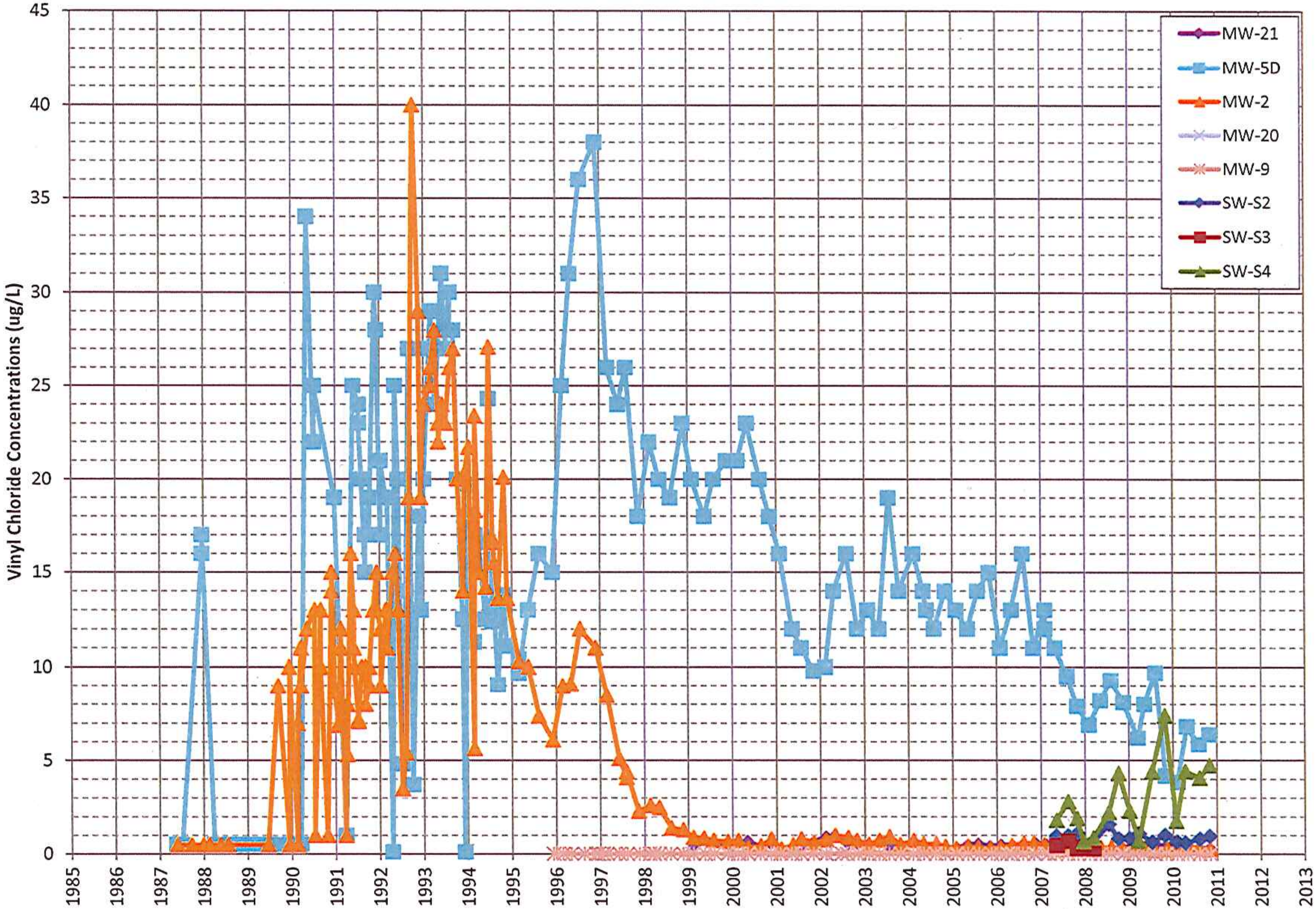

Figure D-2
Vinyl Chloride Concentrations in CC2 Aquifer

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Notes:
One-half of detection limit used for non-detects.

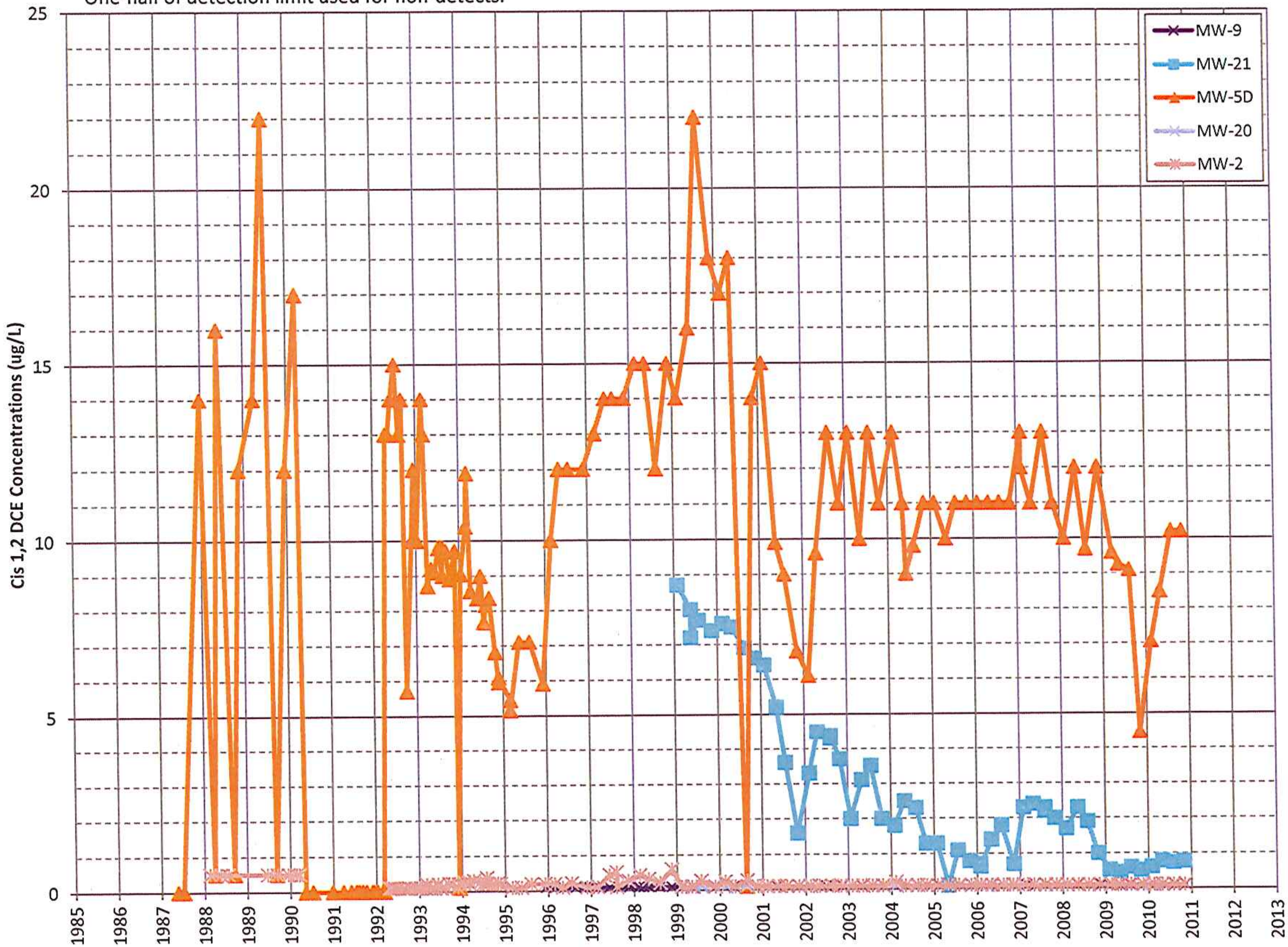

Figure D-3
Cis-1,2 DCE Concentrations in CC2 Aquifer

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Notes:
One-half of detection limit used for non-detects.

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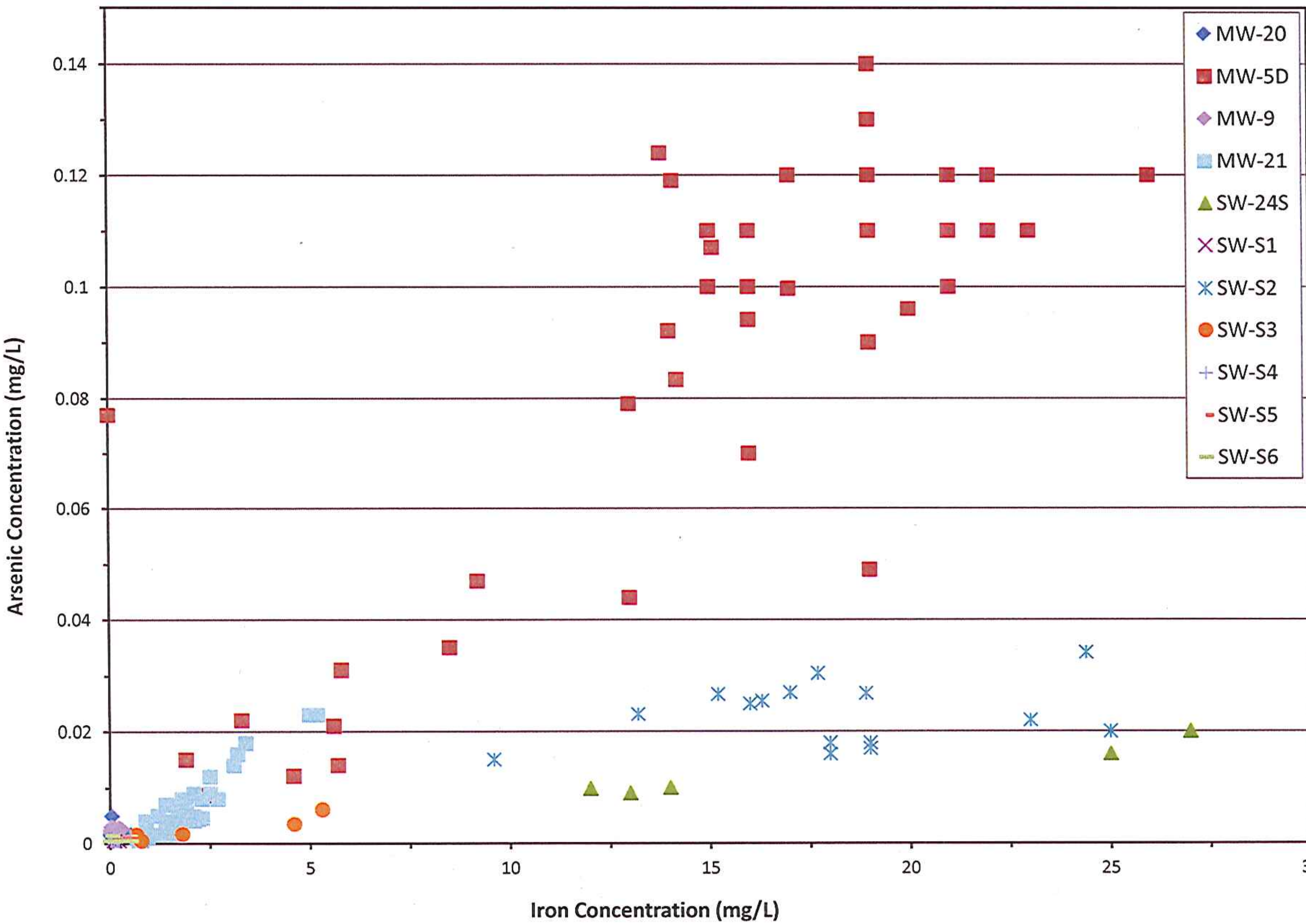

Figure D-4
Cross Plot of Arsenic and Iron Concentrations in CC2 Aquifer

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Notes:
One-half of detection limit used for non-detects.

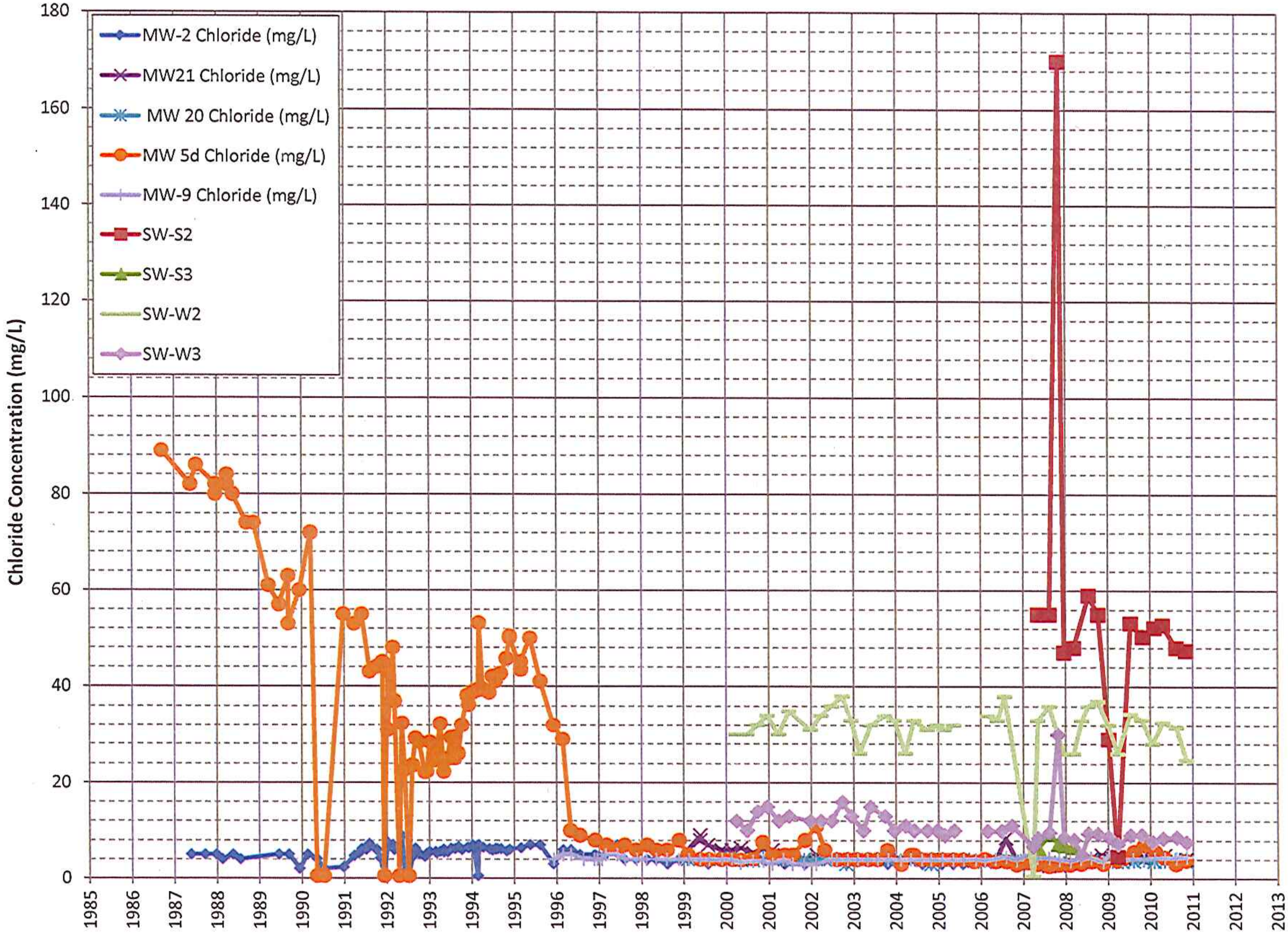

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Figure D-5
Chloride Concentrations in CC2 Aquifer

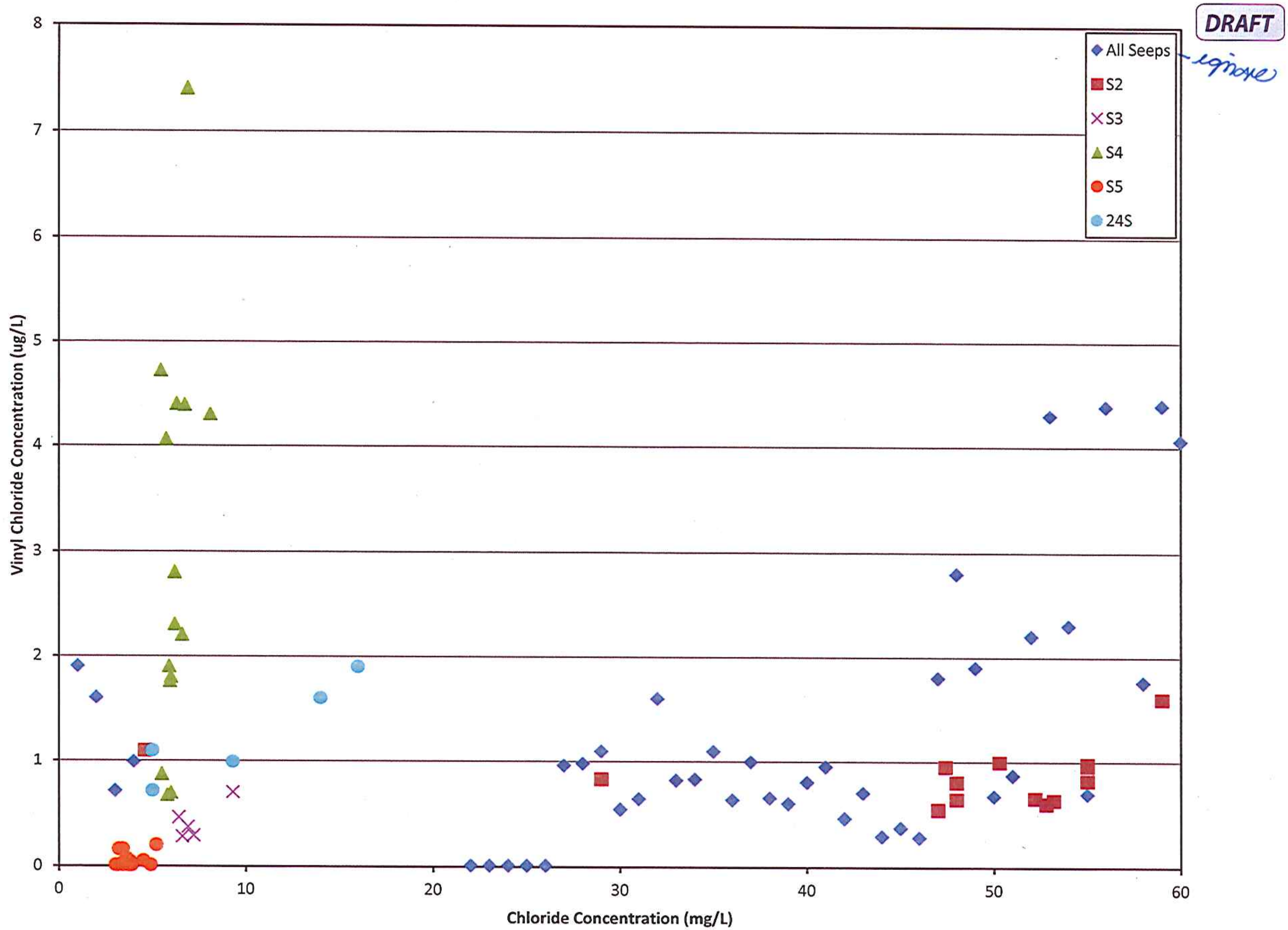

Figure D-6
Cross Plot of Vinyl Chloride and
Chloride Concentrations in CC2 Aquifer Seeps

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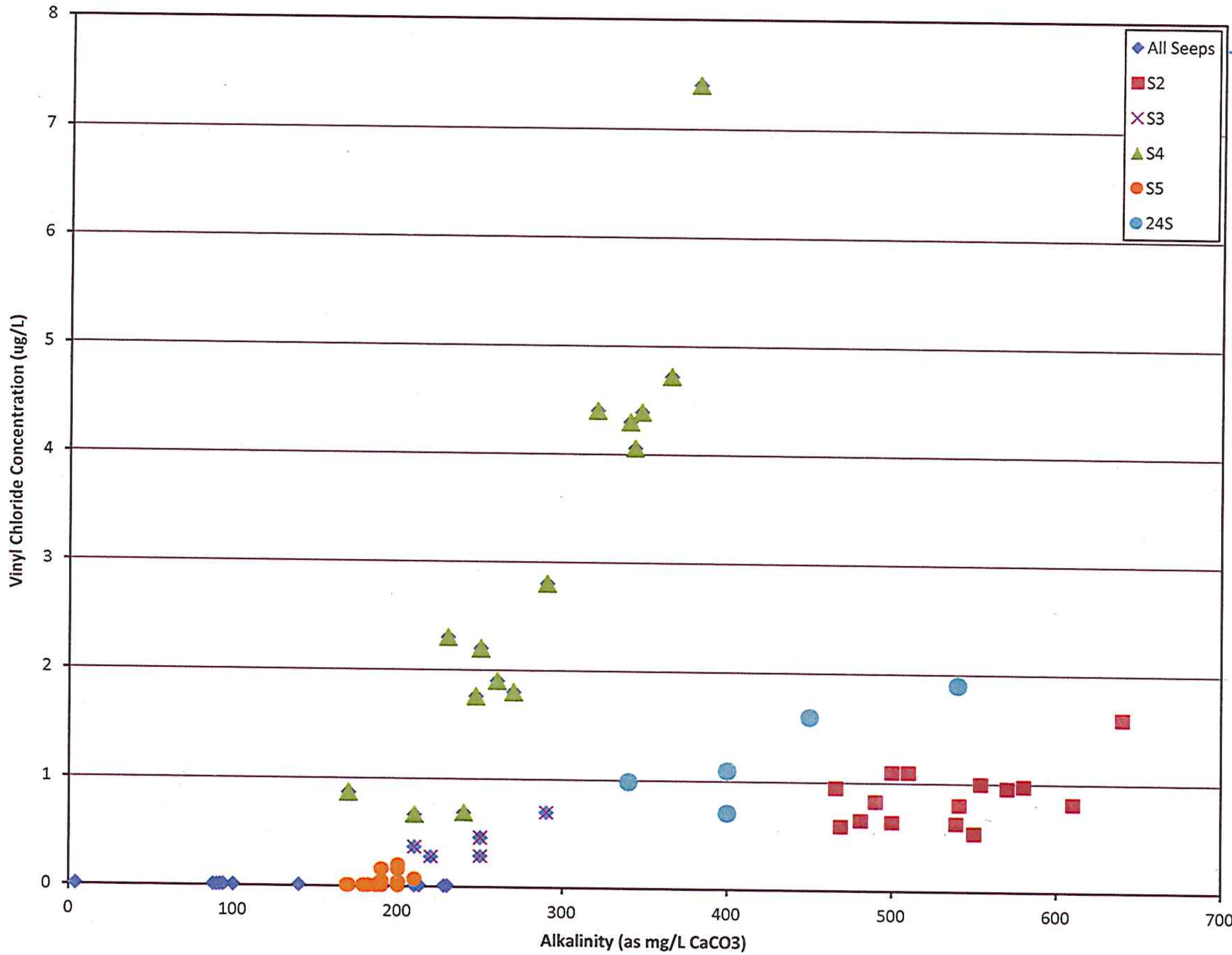

Figure D-7
Cross Plot of Vinyl Chloride and
Alkalinity Concentrations in CC2 Aquifer Seeps

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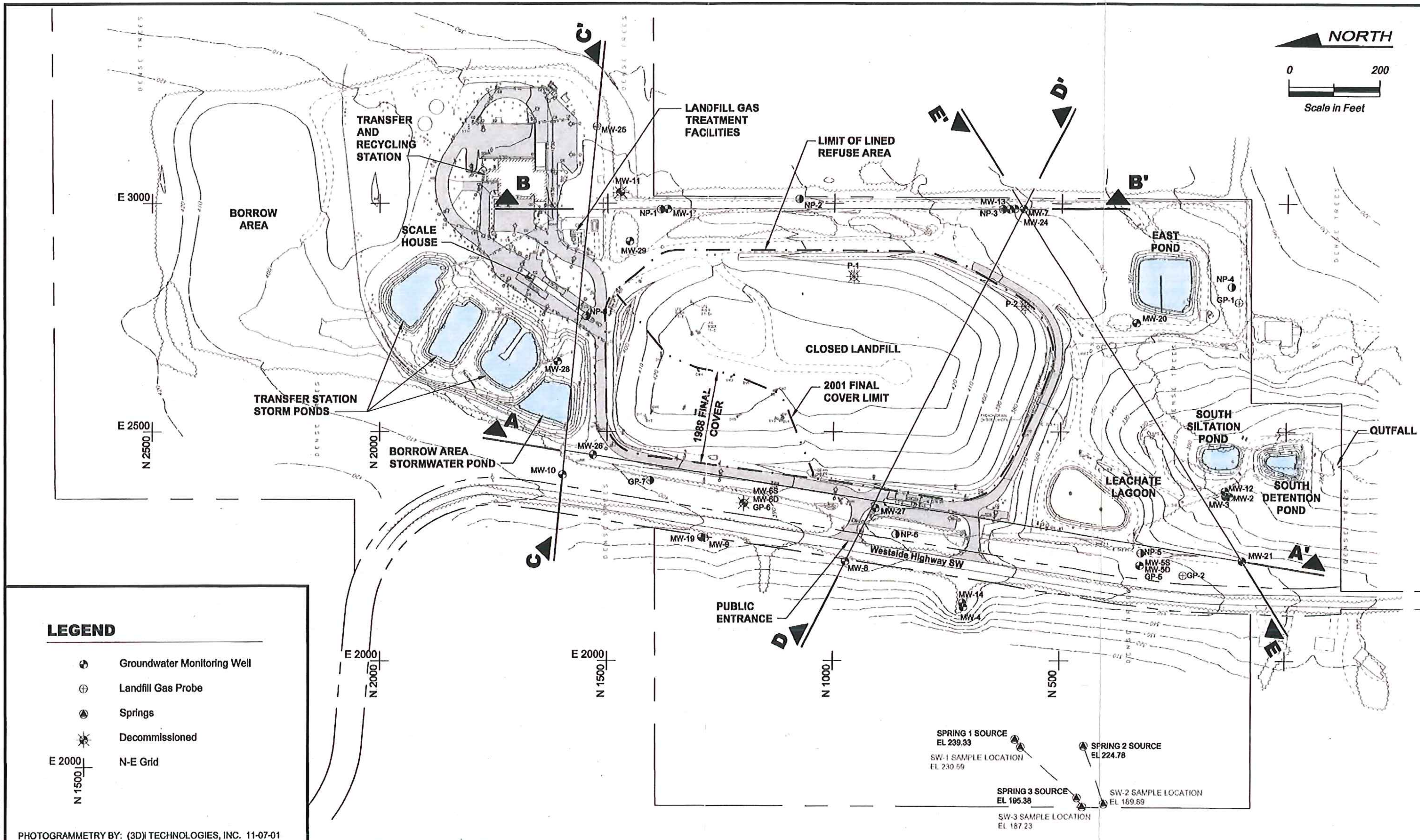
APPENDIX E

Hydrostratigraphic Cross Sections from Berryman and Henigar et al., (2004)



Berryman & Henigar
720 Third Avenue, Suite 1200
Seattle, Washington 98104-1820
206/505-3400
Fax 206/505-3406

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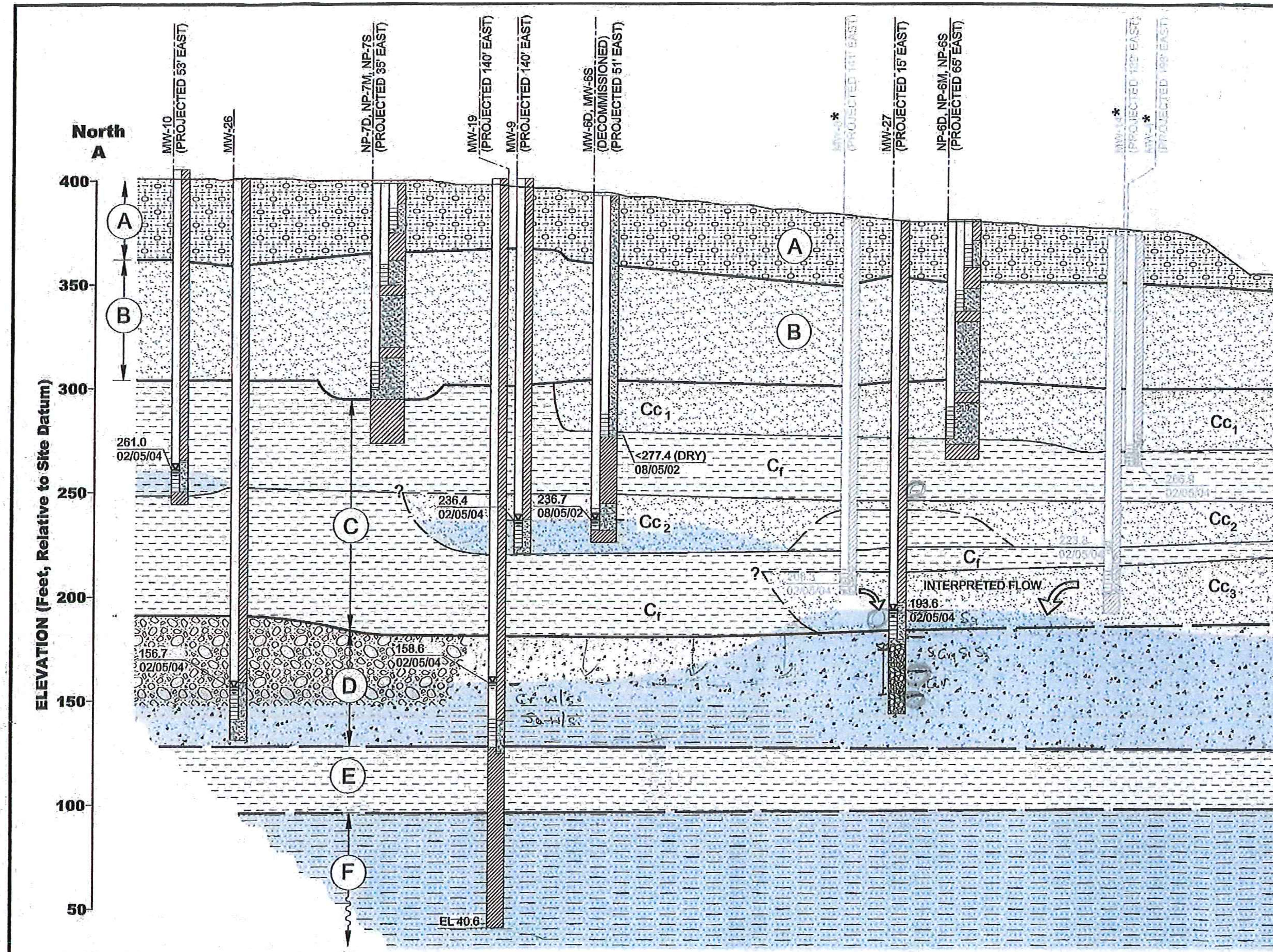
Solid Waste Division

Vashon Island Landfill Hydrogeologic Report Update

Hydrogeologic Cross Section Location Map

Date: December 2004

Figure 3-1



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1 OF 2

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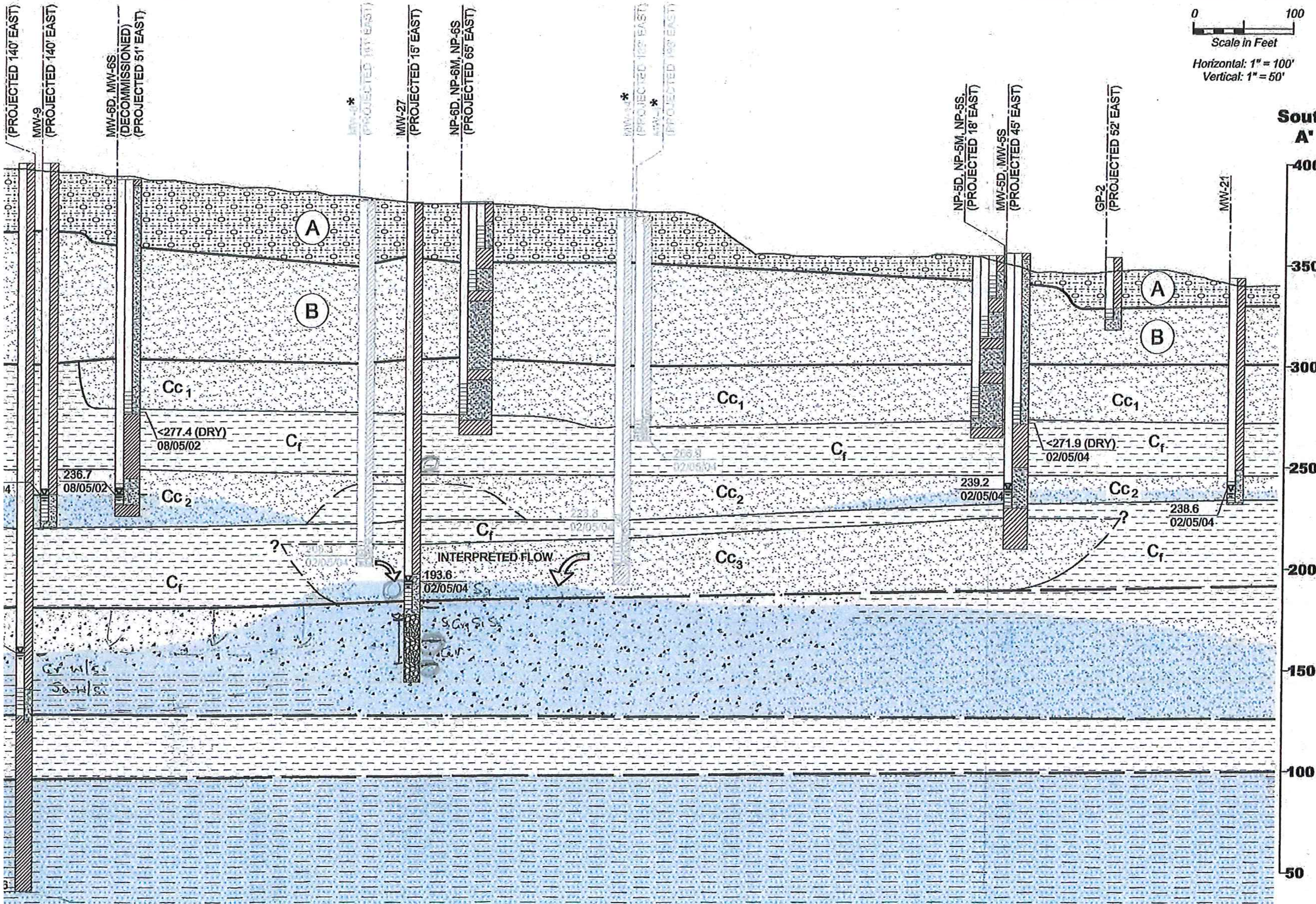

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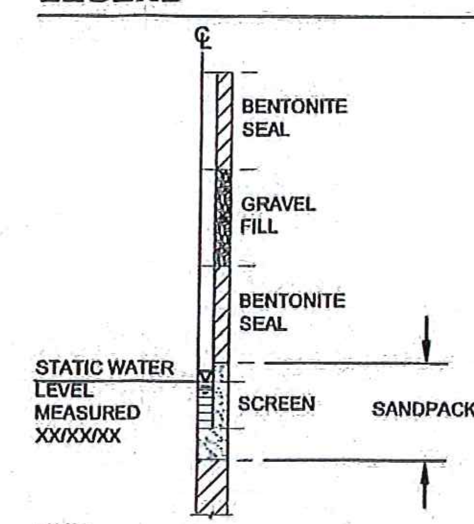

NOTE:
SEE SECTION 2.2 FOR DESCRIPTIONS OF GEOLOGIC UNITS. SEE SECTION 3 FOR DISCUSSION OF HYDROGEOLOGIC INTERPRETATION.

* THE STRATIGRAPHY AT THIS WELL DIFFERS FROM THE STRATIGRAPHY AT WELLS LOCATED CLOSER TO THE SECTION LINE. THIS WELL IS INCLUDED TO ILLUSTRATE ITS POSITION AND INTERPRETED HYDROSTRATIGRAPHIC RELATIONSHIP WITH RESPECT TO NEARBY WELLS.

LIMITS OF CHANNEL DEPOSITS (DASHED WHERE INFERRED)

GEOLOGIC CONTACT (DASHED WHERE INFERRED)

SATURATED ZONE

INTERPRETED POTENTIOMETRIC SURFACE

VASHON TILL

SAND AND SLIGHTLY SILTY SAND (SP-SM, SW-SM)

SILT, CLAYEY SILT, AND CLAY (ML, CL), INCLUDES PRE-VASHON TILL (GM, GW-GM) WITHIN UNIT E

SANDY GRAVELS AND GRAVELLY SANDS (GP, GW, SP, SW)

SLIGHTLY SILTY GRAVEL (GP-GM, GW-GM)

SILTY SAND (SM) WITH SAND (SP, SW), SILT (ML), AND SILTY GRAVEL (GM) INTERBEDS

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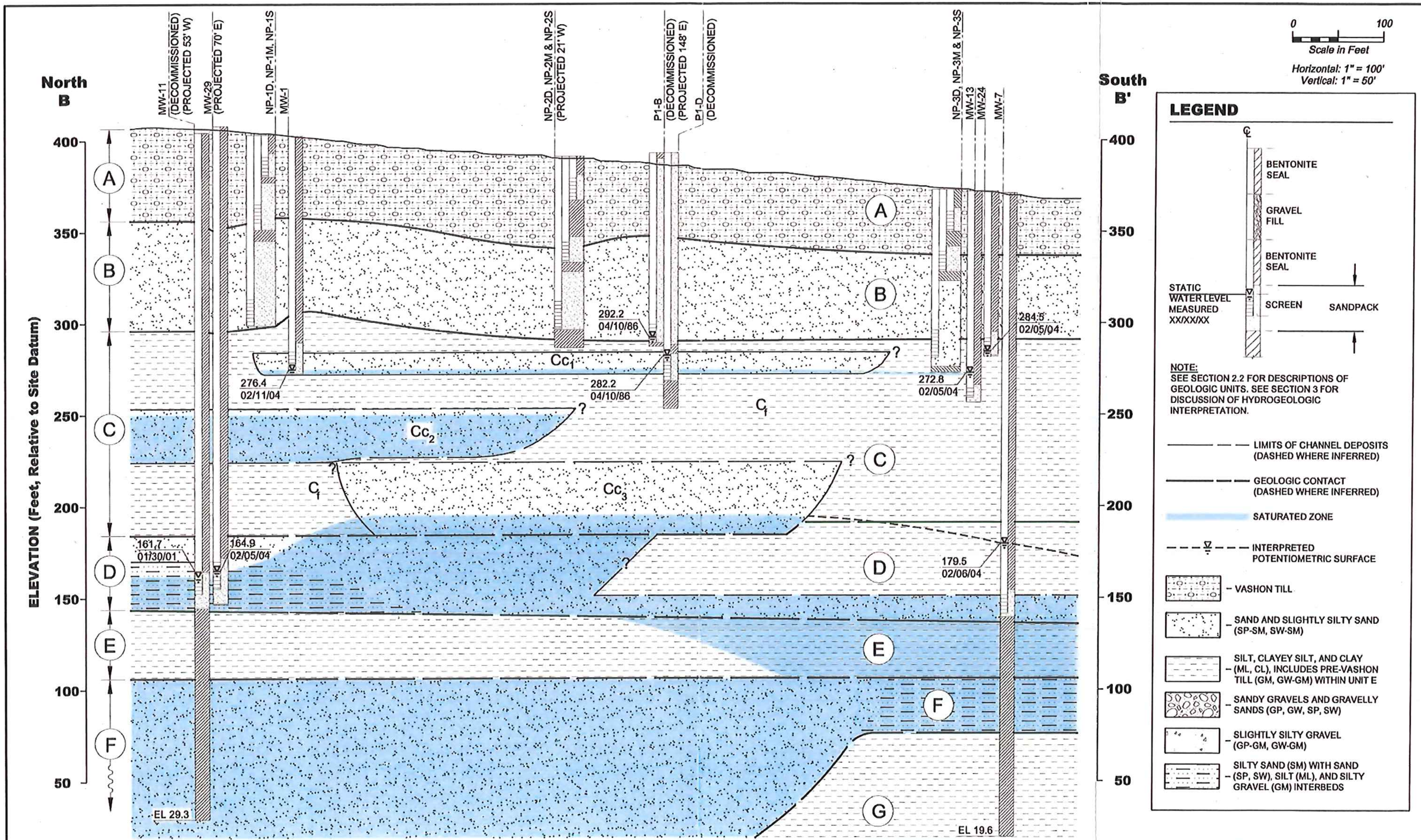
2 OF 2

Vashon Island Landfill Hydrogeologic Report Update — *Figure*

Hydrogeologic Cross Section A-A' **3-2**

Date: December 2004



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Seattle, Washington 98104-1820
206/505-3400
Fax 206/505-3406

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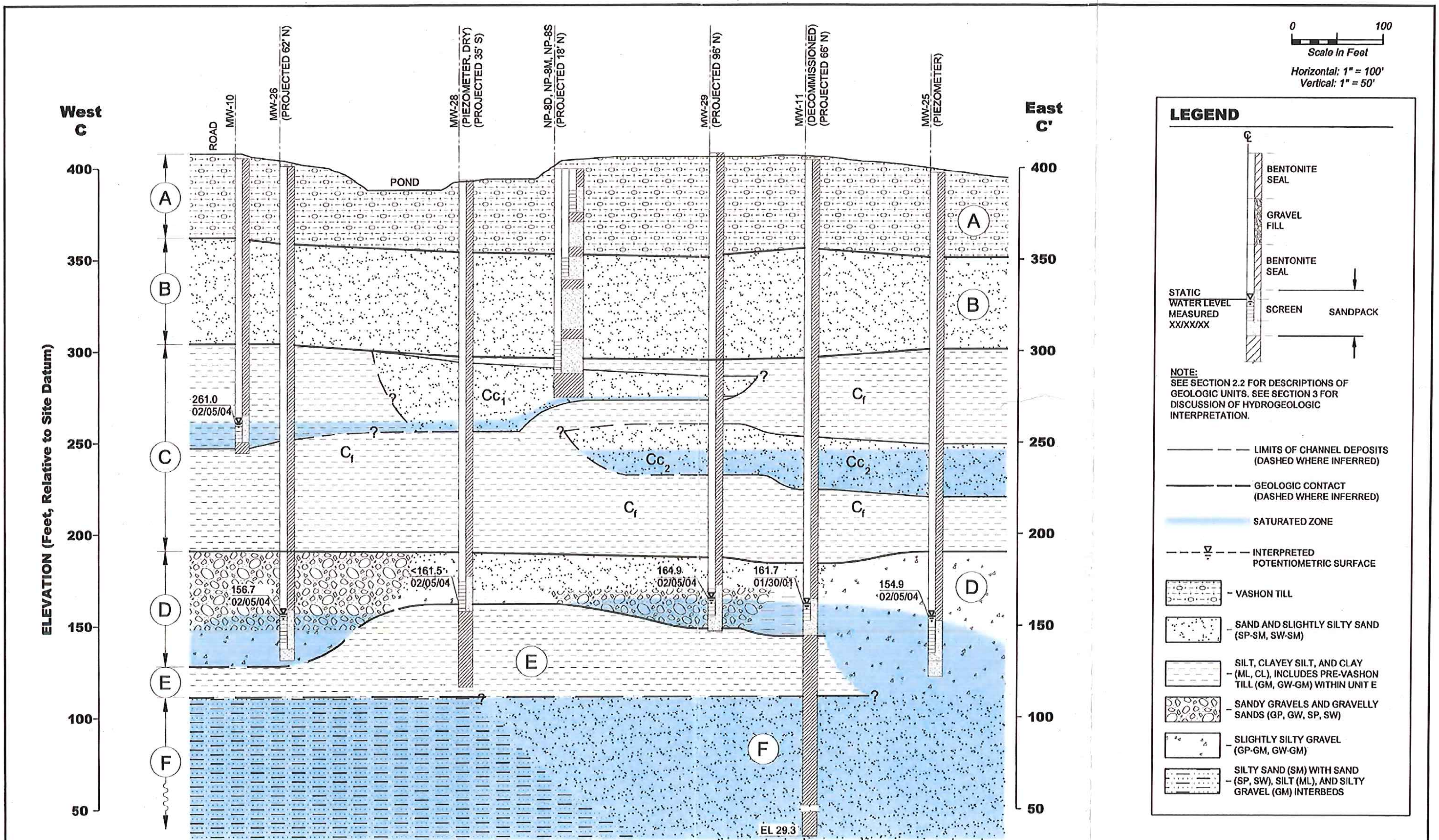
Figure 3-3

Hydrogeologic Cross Section B-B'

Date: December 2004



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Seattle, Washington 98104-1820
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Fax 206/505-3406

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Figure 3-4

Hydrogeologic Cross Section C-C'

Date: December 2004

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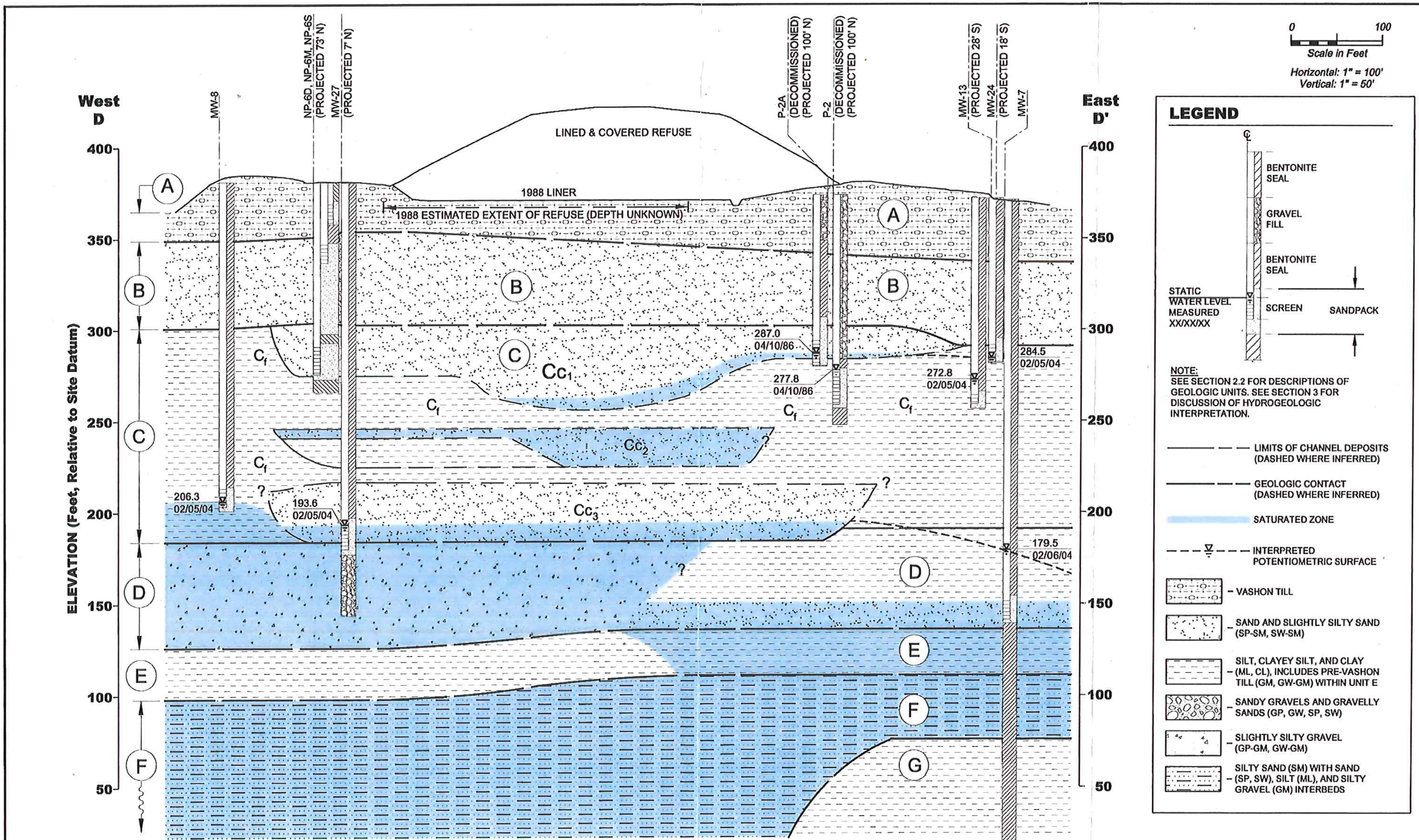

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Seattle, Washington 98104-1820
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Fax 206/505-3406

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Figure 3-5

Hydrogeologic Cross Section D-D'

Date: December 2004

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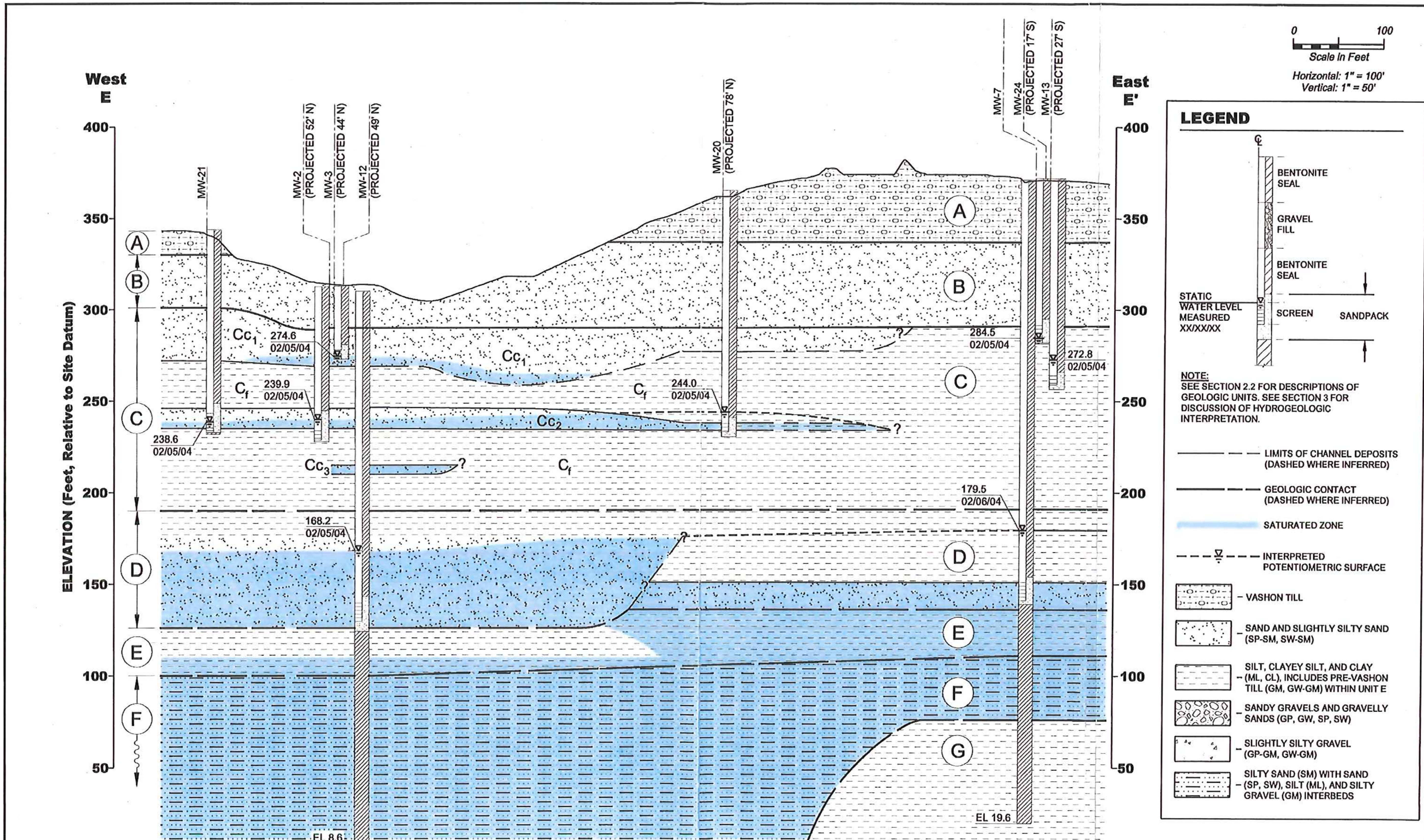

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Vashon Island Landfill Hydrogeologic Report Update

Figure

Hydrogeologic Cross Section E-E'

3-6

Date: December 2004