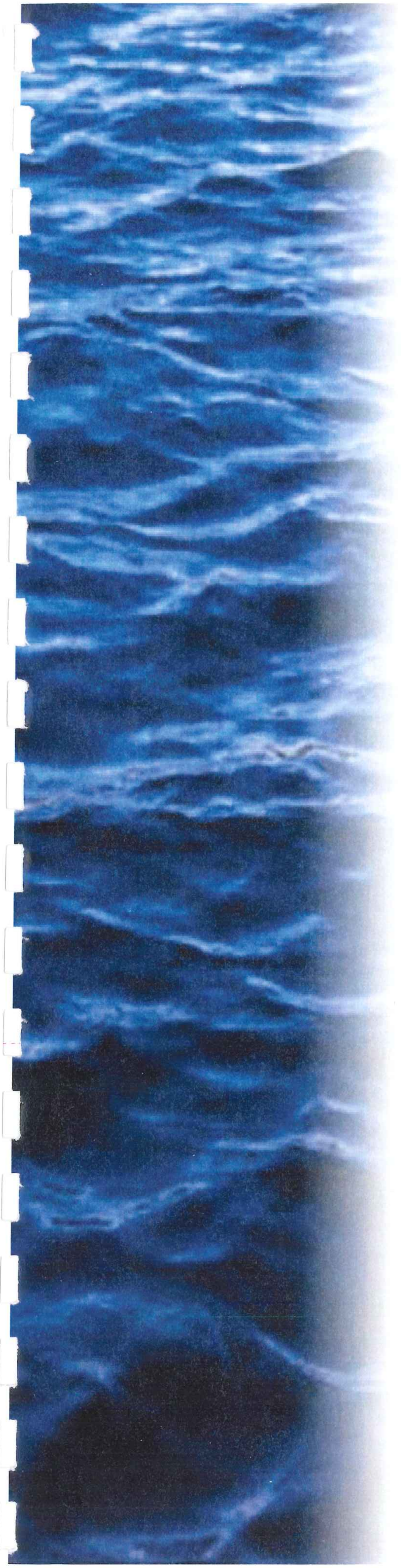

April 2003

Remedial Investigation/ Feasibility Study Holly Street Landfill Redevelopment Project

Prepared for:

City of Bellingham
City Hall
210 Lottie Street
Bellingham, WA 98225

For Submittal to:

Washington State Department of Ecology
US Environmental Protection Agency

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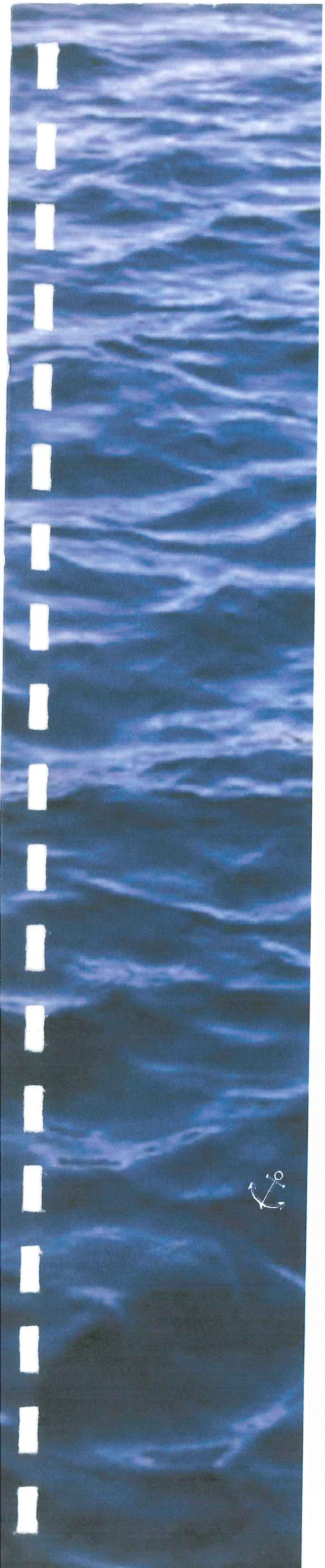
Sit 3.6.1



November 2001

Remedial Investigation/ Feasibility Study Holly Street Landfill Redevelopment Project Draft Final

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REMEDIAL INVESTIGATION/FEASIBILITY STUDY

HOLLY STREET LANDFILL REDEVELOPMENT PROJECT

DRAFT FINAL

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Funded by:
U.S. Environmental Protection Agency
Brownfields Assessment Demonstration Pilot Program

November 2001

TABLE OF CONTENTS

APPENDICES

FIGURES

TABLES

1.0 Executive Summary

The City of Bellingham contracted with Anchor Environmental, LLC and its subconsultants to conduct a remedial investigation/feasibility study (RI/FS) of the Holly Street Landfill Site in Bellingham, Washington. This work was performed with funding from the Bellingham EPA Brownfields Assessment Demonstration Pilot Program for the Holly Street Landfill Redevelopment Project, consistent with an agreement with the U.S. Environmental Protection Agency. The Washington Department of Ecology (Ecology) also provided oversight of this work through its Voluntary Cleanup Program.

Consistent with Work Plans developed for this project, environmental data were collected during this RI/FS from potentially affected media within and immediately adjacent to the Holly Street Landfill Site. Between April 2000 and January 2001, data were collected from upland soil borings, ground water monitoring wells, and shoreline well points and sediments. When combined with earlier site investigation data, the RI/FS successfully characterized the nature and extent of contamination at the site, and provided an evaluation of where concentrations of hazardous substances at the site exceed prospective environmental cleanup levels.

This RI/FS Report presents the integrated results of all sampling and analysis, along with evaluations of cleanup requirements and potentially applicable cleanup technologies, and detailed evaluations of remediation alternatives. The report presents information relevant to the weighing of alternative actions considering net environmental benefits, permanence, implementability, cost, and other Model Toxics Control Act (MTCA) criteria.

This RI/FS Report is intended to facilitate agency, landowner, and public review, and to enable Ecology to select a cleanup action alternative for the Holly Street Landfill Site. The cleanup alternatives described in this document also address the overall objectives of both the EPA Brownfields Assessment Demonstration Pilot Program, as well as the Bellingham Bay Comprehensive Strategy. Cleanup alternatives have been integrated with related redevelopment, public access, and habitat restoration elements, to examine opportunities for a coordinated approach. The Bellingham Bay Comprehensive Strategy Environmental Impact Statement (EIS), issued by Ecology in October 2000, is a companion document to this RI/FS.

2.0 Introduction

The City of Bellingham (City) contracted with Anchor Environmental, LLC (Anchor) and its subconsultants Aspect Consulting, LLC (Aspect; formerly Associated Earth Sciences, Inc. [AESI]), BEK, and Heartland to conduct a remedial investigation/feasibility study (RI/FS) for the purpose of characterizing environmental conditions and developing appropriate cleanup alternatives for the Holly Street Landfill Site in Bellingham, Washington. This work was necessary to implement the Bellingham EPA Brownfields Assessment Demonstration Pilot Program for the Holly Street Landfill Redevelopment Project, and was carried out in a manner consistent with the Cooperative Agreement between the City and the U.S. Environmental Protection Agency (EPA) dated August 25, 1999. The overall scope of services of this project is more fully described in the July 7, 1999, Work Plan provided as supplemental information to the Holly Street Landfill Redevelopment Project Brownfields application submitted by the City on March 22, 1999.

2.1 Site Background and Description

In the late 1800s, the Holly Street Landfill Site was part of the original Whatcom Creek estuary and mudflat. Around 1905, private property owners began filling portions of the site with dredge spoils and other materials to increase useable upland areas. Beginning in 1937, sanitary landfills for municipal waste disposal operated on certain private tidelands under permits issued by the City to property owners wishing to raise their properties above the tide.

Based on a review of available historical records, municipal waste disposal at the Holly Street Landfill Site appears to have occurred over the period between 1937 and 1953. The estimated extent of municipal solid waste at the site, based on available data and historical shoreline maps, comprises an area of roughly 13 acres, located on both sides of Whatcom Creek (Figure 2-1). Most of the wastes disposed at the site were generally described in the historical documents as inorganic materials, largely devoid of putrescible wastes or flammable items, which were disposed at other locations. Specific descriptions of waste materials disposed at the Holly Street Landfill Site have included glass, concrete, household debris, metal scrap, soil, coal slag, ashes, and woody debris, consistent with landfill disposal practices of the time. Few of the waste materials are currently exposed at the surface, but are largely covered by soil fills, gravel, and/or asphalt.

Beginning in 1953 and continuing possibly as late as 1959, municipal waste disposal was curtailed at the Holly Street Landfill Site, when landfill operations were moved to the nearby Cornwall Avenue Landfill Site. Beginning in the late 1960s and continuing through the early 1970s, municipal waste disposal shifted again to the Roeder Avenue Landfill. Separate environmental investigations have been completed at the Cornwall and Roeder Avenue Sites (ReTec 1997; Landau 2000).

2.2 Regulatory Framework

Today, the Holly Street Landfill Site includes two sites, located on either side of Whatcom Creek, which are listed as contaminated sites by Ecology. These properties are subject to investigation and cleanup requirements of the Washington State Model Toxics Control Act (MTCA; Chapter 173-340 Washington Administrative Code [WAC]) and Sediment Management Standards (SMS; Chapter 173-204 WAC).

Landfilled properties located northwest of Whatcom Creek include the Maritime Heritage Center Fish Hatchery, the former Bellingham Sash and Door property, and several other private properties. Landfill areas southeast of Whatcom Creek are largely contained within the Maritime Heritage Park property, though portions of private properties in this area also contain municipal waste. As generally depicted on Figure 2-1, portions of these properties contain historic municipal landfill wastes that are collectively referred to for the purposes of this RI/FS as the Holly Street Landfill Site. Separate and distinct MTCA and/or SMS sites exist elsewhere in the site vicinity, including the Roeder Avenue Landfill Site located to the west and the Whatcom Waterway and Cornwall Avenue Landfill Site located to the southwest.

Using the available site assessment data, Ecology has ranked the Holly Street/Sash & Door Site as a level "2" (medium-high) priority, and the Maritime Heritage Park Site as a level "3" (medium) priority for further investigation and cleanup under the authorities of MTCA and SMS (Ecology 1995 and 1999). Much of Ecology's concern is related to the potential release of metals into the adjacent Whatcom Creek estuary, a critical rearing area for juvenile salmonids and other wildlife.

As set forth under MTCA (WAC 173-340-350), this RI characterizes the nature and extent of contamination at the site, and the associated potential threats to human health and the environment. To this end, environmental data were collected from potentially affected media (i.e., soil, ground water, and sediment) within and immediately adjacent to the Holly Street Landfill Site, and were compared to conservative screening criteria to identify site chemicals of potential concern (COPCs). More detailed evaluations of the COPCs were then undertaken to evaluate whether concentrations of hazardous substances at the site may exceed MTCA cleanup levels.

The FS presented herein integrates the results of all available sampling and analysis data, along with a review of potentially applicable cleanup requirements and existing remediation technologies, to present a detailed evaluation of remediation alternatives. The FS presents information relevant to the weighing of alternative actions considering net environmental benefits, permanence, implementability, cost, and other MTCA criteria, and is intended to facilitate agency, landowner, and public review, and to enable Ecology to select a cleanup action alternative for the Holly Street Landfill Site.

The City, working under the oversight of both EPA and Ecology, prepared the RI/FS report presented herein. EPA's oversight was performed under the terms of a Cooperative Agreement between the City and EPA, and specifically as an element of the Holly Street Landfill Brownfields Redevelopment Project. Ecology's oversight of this RI/FS was performed under the MTCA Voluntary Cleanup Program.

After addressing public and stakeholder comments on this RI/FS report, the City and Ecology anticipate entering into a MTCA Consent Decree to develop and implement a Cleanup Action Plan (CAP) for the Holly Street Landfill Site. Ecology's selected remedy will be articulated in a draft CAP and both the prospective draft Consent Decree and draft CAP will be provided for public review, consistent with MTCA requirements. Design and permitting tasks would be funded in part through a Supplemental Assistance Grant from EPA for the Holly Street Landfill Brownfields Redevelopment Project. Design and permitting of the final remedy may also be coordinated with other actions within the area, including the Section 1135 Ecosystem Restoration Project Feasibility Study currently being initiated by the U.S. Army Corps of Engineers (Corps) and the City. Construction of the selected cleanup remedy may potentially receive funding assistance from the MTCA Remedial Action Grant program and/or the Corps, as appropriate.

2.3 RI/FS Objectives

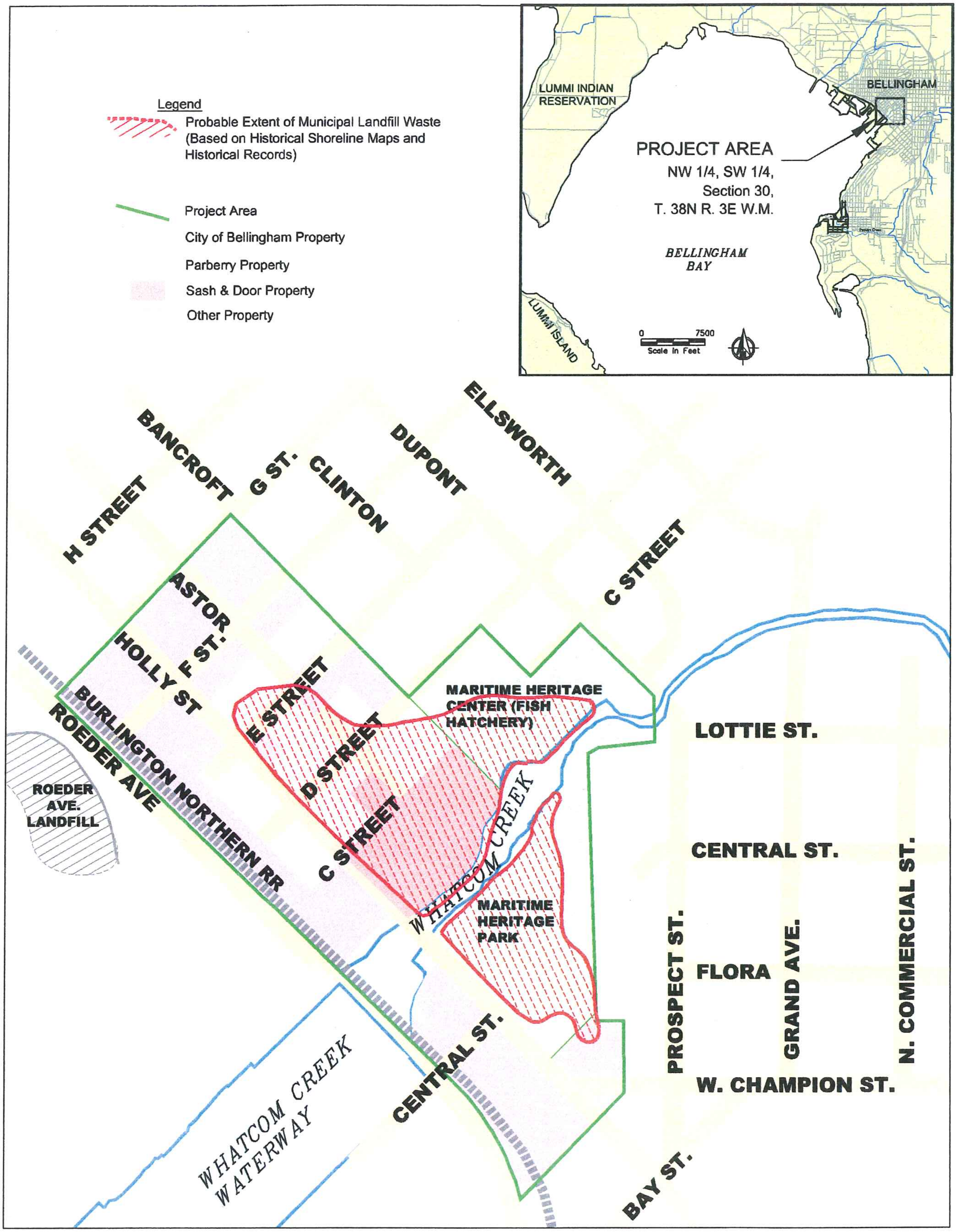
The goal of the RI/FS was to meet MTCA requirements for characterization of environmental conditions at the Holly Street Landfill Site, including characterization of the nature and extent of contamination at the site, and the associated potential threats to human health and the environment. This RI/FS was also intended to present a detailed evaluation of remediation alternatives, and to present information relevant to the weighing of alternative actions considering net environmental benefits, permanence, implementability, cost, and other MTCA criteria, in order to facilitate selection of an appropriate cleanup action alternative for the Site. This work was also necessary to implement the Bellingham Brownfields Assessment Demonstration Pilot Program for the Holly Street Landfill Redevelopment Project. As presented in the Brownfields application package, the broad goals of the Holly Street Landfill Redevelopment Project can be summarized as follows:

- To collect critical data required to identify appropriate environmental cleanup actions for landfill materials present at the site, and assess how these actions may impact habitat enhancement plans and development costs and opportunities;
- To assess the feasibility of redevelopment of this brownfield site, considering geotechnical, economic, and land use constraints under either a City-led or joint public/private partnership approach; and
- To provide an effective decision-making framework to promote environmental cleanup and economic revitalization of the Holly Street Landfill Site, and through which habitat enhancements and public access improvements can be achieved.

2.4 Report Organization

The remainder of this report is organized as follows:

- Section 3.0 of this report presents a summary of activities conducted during previous Site investigations and as part of this RI/FS.
- Section 4.0 presents the results of the RI, including characterization of the nature and extent of contamination.
- Section 5.0 presents the development of provisional MTCA cleanup standards for the Site, and an evaluation of whether such standards may be exceeded at the Site.
- Section 6.0 presents a summary of applicable federal, state, and local laws.
- Section 7.0 presents a screening of cleanup technologies.
- Section 8.0 presents the basis for the design of cleanup alternatives, including integration with the Comprehensive Strategy for Bellingham Bay, the City's redevelopment objectives, habitat requirements, and other constraints.
- Section 9.0 presents a description of the cleanup alternatives that are made up of the cleanup technologies presented in section 7.0 and meet the constraints described in Section 8.0.
- Section 10.0 presents a comparative analysis of the alternatives against MTCA cleanup criteria, as well as other factors that may affect the implementation of the alternatives.
- Section 11.0 presents the references cited in the report.



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ENVIRONMENTAL, L.L.C.

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Scale in Feet

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Figure 2-1
Holly Street Landfill
Project Area

05/09/01 HOL002-02.dwg 99-062-04

3.0 Remedial Investigation Activities

3.1 Previous Environmental Assessments of the Holly Street Landfill Site

Initial environmental assessments of the Sash and Door property and of the Maritime Heritage Park located directly across Whatcom Creek, were performed in 1993 (W.D. Purnell & Associates1993 and Landau 1993, respectively). Additional geotechnical data for the general Site vicinity, including information from adjacent sites, are available from other studies (e.g., CH2M-Hill 1970, ReTec 1996 and 1997, GeoEngineers 1998 and 2001).

The locations of previous soil explorations (test pits and soil borings) performed within the Holly Street Landfill Site are generally depicted on Figure 3-1. Apparent landfill waste materials have consistently been observed within the former tideflat area, beginning at depths ranging from 1 to 20 feet below ground surface, and extending from 2 to 15 feet thick. Roughly 3 to 20 feet of recent soil fill has been placed above waste materials in portions of the Maritime Heritage Park, generally isolating landfill materials below possible contact by park visitors.

Detectable methane levels (below levels of potential explosive concern) have been reported during previous soil explorations. However, compared to other regional landfills, methane levels observed at the Holly Street Landfill Site were relatively low, a result consistent with use of the landfill mainly for inert waste disposal. The highest methane levels (up to 45 percent of the lower explosive limit or LEL) were encountered approximately 20 feet below ground surface in monitoring wells installed at the Maritime Heritage Park (Landau 1993). Slightly higher methane levels were reported in a single monitoring well (A-MW-4) installed during this RI/FS. These data are discussed below in Section 4.3.

Chemical analyses have been performed on five (5) selected waste/soil samples collected from the Holly Street Landfill Site (BEK Purnell 1993; Landau 1993). The samples were analyzed for a range of metals, volatile and semi-volatile organic compounds, total petroleum hydrocarbons, and pesticides/polychlorinated biphenyls (PCBs). These prior soil/refuse sampling data are presented as discussed in Section 4.4 below.

As part of the previous environmental assessment of the Maritime Heritage Park, three ground water monitoring wells were installed and sampled on this (southeastern) portion of the Holly Street Landfill Site (Landau 1993; Figure 3-1). Ground water samples were analyzed for a range of metals, petroleum hydrocarbons, and volatile organic compounds. The site assessment completed at the Sash and Door property (BEK Purnell 1993) included collection of ground water samples; however, samples were collected directly from standing water within the test pit explorations. Relatively high total suspended solids (TSS) levels present in these samples render the data of limited value for ground water characterization, particularly for metals and certain organic chemicals that adsorb strongly to solids (e.g., polynuclear aromatic hydrocarbons [PAHs]). These prior ground water sampling data are presented as discussed in Section 4.6 below.

In 1996, Georgia-Pacific West, Inc. initiated the Whatcom Waterway RI/FS. Part of the scope of that RI/FS was to identify potentially significant ongoing sources of contamination to the Whatcom Waterway Site, and to determine whether sediments upstream of the Holly Street bridge were adversely impacted by ongoing or historic discharges. Based on surface water and sediment sampling data, along with other source evaluation information (BBWG 1999a), the Whatcom Waterway RI/FS concluded that there are no significant ongoing sources of contamination to the Whatcom Waterway Site (Anchor Environmental and Hart Crowser 2000). Similarly, mid-channel sediments in this area did not exceed SMS criteria. Nevertheless, localized shoreline seepage and sediment quality concerns at the Holly Street Landfill Site were not directly evaluated in the Whatcom Waterway RI/FS.

3.2 Remedial Investigation Sampling and Analysis

In March 2000, Anchor and AESI prepared a combined Work Plan/Sampling and Analysis Plan (SAP) that described the approach and tasks required to complete an initial RI of the Holly Street Landfill Site. The Work Plan/SAP (Anchor and AESI 2000) summarized previous environmental data collected within and immediately adjacent to the Holly Street Landfill Site; presented a preliminary conceptual model of environmental conditions; identified objectives for further site characterization efforts; and presented a detailed description of sampling and analysis tasks. The March 2000 Work Plan/SAP, as approved by EPA and Ecology, included the following tasks:

- Upland soil borings and monitoring well sampling;
- Shoreline well point sampling;
- Shoreline sediment sampling; and
- Chemical analysis and data validation.

Initial RI activities, summarized below, were implemented over the period from April to October 2000.

Following initial review of the initial RI sampling data, additional work was deemed necessary to complete the RI of the Site in accordance with MTCA requirements. These additional work requirements were identified during a meeting held on November 20, 2000 between EPA, Ecology, and City. As agreed to at the meeting, the specific objectives of the supplemental RI were as follows:

- To further delineate the extent of solid waste deposits at the northwest and southeast margins of the Site; and
- To further characterize solid waste, soil gas, and ground water quality conditions in the southeast portion of the Site (Maritime Heritage Park).

A Work Plan/SAP Addendum No. 1 was subsequently prepared under EPA and Ecology oversight in December 2000 (Anchor 2000). The supplemental RI tasks were completed between late December 2000 and April 2001, and were coordinated with separate geotechnical investigations performed by the City at the Maritime Heritage Park (GeoEngineers 2001).

3.2.1 Upland Soil Borings and Monitoring Well Sampling

On April 18, 2000, 3 soil borings were advanced on City right-of-way at the locations shown on Figure 3-1. Two of the borings (A-MW-2 and A-MW-3) were advanced on City right-of-way locations adjacent to the Bellingham Sash and Door property, exploring through the landfill waste into underlying native soils. The third boring (A-MW-1), also advanced to the top of the silt/clay confining layer, was located in the north corner of the Maritime Heritage Center Fish Hatchery parking lot, within a local background area that was not filled historically with refuse. On December 28, 2000, 3 additional soil borings were advanced at Maritime Heritage Park at the locations shown on Figure 3-1 (A-MW-4 through -6). All 6 of these soil borings were completed as shallow monitoring wells.

On December 29, 2000, 3 soil borings were advanced at the northwest margin on the Site (A-B1 through A-B3) to delineate the extent of landfill deposits in this area. On April 19 and 20, 2001, 9 additional soil borings were advanced by GeoEngineers (2001) within the Maritime Heritage

Park (GEI-MB-1 and -2; GEI-PL-1 through -7), both to delineate the extent of landfill deposits in this area, and to collect geotechnical data for planned site redevelopment actions. None of these 12 soil borings were completed as monitoring wells.

All borings were advanced using a conventional 4.5-inch internal diameter (ID) hollow stem auger and were terminated in native soils at depths ranging from 10 to 40 feet below ground surface. An AESI (April 2000), BEK (December 2000), or GeoEngineers (April 2001) field geologist logged subsurface geologic conditions during drilling in accordance with American Society for Testing and Materials (ASTM) practice designation D-2488, *Standard Practice for Description of Soils (Visual-Manual Procedure)*. Soil and waste samples were collected using a 2-inch diameter split-spoon sampler (and appropriate down-hole hammer), at approximate 5-foot depth intervals and/or at noted changes in material type. Boring logs are provided in Appendix A.

To supplement other available data (BEK Purnell 1993; Landau 1993; ReTec 1997; Landau 2000), the March 2000 Work Plan/SAP (Anchor and AESI 2000) called for two soil/waste samples to be collected for chemical analysis from each of the borings advanced within the landfill footprint (4 samples total). However, due to low sample recovery, only one sample could be collected from each of the borings (2 samples total) and it was necessary to composite over longer depth intervals (sample A-MW-2-S-1 from 2.5 ft to 11.5 ft and A-MW-3-S-1 from 2.5 ft to 9.0 ft) to obtain sufficient sample volume. These 2 samples were submitted for chemical analyses to verify the quality of landfill materials. Soil cuttings were placed in 55-gallon drums for appropriate off-site disposal based on the soil chemistry results.

As discussed above, 6 soil borings were completed as 2-inch-diameter monitoring wells (A-MW-1 through -6). The monitoring wells were installed in accordance with Chapter 173-160 WAC, Minimum Standards for Construction and Maintenance of Wells. A 7 to 10-foot monitoring well screen was installed in each of these borings. A 0.01-inch machine slot Poly vinyl chloride (PVC) screen was installed with a sand filter pack consisting of Colorado Silica 20-40 sand, placed in the annular space between the screen/pipe and the borehole. The filter sand was placed to 3 feet above the top of the screen. A minimum 2-foot seal consisting of medium bentonite chips was placed in the annular space above the filter sand. The remaining annular space was filled with a bentonite grout. A concrete surface seal and protective monument was placed at the ground surface. The protective monument was constructed with a traffic-bearing steel cover and was completed either flush with the existing ground surface (A-MW-1 through -3) or with a protective above-ground monument (A-MW-4 through -6). The protective covers or monuments were permanently labeled "Monitoring or Observation Well". The monitoring well heads were completed with a locking thermos-type well cap.

The monitoring wells were developed to remove fine-grained material from inside the well casing and filter pack, and to develop hydraulic communication between the well screen and the surrounding aquifer formation. Well development was performed using the Wattera system or equivalent, consisting of a length of high-density polyethylene (HDPE) tubing connected to a foot-valve. Also attached to the tubing is a mechanical surge block that loosens and removes fine-grained aquifer formation material lodged in the filter pack. The system allows for discrete development along specific zones of the well screen. Field parameters such as temperature, specific conductance, pH and turbidity were monitored throughout the development period. Development was considered complete once the turbidity of the well became relatively clear of particulate matter (less than 50 Nephelometric Turbidity Units [NTUs]). Well development logs are provided in Appendix A.

In accordance with the approved Work Plan/SAP and addendum, ground water samples were collected from the monitoring wells during three separate events, as follows:

- April, 2000 - corresponding to peak seasonal ground water discharge "wet season" conditions (only A-MW-1 through -3 were sampled during this period);
- August, 2000 - corresponding to minimum seasonal discharge "dry season" conditions (only A-MW-1 through -3 were sampled during this period); and
- January 2001 - corresponding to intermediate or "rising limb" hydrologic conditions (only A-MW-4 through -6 were sampled during this period).

The samples were collected using the procedures detailed in the March 2000 Work Plan/SAP (Anchor and AESI 2000) and December 2000 Work Plan/SAP Addendum (Anchor 2000). Field measurements included temperature, pH, specific conductance, turbidity, redox potential, and dissolved oxygen.

With the exception of the wet season (April 2000) A-MW-2 sample, all ground water samples contained relatively low turbidity (less than or equal to 12 NTU). However, the ground water sample obtained from A-MW-2 in April 2000 contained relatively elevated turbidity (19 NTU) and also exhibited a relatively high total suspended solids (TSS) concentration of 50 mg/L. Because of potential sampling-induced turbidity, total metals determinations for this sample may be biased high. A more representative ground water sample from A-MW-2 was collected during the subsequent dry season (August 2000) sampling, which exhibited a lower turbidity value of 4 NTU.

The vertical and horizontal positions of the monitoring wells are presented in Table 3-1. Monitoring well boring logs and well construction details are presented in Appendix A.

3.2.2 Shoreline Well Point Sampling

During the initial RI effort, 4 temporary well points (WP-1, WP-2, WP-3, and WP-5) were installed for sampling ground water discharge into Whatcom Creek. As with the ground water sampling of monitoring wells, these well points were sampled during wet season and dry season conditions in April and August, respectively. The Work Plan/SAP (Anchor and AESI 2000) initially called for five well points to be sampled; however, sampling efforts during both of the initial sampling events identified only four seep locations that provided suitable volume for sampling. During the supplemental RI sampling in January 2001, one additional well point (WP-6) was installed southwest of Holly Street at a location potentially downgradient from portions of the Maritime Heritage Park (see below). Well point locations are shown on Figure 3-1.

Well points were installed and sampled during low tide conditions. A combination of vertical and horizontal well point installation methods was used in order to sample the primary seepage pathways to the creek. Due to relatively low seepage rates at stations WP-1, WP-3, and WP-5 during the dry season, horizontal well point installation at these stations was necessary to obtain sufficient sample volume. Similarly, because of relatively low flows at station WP-2, well points were installed horizontally at this location during both the April and August sampling events.

Vertical well points were constructed within 3-inch diameter post-holes advanced up to 3 feet into the shallow waste/sand unit present along the margins of the creek. The post-hole digger was backed out of the boring, leaving a 3-inch-diameter hole. The boring cuttings were left next to the boring and backfilled into the hole after the well points were removed. The well point, consisting of a 1-inch-diameter pre-cleaned stainless steel assembly with a 1-foot-long screen section, was lowered into the hole and placed within the zone of saturation encountered at low tide. The outer annulus of the screen was backfilled with 10/20 sand pack.

Prior to sampling, each vertically-installed well point was developed by purging with a pre-cleaned 1-inch diameter bailer to improve hydraulic connection and minimize turbidity.

Subsequently, pre-cleaned Teflon-coated tubing was lowered into the well point, and water was withdrawn from the well point by operating a peristaltic pump at a relatively low rate to reduce turbidity. The peristaltic pump removed at least three pore volumes from the well points prior to sampling or until the water ran clear of particulate matter (less than 50 NTUs), whichever was longer. Horizontal well points were constructed into the shallow waste/sand unit present along the margins of the creek by hammering in the well point horizontally. The well point consisted of a 1-inch-diameter pre-cleaned stainless steel assembly with a 1-foot-long screen section. All purge water obtained from the well points was collected, contained, and stored in PVC drums and then properly disposed (within the City wastewater treatment plant following receipt of chemical results).

Ground water quality sampling of all well points was conducted near the end of the outgoing (ebb) tide cycle to characterize minimum tidal dilution conditions. Samples were collected from vertically-installed well points using a peristaltic pump and pre-cleaned Teflon-coated tubing assembly. Water samples from horizontally-installed well points were collected directly into laboratory provided sample containers.

Field measurements included temperature, pH, specific conductance, turbidity, redox potential, and dissolved oxygen. The vertical and horizontal positions of the well points are presented in Table 3-1. Well point purging and sampling logs are presented in Appendix A. Well point turbidity was relatively higher (21 to 26 NTU) during the April 2000 sampling, and lower (0.4 to 4.1 NTU) during the August 2000 and January 2001 samplings.

3.2.3 Shoreline Sediment Sampling

Surface sediment samples (6 total, including one upstream reference site) were collected on April 21, 2000 at representative shoreline locations within the Whatcom Creek Estuary. Sediment samples were collected near each of the four well point locations, as well as at an additional station on the southeast side of Whatcom Creek and at the most upstream depositional reference station (approx. 12 percent fines), located across the creek from the Maritime Heritage Fish Hatchery. The locations of the sediment sampling stations are depicted on Figure 3-1.

Sediments were sampled from the biologically active surface layer (0 to 12 cm), using stainless steel spoons at low tide. All sampling was performed in accordance with Puget Sound Estuary Program (PSEP) protocols (PSEP 1997a). Sediment was collected and homogenized in a pre-cleaned stainless steel bowl, then transferred to appropriate containers and placed in coolers on ice for transport to the testing laboratory. Additional details of the sampling procedures are provided in the Work Plan/SAP (Anchor Environmental and AESI 2000). Sediment samples were analyzed for the full list of SMS chemicals.

3.2.4 Chemical Analysis and Data Validation

Analysis of soil, ground water, and seep samples was conducted in accordance with EPA SW-846 Methods. Analyses of sediment samples were conducted in accordance with Puget Sound Estuary Program (PSEP) protocols (PSEP, 1997a,b). Specific analyses for each matrix and the methods used are provided in the Work Plan/SAP and Addendum No. 1.

Data packages were checked for completeness immediately upon receipt from the laboratory to ensure that data and QA/QC information requested were present. Data quality was assessed using current EPA and Ecology protocols by considering the following:

- Holding times
- Surrogate spike results

- Matrix spike/matrix spike duplicate results
- Standard reference material results
- Method blanks
- Detection limits.

The data was validated in accordance with the project specific data quality objectives described in the project Work Plan/SAP and EPA's functional guidelines for the validation of organic and inorganic data. The data validation reports are presented in Appendix B. All data were determined useable as qualified for the purpose of this RI/FS.

Table 3-1. Monitoring Well and Well Point Coordinates and Elevations

Sample Location	Easting in feet	Northing in feet	Surface Sediment/Soil Elevation in feet MLLW
Monitoring Wells:			
A-MW-1	1,242,263	644,523	22
A-MW-2	1,242,064	644,252	21
A-MW-3	1,242,222	643,954	16
A-MW-4	1,242,390	643,879	20
A-MW-5	1,242,239	643,777	17
A-MW-6	1,242,626	643,616	35
L-MW-1	1,242,595	643,654	33
L-MW-2	1,242,653	643,667	36
L-MW-3	1,242,654	643,549	38
Well Point/Sediment Samples:			
WP-1/SD-1	1,242,174	643,841	4.0
WP-2	1,242,236	643,916	7.9
WP-3/SD-2	1,242,359	644,062	3.7
SD-3	1,242,442	644,289	3.5
SD-4	1,242,336	643,918	5.1
WP-5/SD-5	1,242,468	644,121	3.6
SD-6	1,242,583	644,298	5.8
WP-6	1,242,161	643,641	5.5
Sediment Samples:			
HC-SS-38	1,242,199	643,837	-0.2
HC-SS-39	1,242,379	644,089	-2.6

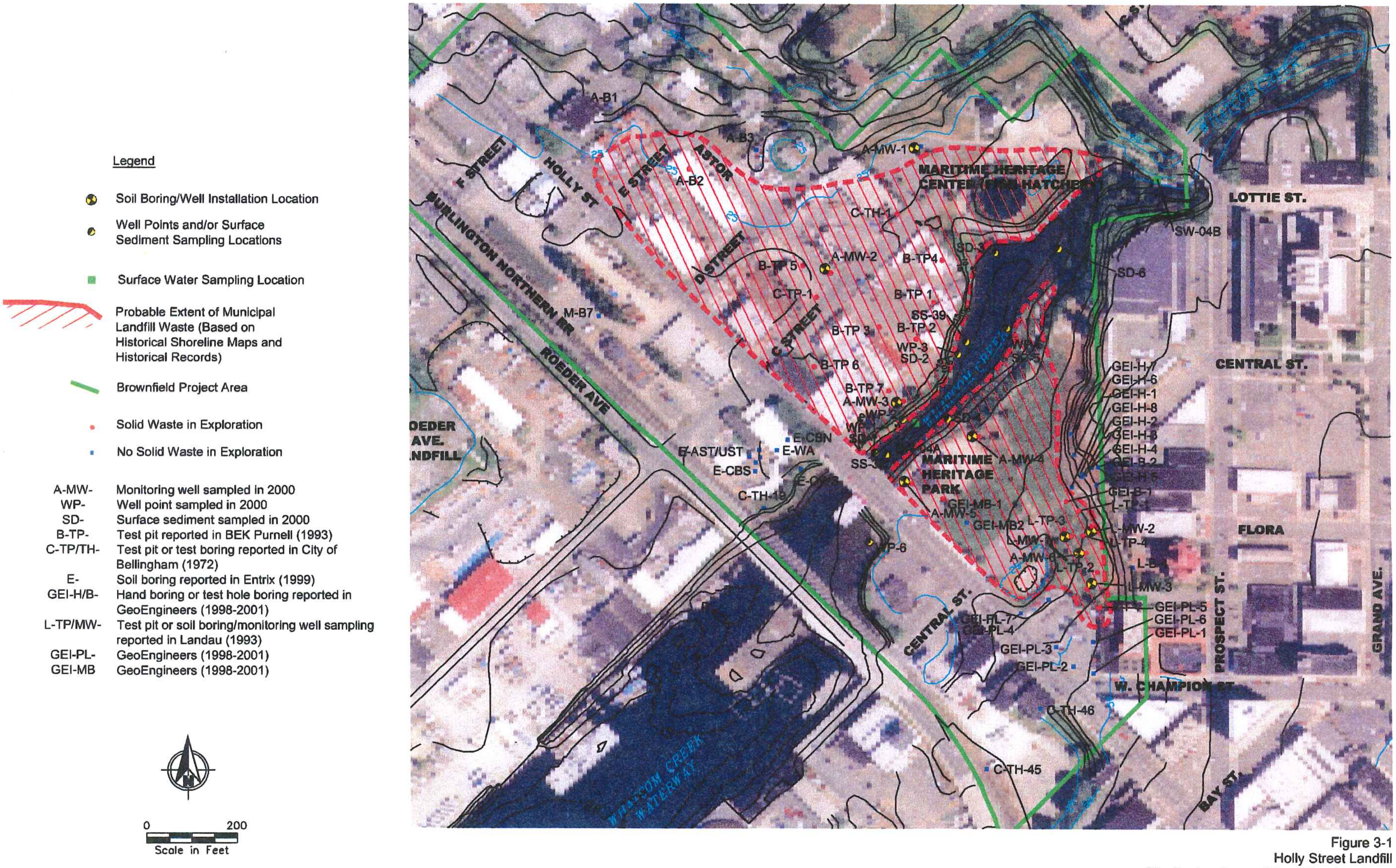


Figure 3-1
Holly Street Landfill
Site Exploration and Sampling Locations

05/09/01 MHP Revised Site Plan (01-05-01) rev05-08-01.dwg 99-062-04

ANCHOR

4.0 Remedial Investigation Results

4.1 Site Topography and Bathymetry

Site topographic and bathymetric conditions within the vicinity of the Holly Street Landfill were evaluated using existing City Geographic Information System (GIS) maps, supplemented with recent site surveys including detailed surveys of the former Sash & Door property, Maritime Heritage Park site and survey measurements performed during the conduct of this RI/FS. All elevation data were referenced to mean lower low water (MLLW), National Ocean Survey datum. Using these data, a generalized composite topographic/bathymetric map of the site was developed, and is presented on Figure 3-1 and Figure 4-1.

4.2 Geology

Geologic and ground water conditions at the Holly Street Landfill Site were evaluated through review of RI/FS soil borings discussed above, review of exploration logs generated during previous site investigations (CH2M-Hill 1970, BEK Purnell 1993, Landau 1993, ReTec 1996 and 1997, GeoEngineers 1998), and geologic mapping by Easterbrook (1976). Site explorations are presented on Figure 3-1 and on the geologic cross section plan (Figure 4-1). To facilitate identification of the borings, a prefix indicating the first letter of the consultant overseeing the work was added to the boring designation.

Based on a review of these explorations and investigations, site soils were divided into five primary stratigraphic units, consisting from top (youngest) to bottom (oldest) of:

- Fill;
- Refuse;
- Recent Alluvium (Recent fluvial and shallow marine deposits);
- Bellingham Drift; and
- Chuckanut Formation

A description of each major unit is presented below, followed by a discussion of the surface and subsurface extent of each unit. A description of the Sumas Outwash geologic unit is also included. Although not encountered at the site, the presence of Sumas Outwash deposits adjacent to and north of the site may have some influence on the site hydrogeology. Detailed descriptions of textural variations in each exploration are presented in the geologic logs (Appendix A).

4.2.1 Fill

The final cover of the landfill consists predominantly of silty sand and gravel of variable thickness, overlain in many areas by asphalt (northern fill unit) or landscaping (southern fill unit). Fill extends into the upland location northwest of well A-MW-1, where a silty fill about 4 feet thick was identified beneath the silty sand fill. About 5 feet of silty fill were apparently encountered in boring TH-1. Thicker fill was noted in test pits B-TP-1 and B-TP-5, where fill up to 8 feet thick was encountered. Fill in B-TP-1 was described as reworked Bellingham Drift. Cover material is generally thicker in the southeast portion of the site (Maritime Heritage Park), where it ranges from about 3 to 20 feet thick. Approximately 25 feet of fill materials were identified in boring L-B-4, located just east of the site.

4.2.2 Refuse

As discussed above, the refuse is divided into two distinct areas separated by the Whatcom Creek estuary. Approximately 9.1 acres of refuse lie on the northwest side of Whatcom Creek and 3.8 acres lie on the southeast side (Figure 4-1). The extent of refuse at the Site, determined from more than 50 soil explorations within the general Site area, closely follows the historical shoreline and is also bounded by Holly Street, which was constructed prior to filling the site. The extent of refuse at the Holly Street Landfill Site appears to be well characterized by the available data.

Refuse on both sides of Whatcom Creek consists of silt, sand, gravel, cobble mixtures with glass, bottles, rusted metal, ash-like material, black sludge, brick and wood debris. Discontinuous layers of reworked Bellingham Drift were identified within the refuse, likely used as temporary cover material. Test pit B-TP-7 encountered a standing wood piling. Complete refuse descriptions are presented on the logs presented in Appendix A.

The refuse on the northwest lobe of the Site was encountered to a maximum depth of 18 feet below ground surface (test pit B-TP-4). Refuse on the southeast portion of the Site was present at deeper depths, extending up to approximately 40 feet below ground surface (in boring GEI-MB-2). Typical thickness and depth characteristics of refuse deposits at the Holly Street Landfill Site are depicted in the Figure 4-2 cross-section.

Ground water was encountered within the base of the refuse during the explorations. In the northwest lobe, saturated refuse thickness ranged from 2 to 6 feet in monitoring wells A-MW-2 and A-MW-3. Saturated refuse thickness was somewhat greater in the southeast lobe, ranging from 4 to 12 feet in monitoring wells A-MW-4 through -6 and L-MW-1 through -3. Seasonal recharge and tidal changes influence the saturated refuse thickness on a seasonal and hourly basis, as described in more detail below.

4.2.3 Recent Alluvium

Recent fluvial and shallow marine deposits formed the mudflat surface prior torefuse deposition beginning in approximately 1937. These uppermost native deposits, collectively referred to as Recent Alluvium, are typically comprised of silt and silty sands with silt interbeds with shells, wood, and organic debris. The deposits are believed to have originated from fine-grained sediment deposited directly from Whatcom Creek or from shallow marine waters. Much of this sediment may have originated from the suspended load of the Nooksack River, which was subsequently transported by local currents and deposited around Bellingham Bay. Similar deposits have been recognized at the Cornwall Avenue Landfill Site (Landau 2000).

Recent Alluvium was found beneath the refuse in all borings that penetrated the refuse in the northwest lobe (A-MW-2, A-MW-3, and B-TP-3) and was also encountered in A-MW-1 beneath the fill. The Recent Alluvium appears to thicken appreciably toward Whatcom Creek, reaching a maximum explored thickness of 29 feet in A-MW-3, located about 15 feet from the Whatcom Creek ordinary high tide line. These deposits were not identified in explorations in the southeast lobe, although they are inferred to be present adjacent to the Whatcom Creek waterway.

Except for the upper 1 to 2 feet in monitoring well A-MW-1, the Recent Alluvium was saturated through its full thickness in all of the explorations completed during this investigation.

4.2.4 Sumas Outwash

Sumas Outwash deposits have been mapped on the upland area adjacent to and north of the project site. The Sumas Outwash was deposited in a glacial outwash channel that occupied the Squalicum Creek drainage. The downstream deposits of Sumas Outwash consist predominantly of sand.

4.2.5 Bellingham Drift

The Bellingham Drift mantles the upland areas of Squalicum Creek and the entire Whatcom Creek drainage. The deposit has been characterized as glaciomarine till comprised predominantly of silt and clay with marine shell fragments and scattered dropstones ranging from sand to boulder in size. The Bellingham Drift was deposited directly on bedrock beneath the project site from melting, rafted ice in a marine environment during the breakup of the Vashon Glaciation about 11,000 years ago. The deposits were not glacially overridden and are, therefore, generally considered normally consolidated. Because of the fine-grained nature of the deposit, the Bellingham Drift restricts downward movement of ground water from the overlying Recent Alluvium.

The full penetrated thickness of the Bellingham Drift in boring C-TH-1, located within the northwest portion of the Holly Street Landfill Site, was about 25 feet. The depth to the bottom (base) of the Bellingham Drift at this location is about 50 feet below ground surface (Figure 4-2). Monitoring well borings A-MW-1 and A-MW-3 were terminated in the Bellingham Drift at depths of 17 and 40 feet, respectively. Beneath the southeast refuse area, both the Recent Alluvium and Bellingham Drift are inferred to pinch out, and refuse in the southeast portion of this area lies directly on bedrock (Chuckanut Formation).

4.2.6 Chuckanut Formation

The oldest geologic unit encountered during subsurface explorations at and near the site is sandstone of the Chuckanut Formation, deposited about 60 million years ago. This formation crops out along portions of the southeastern side of Whatcom Creek. The Chuckanut Formation was encountered in borings C-TH-1 in the northwest refuse area and monitoring well borings L-MW-1 through L-MW-3 and boring L-B-4 in the southeast area. The erosional surface of the Chuckanut Formation appears to dip slightly toward the northwest beneath the site but apparently has substantial variations in elevation that result in outcrops along Whatcom Creek. The Chuckanut Formation was encountered about 50 feet beneath the northwest lobe of the site (boring C-TH-1) and ranged from 27 to 35 feet below ground surface on the southeast portion of the site (borings A-MW-6, L-MW-1 through -3, L-B-4, and GEI-MB-2). These data are consistent with the reported westerly dip (incline) of the Chuckanut Formation.

Typical thickness and depth characteristics of geologic units at the Holly Street Landfill Site are depicted in the Figure 4-2 cross-section.

4.3 Soil Quality

A total of 7 soil/refuse samples have been collected from the Holly Street Landfill Site, including 4 samples collected from the northeast area and 3 from the southeast area. The soil sampling data include (refer to Figure 3-1 and 4-1 for station locations):

- Two soil/refuse samples collected during this focused RI (A-MW-2 and A-MW-3);
- Two soil/refuse samples collected during the Bellingham Sash & Door Environmental Site Assessment (BEK Purnell 1993; B-TP-5 and B-TP-7); and

- Three soil/refuse samples collected during the Environmental Site Assessment of the Maritime Heritage Center Park site (Landau 1993; L-TP-1, L-TP-2, and L-TP-3).

Soil/refuse samples collected as part of this focused RI were submitted for the analysis of total metals, semivolatile organic compounds (SVOCs), total petroleum hydrocarbons (TPH), pesticides, polychlorinated biphenyls (PCBs), and conventional parameters (total solids, grain size, and total organic carbon [TOC]). Soil/refuse samples collected by BEK Purnell (1993) were analyzed for a similar suite of chemical parameters, while the Landau (1993) samples were submitted for analysis of a more focused list of analytes (especially metals). The available soil/refuse chemical determinations are summarized in Table 4-1.

4.3.1 Chemicals of Potential Concern in Refuse – Metals and Hydrocarbons

Chemical concentrations detected in soil/refuse samples collected from the Holly Street landfill Site were compared to conservative MTCA screening criteria to identify site chemicals of potential concern (COPCs). For the purpose of this screening-level evaluation, analytical results were compared to the more stringent of the MTCA Method A or Method B soil cleanup levels for unrestricted land use sites (e.g., assuming residential site uses and conservative ground water protection criteria). A summary of the screening-level evaluation is presented in Table 4-1. Based on this comparison, the following soil/refuse COPCs were identified:

- Arsenic (present above residential use screening levels in 2 of 7 samples);
- Cadmium (present above plant protection screening levels in 3 of 7 samples);
- Lead (present above residential use screening levels in 6 of 7 samples);
- Mercury (present above ground water protection screening levels in 1 of 6 samples); and
- Potentially Carcinogenic Polynuclear Aromatic Hydrocarbons (cPAHs; present above residential use screening levels in 2 of 3 samples).

More detailed evaluations of the COPCs are presented in Section 5.1 below.

4.4 Soil Gas

Methane concentration measured within soil gas at the Holly Street Landfill ranged from less than 30 to approximately 300 percent of the LEL (Table 4-1). These are somewhat lower, but in the same range as methane levels reported for the nearby Roeder and Cornwall Landfills. Only one monitoring well location (A-MW-4) located within the central area of the Maritime Heritage Park contained subsurface soil gas that exceeded the LEL. Considering the isolation of soil gas in this area from the surface, no existing risk to human health or the environment was identified. Moreover, soil gas samples collected near the margins of the Park, and throughout the northwest portion of the Site, were well below the LEL. However, the presence of elevated methane levels in A-MW-4 suggests that any future development in the Maritime Heritage Park will need to include at least a passive gas venting system below the structure, consistent with EPA's Presumptive Remedy for Landfills (EPA 1993; Section 8.0).

4.5 Hydrogeology

4.5.1 Principal Hydrogeologic Units and Regional Ground Water Use

The ground water flow system at the Holly Street Landfill Site consists of a shallow unconfined aquifer within the Recent Alluvial sediments and within refuse units. Ground water levels are shown in profile view in Figure 4-2 relative to the major geologic units at the site. Depth to ground water at the site ranges from about 7 feet in the northwest refuse area to about 25 feet in the southeast lobe of the site. The differences are largely a function of surface topography. The Bellingham Drift forms the lower boundary of the flow system, or where the Bellingham Drift is absent, by the Chuckanut Formation. Saturated thickness of the aquifer ranges from 6 feet at inland locations (near A-MW-1) to more than 30 feet near Whatcom Creek.

Information regarding water supply wells within 1 mile of the site was compiled from Ecology and Whatcom County Health and Human Services records to develop an understanding of the ground water use in the project area. The entire site area is served by an extensive City water supply system with its intake in Lake Whatcom, several miles upstream of the site. However, three wells were identified within 1 mile east of the site. The wells, shown in Figure 4-3, were drilled by City of Bellingham Public Works. These wells encountered unconsolidated sediments, predominantly Bellingham Drift, in the upper 25 to 54 feet, overlying bedrock, presumably of the Chuckanut Formation. The unconsolidated materials were cased off and the wells were completed as open holes within bedrock. No proposed use is listed on the well logs, nor is there any indication that these wells have ever been in service. The closest of these wells is located about 1,800 feet from the site. Static water elevation in this well was estimated at +58 feet MLLW based on information provided in the driller's log and a surface elevation estimated from the regional topographic map. These data, along with other available information, indicate that all local wells are situated hydraulically upgradient of the Holly Street Landfill Site.

4.5.2 Hydraulic Characteristics of the Hydrogeologic Units

Horizontal hydraulic conductivities of the aquifer materials encountered at the Holly Street Landfill Site were determined by slug testing, and ranged from 0.004 to 0.02 centimeters per second (cm/sec) for wells A-MW-3 and A-MW-2, respectively. Slug test results and analyses are presented in Appendix A. The higher permeability value computed for A-MW-2 is consistent with its completion zone being located entirely within the refuse (a refuse conductivity of roughly 0.02 cm/sec is also consistent with tidal monitoring data; see below). The test conducted at monitoring well A-MW-3, on the other hand, is more representative of the Recent Alluvium based on the screened interval, but may be slightly influenced by the refuse permeability. At the time of slug testing, the screened completion zone in A-MW-3 was open to less than 1 foot of saturated refuse. A lower hydraulic conductivity value of 0.0003 cm/sec was computed for the Recent Alluvium at A-MW-1, which is completed entirely within this zone of lower permeability.

Although not tested specifically at the site, slug testing in the finer-grained portions of the Bellingham Drift elsewhere in Whatcom County suggest permeability values to be on the order of 10^{-6} cm/sec, with vertical permeabilities one to two orders of magnitude lower (Cox and Kahle 1999). The Chuckanut Formation is considered a very low-permeability unit with insufficient open joints and fractures, and general low water yield potential (Easterbrook 1976b, Cox and Kahle 1999), although the three wells located within 1 mile of the site produce water from this unit, suggesting that locally it may be water-bearing. Observations made during a previous investigation (Landau 2000) indicated that the underlying Chuckanut Formation sandstone was dry, consistent with the low permeability of this unit.

4.5.3 Ground Water Recharge and Discharge

Ground water flow within the unconfined aquifer is generally directed from the upland areas toward Whatcom Creek. The mean ground water gradient was determined for the northwest portion of the site based on 72-hour tidal monitoring performed between October 6 and 9, 2000 at monitoring wells A-MW-1 through A-MW-3. The 72-hour data were filtered using the method described in Serfes (1991) to determine the mean ground water elevation for each well over the

72-hour period. The computed mean flow direction is shown in Figure 4-1. A horizontal gradient of 0.014 was computed from the mean water level data.

The computed ground water gradient indicates recharge to the shallow aquifer beneath the site occurs as lateral inflow. The lateral inflow originates in the upland area northwest of the site, likely occurring through Sumas Outwash or other upland deposits. Recharge also occurs as a result of direct infiltration of precipitation through the permeable portions of the site. The computed mean potentiometric surface indicates ground water discharges below the base of the refuse, although the elevation of this discharge varies with tidal changes and seasonal recharge.

On the southeast portion of the landfill, recharge is expected to be predominantly from direct infiltration of precipitation. The refuse and Recent Alluvium are bounded by bedrock to the east, effectively eliminating lateral inflow to this portion of the site. The ground water flow direction for the southeast lobe of the site is westerly towards Whatcom Creek, based on water level data at monitoring wells A-MW-4 through -6 and L-MW-1 through -3 (Landau 1993). Shallow ground water flowing through the southwest lobe appears to discharge in Whatcom Creek on either side of Holly Street, as generally depicted on Figure 4-1.

The flux of ground water discharging to Whatcom Creek was estimated using Darcy's Law (Appendix A). The discharge calculations used the average of the estimated values of hydraulic conductivity, along with the hydraulic gradient from the mean (tidally averaged) ground water elevations from the three monitoring wells in the northwest lobe. Assuming a vertical discharge width at Whatcom Creek of 24 feet (the distance from the intersection of the water table with the Creek and the top of the Bellingham Drift), the estimated flux on the northwest side of Whatcom Creek is 14 gallons per day per foot of stream reach. The flux on the southeast side of the creek reach appears to be somewhat less than that estimated for the northwest side, due to the lower hydraulic gradient measured in this area. However, assuming an average of 14 gallons per day per foot over a 1,500 feet reach (including similar discharge on both sides of the creek), the total estimated ground water discharge through the Holly Street Landfill Site is calculated at roughly 15 gallons per minute (gpm). This calculated discharge is less than 0.2 percent of the dry weather discharge reported at the mouth of Whatcom Creek (excluding tidal discharge; Anchor and Hart Crowser 2000). Thus, ground water discharges into Whatcom Creek would be expected to be rapidly diluted within this receiving water environment.

4.5.4 Tidal Effects on Ground Water Flow

The influence of tides on ground water levels has been documented in previous investigations in the general vicinity of the Site (ReTec 1996, Landau 2000), and is evident at the Site from water level monitoring in the three on-site monitoring wells. Rising tides result in a pressure wave that propagates inland, the lateral movement and extent of which are functions of aquifer transmissivity, storage, tidal amplitude, and tidal period. The amplitude of the resulting ground water fluctuations typically decreases inland. Tidal fluctuations in ground water affect the gradient, rate of ground water flow, and the extent of mixing with salt water.

Ground water fluctuation due to tidal influence was evaluated by monitoring ground water levels in the three monitoring wells over a three-day period (Appendix A). Tidal data collected offshore in Rosario Strait (Cherry Point) were used to approximate concurrent tidal fluctuations in the Whatcom Creek estuary. Figure 4-4 summarizes the ground water response to tides based on measurement of water level response to tides at the site.

The greatest tidal influence occurred at monitoring well A-MW-3, located approximately 14 feet from the Whatcom Creek ordinary high water line. Ground water levels at A-MW-3 fluctuated 3.4 feet over the course of the tidal monitoring, or roughly 50 percent of the predicted tidal range in Whatcom Creek during the measurement period. Tidal influence decreased inland, with minimal tidal effects occurring at monitoring wells A-MW-1 and A-MW-2 (less than 0.04 and 0.02 feet, respectively) located 280 and 420 feet inland from Whatcom Creek, respectively.

In addition to slug test measurements summarized above, aquifer hydraulic conductivity was also estimated based on observed tidally induced ground water fluctuations, using the Ferris (1963) method. Details of the calculation are presented in Appendix A. An estimated hydraulic conductivity of 0.04 cm/sec (100 feet/day) was computed using an assumed storage coefficient of 0.15. The Ferris method provides an estimate of the bulk average hydraulic conductivity for the saturated medium through which the tidal changes are propagated. These results are reasonably consistent with the refuse hydraulic conductivity (0.02 cm/sec) computed at well A-MW-2 using slug test methods (see above), and supports the validity of these determinations.

During mean and low tide stages, ground water flow at the Site is directed toward Whatcom Creek. Using the aquifer parameters computed from the tidal study, the range of ground water fluctuation was computed and is represented on Figure 4-5 by the green and red lines. With the incoming tide in Whatcom Creek, a local flow reversal occurs, and ground water flow is locally directed inland, away from Whatcom Creek. During the course of a rising tide, surface water from Whatcom Creek flows inland and mixes with ground water within the refuse and Recent Alluvium. As discussed in Section 4.5.5, the zone of tidal mixing (where salt water intrudes the aquifer) is controlled by the saturated horizontal hydraulic conductivities of the refuse and Recent Alluvium, and is limited by the amount of time that the tidal level exceeds the mean ground water elevation.

4.5.5 Ground Water Velocity, Flux, and Particle Travel Distances

For the purpose of developing a conceptual model of ground water flow at the Holly Street Landfill Site, the mean ground water velocity was computed for flow within the shallow aquifer. Calculations are shown in Appendix A and are summarized in Table A-1. Velocities were calculated using the mean hydraulic gradient computed from the 72-hour tidal monitoring data, porosities representative of the types of materials encountered during drilling (0.15 for silty sand alluvium and 0.30 for refuse), and hydraulic conductivity values from the slug test analyses. Ground water velocities of 0.08 feet/day (30 feet/year) representative of the native, silty Recent Alluvium (A-MW-1) and 2 feet/day (700 feet/year) representative of ground water flow in the refuse (A-MW-2) were computed. The computed velocity at A-MW-3, which is predominantly representative of the Recent Alluvium, is 0.6 feet/day (200 feet/year).

Mixing of ground water and salt water within the nearshore tidal dispersion zone has a significant influence on ground water geochemistry (e.g., oxidation-reduction [redox] potential). Ground water discharged through the refuse is typically depleted in oxygen, and exhibits redox potentials that are reducing (Eh averaging roughly -100 millivolts [mV]). Surface waters in Whatcom Creek, on the other hand, contain relatively high dissolved oxygen concentrations, resulting in an oxidizing environment (Eh averaging roughly +250 mV). The extent of the mixing zone where redox gradients would be expected to be most dramatic was computed based on locally reversed ground water gradients. Gradients were calculated based on estimated tide elevations, measured ground water elevations at A-MW-3, porosity values ranging from 0.15 (more typical of the Recent Alluvium) and 0.3 (more typical of the refuse), and refuse hydraulic conductivity values measured at A-MW-2 and verified using the Ferris method. Details regarding the field methods and data analyses are presented in Appendix A. Computations indicate that a particle of water from Whatcom Creek will travel at least 3 and up to 20 feet into the aquifer (refuse and Recent Alluvium) during a typical tidal cycle (see Appendix A for calculations used to estimate the inland extent of ground water movement). The estimated effective tidal mixing zone within the northwest unit of the Site is shown on Figure 4-5, and appears to encompass nearshore well A-MW-3. The inland extent of tidal mixing on the southeast lobe of the Site is likely somewhat greater due to the lower ground water flow gradient measured in this area. The effect of these tidal mixing processes on ground water geochemistry conditions is discussed below.

4.5.6 Conceptual Hydrogeologic Model

The hydrogeologic model depicting ground water flow at the site is presented conceptually in Figure 4-5. The general conceptual site model provides a framework for describing the transport and chemical/physical transformation of chemicals of concern at the site. The conceptual site model represents a compilation and analysis of information presented in previous sections of this report.

Saturated Recent Alluvium and refuse form a shallow unconfined aquifer beneath the site. Fine-grained silts and clays of the Bellingham Drift and Chuckanut Formation act as confining layers, restricting the downward flow of ground water bound the bottom of the aquifer. Recharge in the northwest refuse lobe occurs through lateral inflow and direct infiltration of precipitation through permeable areas. The southeast refuse lobe is bounded by bedrock to the east, which limits lateral ground water inflow; direct infiltration of precipitation is considered the most important source of recharge in this area.

Leachate is generated from precipitation infiltrating through the refuse and, in the northwest refuse area, from lateral inflow of ground water into the refuse. Tidal influence creates a sinusoidal ground water flow path as the ground water approaches the point of discharge into Whatcom Creek, which becomes a retrograde ellipse as the ground water oscillates in response to tidally propagated waves. As discussed above, ground water mixing with salt water predominates at distances within approximately 20 feet of the shoreline. The effect of these mixing processes on geochemistry and water quality characteristics is discussed below.

4.6 Ground Water Quality

A total of 14 ground water samples (excluding field duplicates) have been collected from the Holly Street Landfill Site, including 2 local upgradient samples at well A-MW-1. The on-site ground water sampling data include (refer to Figure 3-1 and Figure 4-1 for station locations):

- Four on-site refuse unit ground water samples collected during this RI/FS from the northwest lobe of the Site (A-MW-2 and A-MW-3; April and August 2000 sampling);
- Three on-site refuse ground water samples collected during this RI/FS from the southeast lobe of the Site (A-MW-4 through -6; January 2001);
- Three on-site refuse unit ground water samples collected during the Environmental Site Assessment of the Maritime Heritage Center Park site (Landau 1993; L-MW-1 through L-MW-3); and
- Two test pit water samples collected during the Bellingham Sash & Door Environmental Site Assessment (BEK Purnell 1993; B-TP-5 and B-TP-7). However, because of possible turbidity bias associated with these samples, some of the laboratory results (e.g., total metals determinations) for these samples were rejected for the purpose of this RI/FS.

Ground water samples collected as part of this RI/FS were submitted for the analysis of total metals, dissolved metals, SVOCs, volatile organic compounds (VOCs), TPH, fecal coliform, and conventional parameters (total dissolved solids, total suspended solids, TOC, salinity, hardness, alkalinity, chloride, sulfate, ammonia, and nitrate). Ground water samples collected by Landau (1993) were analyzed for a more limited suite of chemical parameters (metals and volatiles). Validated ground water chemical determinations are summarized in Table 4-2.

4.6.1 Chemicals of Potential Concern – Iron and Manganese

Chemical concentrations detected in ground water samples collected from the Holly Street Landfill Site were compared to conservative MTCA risk-based screening criteria to identify ground water COPCs. For the purpose of this screening-level evaluation, analytical results were compared to the more stringent of the MTCA Method A or Method B ground water cleanup levels for drinking water use, even though there is no existing or potential future use of such ground waters for consumptive purposes (see above). The screening-level evaluation also included a preliminary assessment of regional background concentrations, based either on statewide data (e.g., arsenic background concentration of 5 ug/L referenced in the MTCA regulation), or local upgradient well data (from A-MW-1). A summary of the screening-level evaluation is presented in Table 4-2. Based on this comparison, the following ground water COPCs were identified:

- Iron (present above taste/odor thresholds and local background levels in 7 of 9 on-site samples);
- Manganese (present above taste/odor thresholds and local background levels in 2 of 9 on-site samples). However, manganese was not confirmed to be present above local background levels during the RI/FS sampling; and
- Bis(2-ethylhexyl)phthalate (detected above drinking water criteria in 1 of 7 on-site samples).

Besides iron, manganese, and bis(2-ethylhexyl)phthalate, no other COPCs were detected in ground water at the Holly Street Landfill Site, even for those constituents such as mercury and TPH which exceeded conservative ground water protection criteria in overlying soil/refuse samples (Table 4-1). Total lead exceeded the MTCA cleanup levels for ground water during the wet season sampling at one location (A-MW-2; qualified result due to elevated sample turbidity; see above). However, lead was not detected in any of the ground water samples collected during the subsequent dry season sampling, and dissolved lead was not detected in any of the ground water samples collected during the wet or dry season sampling. Thus, lead was not identified as a COPC in on-site ground water. Additional confirmatory sampling is recommended during remedial design to verify this determination.

Only 1 of 7 ground water samples collected from the Site contained a bis(2-ethylhexyl)phthalate concentration above conservative MTCA drinking water criteria. While the maximum concentration reported in this one sample (23 ug/L in A-MW-6) was higher than the measured local background range (up to 5.8 ug/L in two samples collected from A-MW-1), the A-MW-6 value is not statistically different from background (ANOVA; $P > 0.10$). Moreover, bis(2-ethylhexyl)phthalate is a common laboratory contaminant; a somewhat elevated detection in a single ground water sample has often been attributable in other similar studies to field equipment or laboratory residuals. Thus, the apparent identification of bis(2-ethylhexyl)phthalate as a ground water COPC at the Holly Street Landfill Site is considered questionable. Additional confirmatory sampling is recommended during remedial design to verify whether or not this compound is truly present in A-MW-6 ground water. Further ground water sampling and low detection limit analysis for total petroleum hydrocarbons (TPH) is also recommended to confirm that TPH is not a COPC at the Holly Street Landfill Site.

4.6.2 Regional Water Quality and Geochemical Conditions - Iron

Iron and manganese are commonly detected in regional ground waters due to natural sources and normal geochemical processes. In order to compare concentrations of iron detected at the Holly

Street Landfill Site with regional levels, database records maintained by the Whatcom County Health and Human Services were reviewed and summarized. The database as of this writing includes 294 records for water supply wells in the county associated with new construction since 1990. Health and Human Services has general records for the water supply wells discussed above (within 1 mile of the site), but does not have water quality information for these wells. None of the wells in the database are within 1 mile of the site. The evaluation of regional iron levels was therefore based on countywide data.

Total iron concentrations in the regional ground water database ranged from non-detected to 29,200 micrograms per liter (ug/L). Five percent of the concentration records exceeded 2,700 ug/L, and approximately half of the records exceeded the existing secondary drinking water standard for iron of 300 ug/L (based on taste and odor considerations; no risk-based criterion for iron has been developed). Total iron concentrations detected in the local upgradient monitoring well A-MW-1 were similar to the county-wide data, ranging from 3,280 to 6,790 ug/L (Table 4-2). Thus, when compared to countywide water quality data, the local upgradient well A-MW-1 appears to provide appropriate background monitoring data. Also, based on the county-wide comparison, iron concentrations detected in on-site refuse monitoring wells, which ranged up to 49,300 ug/L, appear to be somewhat elevated above normal county levels.

As discussed above, leachate at the Holly Street Landfill Site is generated from precipitation infiltrating through the refuse and, in the northwest refuse area, from lateral inflow of ground water into the refuse. The pH and (especially) redox potential of the leachate control the stability and solubility of dissolved iron in this environment. The redox potential is a measure of whether oxidizing or reducing conditions prevail and is largely dependent on dissolved oxygen levels. In general, iron solubility is low under moderate to strongly oxidizing conditions for pH in the range of 5 to 9 (typical of the Site), when iron exists in the ferric (+3) state. When ground water is low or depleted of oxygen, then iron will be reduced to ferrous iron (+2) that has a much higher solubility.

The presence of relatively elevated concentrations of total iron in "interior" landfill monitoring wells (i.e., more than 50 feet from the shoreline), along with low dissolved oxygen levels and similarly low redox potentials, suggests that iron detected in Site ground water is present as the relatively soluble ferrous (+2) form. That is, the reducing environment created by the landfill brings ferrous iron into solution. This solution then migrates toward Whatcom Creek through the saturated refuse and underlying Recent Alluvium. As these ground waters approach Whatcom Creek, particularly within 20 feet of the shoreline, tidal influences create a sinusoidal flow path, resulting in mixing of salt water with the ground water, increasing the amount of dissolved oxygen and corresponding Eh within these waters.

This change in chemistry is apparent in monitoring well A-MW-3, located about 14 feet from the Whatcom Creek shoreline, where the redox potential becomes more positive (-27 to +13 mV), shifting iron stability towards the less soluble ferric (+3) form. Consistent with this geochemical model, total iron concentrations at A-MW-3 are significantly lower than at A-MW-2. Redox potentials reached a maximum where the ground water discharges in seeps to Whatcom Creek (total iron concentrations in these seepage discharges are below 5,730 ug/L; Table 4-3). That is, iron precipitates out of ground water solution in response to the increased oxygen levels, resulting in significantly lower concentrations in the seeps than in the refuse. These geochemical changes are depicted on Figure 4-6, based on average water quality characteristics. Similar geochemical processes control the mobility of manganese. Geochemical changes also affect the solubility of other metals such as copper and zinc, as outlined below.

4.7 Shoreline Seepage Quality

The evaluation of shoreline seepage quality was based on analytical results from five (5) ground water seep locations sampled during this RI/FS. The upgradient ground water monitoring well A-MW-1 provided local background water quality comparisons. Shoreline seep sampling for well points located upstream of Holly Street bridge (WP-1 through -5) occurred twice, during the wet/rainy season in April 2001 and during the dry season in August 2000. Shoreline seep sampling for well points located downstream of Holly Street bridge (WP-6) occurred once during January 2001. Shoreline seep locations are shown on Figure 3-1 and Figure 4-1.

Shoreline seep samples were submitted for the analysis of total metals, dissolved metals, SVOCs, volatile organic compounds (VOCs), TPH, fecal coliform, and conventional parameters (total dissolved solids, total suspended solids, TOC, salinity, hardness, alkalinity, chloride, sulfate, ammonia, and nitrate). Chemical/physical parameters for the shoreline seep samples are presented in Table 4-3.

4.7.1 Chemicals of Potential Concern - Copper and Zinc

Analytical results for shoreline seep samples were compared to the chronic surface water quality criteria for marine waters (WAC Chapter 173-201A), and also with local background water quality conditions, to identify seepage COPCs. A summary of the screening-level evaluation is presented in Table 4-3. Based on this comparison, the following seepage COPCs were identified:

- Copper (present above aquatic life toxicity criteria and local background levels in 6 of 9 shoreline well point samples); and
- Zinc (present above aquatic life toxicity criteria and local background levels in 5 of 9 shoreline well point samples).

Although elevated fecal coliform levels were detected in the initial seepage sample collected from A-WP-1 (near Holly Street), elevated turbidity and TSS levels encountered in this sample render these results questionable. Since fecal coliform were not detected in the subsequent resampling of this well point in August 2000, coliform were not retained as a constituent of potential concern in site seeps.

4.7.2 Geochemical Conditions Controlling Copper and Zinc Mobility

In contrast to iron (and manganese), reduced forms of copper and zinc are considerably less soluble than their oxidized counterparts. That is, the reducing environment created by the landfill results in the formation and stability of relatively insoluble sulfide complexes, which tends to prevent copper and zinc from becoming mobilized in ground water. However, as discussed above, within approximately 20 feet of the shoreline, salt water begins to mix with the ground water, increasing the amount of dissolved oxygen within these waters, and reducing the stability of sulfide complexes within the refuse, concurrently increasing solubility of these metals.

Changes in the geochemistry of copper and zinc are apparent by examining ground water quality conditions along the flow path through the landfill into Whatcom Creek. Copper and zinc concentrations are low in monitoring well A-MW-2, consistent with the sulfide control mechanism outlined above. However, copper and zinc levels begin to increase in monitoring well A-MW-3, located about 14 feet from the Whatcom Creek shoreline, where the redox potential becomes more positive (Eh range of -27 to +13 mV), shifting copper and zinc stability towards more soluble forms. Consistent with this geochemical model, copper and zinc concentrations reach a maximum in shoreline seeps adjacent to A-MW-3 (i.e., A-WP-2 and A-WP-3), before being diluted upon discharge into Whatcom Creek. These geochemical changes are summarized in Figures 4-6 and 4-7.

4.8 Sediment Quality

The evaluation of sediment quality was based on the analytical results for six surface sediment samples collected along the shoreline of Whatcom Creek during this RI/FS, and two surface sediment samples collected from Whatcom Creek during the Whatcom Waterway RI/FS (Anchor and Hart Crowser 2000). Surface sediment samples were collected from five locations along the shoreline of the Holly Street Landfill Site; three from along the north shoreline and two from along the south shoreline of Whatcom Creek. An additional local area reference sediment sample was collected along the south shoreline of Whatcom Creek upstream of the landfill boundary, at the most upstream depositional area identified within the creek mouth. Surface sediment sample locations are shown on Figure 3-1 and Figure 4-1. Sediment samples were submitted for Ecology's SMS list of analytes including total solids, grain size, TOC, and salinity. Pesticide analysis was also included in these determinations. Chemical/physical parameters for the surface sediment samples are presented in Table 4-4.

Analytical results for surface sediment samples were compared to SMS chemical criteria (Table 4-4). Because pore water salinity in these sediments ranged from 2.4 to 6.1 parts-per-thousand, and given prior SMS determinations within this area (Anchor and Hart Crowser 2000), these "low salinity" sediments were compared with marine sediment quality standards (Chapter 173-204 WAC). Further, the SMS includes two sets of criteria for the protection of biological resources. The more stringent set of criteria, the sediment quality standards (SQS), correspond to a concentration below which no adverse biological effects should occur (including no acute or chronic adverse effects). The less stringent set of criteria, the cleanup screening level (CSL), corresponds to a concentration above which more than minor adverse impacts may occur. No SQS exceedances were observed in sediment samples collected adjacent to the Holly Street Landfill Site. However, the upstream reference sediment sample (SD-6) marginally exceeded both the SQS and CSL criteria, apparently due to upstream sources unrelated to the Holly Street Landfill. Mid-channel sediment samples were also well below SQS chemical criteria (Anchor and Hart Crowser 2000; see Table 4-4). Thus, no sediment COPCs was identified at the Holly Street Landfill Site.

Table 4-1. Soil Chemical Analyses and Screening-Level MTCA Comparisons

	Units	MTCA Method A/B Cleanup Levels	Holly Street RI (2000)		Landau (1993)			Purnell & Associates (1993)	
			MW-2-S1 (2.5') 4/18/00	MW-3-S1 (2.5') 4/18/00	TP-1	TP-2	TP-3	TP 7.3 (11') 9/16/93	TP 5.3/4 (9 to 10') 9/17/93
Conventional Parameters									
Total Solids (%)	%	---	65.0	62.6	---	---	---	57.7	62
Gravel (%)	%	---	32.0	30.0	---	---	---	---	---
Sand (%)	%	---	49	44	---	---	---	---	---
Silt (%)	%	---	13	18	---	---	---	---	---
Clay (%)	%	---	7	9	---	---	---	---	---
Percent Fines (%)	%	---	20	26	---	---	---	---	---
Total Organic Carbon (%)	%	---	3.8	4.7	---	---	---	---	---
Total Metals (mg/kg-dry)									
Arsenic	mg/kg-dry	20	70	30	15	6 U	15	8	7
Cadmium	mg/kg-dry	2	5	3	2	1	4	---	---
Chromium	mg/kg-dry	2,000	65	115	51	40	52	62	50
Copper	mg/kg-dry	2,960	207	1,320	---	---	---	61	140
Lead	mg/kg-dry	250	1,470	984	389	283	2,340	130	430
Mercury	mg/kg-dry	2	0.3 J	4.8 J	0.5	0.3	0.4	0.2	---
Nickel	mg/kg-dry	1,600	---	---	---	---	---	54	51
Silver	mg/kg-dry	400	12 J	3.0 J	---	---	---	---	---
Zinc	mg/kg-dry	24,000	1,640	1,650	374	363	850	280	330
Low Molecular Weight Polycyclic Aromatic Hydrocarbons									
Naphthalene	mg/kg-dry	5	0.08 J	0.4	---	---	---	0.5	---
Acenapththylene	mg/kg-dry	---	0.04 UJ	1	---	---	---	0.2 J	---
Acenaphthene	mg/kg-dry	4,800	0.04 UJ	0.1	---	---	---	0.1 J	---
Fluorene	mg/kg-dry	3,200	0.04 UJ	0.4	---	---	---	0.2 J	---
Phenanthrene	mg/kg-dry	---	0.1 J	8	---	---	---	0.9	---
Anthracene	mg/kg-dry	24,000	0.05 JM	2	---	---	---	0.4	---
2-Methylnaphthalene	mg/kg-dry	5	0.04 UJ	0.2	---	---	---	0.2 J	---
2-Chloronaphthalene	mg/kg-dry	5	---	---	---	---	---	0.3 U	---
Total LPAHs[b]	mg/kg-dry	---	0.3 JM	12	---	---	---	2.2	---
High Molecular Weight Polycyclic Aromatic Hydrocarbons									
Fluoranthene	mg/kg-dry	3,200	0.2 J	22	---	---	---	0.9	---
Pyrene	mg/kg-dry	2,400	0.09 J	16	---	---	---	0.9	---
Benzo(a)anthracene	mg/kg-dry	1	0.06 J	8.3	---	---	---	0.4	---
Chrysene	mg/kg-dry	10	0.1 J	10	---	---	---	0.5	---
Benzo(b)fluoranthene	mg/kg-dry	1	0.1 J	6.8	---	---	---	0.6 T	---
Benzo(k)fluoranthene	mg/kg-dry	1	0.1 J	7.2	---	---	---	0.6 T	---
Benzo(a)pyrene	mg/kg-dry	0.1	0.08 J	7.5	---	---	---	0.3	---
Indeno(1,2,3-c,d)pyrene	mg/kg-dry	1	0.1 J	5.4	---	---	---	0.3 J	---
Dibenzo(a,h)anthracene	mg/kg-dry	0.3	0.04 UJ	1.8	---	---	---	0.3 U	---
Benzo(g,h,i)perylene	mg/kg-dry	---	0.08 J	4.9	---	---	---	0.3	---
Total HPAHs[c]	mg/kg-dry	---	1.0 J	90	---	---	---	4.1	---
Total cPAHs[d]	mg/kg-dry	0.1	0.1 J	11	---	---	---	0.4	---
Miscellaneous Semivolatile Organics (mg/kg-dry)									
Gasoline-range TPH	mg/kg-dry	30	20 U	20 U	---	---	---	---	---
Diesel-range TPH	mg/kg-dry	2,000	1,700 J	670 J	---	---	---	---	---
Oil-range TPH	mg/kg-dry	2,000	820 J	1,400 J	---	---	---	1,300	---
Total TPH	mg/kg-dry	---	2,520 J	2,070 J	---	---	---	---	---
Hexachlorobenzene	mg/kg-dry	0.62	0.0009 U	0.001	---	---	---	0.6 U	---
Dibenzofuran	mg/kg-dry	---	0.04 UJ	0.2	---	---	---	0.08 J	---
Hexachlorobutadiene	mg/kg-dry	13	0.0009 U	0.0009 U	---	---	---	0.3 U	---

Table 4-1. Soil Chemical Analyses and Screening-Level MTCA Comparisons

	Units	MTCA Method A/B Cleanup Levels	Holly Street RI (2000)		Landau (1993)			Purnell & Associates (1993)	
			MW-2-S1 (2.5') 4/18/00	MW-3-S1 (2.5') 4/18/00	TP-1	TP-2	TP-3	TP 7.3 (11') 9/16/93	TP 5.3/4 (9 to 10') 9/17/93
n-Nitroso-diphenylamine	mg/kg-dry	204	0.1 YJ	0.04 U	---	---	---	0.3 U	---
Aniline	mg/kg-dry	175	---	---	---	---	---	1 U	---
4-Chloroaniline	mg/kg-dry	320	---	---	---	---	---	0.3 U	---
2-Nitroaniline	mg/kg-dry	---	---	---	---	---	---	0.6 U	---
3-Nitroaniline	mg/kg-dry	---	---	---	---	---	---	1 U	---
4-Nitroaniline	mg/kg-dry	---	---	---	---	---	---	0.6 U	---
Bis(2-chloroethyl) ether	mg/kg-dry	0.91	---	---	---	---	---	0.3 U	---
Bis(2-chloroisopropyl) ether	mg/kg-dry	3,200	---	---	---	---	---	0.3 U	---
1,2-Dichlorobenzene	mg/kg-dry	7,200	---	---	---	---	---	0.3 U	---
1,3-Dichlorobenzene	mg/kg-dry	---	---	---	---	---	---	0.3 U	---
1,4-Dichlorobenzene	mg/kg-dry	---	---	---	---	---	---	0.3 U	---
Benzyl alcohol	mg/kg-dry	24,000	---	---	---	---	---	0.3 U	---
n-Nitroso-di-n-propylamine	mg/kg-dry	0.14	---	---	---	---	---	0.3 U	---
Hexachloroethane	mg/kg-dry	71	---	---	---	---	---	0.6 U	---
Nitrobenzene	mg/kg-dry	40	---	---	---	---	---	0.3 U	---
Isophorone	mg/kg-dry	1,052	---	---	---	---	---	0.3 U	---
Bis (2-chloroethoxy) methane	mg/kg-dry	---	---	---	---	---	---	0.3 U	---
1,2,4-Trichlorobenzene	mg/kg-dry	800	---	---	---	---	---	0.3 U	---
Hexachlorocyclopentadiene	mg/kg-dry	560	---	---	---	---	---	0.6 U	---
2,6-Dinitrotoluene	mg/kg-dry	80	---	---	---	---	---	0.6 U	---
2,4-Dinitrotoluene	mg/kg-dry	160	---	---	---	---	---	0.6 U	---
4-Chlorophenyl phenylether	mg/kg-dry	---	---	---	---	---	---	0.3 U	---
1,2-Diphenylhydrazine	mg/kg-dry	1.2	---	---	---	---	---	0.6 U	---
4-Bromophenyl phenylether	mg/kg-dry	---	---	---	---	---	---	0.6 U	---
Carbazole	mg/kg-dry	50	---	---	---	---	---	0.3 U	---
Benzidine	mg/kg-dry	0.0043	---	---	---	---	---	7 U	---
3,3'-Dichlorobenzidine	mg/kg-dry	2.2	---	---	---	---	---	3 U	---
Chloromethane	mg/kg-dry	77	---	---	---	---	---	0.002 U	---
Bromomethane	mg/kg-dry	112	---	---	---	---	---	0.002 U	---
Vinyl Chloride	mg/kg-dry	0.53	---	---	---	---	---	0.002 U	---
Chloroethane	mg/kg-dry	---	---	---	---	---	---	0.005 U	---
Methylene Chloride	mg/kg-dry	0.02	---	---	---	---	---	0.009 B	---
Acetone	mg/kg-dry	8,000	---	---	---	---	---	0.02 B	---
Carbon Disulfide	mg/kg-dry	8,000	---	---	---	---	---	0.002 U	---
1,1-Dichloroethene	mg/kg-dry	1.7	---	---	---	---	---	0.002 U	---
1,1-Dichloroethane	mg/kg-dry	11	---	---	---	---	---	0.002 U	---
Trans-1,2-Dichloroethene	mg/kg-dry	1,600	---	---	---	---	---	0.002 U	---
Cis-1,2-Dichloroethene	mg/kg-dry	800	---	---	---	---	---	0.002 U	---
Chloroform	mg/kg-dry	164	---	---	---	---	---	0.002 U	---
1,2-Dichloroethane	mg/kg-dry	11	---	---	---	---	---	0.002 U	---
2-Butanone	mg/kg-dry	---	---	---	---	---	---	0.005 J	---
1,1,1-Trichloroethane	mg/kg-dry	2	---	---	---	---	---	0.002 U	---
Carbon Tetrachloride	mg/kg-dry	7.7	---	---	---	---	---	0.002 U	---
Vinyl Acetate	mg/kg-dry	80,000	---	---	---	---	---	0.002 U	---
Bromodichloromethane	mg/kg-dry	16	---	---	---	---	---	0.002 U	---
1,2-Dichloropropane	mg/kg-dry	15	---	---	---	---	---	0.002 U	---
Cis-1,3-Dichloropropene	mg/kg-dry	5.7	---	---	---	---	---	0.005 J	---
Trichloroethene	mg/kg-dry	0.03	---	---	---	---	---	0.002 U	---
Dibromochloromethane	mg/kg-dry	12	---	---	---	---	---	0.005 U	---

Table 4-1. Soil Chemical Analyses and Screening-Level MTCA Comparisons

	Units	MTCA Method A/B Cleanup Levels	Holly Street RI (2000)		Landau (1993)			Purnell & Associates (1993)	
			MW-2-S1 (2.5') 4/18/00	MW-3-S1 (2.5') 4/18/00	TP-1	TP-2	TP-3	TP 7.3 (11') 9/16/93	TP 5.3/4 (9 to 10') 9/17/93
1,1,2-Trichloroethane	mg/kg-dry	18	---	---	---	---	---	0.002 U	---
Benzene	mg/kg-dry	0.5	---	---	---	---	---	0.002 U	---
Trans-1,3-Dichloropropene	mg/kg-dry	5.6	---	---	---	---	---	0.005 U	---
Bromoform	mg/kg-dry	127	---	---	---	---	---	0.002 U	---
4-Methyl-2-Pentanone	mg/kg-dry	---	---	---	---	---	---	0.005 U	---
2-Hexanone	mg/kg-dry	---	---	---	---	---	---	0.005 U	---
Tetrachloroethene	mg/kg-dry	0.05	---	---	---	---	---	0.002 U	---
1,1,2,2-Tetrachloroethene	mg/kg-dry	---	---	---	---	---	---	0.005 U	---
Toluene	mg/kg-dry	7	---	---	---	---	---	0.002 U	---
Chlorobenzene	mg/kg-dry	1,600	---	---	---	---	---	0.005 U	---
Ethylbenzene	mg/kg-dry	6	---	---	---	---	---	0.002 U	---
Styrene	mg/kg-dry	33	---	---	---	---	---	0.002 U	---
Total Xylenes	mg/kg-dry	9	---	---	---	---	---	0.002 U	---
Phthalates (mg/kg-dry)									
Dimethyl phthalate	mg/kg-dry	80,000	0.04 UJ	0.06	---	---	---	0.3 U	---
Diethyl phthalate	mg/kg-dry	64,000	0.04 UJ	0.04 U	---	---	---	0.3 U	---
Di-n-butyl phthalate	mg/kg-dry	8,000	0.04 UJ	0.2	---	---	---	0.3 U	---
Butylbenzyl phthalate	mg/kg-dry	16,000	0.04 UJ	0.04 U	---	---	---	0.3 U	---
Bis(2-ethylhexyl)phthalate	mg/kg-dry	71	0.2 J	0.08	---	---	---	0.1 JB	---
Di-n-octyl phthalate	mg/kg-dry	1,600	0.04 UJ	0.04 U	---	---	---	0.3 U	---
Pesticides/PCBs (ug/kg DB)									
4,4'-DDE	mg/kg-dry	3	0.005 Y	0.007 Y	---	---	---	6 U	---
4,4'-DDD	mg/kg-dry	4	0.002 UJ	0.01 J	---	---	---	6 U	---
4,4'-DDT	mg/kg-dry	3	0.007 Y	0.005 Y	---	---	---	6 U	---
Total DDT	mg/kg-dry	---	0.002 UJ	0.01 J	---	---	---		---
Aldrin	mg/kg-dry	0.059	0.001 UJ	0.001 Y	---	---	---	3 U	---
alpha-Chlordane	mg/kg-dry	0.77	0.001 U	0.003	---	---	---	29 U	---
Dieldrin	mg/kg-dry	0.062	0.004 Y	0.002 U	---	---	---	6 U	---
Endosulfan I	mg/kg-dry	780	---	---	---	---	---	6 U	---
Endosulfan II	mg/kg-dry	---	---	---	---	---	---	6 U	---
Endosulfan sulfate	mg/kg-dry	---	---	---	---	---	---	6 U	---
Endrin	mg/kg-dry	24	---	---	---	---	---	11 U	---
Endrin aldehyde	mg/kg-dry	---	---	---	---	---	---	6 U	---
Heptachlor	mg/kg-dry	0.22	0.0009 U	0.0009 U	---	---	---	3 U	---
Heptachlor epoxide	mg/kg-dry	0.11	---	---	---	---	---	3 U	---
alpha-BHC	mg/kg-dry	0.16	---	---	---	---	---	3 U	---
beta-BHC	mg/kg-dry	0.56	---	---	---	---	---	3 U	---
delta-BHC	mg/kg-dry	---	---	---	---	---	---	3 U	---
gamma-BHC (lindane)	mg/kg-dry	0.01	0.0009 U	0.0009 U	---	---	---	3 U	---
Methoxychlor	mg/kg-dry	400	---	---	---	---	---	29 U	---
Toxaphene	mg/kg-dry	0.91	---	---	---	---	---	290 U	---
Aroclor 1016	mg/kg-dry	1	0.02 U	0.02 U	---	---	---	57 U	---
Aroclor 1221	mg/kg-dry	1	0.04 U	0.04 U	---	---	---	110 U	---
Aroclor 1232	mg/kg-dry	1	0.02 U	0.04 Y	---	---	---	57 U	---
Aroclor 1242	mg/kg-dry	1	0.02 U	0.04 Y	---	---	---	57 U	---
Aroclor 1248	mg/kg-dry	1	0.02 U	0.04 Y	---	---	---	57 U	---
Aroclor 1254	mg/kg-dry	1	0.33	0.09 Y	---	---	---	57 U	---
Aroclor 1260	mg/kg-dry	1	0.02 U	0.08 Y	---	---	---	57 U	---
Total PCBs	mg/kg-dry	1	0.33	0.09 Y	---	---	---	110 U	---

Table 4-1. Soil Chemical Analyses and Screening-Level MTCA Comparisons

	Units	MTCA Method A/B Cleanup Levels	Holly Street RI (2000)		Landau (1993)			Purnell & Associates (1993)	
			MW-2-S1 (2.5') 4/18/00	MW-3-S1 (2.5') 4/18/00	TP-1	TP-2	TP-3	TP 7.3 (11') 9/16/93	TP 5.3/4 (9 to 10') 9/17/93
Miscellaneous Extractables (ug/kg-dry)									
Phenol	mg/kg-dry	48,000	0.04 U	0.04 J	---	---	---	290 U	---
2-Methylphenol	mg/kg-dry	---	0.04 U	0.04 U	---	---	---	290 U	---
4-Methylphenol	mg/kg-dry	---	0.08	0.2	---	---	---	290 U	---
2,4-Dimethylphenol	mg/kg-dry	---	0.04 U	0.04 U	---	---	---	290 U	---
Pentachlorophenol	mg/kg-dry	8.3	0.2 U	0.2 U	---	---	---	2,900 U	---
Benzyl alcohol	mg/kg-dry	24,000	0.04 UJ	0.04 U	---	---	---	---	---
Benzoic acid	mg/kg-dry	320,000	0.4 U	0.4 U	---	---	---	7,200 U	---
2-Chlorophenol	mg/kg-dry	400	---	---	---	---	---	290 U	---
2-Nitrophenol	mg/kg-dry	---	---	---	---	---	---	580 U	---
2,4-Dichlorophenol	mg/kg-dry	240	---	---	---	---	---	580 U	---
4-Chloro-3-methylphenol	mg/kg-dry	---	---	---	---	---	---	580 U	---
2,4,6-Trichlorophenol	mg/kg-dry	91	---	---	---	---	---	580 U	---
2,4,5-Trichlorophenol	mg/kg-dry	8,000	---	---	---	---	---	580 U	---
2,4-Dinitrophenol	mg/kg-dry	160	---	---	---	---	---	2,900 U	---
4-Nitrophenol	mg/kg-dry	---	---	---	---	---	---	2,900 U	---
4,6-Dinitro-2-methylphenol	mg/kg-dry	---	---	---	---	---	---	2,900 U	---

"B" The analyte was detected in the method blank associated with the sample, as well as in the sample itself.
"J" The analyte was positively identified; the associated numerical value is an estimated quantity.
"N" The analysis indicates the presence of an analyte for which there is presumptive evidence to make a "tentative identification."
"T" The flagged values represent the sum of two co-eluting compounds. The sum of these two values is shown as though it were a result for each of them. The two figures should not be added together.
"U" The analyte was analyzed for but not detected above the reported sample quantitation limit.
"Y" The sample quantitation limit is elevated due to matrix interferences in the sample.

🟨 Concentration exceeds MTCA Method A/B screening level.

Notes:
(a) Value represents total petroleum hydrocarbons (TPH). Source report does not specify TPH range.
(b) Total LPAHs represents the sum of naphthalene, acenapththylene, acenaphthene, fluorene, phenanthrene, and anthracene.
(c) Total HPAHs represents the sum of fluoranthene, pyrene, benzo(a)anthracene, chrysene, total benzofluoroanthenes, benzo(a)pyrene, indeno(1,2,3-c,d)pyrene, dibenzo(a,b)anthracene, and benzo(g,h,l)perylene.
(d) Total cPAHs represents the sum of HPAH concentrations multiplied the toxicity equivalency factor (TEF) specified in EPA and Ecology risk assessment guidance.

Table 4-2. Ground Water Chemical Analyses and Screening-Level MTCA Comparisons

	Units	MTCA Method A/B Cleanup Levels	Focused RI (ug/L)								Holly Street RI				Landau (1993) (ug/L)			W.D. Purnell & Associates (1993)	
			A-MW-1 (bkgd) 4/20/2000 Wet Season	A-MW-2 4/20/2000 Wet Season	A-MW-3 4/20/2000 Wet Season	A-MW-3 (dup.) 4/20/2000 Wet Season	A-MW-1(bkgd) 8/29/2000 Dry Season	A-MW-2 8/29/2000 Dry Season	A-MW-2 (dup.) 8/29/2000 Dry Season	A-MW-3 8/29/2000 Dry Season	A-MW-4 1/3/2001 Supplemental	A-MW-4 (dup.) 1/3/2001 Supplemental	A-MW-5 1/3/2001 Supplemental	A-MW-6 1/3/2001 Supplemental	L-MW-1 11/18/1990	L-MW-2 11/18/1990	L-MW-3 11/18/1990	TP 7.7/6/8 (15') 9/16/1993	TP 5 (10') 9/17/1993
Conventional Parameters																			
Methane Soil Gas	% of LEL		-	-	-	-	0%	16%	-	4%	300%	-	58%	35%	35%	25%	45%		
Total Dissolved Solids	mg/L		2.5	580	3,400	3,400	300	600	590	7,100	580	570	630	460					
Total Suspended Solids	mg/L		6	50	8	7	16 E	73 E	74 E	37 E	79	77	73	86					
Field Turbidity	NTU		9	19	9	NA	7	4	4	12	2	-	3	3					
Lab Conductivity	uS/cm @ 25C		440	910	5,600	5,700	450	880	870	11,000	1,100	1,100	1,400	920					
Total Organic Carbon	mg/L		1.8	6.6	3.3	3.0	2.2	6.3	6.0	5.2	15.0	14.0	20.0	14.0					
Field Temperature	°C		12.0	11.9	11.5	11.5	17.3	15.5	15.5	17.1	13.3	-	12.0	13.4					
Field pH	standard units		7.29	6.73	6.60	NA	7.10	6.90	6.90	6.40	5.50	-	5.60	5.90					
Field Redox	mV		-39	-73	+13	NA	-85	-107	-107	-27	+8	-	+5	-8					
Field Dissolved Oxygen	mg/L		2.8	0.8	4.5	NA	1.5	2.1	2.1	1.5	-	-	-	-					
Salinity	ppt		0.2	0.4	2.9	3	0.2	0.4	0.4	6	0.5	0.5	0.7	0.4					
Hardness	mg-CaCO3/L		160	410	610	530	200	480	460	1,300	-	-	-	-					
Alkalinity	mg/L		150	510	160	160	180	560	560	230	570	560	760	490					
Chloride	mg/L		36	29	2,000	2,100	36	31	30	3,900	30	31	26	17					
Sulfate	mg/L		37.0	6.9	260	260	40	13 J	18 J	450	8 J	6 J	10	6					
Ammonia	mg-N/L		14.0	3.8	1.1	1.0	0.3	3.8	3.9	0.5	14.0	13.0	16.0	13.0					
Nitrate	mg-N/L		0.01 U	0.01 U	0.30	0.32	0.010 U	0.020 U	0.030 U	0.035 U	0.013	0.010 U	0.044	0.012					
Fecal Coliform	#/100mL	14	1 U	2 U	4	5	2 U	3 U	3 U	3 U	1 U	-	1 U	1 U					
Total Metals																			
Antimony	ug/L	---																33 R	12 R
Arsenic	ug/L	5 (a)	3.5	2.2	1.5 J	1.2 J	3.9	1.0	1.1	1.4	1.1 J	0.8 J	2.9	2.3	50 U	50 U	50 U	58 R	38 R
Beryllium	ug/L	0.02													1 U	1 U	1 U	54 R	
Cadmium	ug/L	5.0	0.2 U	0.2	0.3	0.3	0.2 U	0.2 U	0.2 U	0.5 U	0.2 U	0.2 U	0.2 U	0.2 U	2 U	2 U	2 U	720 R	6 R
Calcium	ug/L						46,300	142,000	139,000	104,000	129,000	135,000	231,000	102,000	130,000	143,000	114,000		
Chromium	ug/L	50.0	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	4,200 R	120 R
Copper	ug/L	592.0	2 U	6	12 J	5 J	2 U	2 U	2 U	2	5	2 U	2 U	2	2 U	2 U	2 U	19,000 R	370 R
Cyanide, total	ug/L	320																0.021 R	
Iron	ug/L	6,790 (a)	3,280 J	35,800 J	1,640 J	1,240 J	6,790	49,300	47,900	20,300	33,600	32,600	32,300	39,900	5,220	528	570		
Lead	ug/L	5.0	1 U	39 E	3	1	1 U	3 U	3 U	2 U	2	1	2	3	30 U	30 U	30 U	41,000 R	1,100 R
Magnesium	ug/L						19,600	29,700	28,900	252,000	30,900	32,600	31,200	31,900					
Manganese	ug/L	2,530 (a)	2,340	1,860	350	297	1,190	1,410	1,380	281	479	519	461	1,430	430	3,790	3,330		
Mercury	ug/L	2.0	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	170 R	1.1 R
Nickel	ug/L														10 U	10 U	10 U	5,200 R	210 R
Selenium	ug/L	80.00													50 U	50 U	50 U	5 R	
Silver	ug/L	80	0.5 UJ	0.7 J	0.5 UJ	0.5 UJ	0.5 UJ	0.5 U	0.5 U	1 U	0.5 UJ	0.5 UJ	0.5 UJ	0.5 UJ	3 U	3 U	3 U	74 R	
Zinc	ug/L	4,800	6 U	34	80	67	6 U	6 U	6 U	91	13	6 U	41	8	6	6	16	91,000 R	210 R
Dissolved Metals																			
Arsenic	ug/L	5 (a)	2.0	0.7	1.4 J	0.7 J	0.9	0.3	0.4	0.4 U	0.7	0.8	3.4	1.8					
Cadmium	ug/L	5.0	0.2 U	0.2 U	0.3	0.3	0.2 U	0.2 U	0.4 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U					
Chromium	ug/L	50	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U					
Copper	ug/L	592	2 U	2 U	3	3	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U					
Iron	ug/L	300	90	13,500	350 J	250 J	20 U	6,980 J	870 J	2,390	37,300	37,900	33,500	42,800					
Lead	ug/L	5	1 U	1 U	1 U	1 U	1 U	1 U	1 U	2 U	1 U	1 U	1 U	1 U					
Manganese	ug/L	2,530 (a)	2,530	1,940	354	356	1,230	1,380	1,350	311	546	554	482	1,490					
Mercury	ug/L	2.00	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U					
Silver	ug/L	80	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U					
Zinc	ug/L	4,800	6 U	6 U	76	78	6 U	6 U	6 U	93	6 U	6 U	6 U	6 U					
Volatile Organic Hydrocarbons																			
1,2-Dichlorobenzene	ug/L	720	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U					
1,4-Dichlorobenzene	ug/L	1.8	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.5	0.5	0.2 U	0.2 U					
1,2,4-Trichlorobenzene	ug/L	80	0.5 U	0.5 U	0.5 U	0.5 U	0.5 UJ	0.5 UJ	0.5 UJ	0.5 UJ	0.5 U	0.5 U	0.5 U	0.5 U					
Benzene	ug/L	1.5	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U					
Toluene	ug/L	40.000	0.2	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.3	0.3	0.2 U	0.2 U					
Ethylbenzene	ug/L	30	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U					
Total Xylenes	ug/L	20.0	0.6 U	0.6 U	0.6 U	0.6 U	0.6 U	0.6 U	0.6 U	0.6 U	0.6 U	0.6 U	0.6 U	0.6 U					
Low Molecular Weight Polycyclic Aromatic Hydrocarbons																			
Naphthalene	ug/L	320.00	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 UJ	1 U	1 UJ	1 U				22	
Acenapththylene	ug/L		1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 UJ	1 U	1 UJ	1 U				8 J	
Acenaphthene	ug/L	960.00	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 UJ	1 U	1 UJ	1 U				22	
Fluorene	ug/L	640.00	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 UJ	1 U	1 UJ	1 U				18 J	
Phenanthrene	ug/L		1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 UJ	1 U	1 UJ	1 U				98	
Anthracene	ug/L	4,800.0	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 UJ	1 U	1 UJ	1 U				26	
2-Methylnaphthalene	ug/L		1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 UJ	1 U	1 UJ	1 U				8 J	

Table 4-2. Ground Water Chemical Analyses and Screening-Level MTCA Comparisons

	Units	MTCA Method A/B Cleanup Levels	Focused RI (ug/L)								Holly Street RI				Landau (1993) (ug/L)			W.D. Purnell & Associates (1993)	
			A-MW-1 (bkgd) 4/20/2000 Wet Season	A-MW-2 4/20/2000 Wet Season	A-MW-3 4/20/2000 Wet Season	A-MW-3 (dup.) 4/20/2000 Wet Season	A-MW-1(bkgd) 8/29/2000 Dry Season	A-MW-2 8/29/2000 Dry Season	A-MW-2 (dup.) 8/29/2000 Dry Season	A-MW-3 8/29/2000 Dry Season	A-MW-4 1/3/2001 Supplemental	A-MW-4 (dup.) 1/3/2001 Supplemental	A-MW-5 1/3/2001 Supplemental	A-MW-6 1/3/2001 Supplemental	L-MW-1 11/18/1990	L-MW-2 11/18/1990	L-MW-3 11/18/1990	TP 7.7/6/8 (15') 9/16/1993	TP 5 (10') 9/17/1993
2-Chloronaphthalene	ug/L																	20 U	
Total LPAHs	ug/L		1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 UJ	1 U	1 UJ	1 U					
High Molecular Weight Polycyclic Aromatic Hydrocarbons																			
Fluoranthene	ug/L	640.0	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 UJ	1 U	1 UJ	1 U				100	
Pyrene	ug/L	480.0	1 U	1 U	1 U	1 U	1 UJ	1 UJ	1 UJ	1 UJ	1 UJ	1 U	1 UJ	1 U				130	
Benzo(a)anthracene	ug/L	0.012	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 UJ	1 U	1 UJ	1 U				56	
Chrysene	ug/L	0.012	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 UJ	1 U	1 UJ	1 U				66	
Benzo(b)fluoranthene	ug/L	0.012	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 UJ	1 U	1 UJ	1 U				82 T	
Benzo(k)fluoranthene	ug/L	0.012	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 UJ	1 U	1 UJ	1 U				82 T	
Total Benzofluoranthenes	ug/L		1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 UJ	1 U	1 UJ	1 U				82 T	
Benzo(a)pyrene	ug/L	0.012	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 UJ	1 U	1 UJ	1 U				64	
Indeno(1,2,3-c,d)pyrene	ug/L	0.012	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 UJ	1 U	1 UJ	1 U				40	
Dibenzo(a,h)anthracene	ug/L	0.012	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 UJ	1 U	1 UJ	1 U				20 U	
Benzo(g,h,i)perylene	ug/L		1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 UJ	1 U	1 UJ	1 U				46	
Total HPAHs	ug/L		1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 UJ	1 U	1 UJ	1 U					
PAHs (carcinogenic)	ug/L	0.1	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 UJ	1 U	1 UJ	1 U					
Miscellaneous Semivolatile Organics																			
Gasoline-range TPH	ug/L	1,000	10,000 U	10,000 U	10,000 U	10,000 U	250 U	250 U	250 U	250 U	250 U	250 U	250 U	250 U					
Diesel-range TPH	ug/L	1,000	10,000 U	10,000 U	10,000 U	10,000 U	500 U	500 U	500 U	500 U	500 U	500 U	500 U	500 U					
Oil-range TPH	ug/L	1,000	25,000 U	25,000 U	25,000 U	25,000 U	500 U	500 U	500 U	500 U	500 U	500 U	500 U	500 U					
Vinyl Chloride	ug/L	0.02													2.0 U	2.0 U	2.0 U	1 U	
Methylene Chloride	ug/L	5.0													2.0 U	2.0 U	2.0 U	1 B	
1,2-Dichloroethane	ug/L	5.0													1.0 U	1.0 U	1.0 U	1 U	
1,1,1-Trichloroethane	ug/L	200.0													1.0 U	1.0 U	1.0 U	1 U	
Trichloroethene	ug/L	5.0													1.0 U	1.0 U	1.0 U	1 U	
Tetrachloroethene	ug/L	0.9													1.0 U	1.0 U	1.0 U	1 U	
1,1,2,2-Tetrachloroethene	ug/L	0.2													1.0 U	1.0 U	1.0 U	3 U	
Ethylbenzene	ug/L	30.0													1.0 U	1.0 U	1.0 U	1 U	
Hexachlorobenzene	ug/L	0.0550	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 UJ	1 U	1 UJ	1 U				40 U	
Dibenzofuran	ug/L		1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 UJ	1 U	1 UJ	1 U				6 J	
Hexachlorobutadiene	ug/L	0.560	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 UJ	2 U	2 UJ	2 U				20 U	
n-Nitroso-diphenylamine	ug/L	18.00	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 UJ	1 U	1 UJ	1 U				20 U	
Chloromethane	ug/L	3.40													2.0 U	2.0 U	2.0 U	1 U	
Bromomethane	ug/L	11.00													2.0 U	2.0 U	2.0 U	1 U	
Chloroethane	ug/L														2.0 U	2.0 U	2.0 U	3 U	
Acetone	ug/L	800.00													5.0 U	5.0 U	5.0 U	12 U	
Carbon Disulfide	ug/L	800.00													1.0 U	1.0 U	1.0 U	1 U	
1,1-Dichloroethene	ug/L	0.07													1.0 U	1.0 U	1.0 U	1 U	
1,1-Dichloroethane	ug/L	800.00													1.0 U	1.0 U	1.0 U	1 U	
Trans-1,2-Dichloroethene	ug/L	160.00													1.0 U	1.0 U	1.0 U	1 U	
Cis-1,2-Dichloroethene	ug/L	80.00													1.0 U	1.0 U	1.0 U	1 U	
Chloroform	ug/L	7.20													1.0 U	1.0 U	1.0 U	1 U	
2-Butanone	ug/L														5.0 U	5.0 U	5.0 U	3 U	
Carbon Tetrachloride	ug/L	0.37													1.0 U	1.0 U	1.0 U	1 U	
Vinyl Acetate	ug/L	8,000.00													1.0 U	1.0 U	1.0 U	1 U	
Bromodichloromethane	ug/L	0.71													1.0 U	1.0 U	1.0 U	1 U	
1,2-Dichloropropane	ug/L	0.64													1.0 U	1.0 U	1.0 U	1 U	
Cis-1,3-Dichloropropene	ug/L	80.00													1.0 U	1.0 U	1.0 U	3 U	
Dibromochloromethane	ug/L	0.52													1.0 U	1.0 U	1.0 U	3 U	
1,1,2-Trichloroethane	ug/L	0.77													1.0 U	1.0 U	1.0 U	1 U	
Benzene	ug/L	1.50													1.0 U	1.0 U	1.0 U	1 U	
Trans-1,3-Dichloropropene	ug/L	0.24													1.0 U	1.0 U	1.0 U	3 U	
2-Chloroethylvinylether	ug/L														1.0 U	1.0 U	1.0 U		
Bromoform	ug/L	5.50													1.0 U	1.0 U	1.0 U	1 U	
4-Methyl-2-Pentanone	ug/L														5.0 U	5.0 U	5.0 U	3 U	
2-Hexanone	ug/L														5.0 U	5.0 U	5.0 U	3 U	
Toluene	ug/L	40.00													1.0 U	1.0 U	1.0 U	1	
Chlorobenzene	ug/L	160.00													1.0 U	1.0 U	1.0 U	3 U	
Styrene	ug/L	1.50													1.0 U	1.0 U	1.0 U	1 U	
Total Xylenes	ug/L	20.00													2.0 U	2.0 U	2.0 U	1 U	
Trichlorofluoromethane	ug/L	2,400.00													2.0 U	2.0 U	2.0 U		
1,1,2-Trichlorotrifluoroethane	ug/L														2.0 U	2.0 U	2.0 U		
Aniline	ug/L	15.00																100 U	
4-Chloroaniline	ug/L	64.00																20 U	
2-Nitroaniline	ug/L																	40 U	
3-Nitroaniline	ug/L																	100 U	

Table 4-2. Ground Water Chemical Analyses and Screening-Level MTCA Comparisons

	Units	MTCA Method A/B Cleanup Levels	Focused RI (ug/L)								Holly Street RI				Landau (1993) (ug/L)			W.D. Purnell & Associates (1993)	
			A-MW-1 (bkgd) 4/20/2000 Wet Season	A-MW-2 4/20/2000 Wet Season	A-MW-3 4/20/2000 Wet Season	A-MW-3 (dup.) 4/20/2000 Wet Season	A-MW-1(bkgd) 8/29/2000 Dry Season	A-MW-2 8/29/2000 Dry Season	A-MW-2 (dup.) 8/29/2000 Dry Season	A-MW-3 8/29/2000 Dry Season	A-MW-4 1/3/2001 Supplemental	A-MW-4 (dup.) 1/3/2001 Supplemental	A-MW-5 1/3/2001 Supplemental	A-MW-6 1/3/2001 Supplemental	L-MW-1 11/18/1990	L-MW-2 11/18/1990	L-MW-3 11/18/1990	TP 7.7/6/8 (15') 9/16/1993	TP 5 (10') 9/17/1993
4-Nitroaniline	ug/L																	40 U	
Bis(2-chloroethyl) ether	ug/L																	20 U	
Bis(2-chloroisopropyl) ether	ug/L	320.00																20 U	
1,2-Dichlorobenzene	ug/L	720.00																20 U	
1,3-Dichlorobenzene	ug/L																	20 U	
1,4-Dichlorobenzene	ug/L	1.80																20 U	
Benzyl alcohol	ug/L	4,800.00																20 U	
n-Nitroso-di-n-propylamine	ug/L	0.01																20 U	
Hexachloroethane	ug/L	6.20																40 U	
Nitrobenzene	ug/L	8.00																20 U	
Isophorone	ug/L	92.00																20 U	
Bis (2-chloroethoxy) methane	ug/L																	20 U	
1,2,4-Trichlorobenzene	ug/L	80.00																20 U	
Hexachlorocyclopentadiene	ug/L	112.00																40 U	
2,6-Dinitrotoluene	ug/L	16.00																40 U	
2,4-Dinitrotoluene	ug/L	32.00																40 U	
4-Chlorophenyl phenylether	ug/L																	20 U	
1,2-Diphenylhydrazine	ug/L	0.11																40 U	
4-Bromophenyl phenylether	ug/L																	40 U	
Carbazole	ug/L	4.40																20 U	
Benzidine	ug/L	0.00038																500 U	
3,3'-Dichlorobenzidine	ug/L	0.19																200 U	
Phthalates																			
Dimethyl phthalate	ug/L	16,000.00	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 UJ	1 U	1 UJ	1 U				20 U	
Diethyl phthalate	ug/L	12,800.00	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 UJ	1 U	1 UJ	1 U				20 U	
Di-n-butyl phthalate	ug/L	1,600.00	1 U	1 U	1 U	1 U	1 U	1.1	1 U	1 U	1 UJ	1 U	1 UJ	1 U				6 J	
Butylbenzyl phthalate	ug/L	3,200.00	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 UJ	1 U	1 UJ	1 U				20 U	
Bis(2-ethylhexyl)phthalate	ug/L	6.20	5.8	1.2	2.2	1.0 U	1.3 U	1.4 U	1 U	1 U	1 UJ	1 U	1 UJ	23				20 U	
Di-n-octyl phthalate	ug/L	320.00	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 UJ	1 U	1 UJ	1 U				20 U	
Miscellaneous Extractables																			
Phenol	ug/L	9,600.00	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 UJ	2 UJ				20 U	
2-Methylphenol	ug/L		2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 UJ	2 UJ				20 U	
4-Methylphenol	ug/L		1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 UJ	1 UJ				62	
2,4-Dimethylphenol	ug/L	320.00	3 U	3 U	3 U	3 U	3 U	3 U	3 U	3 U	3 U	3 U	3 UJ	3 UJ				20 U	
Pentachlorophenol	ug/L	0.73	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 UJ	5 UJ				200 U	
Benzyl alcohol	ug/L	4,800.00	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 UJ	5 U	5 UJ	5 U					
Benzoic acid	ug/L	64,000.00	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 UJ	10 UJ				500 U	
2-Chlorophenol	ug/L	80.00																20 U	
2-Nitrophenol	ug/L																	40 U	
2,4-Dichlorophenol	ug/L	48.00																40 U	
4-Chloro-3-methylphenol	ug/L																	40 U	
2,4,6-Trichlorophenol	ug/L	8.00																40 U	
2,4,5-Trichlorophenol	ug/L	1,600.00																40 U	
4,6-Dinitro-2-methylphenol	ug/L																	200 U	
Pesticides/PCBs (ug/kg DB)																			
4,4'-DDE	ug/L	0.26																0.4 U	
4,4'-DDD	ug/L	0.36																0.4 U	
4,4'-DDT	ug/L	0.26																0.4 U	
Aldrin	ug/L	0.0051																0.2 U	
alpha-Chlordane	ug/L	0.067																2 U	
Dieldrin	ug/L	0.0055																0.4 U	
Endosulfan I	ug/L	96																0.4 U	
Endosulfan II	ug/L																	0.4 U	
Endosulfan sulfate	ug/L																	0.4 U	
Endrin	ug/L	4.8																0.8 U	
Endrin aldehyde	ug/L																	0.4 U	
Heptachlor	ug/L	0.019																0.2 U	
Heptachlor epoxide	ug/L	0.0096																0.2 U	
alpha-BHC	ug/L	0.014																0.2 U	
beta-BHC	ug/L	0.049																0.2 U	
delta-BHC	ug/L																	0.2 U	
gamma-BHC (lindane)	ug/L	0.067																0.2 U	
Methoxychlor	ug/L	80																2 U	
Toxaphene	ug/L	0.08																20 U	
Aroclor 1016	ug/L	1.1																4 U	
Aroclor 1221	ug/L																	8 U	

Table 4-2. Ground Water Chemical Analyses and Screening-Level MTCA Comparisons

			Focused RI (ug/L)								Holly Street RI				Landau (1993) (ug/L)			W.D. Purnell & Associates (1993)	
	Units	MTCA Method A/B Cleanup Levels	A-MW-1 (bkgd) 4/20/2000 Wet Season	A-MW-2 4/20/2000 Wet Season	A-MW-3 4/20/2000 Wet Season	A-MW-3 (dup.) 4/20/2000 Wet Season	A-MW-1(bkgd) 8/29/2000 Dry Season	A-MW-2 8/29/2000 Dry Season	A-MW-2 (dup.) 8/29/2000 Dry Season	A-MW-3 8/29/2000 Dry Season	A-MW-4 1/3/2001 Supplemental	A-MW-4 (dup.) 1/3/2001 Supplemental	A-MW-5 1/3/2001 Supplemental	A-MW-6 1/3/2001 Supplemental	L-MW-1 11/18/1990	L-MW-2 11/18/1990	L-MW-3 11/18/1990	TP 7.7/6/8 (15') 9/16/1993	TP 5 (10') 9/17/1993
Aroclor 1232	ug/L																	4 U	
Aroclor 1242	ug/L																	4 U	
Aroclor 1248	ug/L																	4 U	
Aroclor 1254	ug/L	0.32																4 U	
Aroclor 1260	ug/L																	4 U	
Total PCBs	ug/L																	4 U	

"J" The analyte was positively identified; the associated numerical value is an estimated quantity.

"N" The analysis indicates the presence of an analyte for which there is presumptive evidence to make a "tentative identification."

"U" The analyte was analyzed for but not detected above the reported sample quantitation limit.

"UJ" The analyte was analyzed for but not detected above the estimated sample quantitation limit.

"Y" The sample quantitation limit is elevated due to matrix interferences in the sample.

"R" A9

▭ Concentration exceeds MTCA Method A/B screening level.

(a) Background concentrations derived either from the local upgradient well or from WAC 173-340-720(2)(a)(i).

Table 4-3. Shoreline Seep Chemical Analyses and Screening-Level MTCA Comparisons

	Units	Chapter 173-201 WAC Marine Chronic Criteria[a]	Holly Street RI								
			WP-1 4/20/2000 Wet Season	WP-2 4/21/2000 Wet Season	WP-3 4/21/2000 Wet Season	WP-5 4/20/2000 Wet Season	WP-1 8/29/2000 Dry Season	WP-2 8/29/2000 Dry Season	WP-3 8/29/2000 Dry Season	WP-5 8/29/2000 Dry Season	WP-6 1/3/2001 Supplemental
Conventional Parameters											
Total Dissolved Solids	mg/L		5,400	3,900	3,800	8,500	16,000	11,000	10,000	14,000	12,000
Total Suspended Solids	mg/L		33 J	9	11	18	13	3.8	5	4.4	6.7
Field Turbidity	NTU		24	26	21	26	1.0	0.4	2.1	2.2	4.1
Field Conductivity	uS/cm @ 25C		13,700	5,700	5,900	24,700	14,700	11,600	11,400	14,200	21,600
Lab Conductivity	uS/cm @ 25C		9,700	6,500	6,500	13,000	22,000	16,000	15,000	19,000	20,000
Total Organic Carbon	mg/L		6.4	3.3	2.7 J	6.0	1.8	1.5	2	4.4	2.2
Field Temperature	°C		17.2	13.6	11.4	13.0	18	18	18	18	6.9
Field pH	standard units		7.48	6.46	6.86	6.97	6.3	6	6.3	6.4	6.3
Field Redox	mV		-52	+94	+45	-240	+106	+137	+108	-106	-29
Field Dissolved Oxygen	mg/L		0.1	NA	4.3	5.5	2.87	2.58	3.4	0.97	
Salinity	ppt		5.3	3.5	3.5	7.3	13.0	9.4	8.2	11.0	12.0
Hardness	mg-CaCO3/L		660	660	670	1,600	2,600	1,900	1,800	2,200	
Alkalinity	mg/L		250	64	65	370	110	76	77	250	70
Chloride	mg/L		3,700	2,300	2,200	4,900	9,400	7,200 J	7,800 J	9,300 J	7,400
Sulfate	mg/L		420	310	320	570	1,200	960	850	1,000	1,000
Ammonia	mg-N/L	0.035	2.0	0.01 U	0.01 U	2.1	0.02	0.011	0.01	1.4	0.028 U
Nitrate	mg-N/L		0.047	0.420	0.470	0.010 U	0.32	0.21	0.25	0.01 UJ	0.46
Fecal Coliform	#/100mL	14[b]	470 J	8	5	1 U	2 U	2	2	2	1 U
Total Metals											
Arsenic	ug/L	36	11.4	1.2	1.1	1.8	3	1 U	4	2	2
Cadmium	ug/L	9.3	0.2 U	0.3	0.2	0.2 U	1 U	1 U	1 U	1 U	1 U
Calcium	ug/L	---					177,000	131,000	132,000	154,000	166,000
Chromium	ug/L	50	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	10 U
Copper	ug/L	3.1	2 U	20	15	2 U	9	46	17	2 U	4
Iron	ug/L	6,790 (c)	5,730 J	610 J	420 J	1,150 J	110	40	460	60	670
Lead	ug/L	8.1	6	5	3	1	5 U	8	5 U	5 U	6
Magnesium	ug/L	---					536,000	392,000	349,000	437,000	463,000
Manganese	ug/L	2,530 (c)	1,310	14	5	1,230	2	9	13	112	27
Mercury	ug/L	0.10	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U
Silver	ug/L	1.9	0.5 UJ	0.5 UJ	0.5 UJ	0.5 UJ	2 U	2 U	2 U	2 U	2 UJ
Zinc	ug/L	81	14	99	102	6 U	178	282	246	6 U	30
Dissolved Metals											
Arsenic	ug/L	36	2.9	0.7	0.6	1.9	1 U	1 U	1 U	3 U	2 U
Cadmium	ug/L	9.3	0.2 U	0.3	0.2	0.2 U	1 U	1 U	1 U	1 U	1 U
Chromium	ug/L	50	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	10 U
Copper	ug/L	3.1	2	15	11	2 U	8 J	47	14	2 UJ	2 U
Iron	ug/L	---	40	20 U	20 U	510	20 U	20 U	20 U	20 U	40 U
Lead	ug/L	8.1	1 U	2	1 U	1 U	5 U	7	5 U	5 U	5 U
Manganese	ug/L	2,530 (c)	1,860	4	1 U	1,410	1 UJ	10	12	121	11
Mercury	ug/L	0.10	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U

Silver	ug/L	1.9	0.5 U	0.5 U	0.5 U	0.5 U	2 U	2 U	2 U	2 U	2 U
Zinc	ug/L	81	6 U	101	103	6 U	195	316	268	6 U	30 U
Volatile Organic Hydrocarbons											
1,2-Dichlorobenzene	ug/L	---	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
1,4-Dichlorobenzene	ug/L	4.860	0.2 U	0.2 U	0.3	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
1,2,4-Trichlorobenzene	ug/L	---	0.5 U	0.2 U	0.2 U	0.5 U	0.5 UJ	0.5 UJ	0.5 UJ	0.5 UJ	0.5 U
Benzene	ug/L	---	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
Toluene	ug/L	---	0.5	0.2 U	0.3	0.5	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
Ethylbenzene	ug/L	---	0.2 U	0.2 U	0.2 U	0.3	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
Total Xylenes	ug/L	---	1.0 Y	0.6 U	0.6 U	1.8 U	0.6 U	0.6 U	0.6 U	0.6 U	0.6 U
Low Molecular Weight Polycyclic Aromatic Hydrocarbons											
Naphthalene	ug/L	9,880	1 U	1 U	1 U	1 U	1 U	1 U	1 UJ	1 U	1 U
Acenapththylene	ug/L	---	1 U	1 U	1 U	1 U	1 U	1 U	1 UJ	1 U	1 U
Acenaphthene	ug/L	643	1 U	1 U	1 U	1 U	1 U	1 U	1 UJ	1 U	1 U
Fluorene	ug/L	3,460	1 U	1 U	1 U	1 U	1 U	1 U	1 UJ	1 U	1 U
Phenanthrene	ug/L	---	1 U	1 U	1 U	1 U	1 U	1 U	1 UJ	1 U	1 U
Anthracene	ug/L	25,900	1 U	1 U	1 U	1 U	1 U	1 U	1 UJ	1 U	1 U
2-Methylnaphthalene	ug/L	---	1 U	1 U	1 U	1 U	1 U	1 U	1 UJ	1 U	1 U
Total LPAHs	ug/L	---	1 U	1 U	1 U	1 U	1 U	1 U	1 UJ	1 U	1 U
High Molecular Weight Polycyclic Aromatic Hydrocarbons											
Fluoranthene	ug/L	---	1 U	1 U	1 U	1 U	1 U	1 U	1 UJ	1 U	1 U
Pyrene	ug/L	---	1 U	1 U	1 U	1 U	1 UJ	1 UJ	1 UJ	1 UJ	1 U
Benzo(a)anthracene	ug/L	---	1 U	1 U	1 U	1 U	1 U	1 U	1 UJ	1 U	1 U
Chrysene	ug/L	---	1 U	1 U	1 U	1 U	1 U	1 U	1 UJ	1 U	1 U
Benzo(b)fluoranthene	ug/L	---	1 U	1 U	1 U	1 U	1 U	1 U	1 UJ	1 U	1 U
Benzo(k)fluoranthene	ug/L	---	1 U	1 U	1 U	1 U	1 U	1 U	1 UJ	1 U	1 U
Total Benzofluoranthenes	ug/L	---	1 U	1 U	1 U	1 U	1 U	1 U	1 UJ	1 U	1 U
Benzo(a)pyrene	ug/L	---	1 U	1 U	1 U	1 U	1 U	1 U	1 UJ	1 U	1 U
Indeno(1,2,3-c,d)pyrene	ug/L	---	1 U	1 U	1 U	1 U	1 U	1 U	1 UJ	1 U	1 U
Dibenzo(a,h)anthracene	ug/L	---	1 U	1 U	1 U	1 U	1 U	1 U	1 UJ	1 U	1 U
Benzo(g,h,i)perylene	ug/L	---	1 U	1 U	1 U	1 U	1 U	1 U	1 UJ	1 U	1 U
Total HPAHs	ug/L	---	1 U	1 U	1 U	1 U	1 U	1 U	1 UJ	1 U	1 U
Miscellaneous Semivolatile Organics											
Gasoline-range TPH	ug/L	---	10,000 U	10,000 U	10,000 U	10,000 U	250 U	250 U	250 U	250 U	250 U
Diesel-range TPH	ug/L	---	10,000 U	10,000 U	10,000 U	10,000 U	500 U	500 U	500 U	500 U	500 U
Oil-range TPH	ug/L	---	25,000 U	25,000 U	25,000 U	25,000 U	500 U	500 U	500 U	500 U	500 U
Hexachlorobenzene	ug/L	---	1 U	1 U	1 U	1 U	1 U	1 U	1 UJ	1 U	1 U
Dibenzofuran	ug/L	---	1 U	1 U	1 U	1 U	1 U	1 U	1 UJ	1 U	1 U
Hexachlorobutadiene	ug/L	---	2.0 U	2.0 U	2.0 U	2.0 U	2 U	2 U	2 UJ	2 U	2 U
n-Nitroso-diphenylamine	ug/L	---	1 U	1 U	1 U	1 U	1 U	1 U	1 UJ	1 U	1 U
Phthalates											
Dimethyl phthalate	ug/L	---	1 U	1 U	1 U	1 U	1 U	1 U	1 UJ	1 U	1 U
Diethyl phthalate	ug/L	---	1 U	1 U	1 U	1 U	1 U	1 U	1 UJ	1 U	1 U
Di-n-butyl phthalate	ug/L	---	1 U	1 U	1 U	1 U	1 U	1 U	1 UJ	1.4	1 U
Butyl benzyl phthalate	ug/L	---	1 U	1 U	1 U	1 U	1 U	1 U	1 UJ	1.4	1 U
Bis(2-ethylhexyl)phthalate	ug/L	3.6	1.0 U	1.0 U	2.5	1.2	1 U	1 U	1 UJ	1 U	1 U
Di-n-octyl phthalate	ug/L	---	1 U	1 U	1 U	1 U	1 U	1 U	1 UJ	1 U	1 U

Table 4-4. Shoreline Sediment Chemical Analyses and Screening-Level SMS Comparisons

		Washington State Sediment Management Standards Chemical Criteria		Holly Street RI						Whatcom Waterway RI	
	Units	SQS	CSL	SD-1 4/21/2000 0 to 12 cm	SD-2 4/21/2000 0 to 12 cm	SD-3 4/21/2000 0 to 12 cm	SD-4 4/21/2000 0 to 12 cm	SD-5 4/21/2000 0 to 12 cm	SD-6 (bkgd) 4/21/2000 0 to 12 cm	HC-SS-38 9/9/1996 0 to 8 cm	HC-SS-39 9/9/1996 0 to 8 cm
Conventional Parameters											
Total Solids	%	---	---	52%	57%	68%	37%	73%	65%	52	50
Gravel	%	---	---	5%	3%	27%	14%	33%	52%	0	18
Sand	%	---	---	63%	66%	60%	48%	67%	36%	66	61
Silt	%	---	---	24%	22%	9%	32%	0%	10%	26	19
Clay	%	---	---	8%	9%	4%	5%	0%	1%	8	2
Percent Fines	%	---	---	36%	70%	9%	37%	0%	12%	34	21
Total Organic Carbon	%	---	---	3.2%	3.7%	2.5%	9.6%	1.6%	2.6%	3.6	2.9
Salinity	ppt	---	---	4.6	6.1	5.2	3.5	2.4	2.2	20	17.4
Total Metals											
Arsenic	mg/kg dry weight	57	93	12	12	8 J	20	4 J	10	6.3 E	7.2 E
Cadmium	mg/kg dry weight	5.1	6.7	0.6	0.5	0.4	1.7	0.2	0.3	0.89	0.99 U
Chromium	mg/kg dry weight	260	270	53	47	43	71	23	36	29	26
Copper	mg/kg dry weight	390	390	54 J	47 J	52 J	129 J	13 J	111 J	38	34
Lead	mg/kg dry weight	450	530	79 J	73 J	89 J	215 J	18 J	625 J	57	48
Mercury	mg/kg dry weight	0.41	0.59	0.13 J	0.11 J	0.09 J	0.21 J	0.03 J	0.22 J	0.19 U	0.2 U
Silver	mg/kg dry weight	6.1	6.1	0.7	0.4	0.7	0.7 UJ	0.2 UJ	0.2 UJ	1.2	2.9
Zinc	mg/kg dry weight	410	960	209 J	188 J	220 J	356 J	42 J	296 J	140	130
Volatile Organic Hydrocarbons											
1,2-Dichlorobenzene	mg/kg OC	2.3	2.3	0.05 U	0.04 U	0.04 U	0.02 UJ	0.06 U	0.06 U	0.97 U	1.24 U
1,4-Dichlorobenzene	mg/kg OC	3.1	9.0	0.05 U	0.04 U	0.04 U	0.02 UJ	0.06 U	0.06 U	0.89 U	1.14 U
1,2,4-Trichlorobenzene	mg/kg OC	0.81	1.80	0.23 U	0.18 U	0.23 U	0.13 UJ	0.32 U	0.30 UJ	0.83 U	1.07 U
Low Molecular Weight Polycyclic Aromatic Hydrocarbons											
Naphthalene	mg/kg OC	99	170	2.5	2.1	1.8	1.0	1.2 U	1.1	1.4	2.5
Acenapthylene	mg/kg OC	66	66	0.6 U	0.5 U	1.5	0.4 M	1.2 U	0.7 U	0.3 E	1.1 U
Acenaphthene	mg/kg OC	16	57	0.8	0.9	0.9	0.3	1.2 U	0.7 U	1.1	1.0 E
Fluorene	mg/kg OC	23	79	1.3	1.4	1.7	0.4	1.2 U	0.7 U	1.8	1.4
Phenanthrene	mg/kg OC	100	480	12.2	12.2	20.8	3.2	3.7	4.2	15.3	13.5
Anthracene	mg/kg OC	220	1,200	6.3	4.3	4.0	0.9	1.2 U	1.2	3.9	3.3
2-Methylnaphthalene	mg/kg OC	38	64	2.8	2.5	1.8	0.6	1.2 U	1.1	0.8 E	2.3
Total LPAHs(1)	mg/kg OC	370	780	23.1	20.9	30.7	5.8 M	3.7	6.5	23.8	21.6
High Molecular Weight Polycyclic Aromatic Hydrocarbons											
Fluoranthene	mg/kg OC	160	1,200	25.3	20.8	28.8	7.7	7.5	9.2	25.3	20.7
Pyrene	mg/kg OC	1,000	1,400	18.4	18.4	29.2	7.9	4.9	6.9	26.7	24.1
Benzo(a)anthracene	mg/kg OC	110	270	8.8	8.6	10.4	4.4	2.6	3.4	11.7	8.3
Chrysene	mg/kg OC	110	460	13.1	14.3	16.8	5.6	3.9	5.0	17.5	11.7
Benzo(b)fluoranthene	mg/kg OC	---	---	17.5	13.0	14.0	6.1	3.3	4.2	23.9 C	20.0 C
Benzo(k)fluoranthene	mg/kg OC	---	---	12.5	14.3	18.4	4.9	2.9	4.2	23.9 C	20.0 C

Miscellaneous Extractables											
Phenol	ug/L	---	2 U	2 U	2 U	2 U	2 U	2 U	2 UJ	2 U	2 U
2-Methylphenol	ug/L	---	2 U	2 U	2 U	2 U	2 U	2 U	2 UJ	2 U	2 U
4-Methylphenol	ug/L	---	1 U	1 U	1 U	1 U	1 U	1 U	1 UJ	1 U	1 U
2,4-Dimethylphenol	ug/L	---	3 U	3 U	3 U	3 U	3 U	3 U	3 UJ	3 U	3 U
Pentachlorophenol	ug/L	7.9	5 U	5 U	5 U	5 U	5 U	5 U	5 UJ	5 U	5 U
Benzyl alcohol	ug/L	---	5 U	5 U	5 U	5 U	5 U	5 U	5 UJ	5 U	5 U
Benzoic acid	ug/L	---	10 U	10 U	10 U	10 U	10 U	10 U	10 UJ	10 U	10 U

"J" The analyte was positively identified; the associated numerical value is an estimated quantity.

"N" The analysis indicates the presence of an analyte for which there is presumptive evidence to make a "tentative identification."

"U" The analyte was analyzed for but not detected above the reported sample quantitation limit.

"UJ" The analyte was analyzed for but not detected above the estimated sample quantitation limit.

"Y" The sample quantitation limit is elevated due to matrix interferences in the sample.

▨ Concentration exceeds MTCA Method A/B screening level.

Notes:

(a) Chapter 173-201 WAC applies the marine criteria to all locations where the salinity exceeds 1 ppt.

(b) Criteria based on Class A designation of Whatcom Creek under Chapter 173-201 WAC. A second component of the criteria is that not more than 10 percent of all samples obtained exceed 43 colonies/100 mL.

(c) Background concentrations derived either from the local upgradient well or from WAC 173-340-720(2)(a)(I).

Legend

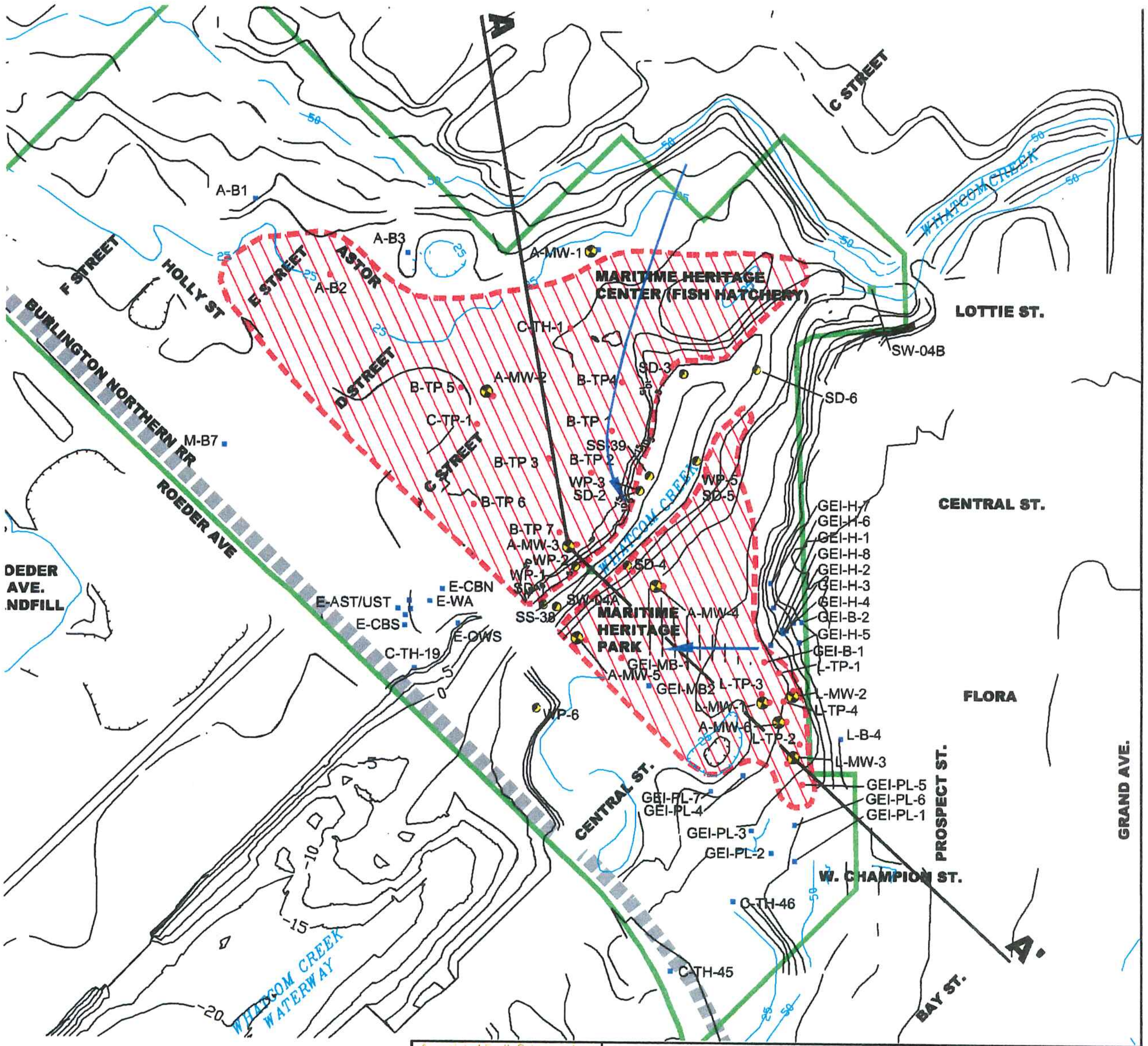
- Conceptual ground water flow direction based on data collected during the RI/FS.
- ● Soil Boring/Well Installation Location
- ● Well Points and/or Surface Sediment Sampling Locations
- 🟩 Surface Water Sampling Location
- ▨ Probable Extent of Municipal Landfill Waste (Based on Historical Shoreline Maps and Historical Records)
- Brownfield Project Area
- ● Solid Waste in Exploration
- ■ No Solid Waste in Exploration

A-MW-	Monitoring well sampled in 2000
WP-	Well point sampled in 2000
SD-	Surface sediment sampled in 2000
B-TP-	Test pit reported in BEK Purnell (1993)
C-TP/TH-	Test pit or test boring reported in City of Bellingham (1972)
E-	Soil boring reported in Entrix (1999)
GEI-H/B-	Hand boring or test hole boring reported in GeoEngineers (1998-2001)
L-TP/MW-	Test pit or soil boring/monitoring well sampling reported in Landau (1993)
GEI-PL-	GeoEngineers (1998-2001)
GEI-MB	GeoEngineers (1998-2001)

A — A' Line of Cross Section

0 200
Scale in Feet

ANCHOR ENVIRONMENTAL, L.L.C.



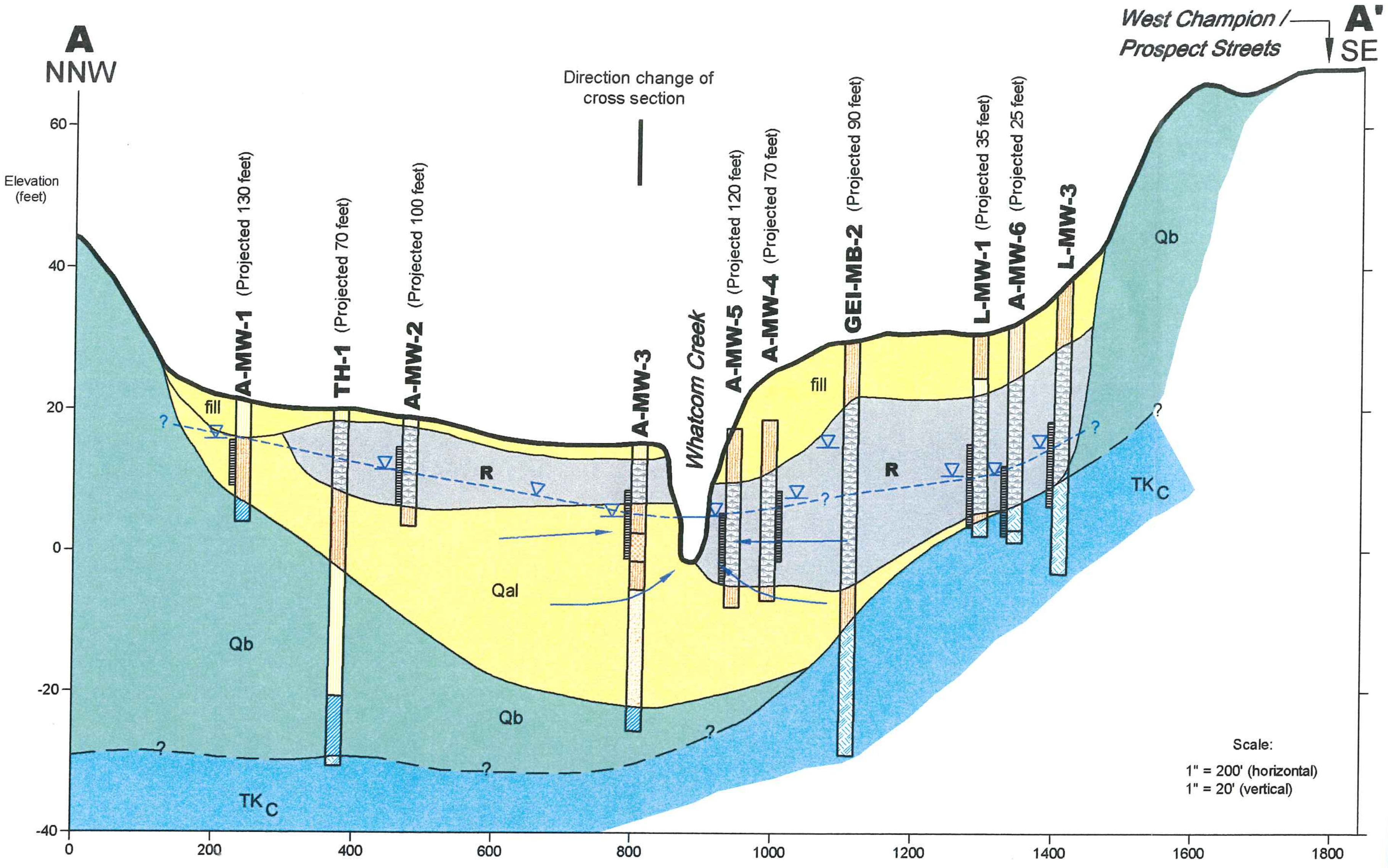
Associated Earth Sciences, Inc.

Conceptual Ground Water Flow

Holly Street Landfill
Bellingham, Washington

PROJECT NO.	BV99139
FIGURE NO.	4-1

as shown
SJS
SK 05/08/01
JJR



Symbols

▽ Measured water level

- -▽- - Inferred water table

Well

Screened casing with filter pack

Conceptual ground water flow path

Water level data for A-MW-1, A-MW-2, and A-MW-3 obtained 10/08/00
(corrected for tidal fluctuation)

Water level data for L-MW-1 and L-MW-3 obtained 11/18/92

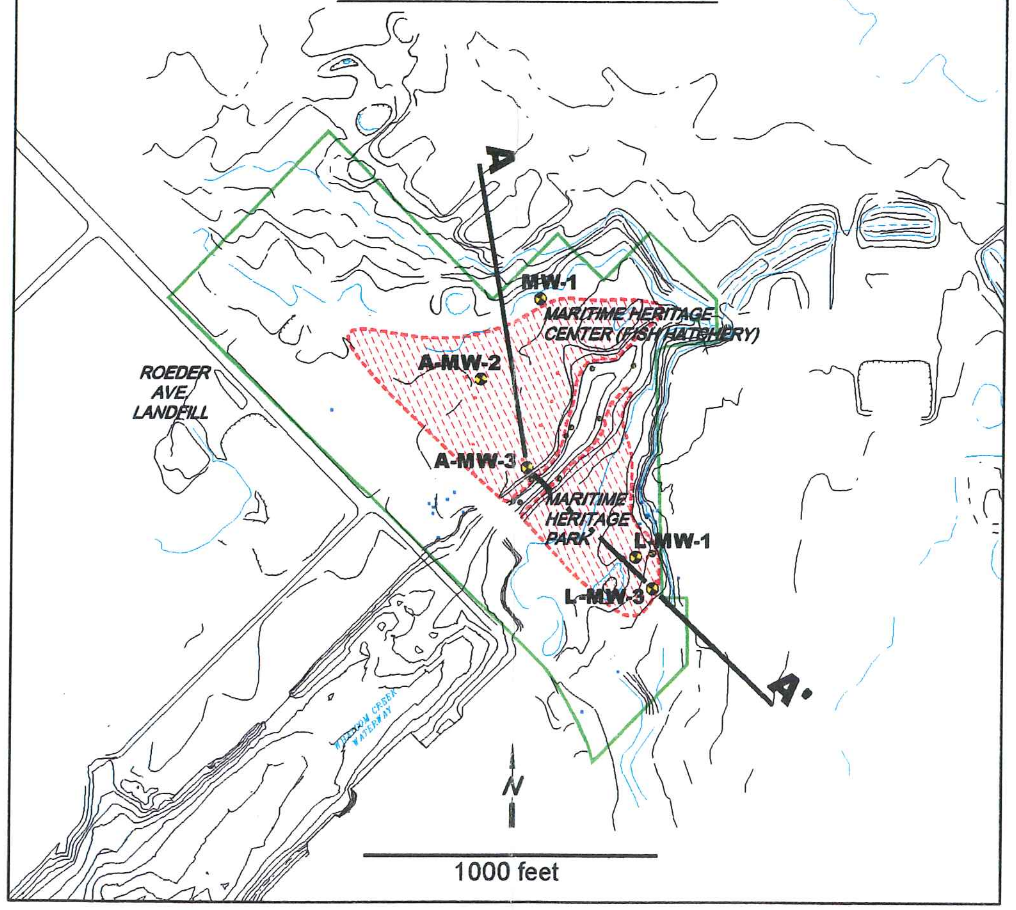
TH series borings advanced in 1969 (CH 2M Hill, 1972).

A-MW-1, A-MW-2 & A-MW-3 wells installed April, 2000.

L-MW series wells installed November, 1992.

A-MW-4, A-MW-5 & A-MW-6 wells installed December 2000.
GEI-MB-2 boring drilled April 2001.

Cross Section Location Map



Geologic Reference

fill	Sand, silt and gravel with occasional debris of anthropogenic origin, but not associated with landfill refuse.
R	Refuse: Landfill debris emplaced specifically in the Holly Street Landfill.
Qal	Quaternary Alluvium: Includes recent mudflat sediment, reworked deposits derived from the Nooksack River, and recent alluvial deposits from Whatcom Creek.
Qso	Sumas Outwash: Sandy outwash of Sumas glacial stade. Inferred to be present northwest of site based on Easterbrook (1976).
Qb	Bellingham Drift: Glacio-marine sandy silt and clay.
TKC	Chuckanut Formation: Sandstone and carbonaceous shale. Outcrops south-southeast of end of cross section.

Coarse-Grained Soils - More than 50% (1) Retained on No. 200 Sieve	Sands - 50% or More of Coarse Fraction Passes No. 4 Sieve	≤5% Fines	Well-graded sand and sand with gravel, little to no fines
			Poorly-graded sand and sand with gravel, little to no fines
		£ 15% Fines ? 10% Fines	Silty sand and silty sand with gravel
Fine-Grained Soils - 50% (1) or More Passes No. 200 Sieve	Silts and Clays Liquid Limit Less than 50	≥15% Fines	Silt, sandy silt, gravelly silt, silt with sand or gravel
			Clay of low to medium plasticity; silty, sandy, or gravelly clay, lean clay
			R Refuse

(1) Percentage by dry weight

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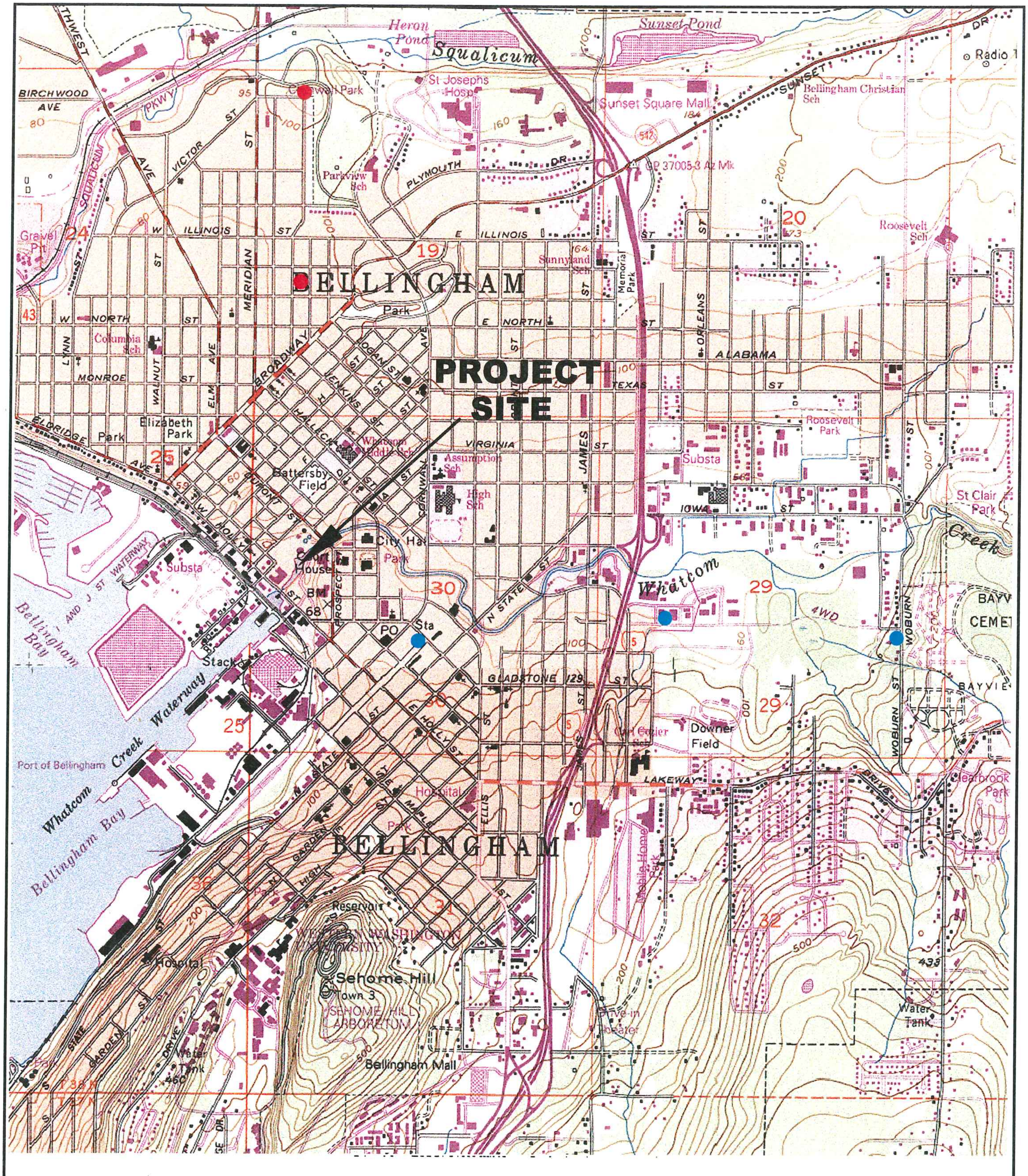
Geologic Cross Section A-A'

Holly Street Landfill
Bellingham, Washington

REFERENCE:	
DATE: 05/16/01	SCALE: As Noted
DESIGNED BY: PSB	REVISED:
DRAWN BY: JJR	FILENAME: BV99139XE.dwg

PROJECT NO.
BV99139
FIGURE NO.
4-2



Reference: Topo!, Wildflower Productions (1997)

Legend

● Public Works Department wells ("other use")

● Documented Well

Associated Earth Sciences, Inc.

Documented Water Supply Wells

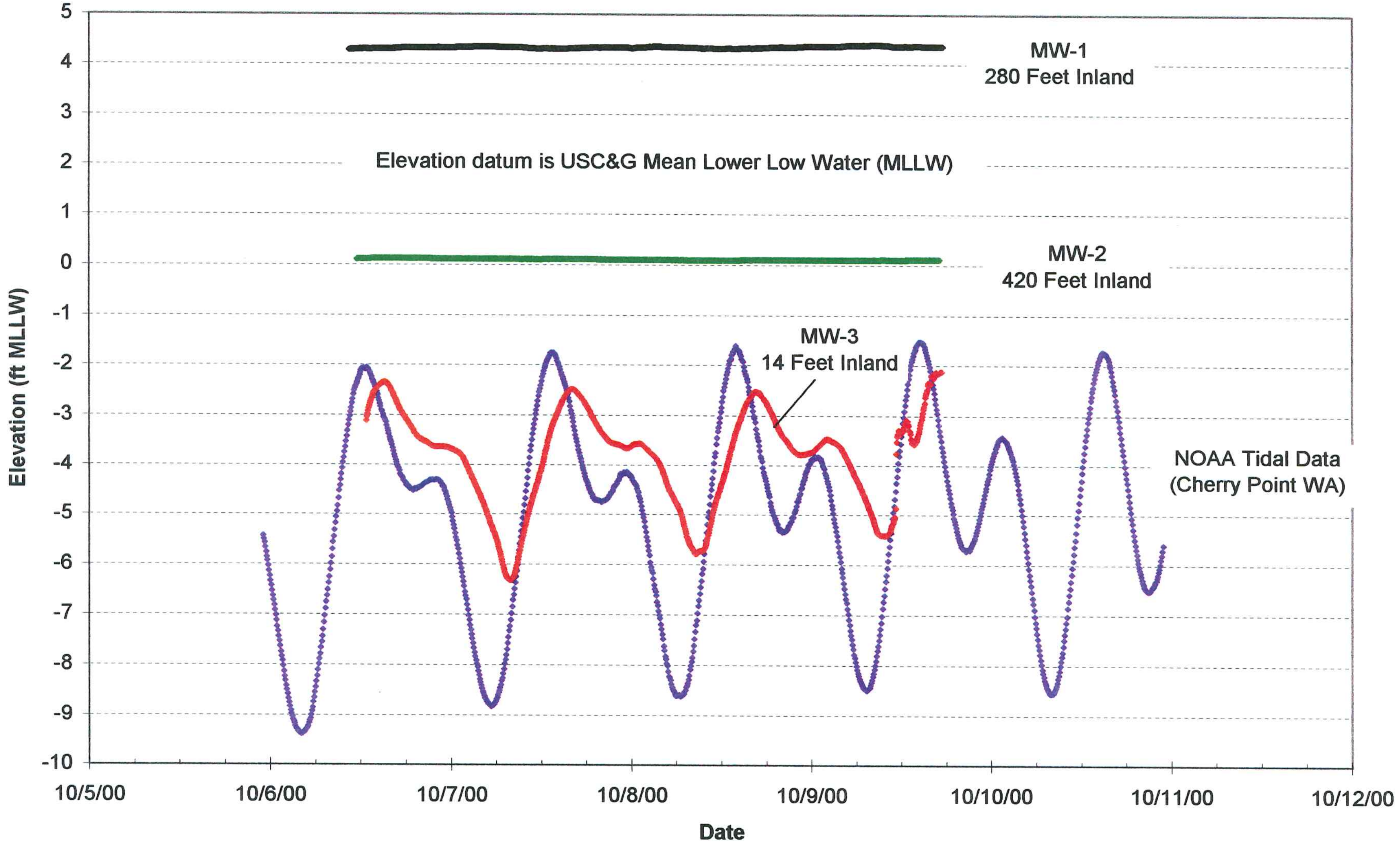
Holly Street Landfill

Bellingham, Washington

DATE:	SCALE:
11/03/00	1" = 2000'
DRAWN BY:	DESIGNED BY:
JJR	SJS
PROJECT NO.	FIGURE NO.
BV99139	4-3

BV99139-4.dwg

Figure 4-4
Ground Water Response to Tides



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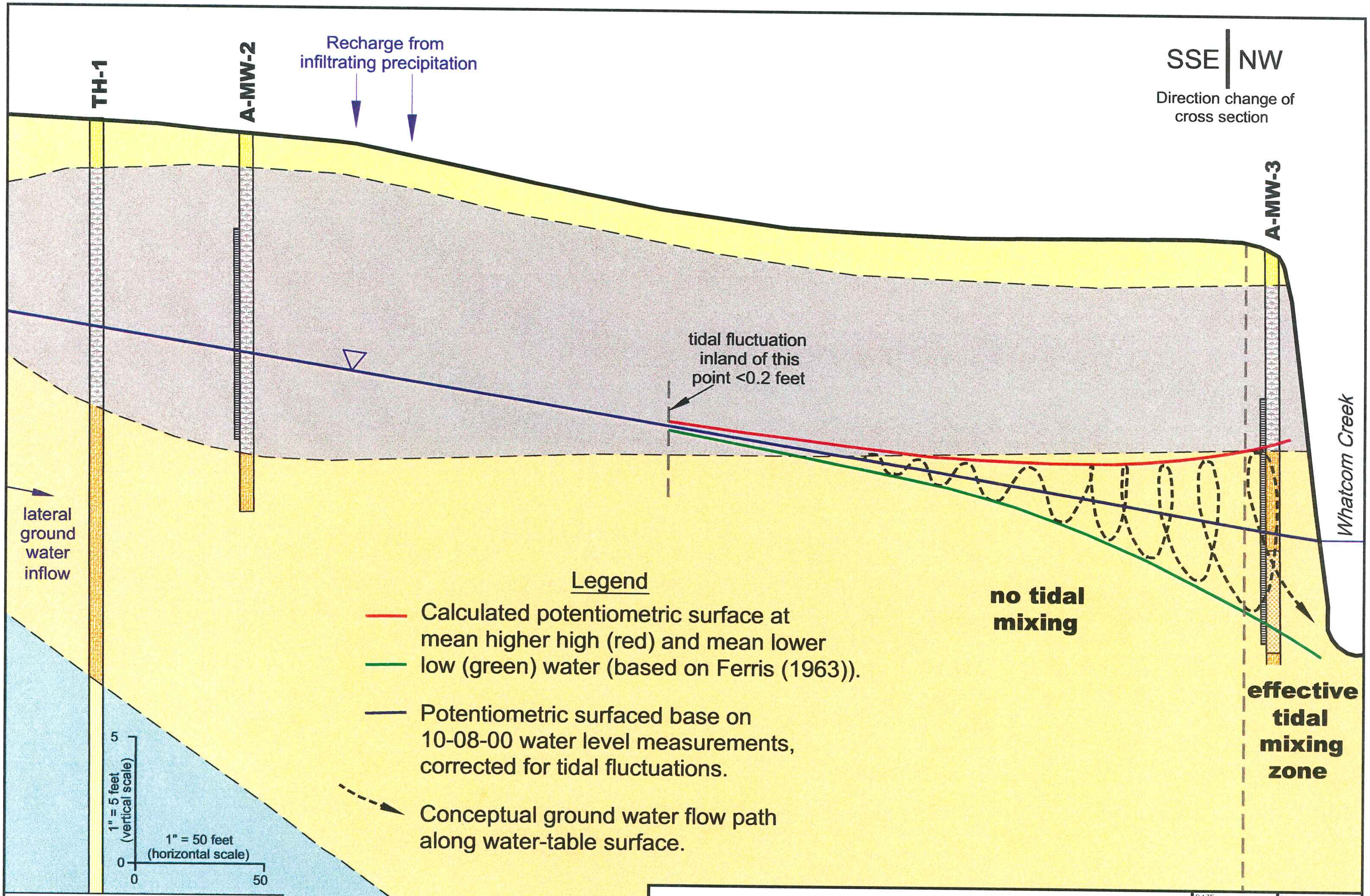
HollyStreetTide 11/7/00



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BV99139-2.dwg

Conceptual Hydrogeologic Model

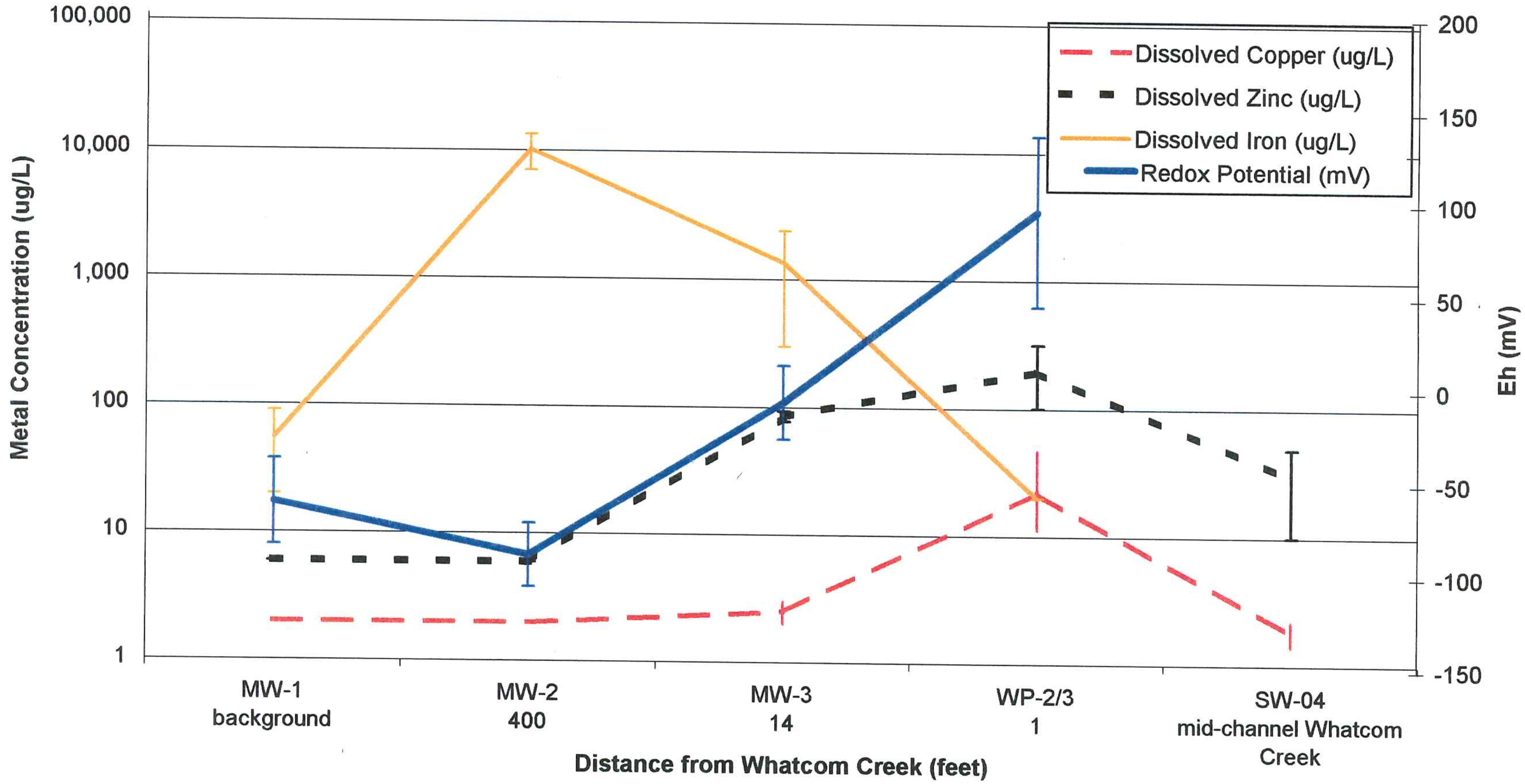
Holly Street Landfill
Bellingham, Washington

DATE: 11/03/00	SCALE: As Noted
DRAWN BY: JJR	DESIGNED BY: SJS
PROJECT NO. BV99139	FIGURE NO. 4-5

Figure 4-6

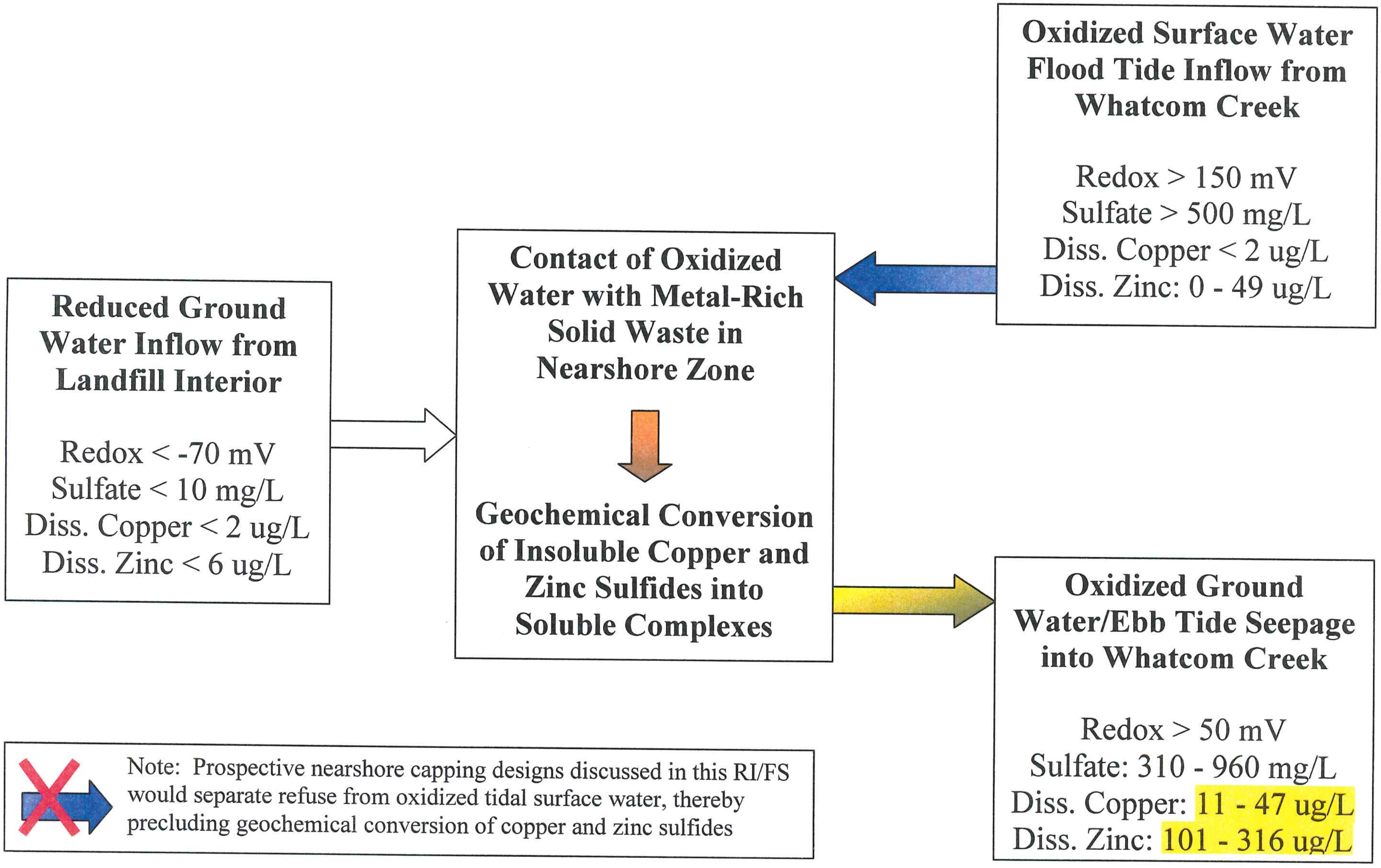
Dissolved Metal Concentrations Controlled by Redox Potential
Holly Street Ground Water Discharge to Whatcom Creek

(Error bars depict minimum and maximum concentrations measured)



Note: Calculation of mean and minimum values used the detection limit in cases where there were undetected concentrations.

Figure 4-7
Conceptual Model of Metal Release from Refuse Contacting Oxidized Surface Water



Reduced Ground Water Inflow from Landfill Interior

Redox < -70 mV
Sulfate < 10 mg/L
Diss. Copper < 2 ug/L
Diss. Zinc < 6 ug/L

Contact of Oxidized Water with Metal-Rich Solid Waste in Nearshore Zone

Geochemical Conversion of Insoluble Copper and Zinc Sulfides into Soluble Complexes

Oxidized Surface Water Flood Tide Inflow from Whatcom Creek

Redox > 150 mV
Sulfate > 500 mg/L
Diss. Copper < 2 ug/L
Diss. Zinc: 0 - 49 ug/L

Oxidized Ground Water/Ebb Tide Seepage into Whatcom Creek

Redox > 50 mV
Sulfate: 310 - 960 mg/L
Diss. Copper: 11 - 47 ug/L
Diss. Zinc: 101 - 316 ug/L

Note: Prospective nearshore capping designs discussed in this RI/FS would separate refuse from oxidized tidal surface water, thereby precluding geochemical conversion of copper and zinc sulfides

5.0 Prospective MTCA Cleanup Standards

5.1 Soil/Refuse

As discussed above in Section 4.3.1 and summarized in Table 4-1, a range of metals and hydrocarbon compounds were identified as soil/refuse COPCs based on an initial, conservative screening-level comparison. However, one of these COPCs – mercury – was only identified as being of potential concern based on screening-level ground water protection considerations. Since ground water samples collected immediately below the only soil location (A-MW-3) exceeding the ground water protection criterion did not contain detectable mercury levels (Table 4-2), and because the maximum soil/refuse mercury concentration (4.8 mg/kg) was well below other risk-based criteria (e.g., below residential direct contact standards), mercury was not confirmed as a COPC. Thus, the list of confirmed soil/refuse COPCs at the Holly Street Landfill Site includes the following:

- Arsenic (present above residential use screening levels in 2 of 7 samples);
- Cadmium (present above plant protection screening levels in 3 of 7 samples);
- Lead (present above residential use screening levels in 6 of 7 samples); and
- cPAHs (present above residential use screening levels in 2 of 3 samples).

More detailed evaluations of the COPCs were performed to determine whether concentrations of these hazardous substances detected in soil/refuse at the Holly Street Landfill Site exceed prospective site-specific MTCA cleanup levels. In making this determination, the existing and prospective future zoning of the Site area was considered under the MTCA cleanup standard framework. The MTCA cleanup standards generally categorize sites into unrestricted (residential), restricted (park/commercial), and industrial use areas for the purpose of reasonable maximum exposure evaluations. A statistical analysis of the available soil/refuse sampling data was also performed, consistent with MTCA guidelines, to provide an improved measure of how existing site conditions compare with this range of land use-based criteria. The results of the prospective MTCA cleanup level comparison are summarized in Table 5-1.

Table 5-1. Prospective MTCA Soil/Refuse Cleanup Levels (all units in mg/kg dry wt)

Chemical of Potential Concern	Average/95th UCL Soil/ Refuse Concentration (b)	Residential Criterion	Park/ Commercial Criterion	Industrial Criterion
Total Arsenic	22/70	20	20	20
Total Cadmium	3/5	2	2	2
Total Lead	860/2,300	250	500	1,000
Total cPAHs (a)	4/11	0.1	5	18

Notes:

(a) Calculated using toxicity equivalency factors (TEFs) specified in MTCA guidance.

(b) Upper confidence level (UCL) concentration calculated using Ecology's MTCAStat program, using data presented in Table 4-1.

Based on the Table 5-1 comparison, all four of the COPCs in soil/waste at the Holly Street Landfill Site exceed MTCA cleanup standards for unrestricted (residential) site uses. Average and/or upper-bound concentrations of arsenic, cadmium, lead, and cPAHs also exceed restricted (park/commercial) and/or industrial cleanup standards.

Similar to remedial action objectives developed for the Cornwall Avenue Landfill Site (Landau 2000), performance-based cleanup standards may be needed at the Holly Street Landfill Site to minimize potential human and environmental exposure to refuse and associated soil contaminants. These exposure control measures could potentially be met through construction and maintenance of a minimum 3-foot-thick permeable cap or equivalent, depending on whether or not further ground water controls may also be necessary (Section 5.2 below). Caps meeting this specification appear to be already in place throughout the southeast lobe of the landfill (i.e., Maritime Heritage Park) and in most of the northwest lobe of the Site. However, based on available soil boring and test pit logs, an approximate 0.4-acre portion of the City's Maritime Heritage Center (fish hatchery) property contains only a thin cover (less than 3-feet-thick) of capping material (Figure 5-1). Additional evaluations of potential soil/refuse cleanup remedies for the Holly Street Landfill Site are presented below in Sections 7.0 through 10.0.

5.2 Ground Water

As discussed above in Section 4.6.1 and summarized in Table 4-2, only iron, manganese, and bis(2-ethylhexyl)phthalate were identified as ground water COPCs based on an initial, conservative screening-level comparison. However, elevated manganese concentrations, at levels exceeding local background levels, were not confirmed during the RI/FS sampling. In addition, the single detection of bis(2-ethylhexyl)phthalate, a common laboratory contaminant, is considered questionable. Additional confirmatory sampling is recommended during remedial design to confirm that this compound, and other chemicals such as lead and TPH, is not present in Site ground water at levels of potential concern.

Thus, only iron was retained as a verified ground water COPC at the Holly Street Landfill Site. Prospective MTCA ground water cleanup levels are summarized in Table 5-2.

Table 5-2. Prospective MTCA Ground Water Cleanup Levels (all units in ug/L)

Chemical of Potential Concern	Average/95th UCL Ground Water Concentration in A-MW-2 (a)	Local Background Concentration (from A-MW-1)	Taste/ Odor Level	Drinking Water Risk Criterion
Total Iron	42,200/49,300	6,790	300	N/A

Notes:

(a) Calculated using Ecology's MTCAStat program, using data presented in Table 4-2.

Based on the Table 5-2 comparison, no human health risks are likely to be associated with potential drinking water consumption of ground water at the Holly Street Landfill Site (in addition, no existing or future drinking water use has been identified). However, total iron concentrations detected in ground water at the Site may exceed secondary drinking water standards based on taste/odor and aesthetic considerations.

5.3 Shoreline Seepage

As discussed above in Section 4.7 and summarized in Table 4-3, only copper and zinc were identified as seep COPCs based on an initial, conservative screening-level comparison. Prospective MTCA surface water/seep cleanup levels are summarized in Table 5-3.

Table 5-3. Prospective MTCA Seep/Surface Water Cleanup Levels (all units in ug/L)

Chemical of Potential Concern	Average/95th UCL Seep Concentration in A-WP-2 & A-WP-3 (a)	Local Background Concentration (from A-MW-1)	Chronic Toxicity (24-hour) Criterion	Acute Toxicity (1-hour) Criterion
Copper (dissolved)	22/47	<2	3.1	4.8
Zinc (dissolved)	197/316	<6	81	90

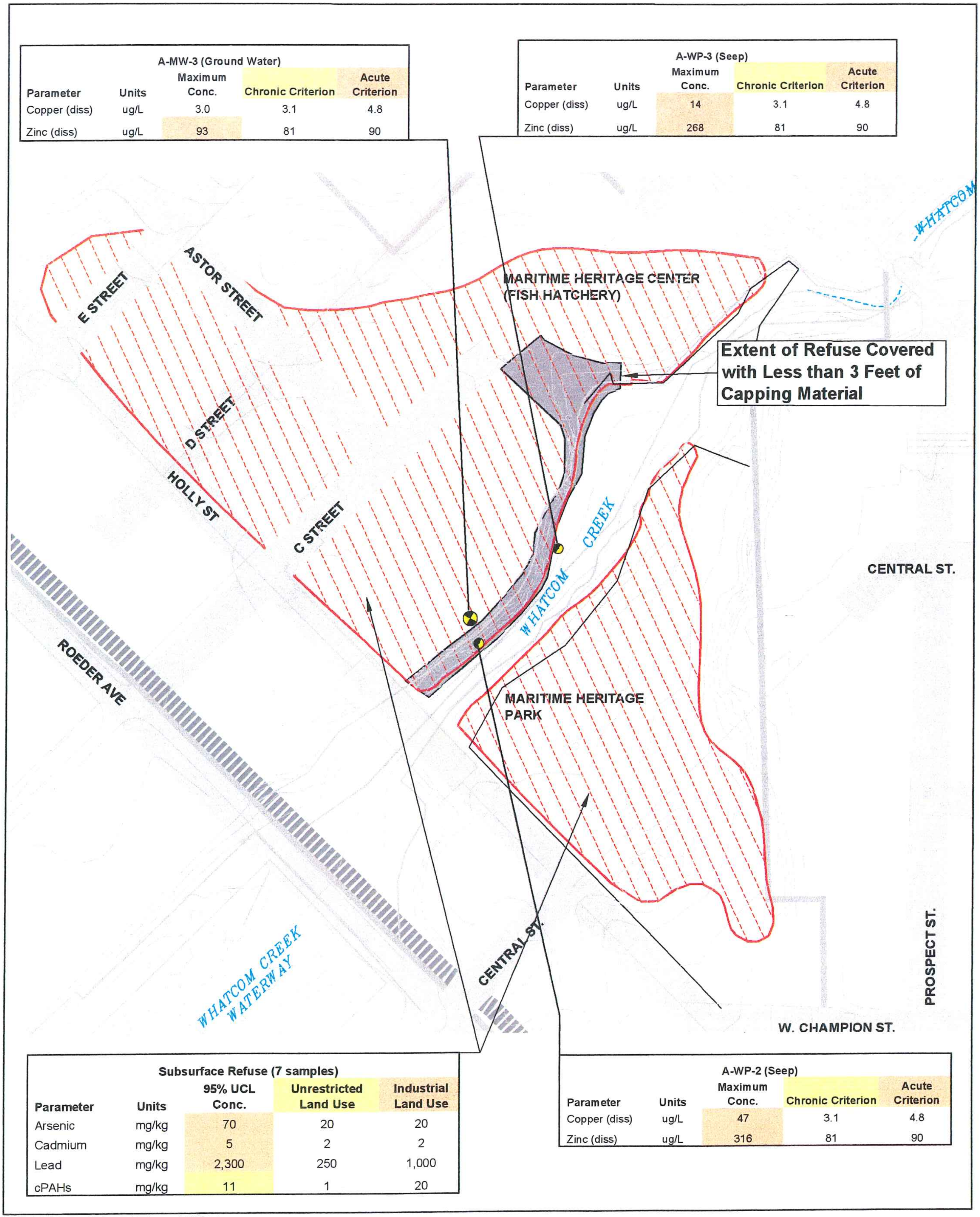
Notes:

(a) Calculated using Ecology's MTCAStat program, using data presented in Table 4-3.

Based on the Table 5-3 comparison, shoreline seepage discharges from portions of the Holly Street Landfill Site have the potential to result in both chronic and acute toxicity to sensitive aquatic life. Copper and zinc concentrations peak in shoreline seeps adjacent to the northwest lobe of the site, before being diluted upon discharge into Whatcom Creek (Figure 5-1). The large dilution potential of Whatcom Creek (Section 4.5.3) likely restricts such exceedances to the immediate shoreline area of the estuary. Mid-channel concentrations of dissolved copper and zinc are well below water quality criteria (Anchor and Hart Crowser 2000).

While seepage samples collected adjacent to the northwest landfill lobe (e.g., WP-2 and -3) regularly and substantially exceeded both acute and chronic toxicity criteria for copper and zinc (Table 5-3), only a single seepage sample (WP-6) collected from the southeast landfill lobe marginally exceeded conservative chronic toxicity screening criteria. Moreover, the only "exceedance" detected at this location was a concentration of dissolved copper (4.0 ug/L) that was marginally above the chronic criterion (3.1 ug/L), but below the acute criterion (4.8 ug/L). Since this sample was collected during transient low tide discharge conditions when seepage concentrations are expected to peak, the appropriate MTCA compliance comparison in this case is with the acute criterion, which it was below. Further, based on the results of preliminary ground water transport/tidal mixing modeling (Section 4.5.5), 24-hour-average water concentrations at this estuarine location are predicted to be well below the chronic criterion. All information considered, no exceedance of surface water quality criteria was identified in any seepage sample collected adjacent to the southeast landfill lobe. Additional confirmatory sampling is recommended during remedial design to confirm that copper is not present in WP-6 seepage at levels of potential concern

Based on a consideration of geochemical processes controlling copper and zinc mobility at the Site (Section 4.7.2), shoreline capping systems could potentially be designed to restrict tidal mixing and associated oxygen transfer into nearshore refuse deposits of the northwest landfill lobe. Such cap systems may be effective in controlling the release of copper and zinc into Whatcom Creek, and may also offer concurrent opportunities to improve the quality of intertidal habitat in this area. Additional evaluations of potential surface water cleanup remedies for the Holly Street Landfill Site are presented below in Sections 7.0 through 10.0.



A-MW-3 (Ground Water)

Parameter	Units	Maximum Conc.	Chronic Criterion	Acute Criterion
Copper (diss)	ug/L	3.0	3.1	4.8
Zinc (diss)	ug/L	93	81	90

A-WP-3 (Seep)

Parameter	Units	Maximum Conc.	Chronic Criterion	Acute Criterion
Copper (diss)	ug/L	14	3.1	4.8
Zinc (diss)	ug/L	268	81	90

Subsurface Refuse (7 samples)

Parameter	Units	95% UCL Conc.	Unrestricted Land Use	Industrial Land Use
Arsenic	mg/kg	70	20	20
Cadmium	mg/kg	5	2	2
Lead	mg/kg	2,300	250	1,000
cPAHs	mg/kg	11	1	20

A-WP-2 (Seep)

Parameter	Units	Maximum Conc.	Chronic Criterion	Acute Criterion
Copper (diss)	ug/L	47	3.1	4.8
Zinc (diss)	ug/L	316	81	90

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ANCHOR
ENVIRONMENTAL, L.L.C.

0 200
Scale in Feet

N

Figure 5-1
Geographic Extent of MTCA Risk-Based Cleanup Levels Exceedances
Holly Street Landfill

6.0 Applicable Federal, State, and Local Laws

Many environmental laws may apply to a cleanup action. In addition to meeting MTCA requirements, a cleanup action must also meet the environmental standards set forth in other applicable laws (this is required under both the MTCA *cleanup standards* and *remedy selection criteria*). In addition, even though Ecology may select the cleanup remedy under the state hazardous waste cleanup laws, the cleanup action will require, at a minimum, compliance with substantive elements of other applicable environmental reviews and permitting requirements. Though a cleanup action performed under formal MTCA authorities (e.g., as set forth in a Consent Decree between Ecology and the implementing parties) would be exempt from the procedural requirements of certain state and local environmental laws, the action must nevertheless comply with the substantive requirements of such laws. Potentially applicable federal, state and local laws that may influence cleanup levels and remedial action(s) for the Holly Street Landfill Site are summarized below.

6.1 Model Toxics Control Act Cleanup Standards

The MTCA Cleanup Standards Regulation, implemented under Chapter 70.105D RCW, authorizes Ecology to adopt cleanup standards for remedial actions at hazardous sites. The processes for identifying, investigating, and cleaning up hazardous sites are defined and cleanup standards are set for ground water, soil, surface water, and air in Chapter 173-340 WAC. However, as summarized in Section 5.0 above, only soil/refuse and surface water media at the Holly Street Landfill Site exceed prospective hazardous substance cleanup standards. These media are thus the focus of MTCA cleanup. Further remedial actions at the Site are not required to achieve ground water or sediment cleanup standards.

6.2 Other Federal and State Laws

6.2.1 Federal Requirements

Potential federal requirements are specified in several statutes, codified in the U.S. Code (USC), and promulgated in the Code of Federal Regulations (CFR), as discussed in the following sections.

The **National Environmental Policy Act (42 USC 4321 *et seq.*)**. The National Environmental Policy Act (NEPA) is intended to help the federal lead agency make decisions based on an understanding of the environmental consequences of their actions, and to help the federal government take actions that protect, restore, and enhance the environment. Any federal project, or a private or state project requiring a permit from a federal agency, must meet the NEPA requirements. If a proposal is determined by a federal lead agency to have a "probable significant adverse impact," the agency must prepare an Environmental Impact Statement (EIS). The EIS is a public disclosure document that analyzes alternative means of attaining the applicant's goal for the proposal, and analyzes the environmental consequences of each alternative and the potential options for mitigating the impacts. The U.S. Army Corps of Engineers (Corps) may prepare a NEPA EIS supplement for habitat restoration actions in Bellingham Bay, including prospective actions at the Holly Street Landfill Site.

The **Clean Water Act (CWA) (33 USC Section 1251 *et seq.*)** requires the establishment of guidelines and standards to control the direct or indirect discharge of pollutants to waters of the United States. Section 304 of the CWA (33 USC Section 1314) requires EPA to publish **Water Quality Criteria**, which are developed for the protection of human health and aquatic life. Federal water quality criteria are published as they are developed, and many of them are included in *Quality Criteria for Water 1986*, EPA 440/5-86-001, May 1, 1986 (51 FR 43665), commonly known as the "Gold Book." Publications of additional criteria established since the Gold Book was printed are announced in the Federal Register. Federal water quality criteria are used by states, including Washington State, to set water quality standards for surface water. These standards are relevant and appropriate for possible actions in the Holly Street Landfill Site, and are also adopted under MTCA.

Sections 301, 302, and 303 of the CWA (33 USC Sections 1311, 1312, and 1313), and 40 CFR Part 131, require states to develop **Water Quality Standards** and to control direct discharges by establishing effluent limitations as necessary to meet applicable water quality standards. Numerical state water quality standards are usually based on federal ambient water quality criteria developed by EPA (discussed above). Washington State water quality standards are promulgated under the Washington Water Pollution Control Act (Chapter 90.48 RCW; Chapter 173-201A WAC).

National Pollution Discharge Elimination System (NPDES), State Waste Discharge Program (33 USC 1432; 40 CFR 21-25; RCW 90.48.260; WAC 173-216). The NPDES and State Waste Discharge programs implement permit systems applicable to industrial and commercial operations that discharge to ground water, surface water, or municipal sewerage systems. In Washington, EPA has delegated the responsibility of administering the NPDES program to Ecology.

Safe Drinking Water Act (42 USC Section 300f *et seq.*; 40 CFR Parts 141 and 143). The Safe Drinking Water Act (SDWA) establishes standards designed to protect human health from the potential adverse effects of drinking water contaminants. Primary drinking water regulations include maximum contaminant levels (MCLs) for specific contaminants. Since MCLs are only applicable to suppliers of public drinking water, they are not applicable to the Holly Street Landfill Site. However, MCLs for surface water or ground water that are current or potential sources of drinking water are generally relevant and appropriate for ensuring that contaminant levels in the water are adequately protective. Ground water may be impacted by remediation alternatives that include upland disposal options.

Discharges of Material into Navigable Waters are regulated under Sections 401 and 404 of the CWA (33 USC Sections 1341 and 1344), 40 CFR Part 230 [Section 404(b)(1) guidelines], 33 CFR Parts 320 (general policies), 323 and 325 (permit requirements), and 328 (definition of waters of the United States). These requirements regulate the excavation of shoreline materials (including solid wastes) and the placement of fill material (including caps) below the ordinary high water elevation (approx. +11 ft MLLW) of waters of the United States. The Corps and EPA implement the 401/404 regulations. Under the Section 404(b)(1) guidelines, 40 CFR 230.10(b), no discharge (i.e., excavation or cap) shall be allowed if it:

- Causes or contributes to violations of any additional state water quality standard, pursuant to Section 401 of the CWA, after consideration of local dilution and dispersion;
- Violates any applicable toxic effluent standard or discharge prohibition under Section 307 of the CWA;
- Jeopardizes the continued existence of any endangered or threatened species, or contributes to the destruction or modification of any critical habitat for such species; or
- Violates any requirement imposed by the Secretary of Commerce to protect any marine sanctuary.

The guidelines in 40 CFR 230.10(c) also provide that no discharge will be authorized that contributes to significant degradation of the waters of the United States. Where there is no practicable alternative to a discharge, 40 CFR 230.10(d) requires the use of appropriate mitigation measures to minimize potential adverse impacts of the discharge on the aquatic ecosystem. The term "practicable" is defined in 40 CFR 230.3(q) to mean "available and capable of being done after taking into consideration cost, existing technology, and logistics in light of overall project purposes." Examples of specific steps that may be taken to minimize adverse impacts are set forth in 40 CFR Part 230, Subpart H. As discussed above, Section 401 and Section 404 requirements of the CWA may be applicable to a shoreline cleanup project if waste removal and/or capping are implemented.

Memorandum of Agreement between EPA and U.S. Army Corps of Engineers [Mitigation under Clean Water Act Section 404(b)(1)]. The Agreement sets forth policy and procedures for developing mitigation for compliance under Section 404, but does not alter any of the requirements under this section. These guidelines for mitigation include, in order of importance, avoidance, minimization, and compensatory mitigation.

Rivers and Harbors Act (33 USC Section 403; 33 CFR Parts 320, 322). This Act prohibits unauthorized activities that obstruct or alter a navigable waterway. However, the closest navigable waterway – the Whatcom Waterway – is not located within the prospective remedial action area of the Holly Street Landfill Site.

Coastal Zone Management Act (CZM) (16 USC 1451 *et seq.*; 15 CFR 923) is a federal law requiring federal agencies to act consistently with state and local shoreline regulations. A CZM consistency determination will be required prior to implementation of actions that affect the Site shoreline.

Resource Conservation and Recovery Act. The Resource Conservation and Recovery Act (RCRA) addresses the generation and transportation of hazardous waste, and waste management activities at facilities that treat, store, or dispose of hazardous wastes. Subtitle C (Hazardous Waste Management) mandates the creation of a cradle-to-grave management and permitting system for hazardous wastes. RCRA defines "solid wastes" that may cause or significantly contribute to an increase in mortality or serious illness, or that pose a substantial hazard to human health or the environment when improperly managed as hazardous wastes. In Washington State, RCRA is implemented by Ecology under the State's Dangerous Waste Regulations, Chapter 173-303 WAC.

One objective of RCRA is to minimize the generation of hazardous waste and the land disposal of hazardous waste by encouraging process substitution, materials recovery, properly conducted recycling and reuse, and treatment (RCRA Section 3003). To further this objective, EPA has set various goals for the Waste Minimization National Plan, including reducing the generation and mobility of hazardous wastes and establishing treatment standards as part of several rulemakings under the Land Disposal Restrictions (LDR) in 40 CFR Part 268.

Low concentration solid wastes such as those present the Holly Street Landfill Site are not subject to specific treatment technologies, but must meet Toxicity Characteristic Leaching Procedure (TCLP) designation limits. The TCLP designation limits define when a waste is hazardous and are used to determine when more stringent management standards apply than would be applied to typical solid wastes. Thus, the TCLP contaminant-specific criteria may be used to determine cleanup levels or when RCRA-equivalent waste management standards must be met (including LDR). Existing soil quality and TCLP data collected at the Holly Street Site, as well as other local landfills that received similar wastes, do not indicate any exceedance of characteristic dangerous or hazardous waste criteria within the prospective cleanup area. The materials are also not subject to upland landfill disposal restrictions, either under existing regulations or proposed revisions to the LDR (Federal Register: May 28, 1999 [Volume 64, Number 103]).

Federal and State Clean Air Acts (42 USC 7401 *et seq.*; 40 CFR 50; Chapter 70.94 RCW; Chapter 173-400 WAC, 403). The Clean Air Act regulates emissions of hazardous pollutants to the air. Controls for emissions are implemented through federal, state and local programs. The Clean Air Act is implemented in the state of Washington through the Washington Clean Air Act (Chapter 70.94 RCW). The regional air pollution contract authorities, activated under the Washington Clean Air Act, have jurisdiction over regulation and control of the emission of air contaminants and the requirements of state and federal Clean Air Acts in their districts. In 1993, EPA issued a rule that requires federal agencies to demonstrate that projects they are involved with are in compliance with federally-approved Clean Air Act state implementation plans.

Endangered Species Act (16 USC 1536 (a) through (d); 50 CFR Part 402). Section 7(a) of this Act grants authority to and imposes requirements upon Federal agencies regarding endangered or threatened species of fish, wildlife, or plants ("listed species") and habitat of such species that has been designated as critical. The Act also applies to species that have been proposed for listing (such as spring Chinook salmon known to reside in the Whatcom Creek system, and bull trout that are suspected to reside within the system). Federal agencies must confer with the National Marine Fisheries Service (NMFS) and U.S. Fish and Wildlife Service (USFWS) on any action that is likely to jeopardize the continued existence of spring Chinook salmon or bull trout, respectively, or any other proposed species, or result in the destruction or adverse modification of any critical habitat important to these species. The conference/ consultation process is directed at making a biological opinion regarding the proposed action. The opinion evaluates whether or not the action will jeopardize the continued existence of a species, or result in the destruction or adverse modification of critical habitat; and may include modification to the action that would avoid the likelihood of adverse effects to listed species or their critical habitat. Formal or informal consultation with NMFS and USFWS will be required prior to implementation of those cleanup remedies that trigger a federal action, such as a Section 404 permit (see above).

U.S. Fish and Wildlife Mitigation Policy (46 FR 7644). This policy establishes guidance for U.S. Fish and Wildlife personnel involved in making recommendations to protect or conserve fish and wildlife resources.

Fish and Wildlife Coordination Act (16 USC 661 *et seq.*). This Act is a federal law requiring consultation with fish and wildlife agencies on activities that could affect fish and wildlife.

Protection of Wetlands, Executive Order 11990 (40 CFR Part 6, Appendix A). This executive order requires that federal agencies avoid adversely impacting wetlands wherever possible, minimize wetland destruction, and preserve the value of wetlands. Appendix A of 40 CFR Part 6 provides EPA procedures for managing floodplains and protecting wetlands.

Treaty of Point Elliott (12 Stat. 927), Treaty of Medicine Creek (10 Stat. 1132). In 1854 and 1855, Native American Tribes, in what is now the state of Washington, signed treaties with the United States government conveying their right, title, and interest in and to the lands occupied by them. These treaties and subsequent court decisions protect Indian tribes' property and water rights, including their rights to fish and co-manage fishery resources in Puget Sound.

Environmental Justice (E.O. 12989). Environmental justice concerns arise from environmental impacts on minority populations, low-income populations, and Indian Tribes. Executive Order 12989, "Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations", requires that each federal agency research, collect data and analyze the environmental effects (which may be cumulative and multiple) of federal actions on low-income populations, minority populations, and Indian Tribes. Environmental and human health impacts must be evaluated to ensure that any federal actions do not have disproportionately high or adverse effects on the populations of concern.

Environmental justice issues are addressed during the NEPA process. Agencies are required to work to ensure effective public participation, community and Tribal representation, and information access. EIS preparation must consider both impacts on the natural or physical environment and interrelated social, cultural, and economic impacts on low-income and minority populations or Indian Tribes. Mitigation measures may include steps to avoid, reduce, or eliminate impacts.

National Historic Preservation Act (36 CFR 800). When proponents seek a federal approval, the responsible federal agency must consult with the State Historic Preservation Officer and the federal Advisory Council on Historic Preservation to determine if the project would affect cultural or historic sites on or eligible for the National Register of Historic Places.

6.2.2 Washington State and Local Requirements

Potential state requirements are specified in several standards, codified in the Revised Code of Washington and promulgated in the Washington Administrative Code.

State Environmental Policy Act (SEPA) (RCW 43.21C; WAC 197-11). The State Environmental Policy Act is intended to ensure that state and local government officials consider environmental values when making decisions. The SEPA process begins when someone submits a permit application to an agency, or an agency proposes to take some official action such as implementing a plan or policy. Prior to taking any action on a proposal, agencies must follow specific procedures to ensure that appropriate consideration has been given to the environment. The severity of potential environmental impacts associated with a project determines whether an EIS is required. Like NEPA, the EIS is a public disclosure document that analyzes alternative means of attaining the applicant's goal for the proposal, and analyzes the environmental consequences of each alternative and the potential options for mitigating the impacts. This assessment includes looking at alternatives that would meet the project's objectives with less environmental damage.

State cleanup action plans for MTCA sites typically require SEPA compliance. Decisions by federal agencies to permit these actions require NEPA compliance, as outlined above. Both NEPA and SEPA require government agencies to cooperate as much as possible to integrate environmental studies with permitting requirements and encourage public involvement in the EIS process. As discussed above, the Corps may prepare a combined NEPA/SEPA EIS supplement for habitat restoration actions in Bellingham Bay, including prospective actions at the Holly Street Landfill Site. The NEPA/SEPA EIS supplement would build on the Final EIS prepared by Ecology for the Bellingham Bay Comprehensive Strategy, issued in October 2000 (Ecology 2000).

Washington Water Pollution Control Act (Chapter 90.48 RCW; Chapter 173-201A WAC). This Act provides for the protection of surface water and ground water quality. Chapter 173-201A WAC establishes water quality standards for surface waters of the state. Toxic substance criteria for marine acute and marine chronic exposure, and criteria for human consumption of aquatic organisms, have been established under Chapter 173-201A-047 WAC. These criteria are in effect beyond the "dilution/mixing/release zone," which is limited under Chapter173-201A-035(7) WAC to the zone that will 1) not cause acute mortalities of sport, food, or commercial fish and shellfish species or important species to a degree that damages the ecosystem, and 2) not diminish aesthetic values or other beneficial uses disproportionately. The Surface Water Quality Standards (Chapter 173-201A WAC) are currently undergoing revision; following public review, substantive changes to the regulation could be adopted by late 2001.

Consistent with the requirements of Chapter 90.48 RCW, Ecology issues a water quality certification for any activity, including MTCA cleanup actions, which may result in a discharge to state water. As outlined above, shoreline waste excavation and/or capping actions typically constitute a "discharge" under this state regulation. The need for mitigation resulting from these activities has been further defined by the Washington State Legislature in the section below entitled "Compensatory Mitigation Policy for Aquatic Resources".

Washington Shoreline Management Act (Chapter 90.58 RCW; Chapter 173-14 WAC); Bellingham Bay Shoreline Master Program. The Shoreline Management Act and regulations promulgated thereunder establish requirements for substantial developments occurring within water areas of the state or within 200 feet of the shoreline. The City of Bellingham has set forth requirements based on local considerations such as shoreline use, economic development, public access, circulation, recreation, conservation, historical and cultural features. Local shoreline management plans are adopted under state regulations, creating an enforceable state law.

The Holly Street Landfill Site is located within the jurisdictional area of the Bellingham Bay Shoreline Master Program (BBSMP), which was recently updated. The BBSMP has designated the shoreline in the Site vicinity for urban maritime use. Cleanup actions within the Holly Street Landfill Area will need to address the requirements of the BBSMP and land use authorizations.

Regulations for new shoreline landfills are addressed in Section 27 Part J of the BBSMP and are summarized below:

- Landfills resulting in water surface reduction are permitted to accommodate water dependent and/or public uses only;
- The construction of all landfills must include erosion preventative measures such as vegetation, retaining walls, bank protection, and/or other mechanisms;
- Retaining walls or bank protection must conform to regulations pertaining to bulkheads;
- If dredge spoils are used for fill materials, the fill must be placed behind an impermeable dike or bulkhead, or it must be demonstrated that the fill material will not pose a potential threat to water quality;
- Landfills must blend in with existing topography such that the landfill does not interfere with the visual and/or physical shoreline access of public or adjacent residences; and
- Landfills located within 200-feet of the entrance of a freshwater stream into marine waters will not interfere with or endanger the migration of anadromous fish species nor reduce the area of estuarine mudflats which are exposed at low tide.

Washington Solid Waste Management Act (Chapter 70.95 RCW; Chapter 173-304 WAC) establishes standards for the handling and disposal of solid waste, including requirements applying to landfill location, design, maintenance, monitoring, and closure. However, because solid waste disposal at the Holly Street Landfill ceased well before the effective date of this regulation, the Solid Waste Management Act is not applicable to the management of existing solid waste at the Site.

Washington Hydraulics Code (Chapter 75.20 RCW; Chapter 220-110 WAC) establishes requirements for performing work that would use, divert, obstruct, or change the natural flow or bed of any salt or fresh waters. Mitigation is required for projects that directly or indirectly harm fish.

Consistent with the requirements of Chapter 75.20 RCW, the Washington Department of Fish and Wildlife (WDFW) issues a Hydraulic Project Approval (HPA) for any project that will use or change the natural flow of any waters of the state. Shoreline excavation and/or capping actions would likely require a HPA under this state regulation. In addition, WDFW typically requires that impacts to wetlands or aquatic resources occurring as a result of cleanup actions be mitigated on the project site and with a similar habitat type. The need for mitigation resulting from these activities has been further defined by the Washington State Legislature in the section below entitled “Compensatory Mitigation Policy for Aquatic Resources”.

Washington Hazardous Waste Management Act (Chapter 70.105 RCW; Chapter 173-303 WAC). The Act, and regulations promulgated thereunder, is the state equivalent of RCRA requirements for designating solid wastes to determine whether they are "dangerous waste." It also presents requirements for management of those solid wastes that are determined to be "dangerous waste."

Puget Sound Water Quality Act (Chapter 90.70.011 RCW). The Puget Sound Water Quality Action Team (PSWQAT) has been authorized under this Act to develop a comprehensive plan for water quality protection in Puget Sound to be implemented by existing state and local agencies. Several elements of the Plan provide pertinent guidance:

- Elements P-6 and P-7. All known and reasonable forms of treatment (AKART) guidelines and effluent limits for toxicants and particulates; and
- Elements S-4, S-7, and S-8. Guidelines for confined disposal, cleanup decisions, and investigations, respectively.

Washington Department of Fisheries Habitat Management Policy, POL-410. This policy includes the following provisions:

- Achieve no net loss of productive capacity of the habitat of food fish and shellfish resources of the state
- Create productive capacity of habitats that have been damaged or degraded by natural causes or as a result of human activities
- Improve the productive capacity of existing habitat and create new habitat

In addition, in-water actions will need to address the requirements of a HPA, including seasonal fisheries closures and water quality and habitat protection.

Compensatory Mitigation Policy for Aquatic Resources (Chapters 75.20 and 90.48 RCW). In 1997, the Legislature added new sections to Chapters 75.20 and 90.48 RCW to establish a clear state policy relating to the mitigation of wetlands and aquatic habitat for infrastructure development and the cleanup of aquatic resources. Compensatory mitigation is defined to include mitigation that occurs in advance of a project's planned environmental impacts, either on or off the project site, and that may provide different biological functions from the functions impacted by the project. The new policy encourages mitigation proposals that are timed, designed, and located in a manner to provide equal or better biological functions and values compared to "traditional" on-site, in-kind mitigation proposals. In addition, the new policy provides that the state shall not require mitigation for sediment dredging or capping actions that result in a cleaner aquatic environment and equal or better habitat functions and values, if the actions are taken under a state or federal cleanup action.

Water Resources Act (Chapter 90.54 RCW). The Water Resources Act establishes fundamental water resource policies for preservation of Washington State water resources.

Growth Management Act (GMA) (Chapters 36.70A; 36.70.A.150; and 36.70.A.200 RCW). The Growth Management Act requires counties and cities to classify and designate natural resource lands and critical areas (which include "waters of the state"). Additionally, the state's fastest growing cities and counties must adopt comprehensive plans and development regulations regarding land use within their jurisdiction. In particular, each plan must identify land within the jurisdiction that is useful for public purposes, and include a process for siting essential public facilities, including solid waste handling facilities.

State Historic Preservation Act (Chapter 27, 34, 44, 53, RCW) is a state law to ensure that cultural resources, such as historical and archaeological sites, are identified and protected.

7.0 Screening of Cleanup Technologies

In this section, cleanup alternatives are developed for possible application to the Holly Street Landfill Site. The identification and assembly of cleanup technologies into site-specific alternatives followed both MTCA guidance and additional direction provided by Ecology.

Alternatives for MTCA site cleanup actions generally have three components:

- **General response actions** – major categories of cleanup activities such as institutional controls, containment, or treatment;
- **Cleanup technologies** - general categories of technologies such as different containment options, ranging from in-place confinement/capping, to excavation coupled with off-site confined disposal at an active upland landfill facility; and
- **Process options** – specific technologies within each technology type such as variations in excavation and capping specifications.

The remainder of this section presents the evaluation and screening of no action, institutional controls, *in situ* containment, removal and disposal, and treatment technologies. The results of the cleanup technology and process option screening evaluations are presented in the remaining portion of this section. Technical considerations related to assembly of different cleanup technologies into cleanup alternatives are discussed in Section 8.0. The assembled cleanup alternatives are presented in Section 9.0. Section 10.0 of this report presents a detailed evaluation of each alternative relative to MTCA evaluation criteria and other implementation opportunities and constraints.

7.1 MTCA Screening Criteria

The identification of applicable remedial technologies and process options for each general response action should initially consist of a broad evaluation of the applicable remedial technologies that are available and effective in remediating threats identified at the site. Process options and cleanup technologies may be eliminated from further evaluation on the basis of technical implementability. Subsequent to this initial screening, process options may be further screened on the basis of the following criteria:

7.1.1 Effectiveness

This effectiveness criterion evaluates the technology for its effectiveness in providing protection and the reductions in toxicity, mobility, or volume that it will provide. Both short-term and long-term effectiveness are evaluated. Short-term effectiveness addresses the construction and implementation periods. Long-term effectiveness evaluates the technology after the action is in place.

7.1.2 Implementability

The implementability criterion evaluates the technology for the technical and administrative feasibility. Technical feasibility refers to the ability to construct, operate, maintain, and monitor the action during and after construction and meet technology-specific regulations during construction. Administrative feasibility refers to the ability to obtain permits for offsite actions and availability of specific equipment and technical specialists.

7.1.3 Cost

The cost criterion is used to compare different technologies. Typically, the full cost of a given solution can not be determined at the feasibility study level; however, costs obtained from venders, conventional cost-estimating guides, prior project costs, and engineering judgment are used to develop costs estimates. The same level of detail should be used to compare different alternatives so they will be comparable.

7.2 EPA's Presumptive Cleanup Remedies for Municipal Landfills

In 1993, EPA released a directive entitled Presumptive Remedy for CERCLA Municipal Landfill Sites (EPA 1993). EPA developed this remedy to streamline and accelerate the federal Superfund remediation process. The federal presumptive remedy for CERCLA municipal landfills described by EPA (1993) includes:

- Containment of the landfill mass through one or more engineering controls, including a landfill cap (e.g., 3-foot-thick) designed to isolate waste materials from human and wildlife contact;
- Leachate/ground water collection and control, if shallow ground water exceeds cleanup standards;
- Collection and/or treatment of landfill gas, if soil gas exceeds the LEL or otherwise presents a human health risk; and
- Institutional controls to ensure that future uses of the landfill area continue to maintain the integrity and protectiveness of the engineering controls.

7.3 No Action/Natural Attenuation

No action/natural attenuation of contaminated media may occur over time through a combination of processes including chemical degradation or diffusion from soil or refuse into adjacent waters. As described in Sections 4.0 and 5.0, while shallow ground water at the Holly Street Landfill Site generally did not contain chemical concentrations exceeding risk-based criteria, shoreline seepage discharges from the Site exceeded surface water quality standards within the Whatcom Creek estuary. Moreover, refuse and associated soil at the Holly Street Landfill Site contained concentrations of arsenic, cadmium, lead, and certain hydrocarbons that exceed prospective MTCA cleanup standards, regardless of land use.

Natural attenuation of contaminants present in soil and shoreline seepage discharges would require the supply of contaminants (especially metals) in these media to be flushed out over time. While this natural recovery process will eventually lead to attainment of cleanup standards in all media, preliminary mass balance calculations suggest that natural attenuation would require at least another 100 years before reductions in concentrations in soil or seepage could be reasonably detected. Because of expected limited effectiveness, natural attenuation was not carried forward for more detailed analysis in this FS.

7.4 Institutional Controls

Although generally not preferred under MTCA as a sole component of the cleanup remedy, institutional controls can be a component of any remedial scenario in which contamination above cleanup standards remains on site. A list of potential institutional controls that could be implemented at the Holly Street Landfill Site is presented below:

- Deed restrictions
- Monitoring of site conditions
- Access restrictions and/or signage
- Permit and review processes.

Deed restrictions could be used to restrict future land uses for the parcel (e.g., to prohibit ground-floor residential uses), ensure that caps and soil covers are maintained, or prohibit the planting of certain fruit bearing trees or vegetable gardens that are potential pathways for chemical exposure.

Monitoring requirements could include maintenance of caps and soil covers, and periodic soil gas, ground water, or seep monitoring.

Access restrictions and/or signage could prevent the excavation of contaminated materials except by trained, qualified personnel and would inform the public that contaminated materials exist below the ground surface and that uncontrolled digging is not allowed.

The departments, commissions, or boards of the City which are responsible for the review and issuance of permits could be tasked with routinely reviewing property compliance with institutional controls required as a part of any remedial action selected.

Subject to a balancing of environmental benefits, technical feasibility, and cost, institutional controls are considered implementable and highly cost effective. Consistent with MTCA requirements, institutional controls were carried forward as a component of overall landfill cleanup alternatives in this FS.

7.5 In Situ Containment Technologies

As discussed above, containment (i.e., capping) has been utilized relatively frequently in landfill cleanup projects conducted in Washington State and throughout the U.S., and is a major component of EPA's (1993) CERCLA presumptive remedy directive. Monitoring results to date have shown that, when properly designed, containment can provide effective long-term isolation of underlying waste materials from potential human and wildlife contact and exposure.

If selected as part of the overall cleanup remedy in the Holly Street Landfill Site, the final cap thickness and specification would be determined as part of remedial design. The cap would be designed to effectively contain and isolate the contaminated soil and landfill debris from the environment. Moreover, shoreline portions of the cap would be designed to prevent oxygen from reaching the contaminated refuse material, thereby maintaining a reducing environment and minimizing the potential for contaminant transport. In the intertidal areas, the cap would be designed to be thick enough and of sufficient grain size to resist erosion from mechanical scour, wave action, or burrowing organisms.

The most common type of capping materials used for landfill containment applications in this region include sands available from local upland quarries, or suitable dredged materials (including Corps maintenance material). The capping material would need to meet certain performance specifications (e.g., below MTCA and SMS standards), and would likely be placed using construction equipment operated from uplands (there is no barge access to the Holly Street Landfill Site).

Subject to a balancing of environmental benefits, technical feasibility, and cost, capping is considered implementable and highly cost effective. Therefore, *in situ* containment was carried forward for more detailed evaluation in this FS. Institutional controls are a typical element of containment remedies used to accomplish landfill cleanup.

7.6 Removal and Disposal Technologies

Removal and disposal/consolidation of solid waste has been performed within the Puget Sound region using process options appropriate for site-specific conditions. At the Holly Street Landfill Site, upland construction equipment (backhoes and excavators) would likely be used to remove the contaminated soil/refuse material. The excavated material would be placed in trucks and either hauled directly to an approved disposal facility or placed on rail cars for shipment to an approved landfill.

For those alternatives that do not accomplish complete removal of contaminated soil/refuse from the Holly Street Landfill (e.g., short of completing the excavation into native materials), removal and disposal must be combined with another suitable cleanup technology such as containment.

Solid waste currently being generated within the Bellingham area is transported to the Roosevelt Landfill, a large, active Subtitle D solid waste landfill located in eastern Washington approximately 220 miles by rail from Bellingham. This facility would also likely be used for disposal of contaminated soil/refuse excavated from the Holly Street Landfill.

7.7 Treatment Technologies

Various treatment technologies have been developed that can address the specific hazardous chemicals and chemical groupings detected at the Holly Street Landfill Site. However, the heterogeneous nature of these waste materials would first require considerable separation of the various constituents. Moreover, the resulting categorized wastes would be comprised predominantly of relatively high volumes of materials with low chemical concentrations, further complicating the application of potential treatment technologies. As described in EPA's (1993) presumptive remedy directive, and consistent with landfill cleanup remedy decisions throughout the region, treatment of contaminants in the soil/refuse is impracticable. Because of expected limited effectiveness and implementability, along with high costs, treatment technologies were not carried forward for more detailed analysis in this FS.

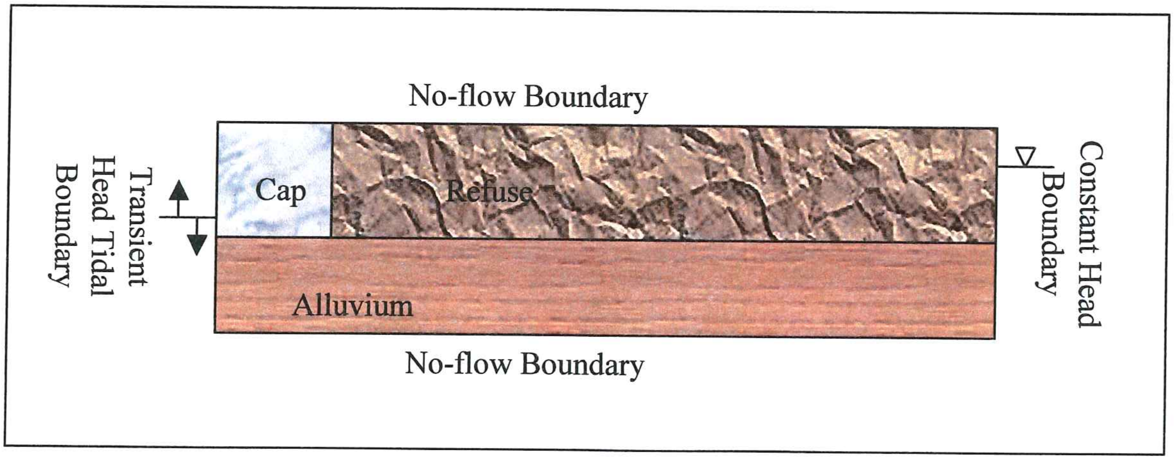
8.1.1 Ground Water Model Setup

The ground water flow system at the Holly Street Landfill Site consists of a shallow unconfined aquifer within the refuse and underlying Recent Alluvial sediment (Section 4.5). Ground water flow within this unconfined aquifer is generally directed from the upland areas toward Whatcom Creek. Fine-grained silts and clays present beneath the aquifer function as confining layers, restricting the downward flow of ground water into deeper units.

Leachate within the refuse is generated from infiltration of incident precipitation and from lateral inflow of ground water into the landfill area. Tidal influence creates a sinusoidal ground water flow path as the ground water approaches the point of discharge into Whatcom Creek, and oscillates in response to tidally propagated waves. These oscillations are most pronounced within approximately 20 feet of the shoreline.

A numeric ground water model of the nearshore ground water flow system was developed by AESI using Visual MODFLOW (Waterloo Hydrologic, Inc.; MacDonald and Harbaugh 1988), a three-dimensional ground water modeling flow code. A schematic cross section showing the model boundary conditions and layers is provided in Figure 8-1.

Figure 8-1. Schematic Diagram of the Holly Street Landfill MODFLOW Model



The model was configured as a two-dimensional cross section. The model transect extends from about 500 feet inland, through the northwest landfill lobe (i.e., through monitoring wells A-MW-2 and -3) and into the Whatcom Creek estuary. The inland boundary of the model is a constant head boundary based on interpolated water levels from existing monitoring wells. The shoreline boundary is a variable head boundary that simulates the tidal fluctuation in the Whatcom Creek estuary. The tidal input data used for this model are from the National Oceanographic and Atmospheric Administration (NOAA) gauging station at Cherry Point, Washington. The remaining boundaries are considered no-flow boundaries, thus the model approximates a two dimensional model.

Two layers were selected to model the refuse and the alluvium. A summary of hydraulic parameters assigned to the model layers is presented in Table 8-1. The alluvium was modeled in a bottom layer extending from 0 to +7 feet MLLW and was assigned representative values for hydraulic conductivity (*K*) and storativity (S) of 0.00031 centimeters per second (cm/s) and 0.1,

8.0 Basis for Assembly of Cleanup Alternatives

This section reviews the technical basis for assembly of different remedial technology process options into cleanup alternatives that are implementable at the Holly Street Landfill Site. Pertinent cap thickness, geochemical, geotechnical and soil gas considerations of site cleanup actions are first reviewed, followed by a review of habitat mitigation requirements that must be met by the cleanup action. This section concludes with a discussion of how cleanup may be effectively and efficiently combined with site redevelopment objectives and related local initiatives such as public access and habitat restoration.

As summarized in Section 4.0, the Whatcom Creek estuary divides the Holly Street Landfill into two separate lobes: (1) the northwest lobe, which includes Sash and Door and other properties; and (2) the southeast lobe, which includes the Maritime Heritage Park. These two areas have different characteristics. For example, land use within the northwest lobe is predominantly industrial and commercial, while the southwest lobe is the site of a major City Park. In addition, soil explorations within the northwest lobe of the landfill indicated a surface cap thickness ranging from approximately 1 to 8 feet, underlain by predominantly inorganic material in the refuse matrix, with little undecayed wood. By comparison, the southwest lobe currently has a relatively thick (3 to 20 feet) surface cap, underlain by more undecayed wood and a higher overall organic content. In addition, the bearing layer beneath the landfill, which consists of either Glaciomarine drift or Chuckanut Sandstone bedrock, is present at approximately 40 feet below ground surface (BGS) within the northwest lobe, and approximately 30 feet BGS within the southeast lobe, with deeper depths near the creek. Thus, where appropriate, the technical issues presented herein include separate discussions for the northwest and southeast lobes of the landfill.

8.1 Cap Thickness

Typical surface containment systems constructed at upland cleanup sites similar to the Holly Street Landfill have been constructed using a nominal 3-foot-thick permeable soil cap or equivalent, providing isolation of the underlying hazardous substances from potential human and wildlife contact (Ecology 1999b). Alternatively, an equivalent isolation layer could be provided by construction of a building or pavement cap.

As discussed above in Sections 4.7 and 5.3, copper and zinc concentrations currently exceed MTCA surface water cleanup levels in shoreline seeps along portions of the northwest lobe of the Holly Street Landfill. Geochemical data suggest that brackish water within the Whatcom Creek estuary, high in dissolved oxygen, migrates into the shallow ground water zone during high tides and creates oxidizing conditions within the saturated refuse, which in turn mobilizes copper and zinc present within the refuse (Figure 4-7). In order to support the conceptual design of a shoreline capping system that would control this geochemical release pathway, a simplified ground water transport model was developed and applied to the Holly Street Landfill Site. The model provides a preliminary evaluation of the required thickness of a permeable shoreline cap that would displace the zone of mixing outward from the refuse. Such displacement would separate the reduced geochemical environment within the refuse from oxidizing surface water, which in turn would control the release of copper and zinc. The ground water model is briefly described below.

Figure 8-2 shows a comparison of the modeled and observed heads for monitoring wells A-MW-2 and A-MW-3. The normalized root mean square error (RMSE) between the modeled and observed values, which provides a measure of model accuracy, was calculated using the following equation:

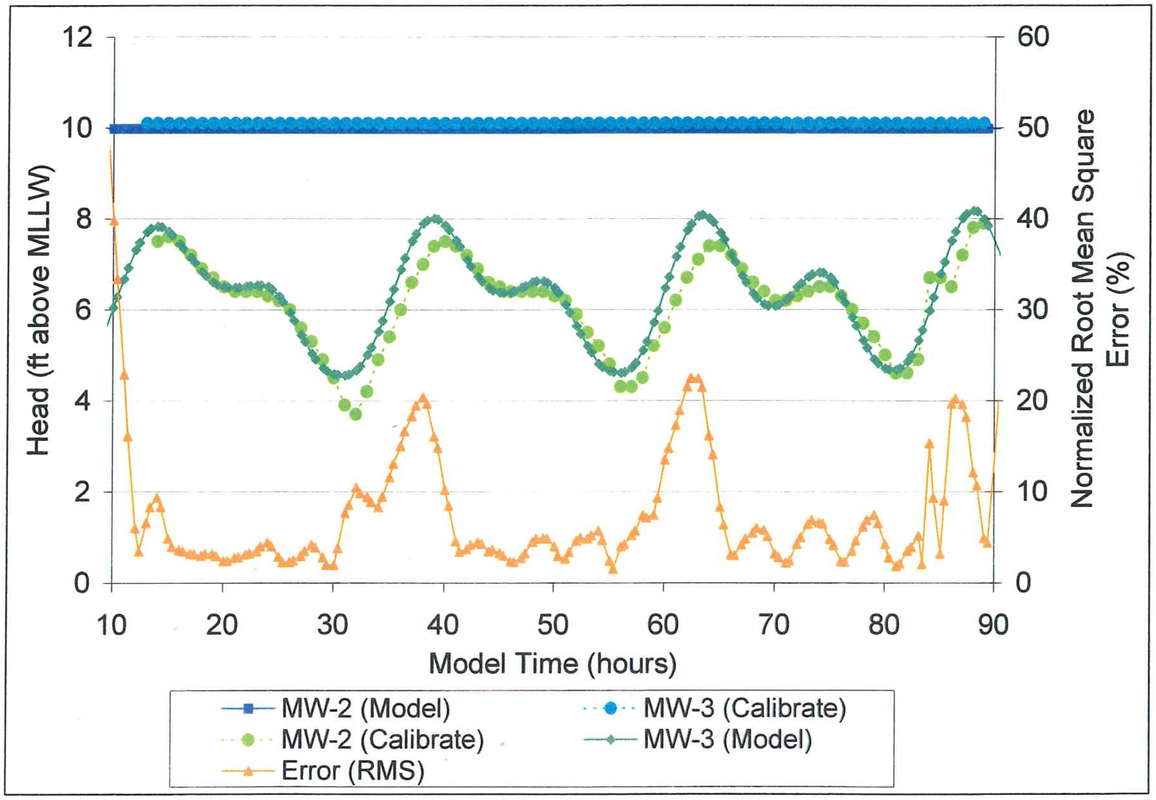
$$normalizedRMSE = \frac{\frac{1}{n}\sqrt{\sum_{i=1}^{n}(X_{calc} - X_{obs})_i^2}}{(X_{obs})_{\max} - (X_{calc})_{\min}}$$

where:

n = the number of observations
X_{calc} = the calculated value
X_{obs} = the observed value
$(X_{obs})_{\max}$ = the maximum observed value
$(X_{calc})_{\min}$ = the minimum calculated value

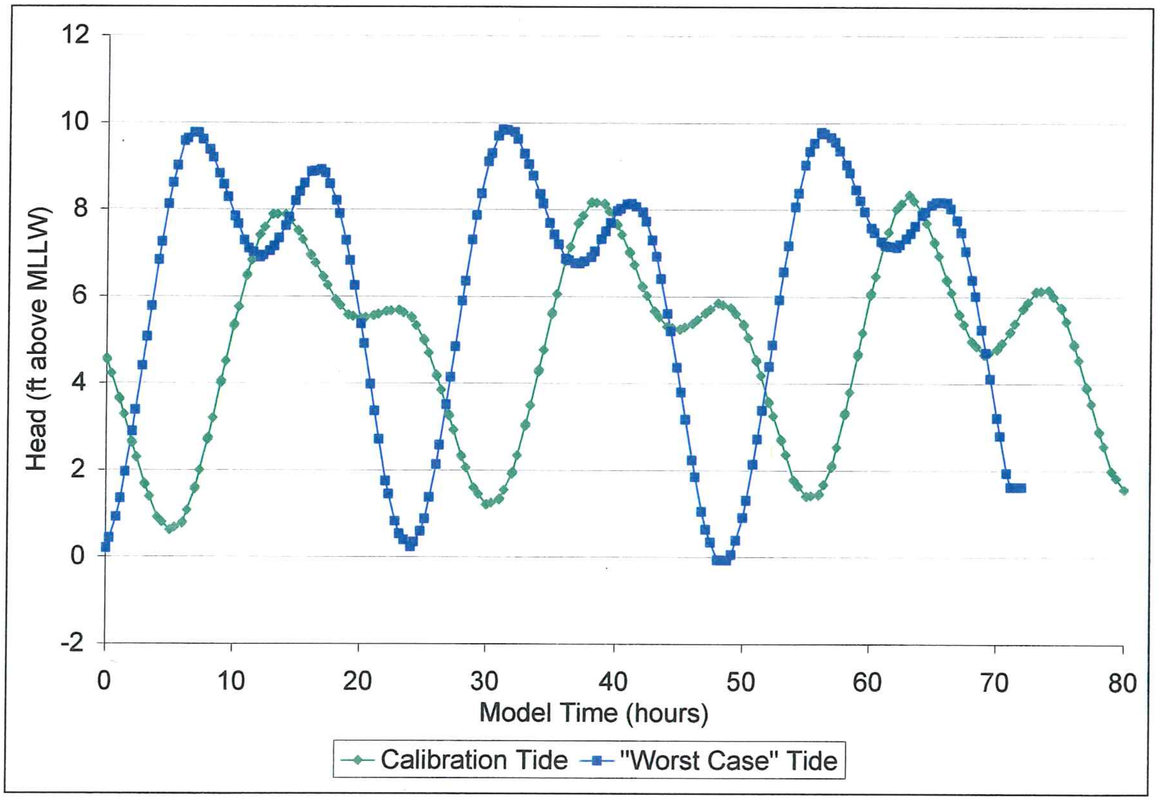
The average normalized RMSE for the model calibration was 6.9 percent (i.e., on average, modeled values were within 6.9% of observed measurements). The generally accepted RMSE target for model calibration is less than 10 percent. For the time steps when the RMSE exceeded 10 percent (all associated with high tide conditions), the model always overestimated the shoreward ground water gradient and particle travel distance into the Holly Street Landfill. Thus, model predictions in this case are considered conservative; that is, the model overestimated the extent of tidal-induced ground water transport into the refuse.

Figure 8-2. Model Calibration – Observed and Modeled Heads



The model was also applied to a reasonable worst-case "spring" tide condition, when tidal fluctuations and predicted tidal-induced ground water transport would be at a seasonal maximum. Based on a review of NOAA tidal monitoring data at Cherry Point, a reasonable worst-case spring tide condition was identified between November 9 and 12, 1999. Figure 8-3 presents a comparison of this spring tide event with measured tidal conditions used for model calibration. During this reasonable worst-case spring tide event, the model predicted that tidal-induced inshore migration of ground water, and associated oxidation of refuse, may extend as much as 6 feet into the refuse. This estimate is consistent with the preliminary analytical transport model discussed in Section 4.7, and also with the available water quality data, as elevated copper and zinc concentrations were found to be restricted to the immediate shoreline area. The consistency of model results and water quality data provides further support for the validity of the model predictions.

Figure 8-3. Spring Tide Event and Calibration Model Tides



Based on the calibration comparisons presented above, the MODFLOW model was considered acceptable for the purpose of the Holly Street Landfill RI/FS. However, should shoreline capping be selected as a part of the cleanup remedy for this site, further model refinements would be appropriate during remedial design.

8.1.3 Modeling of Different Shoreline Cap Thicknesses

Using input parameters discussed above, the MODFLOW model was run with a variable thickness of potential shoreline caps constructed adjacent to the northwest landfill lobe. Simulated caps applied to these model runs were varied from 2 to 10 feet-thick. Figures 8-4 and 8-5 present predicted particle travel distances for this range of cap thickness.

Figure 8-4. Particle Travel Distance vs. Time for Variable Cap Thickness

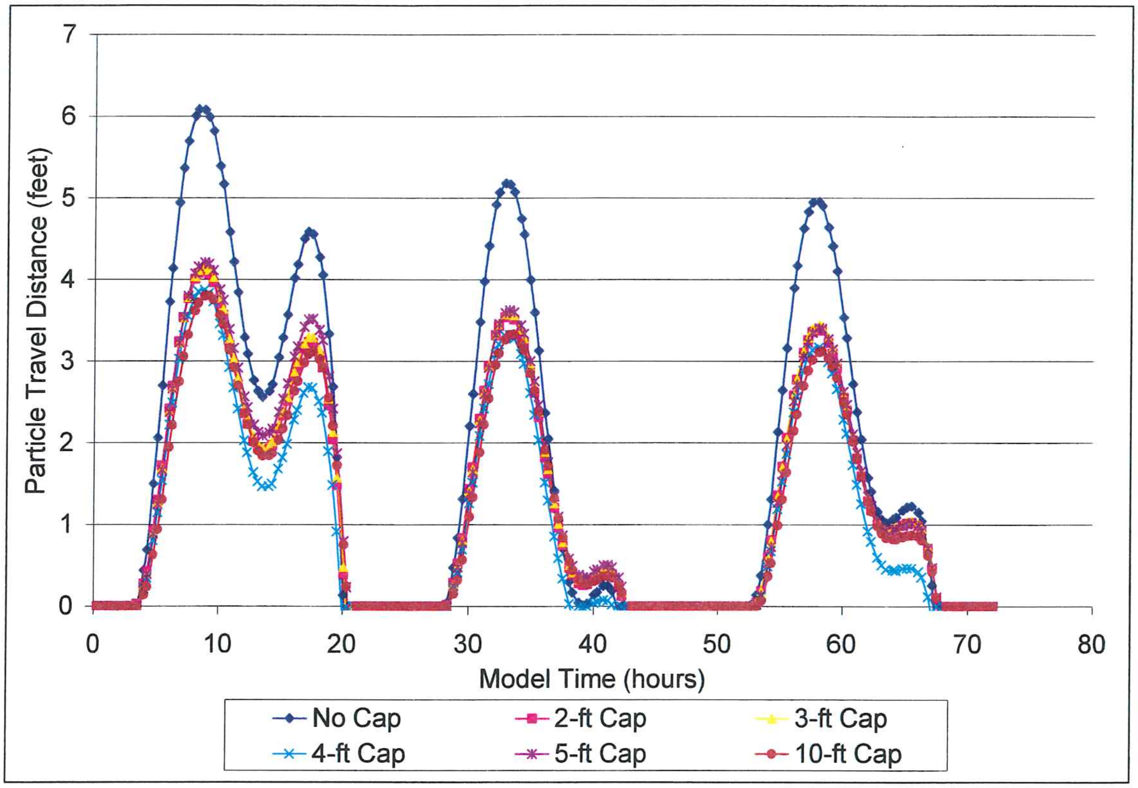
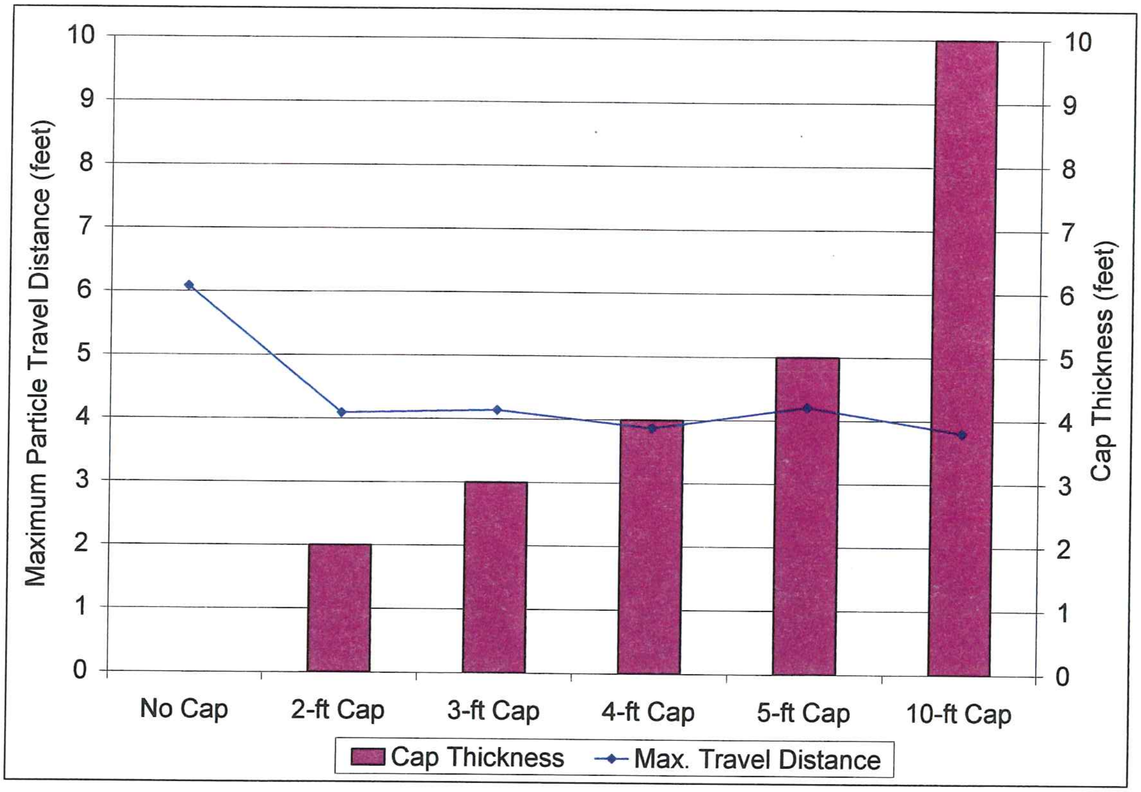


Figure 8-5. Cap Thickness and Maximum Particle Travel Distances



Model results indicate that surface water would be expected to still intrude into the refuse if the cap was constructed to a thickness of less than 4 feet. The predicted tidal-induced transport distance for caps 4-feet-thick and greater was about 4 feet (range: 3.8 to 4.2 feet). Thus, based on the model results, a nominal shoreline cap thickness of 5 feet should provide sufficient separation of incoming tidal flows from the refuse.

The similarity of predicted ground water travel distances through caps greater than 5 feet is consistent with transport from a lower permeability zone into a higher permeability zone, such that little resistance to flow occurs as water exits the cap and enters the refuse. Thus, for a given tidal condition, the transport distance is controlled by the cap permeability.

Based on the MODFLOW model results discussed above, to shift the zone of surface water mixing out of the refuse, the minimum cap thickness should be about 5 feet, particularly at elevations below mean higher high water (MHHW; +8.5 feet MLLW). Thicker caps will provide a greater safety factor.

Should shoreline capping be selected as a part of the cleanup remedy for this site, further model refinements would be appropriate during remedial design. Further modeling evaluation is also recommended to evaluate chemical diffusion effects and to assess the effectiveness of alternative cap designs (e.g., a thinner cap constructed of lower permeability material). Design-level modeling should also include a sensitivity analysis of hydraulic and diffusion parameters, so that the protectiveness/effectiveness of the final cap design can be ensured.

respectively. The bottom of the flow system was taken as 0 feet MLLW, as the deeper part of the flow system is not expected to influence ground water flow within the refuse. The refuse was modeled in an upper layer that extends from +7 to +15 feet MLLW and was assigned *K* and S values of 0.037 cm/s and 0.15, respectively. The modeled hydraulic parameters, including refuse thickness and location of the contact between the refuse and the alluvium, were based on hydrogeologic data presented above in Section 4.5.

Table 8-1. Summary of Hydraulic Parameters Used in Ground Water Modeling

Hydraulic parameters	Alluvium	Refuse	Cap
Hydraulic Conductivity, *K* (cm/s)	0.00031	0.037	0.02
Storativity, S	0.1	0.15	0.15

For modeling of cap conditions, a *K* value of 0.02 cm/s was used, based on grain size distribution parameters and density information typical of prospective shoreline capping materials for this application. Hydraulic parameters of the cap were consistent with a compacted sand cap (D-50 of 0.4 mm and a D-10 of 0.1 mm; Driscoll 1986, page 738). The S of the cap was modeled at 0.15. This value is at the low end of the range for fine to medium sand (Fetter 1980), but is conservative with respect to travel distances (i.e., resulting in a conservative overestimate of required cap thickness).

Because of the limitation of MODFLOW to perform particle tracking on transient simulations, the modeled heads were input into a spreadsheet to compute a particle travel distance:

$$Distance = t \times v_{Darcy} = t \times \left(\frac{-K}{n_e} \frac{\Delta h}{\Delta l} \right)$$

where:
t = time
K = hydraulic conductivity
n_e = effective porosity
$\Delta h / \Delta l$ = ground water gradient

The MODFLOW output heads were used to calculate the ground water gradient. Conservative values of hydraulic conductivity ($K = 0.037$ cm/s) and effective porosity ($n_e = 0.15$) were used in the model runs.

8.1.2 Ground Water Model Calibration

The model was calibrated based on water level observations made during a 72-hour tidal study at the site performed between November 6 and 9, 2000. Monitoring wells A-MW-2 and A-MW-3 were used as calibration points. Vertical anisotropy (K_h/K_z) was varied to obtain the best match between calculated and observed head distributions. A vertical anisotropy of 20 was found to give the best calibration of modeled heads to observed heads, and is within the range of typical values for an alluvial environment.

8.2 Geotechnical Considerations

Any cleanup action or future site development should consider the short- and long-term geotechnical requirements of construction on a landfill, including total and differential settlement and liquefaction potential. These considerations are discussed below.

8.2.1 Landfill Containment Design Considerations

Because ground water quality concerns have not been identified at this site (beyond the shoreline seepage issues discussed above), a permeable soil cap could be constructed - or existing caps maintained - within both the upland and shoreline areas of the site. As discussed in Section 4.2.1, the existing final cover on the landfill consists predominantly of silty sand and gravel of variable thickness. Cap thickness within the northeast landfill lobe ranges from approximately 1 to 8 feet, and in many cases is overlain by asphalt or concrete structures that also provide a suitable isolation from underlying refuse. The existing cap thickness in the southeast lobe (Maritime Heritage Park) generally ranges from about 3 to 20 feet, and is overlain by landscaping materials.

In those relatively limited areas of the Holly Street Landfill where the existing cap is insufficient (e.g., less than 3-feet-thick and also not overlain by asphalt or concrete barriers; see Figure 5-1), the cap could be augmented by placing additional sands available from local upland quarries. Placement in this case would normally be performed during the drier summer months in order to maintain quality control and to minimize runoff concerns. The cap design would need to consider potential short- and long-term settlement, as described below.

Northwest Lobe - With the preponderance of inorganic refuse material underlying this area, most of the potential cap settlement within the northwest landfill lobe would occur very soon after placement of the cap. Consolidation tests on the underlying refuse material are recommended if an accurate short-term settlement estimate is desired. However, typical short-term consolidation on the order of 4 to 6 inches is expected below the cap. If cap placement activities were extended over several months, almost all of this settlement would likely occur during the placement period. However, some landfill areas, particularly those with higher amounts of underlying organic materials such as undecayed wood, will likely continue to settle, and regrading for surface water control may become necessary from time to time. A survey of the existing buildings and other structures within the landfill area may provide additional empirical data on refuse settlement.

Southeast Lobe -With the prevalence of undecayed wood within the refuse, less initial settlement may be expected in the southeast lobe area. However, a greater total settlement may occur over time due to the secondary consolidation of wood within the refuse. Rough regrading may be required to maintain surface water control as a result of differential settlement. A total organic content determination of underlying refuse materials is recommended in those areas where an accurate estimate of potential total settlements is desired.

8.2.2 Conceptual Building Foundation Systems

As discussed above, existing buildings and associated foundation systems that overlie much of the Holly Street Landfill Site currently provide adequate isolation from the underlying refuse. However, for property owners or developers that are considering new construction at the Site, differential settlement concerns may necessitate installation of pile foundations or structural mats. Geotechnical engineering studies performed at the adjacent Roeder Avenue Landfill (underlain by similar soil profiles as the Holly Street Site) suggest that, of the available pile foundation systems, drilled augercast concrete piles are most likely to be used in this area (ReTec 1996).

Piles would typically be founded in the lower glacial-marine drift, which is encountered from roughly 30 to 40 feet BGS in the landfill footprint area.

Because shallow ground water beneath the Holly Street Landfill Site currently meets risk-based cleanup criteria (see above), and since there are no known aquifers beneath the shallow ground water system at the Site, pile penetration into an underlying aquitard does not present an environmental concern at the Site. Thus, limited "drag-down" of refuse into the Glaciomarine drift aquitard and bedrock could be expected without the need for mitigation.

Long-term stability of containment structures and buildings at the Holly Street Landfill Site may also need to consider liquefaction potential, determined in part by the assumed magnitude of the design-level earthquake. Initial evaluation of the site data indicates that some of the refuse and potentially all of the upper native alluvial deposits could liquefy during a code-mandated design earthquake event. While a structural mat would likely provide sufficient protection for human safety during the code-level earthquake, building damage in the form of tilting or settlement may be expected. Under larger acceleration events, some lateral spreading of the landfill material into Whatcom Creek could be expected. However, the cap could likely be designed to minimize such lateral spreading, and also to prevent a breach of the containment system to control potential future releases of waste materials into the Whatcom Creek estuary. If capping were selected as a component of the shoreline cleanup remedy for the Holly Street Landfill Site, more detailed evaluation of liquefaction potential would normally be completed during remedial design. Design of upland capping systems, if necessary, would normally be performed as a part of site development.

8.3 Soil Gas (Methane) Venting Systems

As discussed in Section 4.4, only one sampling location (A-MW-4), located within the central area of the Maritime Heritage Park, contained subsurface soil gas that exceeded the LEL for methane. All other soil gas samples, including samples collected near the margins of the Park, and throughout the northwest landfill lobe, were well below the LEL. Considering the isolation of subsurface soil gas in the Maritime Heritage Park from the surface (i.e., an 8-foot-thick sand cap overlies refuse deposits at A-MW-4), no existing risk to human health or the environment was identified. However, the presence of elevated methane levels in A-MW-4 suggests that any future development in the central area of Maritime Heritage Park should include at least a passive gas venting system below new structures.

A gas barrier constructed either of a geosynthetic material or natural clay can be used under prospective future building structures in the Maritime Heritage Park. Similar systems have been proposed on other projects that provide for a bentonite seal layer under the building, which seals around any foundation piles. Other landfill gas mitigation systems for structures rely on venting beneath the structure using a raised open vented floor/framing, or forced air crawl space. Design of appropriate gas venting systems would normally be performed as a part of site development within the Maritime Heritage Park.

8.4 Shoreline Aquatic Habitat Mitigation/Restoration

Aquatic habitat may be affected by implementation of remedial actions along the shoreline of the Holly Street Landfill Site. Refuse capping or removal actions in this area may result in permanent conversion of one habitat type to another, potentially resulting in net changes in aquatic area and/or changes in aquatic habitat functions. Depending on the cleanup remedy selected, and design specifics, cleanup actions at this site could potentially lead to either a net loss or net gain in aquatic habitat. Under existing regulatory programs (Section 6.2), those actions that lead to a net loss in habitat area or function may require compensatory mitigation.

As part of the Bellingham Bay Comprehensive Strategy (Ecology 2000), a draft mitigation framework was developed to provide an ecosystem context for habitat mitigation within Bellingham Bay, including those that may be required as a result of implementing cleanup actions. Building on existing regulatory programs, the draft mitigation framework provides management and mitigation guidance to help direct cleanup and other projects achieve the habitat goals of the Comprehensive Strategy, also providing incentives and disincentives for undertaking certain actions. However, it is important to note that the draft mitigation framework contained in the Comprehensive Strategy only provides guidance that may or may not be used at the discretion of the relevant regulatory agencies. Mitigation in this context includes the following sequential elements:

- Avoiding the impact altogether by not taking a certain action or parts of an action.
- Minimizing impacts by limiting the degree or magnitude of the action and its implementation, by using appropriate technology, or by taking steps to reduce impacts.
- Compensating for the impact by replacing, enhancing, or providing substitute resources or environments.
- Repairing, rehabilitation, or restoring the affected environment, where possible.
- Reducing or eliminating the impact over time by preservation and maintenance operations during the life of an action.
- Monitoring the impact and taking appropriate corrective actions.

In assessing adverse impacts to marine resources, functions, and physical process, a number of functions, habitats and specific areas within Bellingham Bay receive priority consideration including (among other elements):

- Use by Threatened and Endangered Species (e.g., Chinook salmon)
- Habitats or physical processes difficult to replace (e.g., estuaries)
- Reproductive and rearing habitat (e.g., intertidal and shallow subtidal areas)
- Habitats that provide multiple functions for a variety of species
- Estuaries within Bellingham Bay that support juvenile salmon during their transition from freshwater to marine waters

Because the Whatcom Creek estuary immediately adjacent to the Holly Street Landfill Site contains many priority habitat attributes, as summarized in the Comprehensive Strategy, habitat mitigation is particularly relevant to cleanup actions considered at this Site.

Compensatory mitigation requirements for identifiable, unavoidable impacts also take into account other elements that can influence the type and extent of mitigation that could be required. The Draft Habitat Mitigation Framework contained in the Comprehensive Strategy (Ecology 2000) presents a table of "modifiers" that may be used when determining the extent and type of compensatory mitigation required for a given action. Different modifiers were proposed for the following mitigation actions:

- In-kind habitat replacement is defined as providing the same functions as those that are impacted (e.g., estuary habitat for estuary habitat). Out-of-kind is defined as providing a different function within the same sub-area.
- On-site is defined as providing habitat replacement within the same sub-area as where the impact occurs (e.g., estuary habitat replacement within the same sub-area where a project impacts estuarine habitat). Off-site habitat replacement is defined as replacing habitat functions in other sub-areas than where the impact occurs, but still within Bellingham Bay.
- In addition, the following types of mitigation actions have different mitigation ratios:
    - Creation: The establishment of marine habitat area and function in an area where they do not exist (e.g., convert upland to in-water habitat).
    - Restoration: The establishment of marine habitat area and/or function in areas where they historically existed, or where they currently exist in a disturbed condition (e.g., Whatcom Creek estuary).
    - Enhancement: To modify physical attributes of the aquatic environment that provides additional function (e.g., placing finer-grained substrate over rip-rap or debris).
- Different modifiers were also developed to address whether an impact or action does or does not provide for the protection and restoration of estuaries, the restoration of habitat connective corridors, or the overall health of the aquatic environment. Thus, for an action that involves cleanup, the mitigation framework provides the flexibility of applying a discount factor when assessing the overall mitigation requirements for an action.

Mitigation ratios are typically used to determine how much additional mitigation area is required to compensate for lost area, function, and temporal losses, and takes into account potential risk from implementing a mitigation action. Ratios are essentially multipliers applied to the habitat area impacted and are subject to the modifiers as defined above. The ratios assigned to the modifiers, as summarized in Table 8-2, are intended to achieve the overall regulatory goal of no net loss of habitat area and function.

Table 8-2 – Draft Habitat Mitigation Ratios - Bellingham Bay Comprehensive Strategy

Modifier	Suggested Ratio
In kind	1:1
Out of kind	1.25:1
On site	*1:1*
Off-site	1.25:1
Mitigation Type:	
Restore	1:1
Create	1:1
Enhance	1.5:1
Habitat Incentives/Disincentives:	
Incentive – mitigation type and location in priority habitat area	Discount 0.25
Incentive – impact area avoids a priority habitat	Discount 0.25

Disincentive – impact type and location in priority habitat	*Increase 0.5*
Incentive – benefit of cleanup	Discount 0.5

As generally outlined in the sections above, a possible cleanup scenario at the Holly Street Landfill, which would be consistent with EPA's (1993) presumptive remedy directive, is placement of a 3-foot-thick upland cap or equivalent, along with a nominal 5-foot-thick cap along the Whatcom Creek shoreline. If the shoreline cap were to be placed adjacent to the northern lobe of the landfill (i.e., within the seepage area that currently exceeds surface water cleanup levels), the action would displace the shoreline in this area further offshore. Based on a preliminary cap layout, such an action could result in a net loss of roughly 0.1 acres of estuarine habitat. As discussed in the Comprehensive Strategy, the mitigation analysis in this case would consider the following:

- Although the capping action would accomplish cleanup of seepage discharges, the cap in this case could also adversely affect adjacent priority habitat (e.g., existing high function mudflat located a short distance offshore of the seepage area). Thus, the two incentive and disincentive factors that apply to this scenario would likely offset, resulting in no net change in mitigation requirements.

- If off-site, out-of-kind enhancement of a non-priority habitat area were to be used to offset the 0.1-acre loss, the required mitigation site would need to be roughly 0.23 acres (0.1 acres x 1.5 x 1.25 x 1.25).

- If on-site, in kind mitigation were to be used to offset this loss, and if the cap were designed both to avoid/minimize impacts to adjacent mudflat and to create additional estuarine habitat, the required mitigation site would only need to be 0.06 acres (0.1 acres x 0.75 x 0.75).

Clearly, both the mitigation sequencing and mitigation ratio guidelines presented in the Bellingham Bay Comprehensive Strategy strongly encourage avoidance of impacts to the Whatcom Creek estuary, and/or integration of habitat creation/restoration into the overall on-site cleanup plan.

The Comprehensive Strategy was designed to integrate a variety of environmental issues into one coordinated approach addressing source control, cleanup, habitat restoration, public access, and land use (Ecology 2000). One of the key areas of focus of the Comprehensive Strategy was the identification and prioritization of habitat restoration opportunities in Bellingham Bay, considering the broad implications of the listing of several endemic fish species as threatened under the Endangered Species Act.

Because of the expected benefit to endangered salmon recovery efforts and other ecosystem restoration objectives, one of the highest-ranking habitat restoration opportunities identified by the Comprehensive Strategy was the removal of fill from portions of the northwest lobe of the Holly Street Landfill. The habitat restoration concept envisioned that refuse within a nominal ½-acre area would be removed, and the excavation area backfilled with a clean cap graded to relatively flat slopes, restoring mudflat and salt marsh habitats and adjoining riparian vegetation. Such an action, which could potentially be integrated into the overall cleanup and redevelopment plan for the site, would restore critical estuarine riparian buffer, marsh, and mudflat banks which existed historically in this area of Bellingham Bay. Provided that the action could be designed and implemented cost-effectively, and that it did not conflict with land uses, integration of this habitat restoration action into the Holly Street Landfill cleanup may provide an opportunity to achieve substantial overall environmental enhancements, consistent with the Comprehensive Strategy.

8.5 Public Access and Redevelopment Objectives

The Holly Street Landfill Site is within a targeted redevelopment area, located within the Lettered Streets Neighborhood and adjacent to Bellingham's Central Business District (CBD). Current property ownership within the Site area is depicted on Figure 8-6. Selected planning influences and zoning designations within the area are depicted on Figures 8-7 and 8-8, respectively.

The Holly Street Landfill Site vicinity has been included in a range of planning and strategic analyses including the Whatcom Creek Waterfront Action Program (WCWAP), Downtown Development Workshop (DDW), and the City Center Master Plan (CCMP). Goals for the area outlined in these documents include increasing public access to the waterfront, enhancing habitat quality, preserving historic structures, improving street, sidewalk, trail and parking facilities, and encouraging a mixture of land uses.

Although the southern lobe of the landfill is the site of the Maritime Heritage Park, currently there is no public access along the north shore of the Holly Street Landfill. The City of Bellingham, the responsible agency for greenspace and shorelines, is committed to provide a park-like setting allowing citizens trail access along the entire stretch of the north bank of Whatcom Creek estuary. This link is part of the larger Whatcom Creek Trail Master Plan. Construction of this four-mile trail is underway and will eventually span the shoreline from Bellingham Bay to Lake Whatcom.

The citizens of Bellingham have placed an extremely high value on parks and open space as evidenced by two successful greenway levies totaling $30 million. The most recent levy package includes $2 million for the Old Town area, which will fund docks in Whatcom Waterway, acquisition of open space, and park improvements in Maritime Heritage Park. Incorporating public access design with cleanup and habitat restoration would meet additional community open space goals and planning objectives, leverage additional community support and funding, and provide an opportunity to educate the public about critical estuarine environments.

WCWAP identified both short and long-term actions for the Old Town area. The CCMP discusses several properties such as the old Burlington Northern Railroad train depot and the former Sash and Door site. The CCMP addressed the targeted redevelopment area as part of the Old Town Character Area and identified the Old Town area and, more specifically, the Sash and Door property, as "Special Project & Opportunity Sites." The Plan suggests that development in Old Town capitalize on the area's historic and maritime character. Recommended uses include a combination of specialty retail, small-scale restaurants and institutional uses. Old Town redevelopment could capitalize on the area's proximity to the Whatcom Creek estuary and its position as a linkage between downtown, the Civic Center, waterfront destinations such as Bellweather, Zuanich Park, Squalicum Marina, and Whatcom Waterway and also to nearby residential neighborhoods.

A defining quality of the project area is its proximity to Bellingham's historic working waterfront. Adjacent to the property to the southeast is the Port of Bellingham's Central Waterfront Redevelopment Project. Cleanup and redevelopment strategies are currently being planned and implemented for this 50-acre industrial area. Proximity to the waterfront and the redevelopment activity planned for the Central Waterfront may enhance the redevelopment potential of the Holly Street Landfill Site area and vice versa. Again, integration of public access and redevelopment actions into the Holly Street Landfill cleanup may provide an opportunity to achieve substantial overall enhancements of the Lettered Streets Neighborhood, consistent with the Comprehensive Strategy.

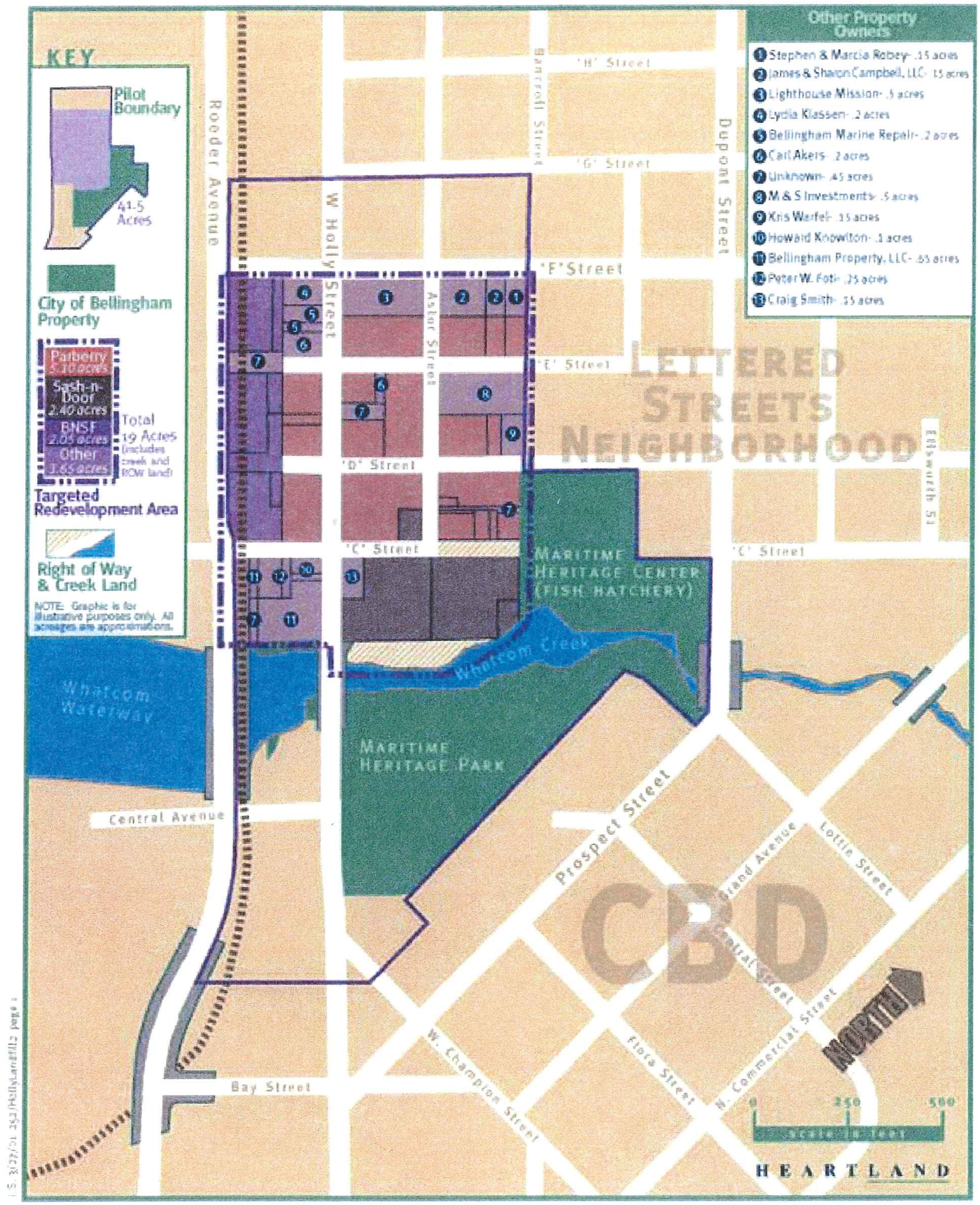


Figure 8-6
Holly Street Landfill
Property Ownership

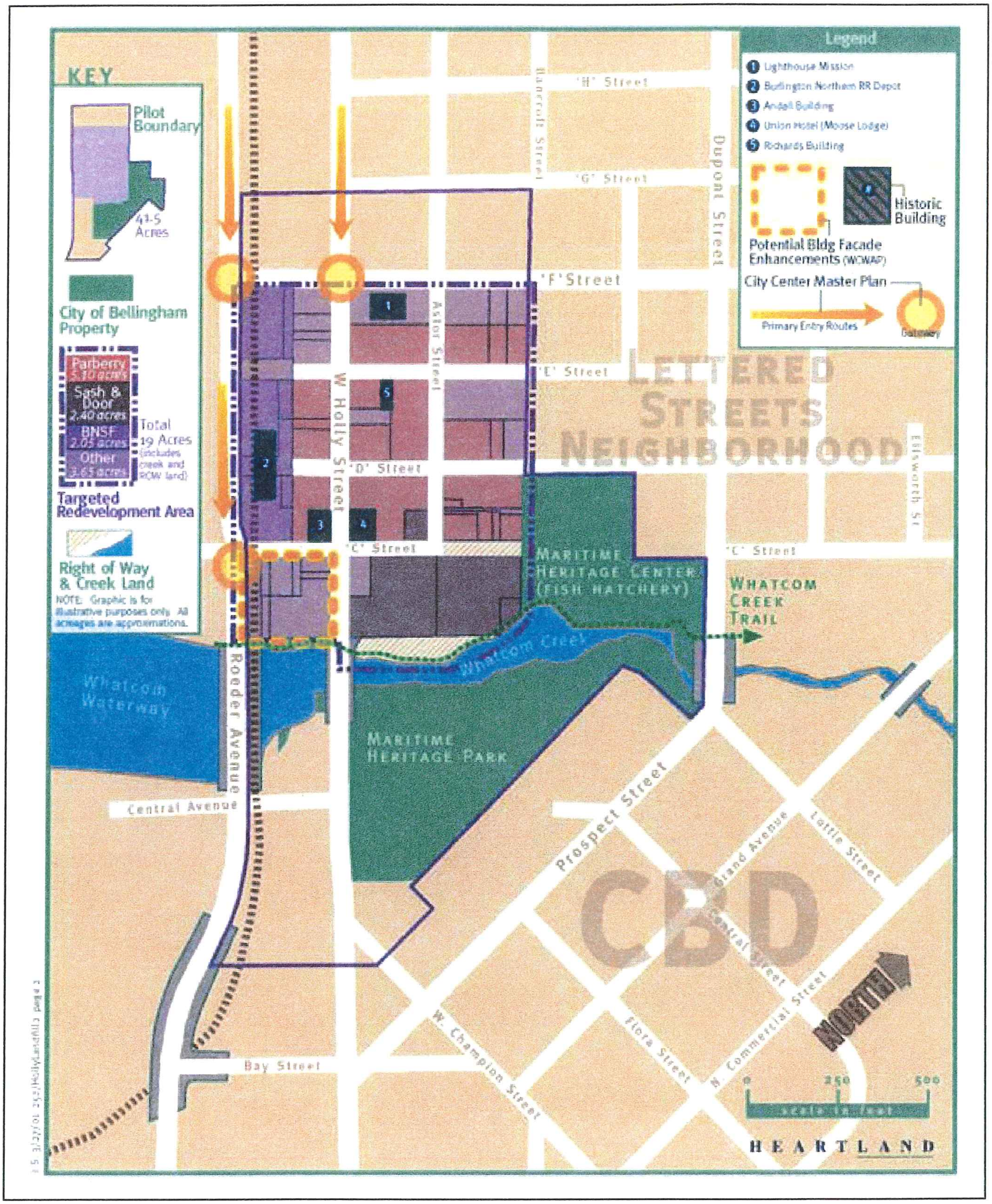


Figure 8-7
Holly Street Landfill
Selected Planning Influences

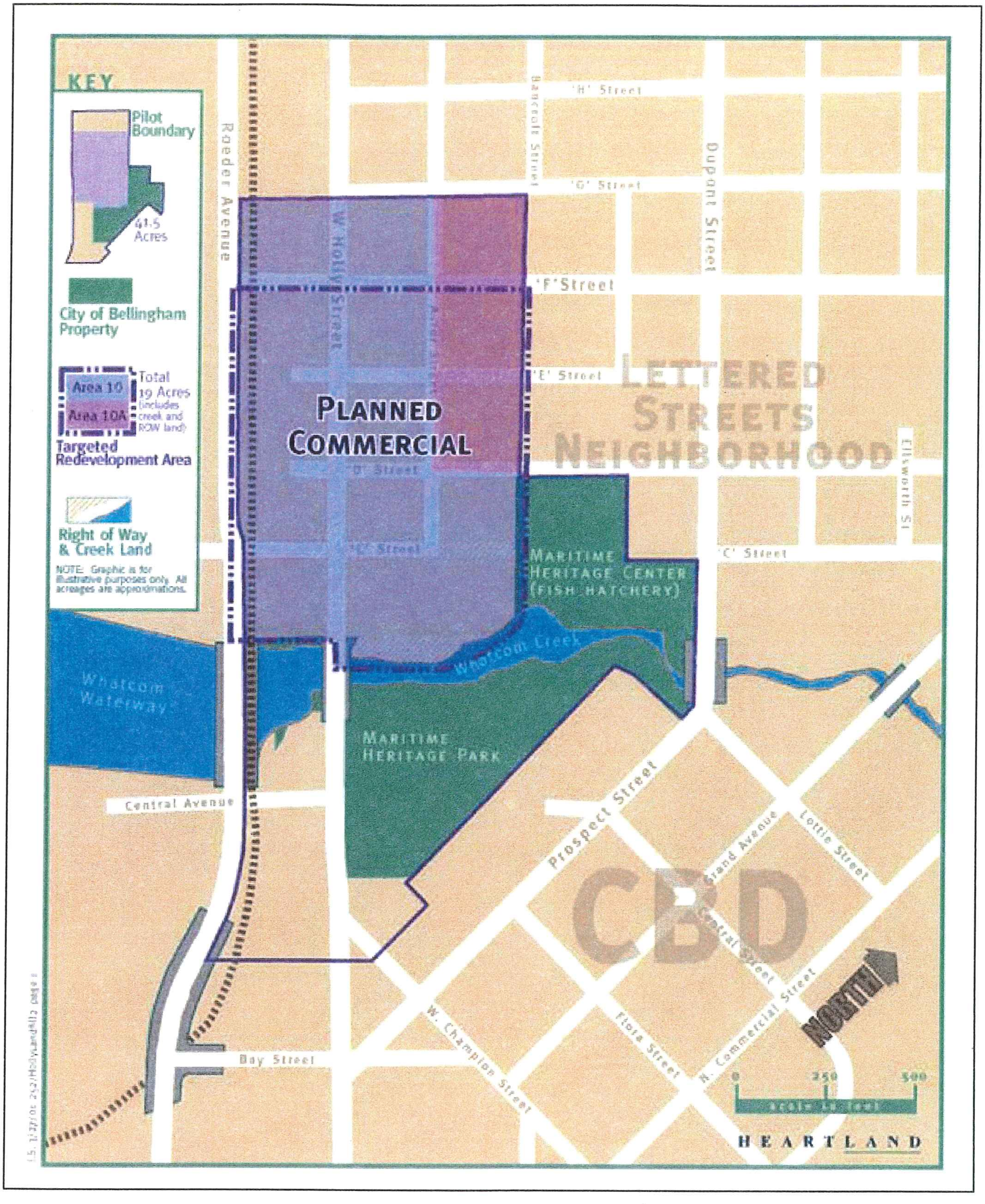


Figure 8-8
Holly Street Landfill
Zoning Designation

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9.0 Description of Cleanup Alternatives

In this section, cleanup alternatives retained for detailed evaluation are assembled and described. The assembly of different technologies, process options, and integration with related project objectives was based on the following sets of criteria:

- Cleanup technology screening (Section 7.0);
- Technical considerations related to assembly of different technologies into cleanup alternatives (Section 8.0);
- Consistency with the Bellingham Bay Comprehensive Strategy (Ecology 2000), including integration of a variety of environmental issues into one coordinated approach addressing cleanup, habitat restoration, public access, and land use (Section 8.0); and
- MTCA guidance and additional direction provided by Ecology, including the regulatory requirement to evaluate a broad continuum of potential cleanup response actions, ranging from no action to complete refuse removal.

The assembled cleanup alternatives include:

- Alternative 1 – No Action
- Alternative 2 – Capping with Upland Development
- Alternative 3 – Limited Removal/Capping with Habitat Restoration and Upland Development
- Alternative 4 – Maximum Removal and Habitat Restoration

Each of these alternatives is described below. Section 10.0 of this report presents a detailed evaluation of each alternative relative to MTCA evaluation criteria, and also addresses various implementation opportunities and constraints.

9.1 *Alternative 1 – No Action*

This alternative is included as a baseline alternative to which other alternatives can be compared. Under this alternative, no cleanup action or other construction activities would occur beyond independent site development actions as may be undertaken by individual property owners. No institutional controls would be implemented and no long-term monitoring would occur.

9.2 *Alternative 2 – Capping with Upland Development*

The objective of this alternative is to accomplish landfill cleanup using *in situ* containment technologies for both the upland and shoreline areas of the landfill, consistent with the EPA (1993) presumptive remedy directive for federal CERCLA sites. Upland capping within the Maritime Heritage Center would be integrated with the shoreline cleanup project. Upland and shoreline elements of this alternative are described below.

9.2.1 Upland Capping and Institutional Controls

The existing final cover on the landfill consists predominantly of silty sand and gravel of variable thickness. Cap thickness within the northeast landfill lobe ranges from approximately 1 to 8 feet, and in many cases is overlain by asphalt or concrete structures that also provide a suitable isolation from underlying refuse. The existing cap thickness in the southeast lobe (Maritime Heritage Park) generally ranges from about 3 to 20 feet, and is overlain by landscaping materials. Thus, in most areas of the Site, the existing cap would be maintained, with no further cleanup action required.

In limited areas of the northwest lobe of the Holly Street Landfill where the existing cap is insufficient (e.g., less than 3-feet-thick and also not overlain by asphalt or concrete barriers; see Figure 5-1), the cap would be augmented to meet containment specifications. Based on a review of available boring and test pit logs within this area of the site, approximately 0.4 acres of the Maritime Heritage Center (fish hatchery) may require a cap amendment. In this case, the upland cap would be constructed, concurrent with the shoreline capping action discussed below, using one of two methods:

(1) To achieve a minimum 3-foot total thickness of clean soil materials (e.g., sands) overlying refuse; or

(2) With an equivalent standard concrete cap or asphalt section (e.g., 2-inch paving layer overlying ballast), which could be integrated into site development or building foundation designs.

Future construction of buildings within the Maritime Heritage Park would include installation of a passive soil gas (i.e., methane) venting system, constructed using geosynthetic or natural clay materials. Landfill gas mitigation systems for structures in this area would generally rely on venting beneath the structure. Design of both the cap and gas venting systems would normally be performed as a part of site development, with City review.

Because concentrations of a range of metal and organic hazardous substances in underlying soil and refuse throughout the landfill area exceed MTCA residential use standards (Table 5-1), ground-floor residential and other relatively high soil exposure/risk uses such as day-care centers would likely be precluded throughout the landfill footprint area. However, since average chemical concentrations within the landfill refuse only marginally exceed less restrictive park/commercial and industrial use criteria (i.e., relatively few of the refuse samples exceeded soil cleanup standards for these uses), a surface cap would provide suitable protection for these land use exposures. Risk-based MTCA cleanup levels for park uses are generally equivalent to those for commercial areas. As the entire landfill footprint area is currently zoned and used for non-residential (e.g. commercial and park uses) this land use control would not represent a change from current conditions.

In order to facilitate these actions, a range of different institutional controls would be implemented throughout the 13-acre Holly Street Landfill footprint, including:

- Permits issued by the City for future construction within the landfill footprint would be conditioned on maintenance of caps meeting the minimum specifications outlined above and passive methane venting systems (Maritime Heritage Park), as appropriate;
- Property owners would place deed restrictions on their property, ensuring that the property would not be used in the future for ground floor residential or day-care center uses. The deed

restrictions would state that materials exceeding MTCA cleanup standards are present in subsurface soils at the site. The deed restriction would also state that caps and soil covers meeting the minimum specifications outlined above would be maintained in the future. Certain fruit bearing trees or vegetable gardens that are potential pathways for chemical exposure could also be prohibited;

- Where utility or other work is required at the Site that will require excavation, trenches will be constructed in accordance with state and City standards, with the additional requirement that 1 foot of overexcavation, or a geofabric lining, be used to provide a clean perimeter around the outside of the utility trench. All excavated refuse materials would be disposed off-site at a permitted solid waste disposal facility. Because chemical concentrations within the landfill refuse generally meet MTCA Method C direct contact soil cleanup standards for industrial uses, and also because these materials are overlain with clean cap materials, excavations at the Site can be performed using personnel without hazardous substance health and safety training; and
- The City and/or individual property owners would periodically monitor the integrity of the caps, and report these findings to Ecology.

9.2.2 Shoreline Capping and Monitoring

A shoreline cap would be constructed adjacent to the northwest lobe of the landfill, extending into the Whatcom Creek estuary. In order to avoid the need for off-site aquatic habitat mitigation (Section 8.4), this alternative includes localized excavation of approximately 3 to 5 feet of material along the northwest bank of the creek, prior to placing a cap over the exposed face (Figures 9-1 and 9-2). Approximately 640 cubic yards (cy; 900 tons) of shoreline refuse materials would be removed (likely using an upland excavator) and transported to the Roosevelt Regional Landfill (or equivalent) for disposal. Approximately twice this quantity of material (1,400 cy; 1,800 tons) would be backfilled to construct the shoreline cap. Based on a preliminary application of the Table 8-2 habitat mitigation ratios, there would be no net loss of aquatic habitat area or function associated with implementation of this alternative. Water quality controls such as restriction of in-water work windows to low tide conditions would be implemented as practicable as a part of this action.

Connecting with the upland cap section discussed above, the shoreline cap would be constructed of quarry spalls or equivalent materials to a minimum thickness of 3 feet from the top of bank down to extreme high water (EHW; approximately +10.5 feet MLLW). Consistent with the results of ground water transport modeling (Section 5.1.3), the cap would then grade into a minimum thickness of five feet at and below MHHW (+8.5 feet MLLW). Cap thickness in this case is measured horizontally (the nominal ground water flow direction). In order to improve habitat functions of the cap and also to ensure long-term integrity of the cap, a shelf with a nominal slope of 4 horizontal to 1 vertical (4H:1V) would be constructed of sand and gravel materials between approximately +8.5 feet MLLW and +6.0 feet MLLW. The total amount of cap fill anticipated under this alternative is approximately 1,400 cy. Cap specifications would be refined during remedial design, incorporating detailed seismic, erosion, water quality protection, and other evaluations to ensure the long-term integrity and effectiveness of the containment structure.

Following construction, periodic physical surveys and shoreline seepage water quality sampling activities would be performed to verify that the cap system achieves its intended design objectives. Monitoring would initially be performed once annually (e.g., during spring "wet season" conditions) during years 1, 2, 5, and 10 following construction, and the results reported to

Ecology. The need for and/or scope of further long-term monitoring would be assessed by Ecology.

9.3 Alternative 3 – Limited Removal/Capping with Restoration and Development

The objective of this alternative is to integrate a range of objectives for the Holly Street Landfill Site issues into a single coordinated approach addressing cleanup, habitat restoration, public access, and land use, consistent with the Bellingham Bay Comprehensive Strategy (Ecology 2000). Cleanup in this case would be accomplished through *in situ* containment, consistent with Alternative 2 and with the EPA (1993) presumptive remedy directive for federal CERCLA sites. The habitat restoration concept for the Site presented in the Comprehensive Strategy would be incorporated into this alternative. That is, refuse within a nominal 0.34-acre area within existing City right-of-way could be removed, and the excavation area backfilled with a clean cap graded to relatively flat slopes, restoring mudflat and salt marsh habitats and adjoining riparian vegetation. Alternatively, other shoreline refuse areas adjacent to the Whatcom Creek Estuary could be removed. Regardless of the location of the excavation, such an action would restore critical estuarine riparian buffer, marsh, and mudflat banks that existed historically in this area of Bellingham Bay, and could also be designed to provide a park-like setting allowing citizens trail access along this stretch of Whatcom Creek to the Maritime Heritage Center. Such a trail could be linked into the larger Whatcom Creek Trail Master Plan. Incorporating public access design with cleanup and habitat restoration would meet community open space goals and planning objectives, leverage additional community support and funding, and provide an opportunity to educate the public about critical estuarine environments.

Similar to Alternative 2, upland cleanup would be implemented concurrently with the shoreline remedy. The conversion of uplands into aquatic habitat, along with shoreline cleanup, would be undertaken as a single combined remediation/restoration/public access project. Upland and shoreline elements of this alternative are described below.

9.3.1 Upland Capping and Institutional Controls

Similar to Alternative 2, in those areas of the Holly Street Landfill Site that already have a suitable cap meeting containment specifications (e.g., all of the Maritime Heritage Park and most of the northwest landfill lobe), the existing cap section would be maintained. In limited areas of the northwest lobe where the existing cap is insufficient (e.g., less than 3-feet-thick and also not overlain by asphalt or concrete barriers; Figure 5-1), the cap would be augmented to meet containment specifications. Based on a review of available boring and test pit logs within this area of the site, approximately 0.4 acres within the Maritime Heritage Center (fish hatchery) may require a cap amendment. This area would be capped concurrent with the shoreline remedy (see below).

Future construction of buildings within Maritime Heritage Park would include installation of a passive soil gas (i.e., methane) venting system, constructed using geosynthetic or natural clay materials. Design of both the cap and gas venting systems would normally be performed as a part of site development, with City review.

Institutional controls would also be implemented as in Alternative 2, including:

- Permits issued by the City for future construction within the landfill footprint would be conditioned on maintenance of a cap meeting the minimum specifications outlined above and passive methane venting systems (Maritime Heritage Park), as appropriate;
- Property owners would place deed restrictions on their property, ensuring that the property would not be used in the future for ground floor residential or day-care center uses. The deed restrictions would state that materials exceeding MTCA cleanup standards are present in subsurface soils at the site. The deed restriction would also state that caps and soil covers meeting the minimum specifications outlined above would be maintained in the future. Certain fruit bearing trees or vegetable gardens that are potential pathways for chemical exposure could also be prohibited;
- Where utility or other work is required at the Site that will require excavation, trenches will be constructed in accordance with state and City standards, with the additional requirement that 1 foot of overexcavation, or a geofabric lining, be used to provide a clean perimeter around the outside of the utility trench. All excavated refuse materials would be disposed off-site at a permitted solid waste disposal facility. Because chemical concentrations within the landfill refuse generally meet MTCA Method C direct contact soil cleanup standards for industrial uses, and also because these materials are overlain with clean cap materials, excavations at the Site can be performed using personnel without hazardous substance health and safety training; and
- The City and/or individual property owners would periodically monitor the integrity of the caps, and report these findings to Ecology.

9.3.2 Shoreline Capping and Monitoring

As generally described in the Comprehensive Strategy (Ecology 2000), refuse within a nominal 0.34-acre area within the existing B Street right-of-way (ROW) or alternate location would be removed, and the excavation area backfilled with a clean cap graded to relatively flat slopes. Under this alternative, the refuse excavation area would be restricted to the City's B Street ROW and adjacent shoreline (Figures 9-3 and 9-4). This alternative would result in a net conversion of approximately 0.34 acres of uplands into aquatic habitat, providing a substantial net gain in habitat area and function.

Approximately 5,700 cy (8,000 tons) of material would be removed (likely using an upland excavator) and transported to the Roosevelt Regional Landfill (or equivalent) for disposal. Nearly half of this quantity of material (2,700 cy; 3,500 tons) would be backfilled to construct the shoreline cap. Water quality controls such as restriction of in-water work windows to low tide conditions would be implemented as practicable as a part of this action.

Connecting with the upland cap section, the upper portion of the shoreline cap would be constructed in two 12 inch lifts at a 3H:1V slope. The first lift would consist of clean fill soil, such as pit run sand or equivalent material. The second lift would consist of a manufactured topsoil (60 percent sand and sandy loam, and 40 percent composted organic matter by volume). The total minimum thickness measured horizontally would be of 6 feet from the top of bank down to +9 feet MLLW 1.5 feet below extreme high water). This upper bank area would be covered with a biodegradable erosion control fabric and planted with woody riparian vegetation (native trees and shrubs) since it is above the area of normal tidal inundation.

A shoreline trail could be located in this portion of the bank near the top of the slope. The trail could consist of a boardwalk structure with a foundation design that is compatible with the cap and refuse beneath it.

The lower portion of the shoreline begins at elevation +9 feet MLLW, where the cap would becomes a relatively flat slope (30H:1V or flatter) until it reaches the +8 foot elevation. At this point the slope increases to 10H:1V until the cap ends at the limit of excavation (+6 feet MLLW). The portion of the cap between elevation +9 to +8 feet MLLW forms a bench that would be designed to recolonize with emergent marsh vegetation. This type of vegetation grows in a narrow band of elevation based on the degree of tidal inundation it requires (Thom et al. 2000). The substrate in this bench would consist two lifts of material. The first lift would be of variable depth to a maximum of two feet and consist of relatively fine-grained materials (e.g., sands and silts). The second lift would consist of 1 foot of topsoil that is more moisture retentive and has slightly lower organic matter content than the topsoil used in the upper bank. The cap from elevation +8 to +6 feet MLLW would consist of one lift of the fine-grained materials (e.g., sands and silts) to maximize habitat functions. Measured horizontally along the anticipated post-construction ground water flow direction, the minimum cap thickness in the lower shoreline cap would generally exceed 10 feet. The total amount of cap fill that would be placed under this alternative is approximately 2,700 cy. Several dead end extensions of the shoreline trail over this lower cap could be constructed to allow for better views of the creek, and to provide fishing access in selected locations. The cap, landscape, and trail elements of this alternative would be refined during remedial design.

Following construction, periodic physical surveys, shoreline seepage water quality sampling, and habitat development monitoring activities would be performed to verify that the cap and landscape plan achieves its intended design objectives. Monitoring would initially be performed annually during years 1, 2, 5, and 10 following construction, and the results reported to Ecology and other stakeholders. Ecology and other regulatory agencies with jurisdiction would assess the need for and/or scope of further long-term monitoring.

9.4 Alternative 4 – Maximum Removal and Habitat Restoration

This alternative includes the removal of all refuse from the site. Historical mudflats would be restored throughout the 13-acre landfill area, with a corresponding loss of uplands and associated development. Final mudflat elevations would be established with benches at elevation +6 feet MLLW in the northwest lobe of the Site, and at elevations of -6 feet MLLW and +2.5 feet MLLW in the southeast lobe of the Site (Figure 9-5). The slopes from top of bank to the target elevations would be at 3H:1V. Including overdredge allowances, approximately 420,000 cy (590,000 tons) of material would be removed under this alternative (likely using large-capacity equipment) and transported to the Roosevelt Regional Landfill (or equivalent) for disposal. Water quality controls such as restriction of in-water work windows to low tide conditions would be implemented as practicable as a part of this action.

Because all MTCA cleanup criteria would be met by this maximum removal action, no institutional controls or long-term monitoring would be required under this alternative.

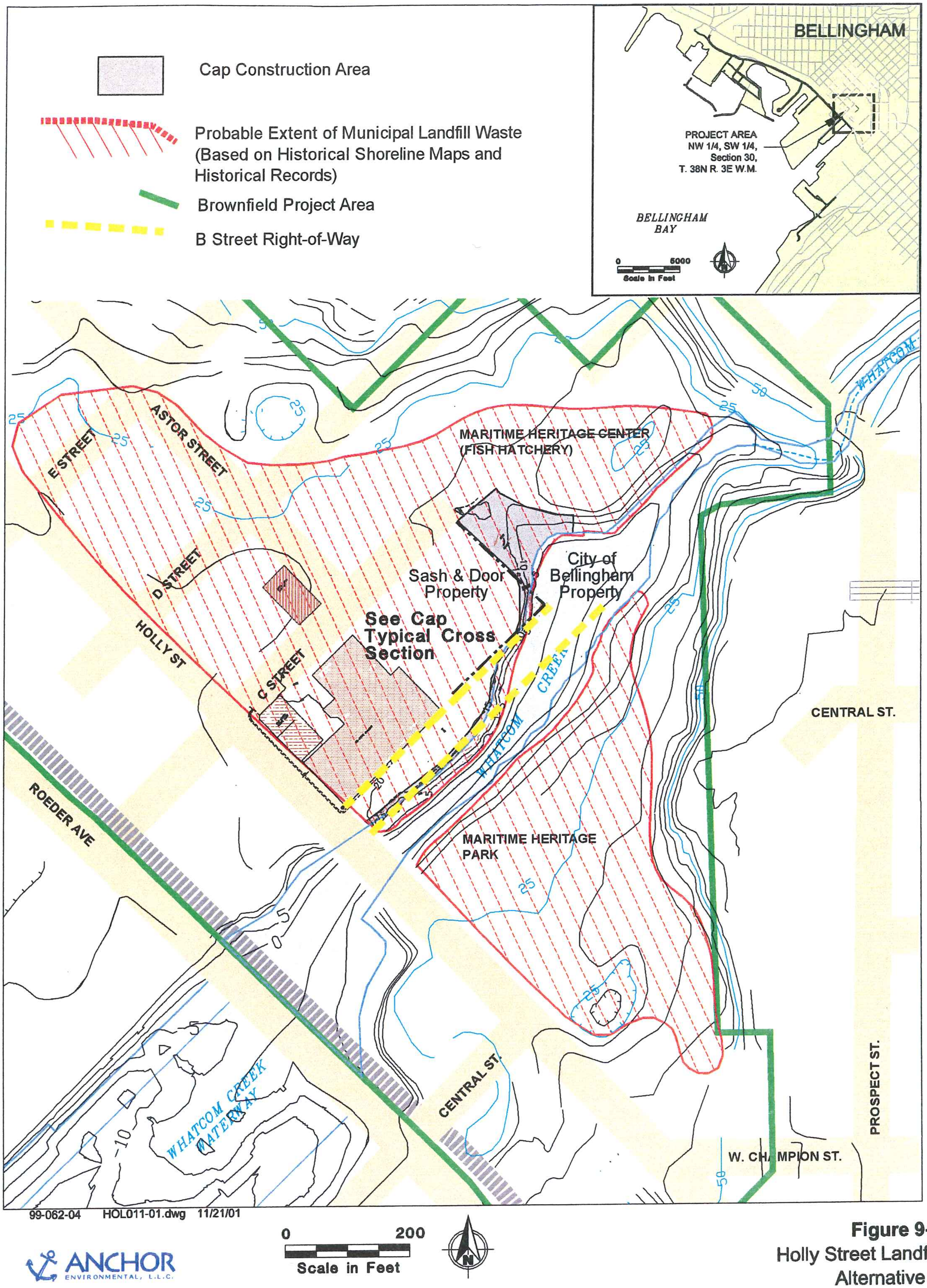

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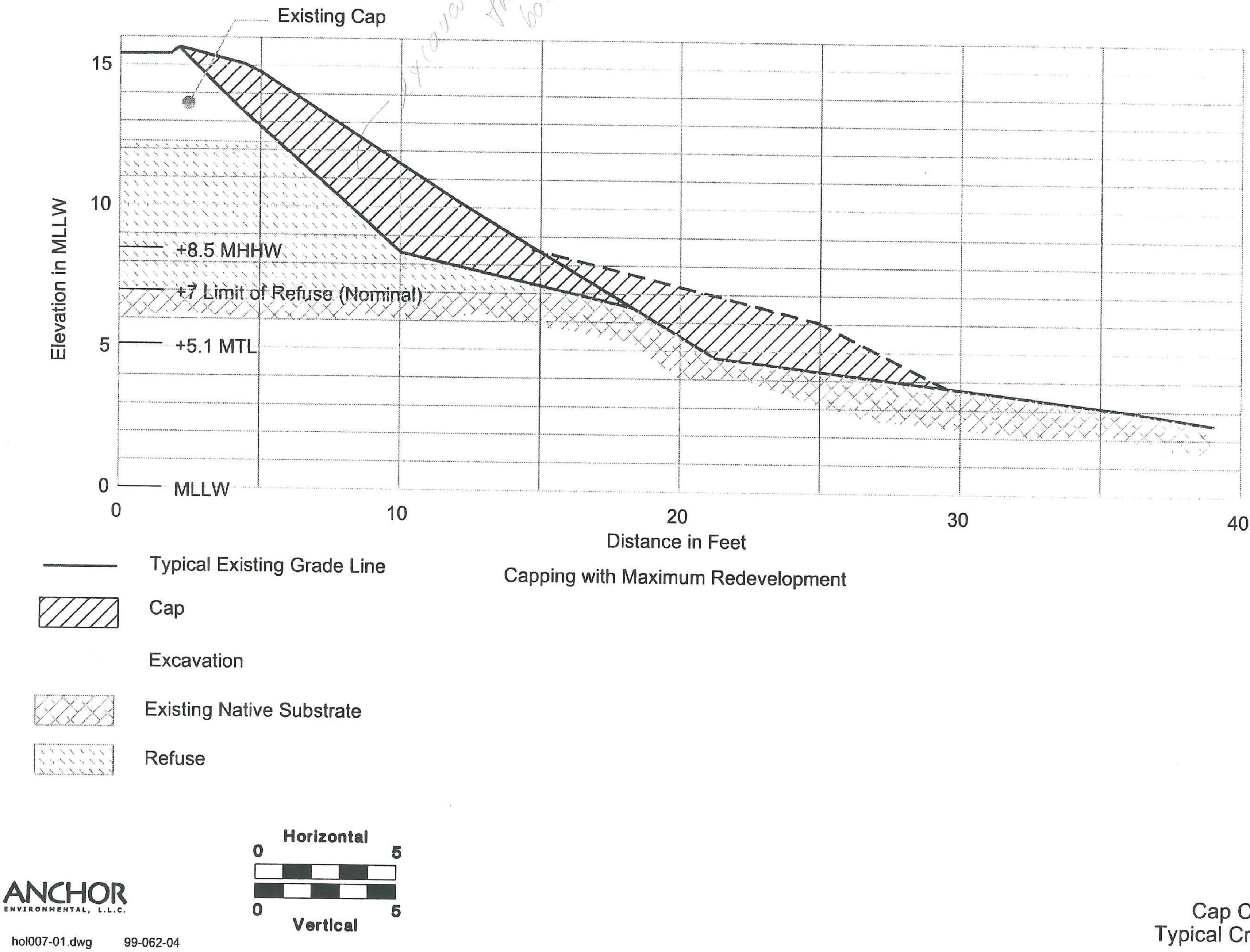
Figure 9-1
Holly Street Landfill
Alternative 2



excavated then backfilled

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Figure 9-2
Cap Construction
Typical Cross Section

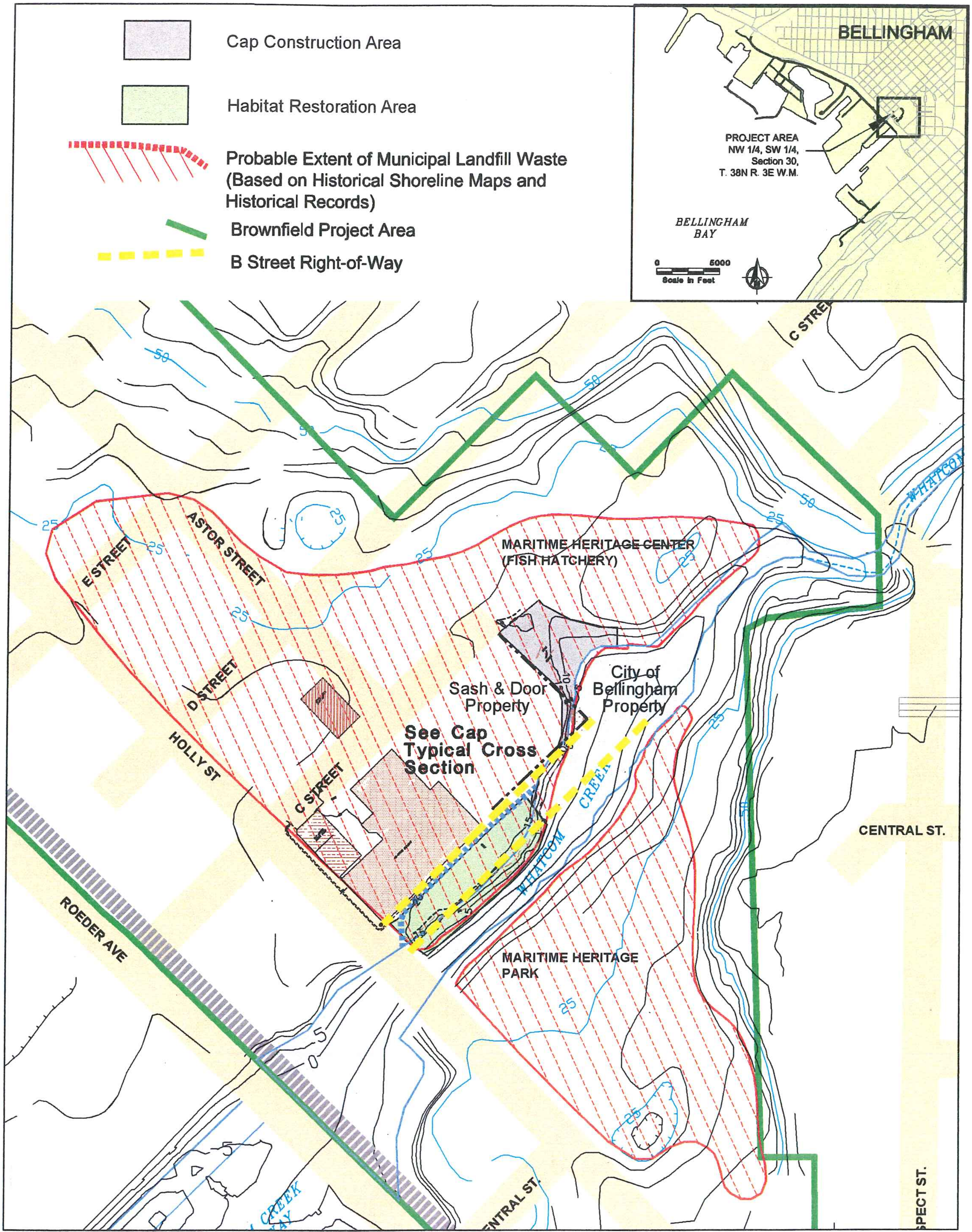

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Figure 9-3
Holly Street Landfill
Alternative 3

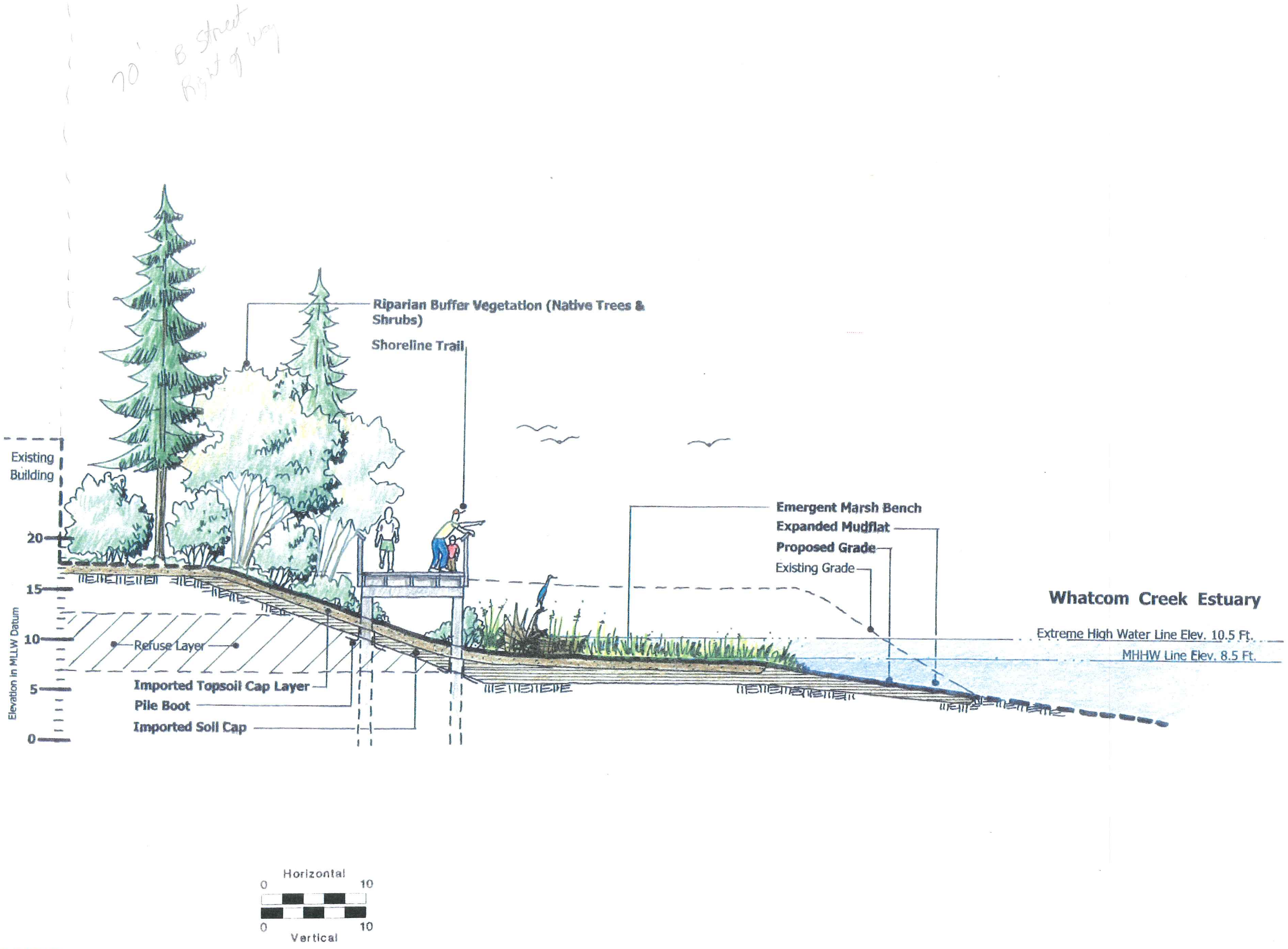

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Figure 9-4
Alternative 3 – Cross Section

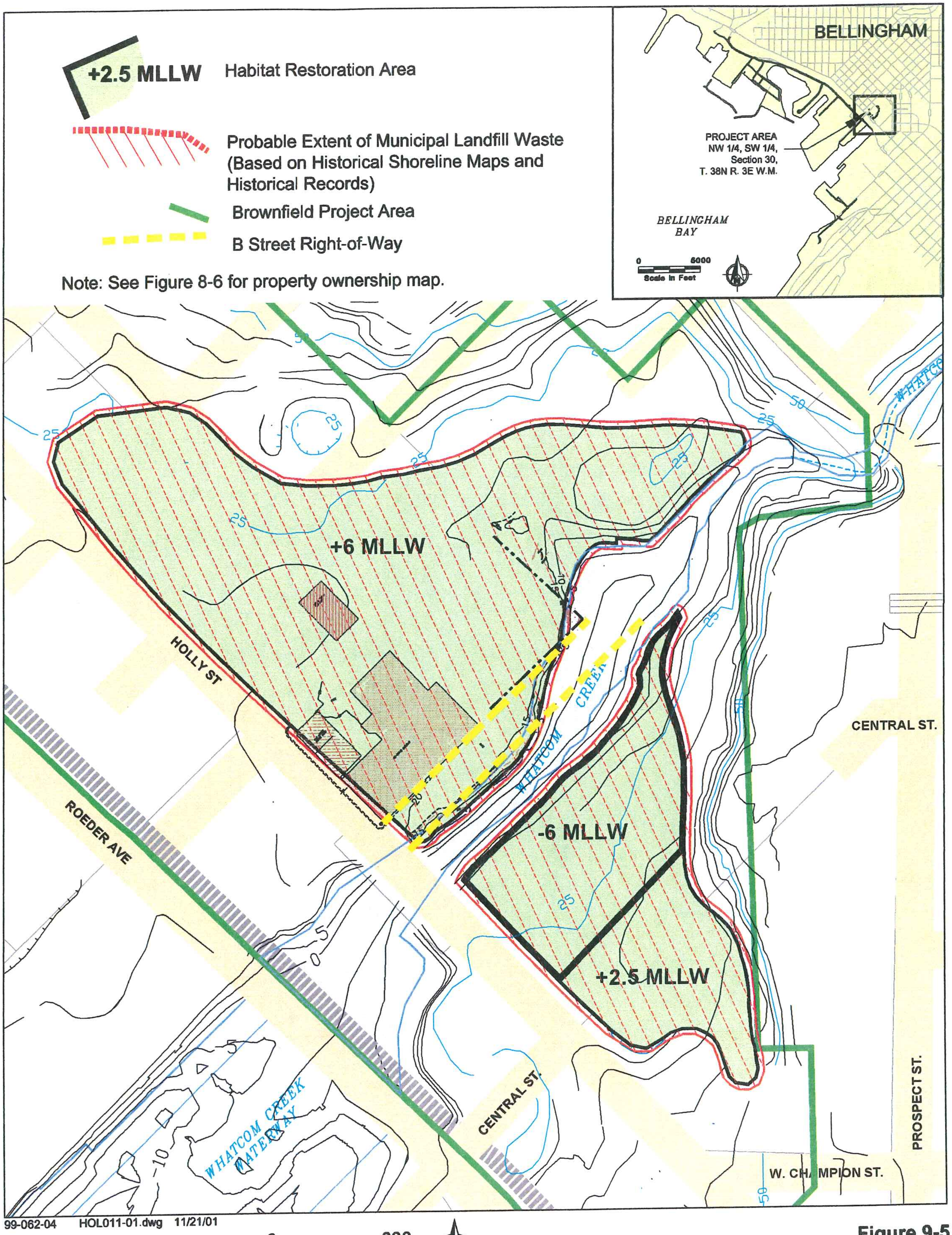

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Figure 9-5
Holly Street Landfill
Alternative 4

10.0 Comparative Evaluation of Cleanup Alternatives

This section presents a detailed evaluation of each of the four alternatives described in Section 9.0, relative to MTCA evaluation criteria. The section also addresses various implementation opportunities and constraints.

10.1 Threshold Protection Requirements

As specified in WAC 173-340-360(2), all cleanup actions conducted under MTCA shall meet the following threshold requirements:

- **Comply with cleanup standards specified under MTCA** - prospective MTCA cleanup standards at the Holly Street Landfill Site are summarized in Section 5.0. Cleanup standards for soil/refuse are dependent on land use (e.g., cleanup standards for ground floor residential uses are different from standards to protect commercial and park uses).
- **Comply with applicable state and federal laws** - the assessment against this criterion describes how the alternative complies with other applicable cleanupstandards and laws, as generally summarized in Section 6.2.
- **Protect human health and the environment** - the evaluation assesses the degree to which the cleanup alternative may perform to a higher level than regulatory criteria, and also considers the on-site and off-site risks resulting from implementation of the alternative.
- **Provide for compliance monitoring** - all cleanup actions must be monitored to verify that cleanup standards and other applicable requirements are achieved.

10.2 Permanence Criteria

MTCA also requires that permanent solutions should be used to the maximum extent practicable [WAC 173-340-360(3)(a)]. A permanent solution is defined in WAC 173-340-360(5)(b) as one in which cleanup standards can be met without further action being required at the original site or any other site involved with the cleanup action, other than the approved disposal of treatment residues, if applicable. Among the retained containment technologies included in this RI/FS, the MTCA preference for permanent solutions ranks contaminated soil and refuse disposal at an engineered containment facility higher than *in situ* containment.

Ecology recognizes that permanent solutions may not be practicable for all sites and provides the following criteria for determining whether a cleanup action is "permanent to the maximum extent practicable" [WAC 173-340-360(5)(d)]:

- Overall protectiveness of human health and the environment including the degree to which existing risks are reduced, time required to reduce risk at the facility, and attain cleanup standards, on-site and off-site risks resulting from implementing the alternative, the degree the cleanup action may perform to a higher level than specific standards in MTCA and improvement of the overall environmental quality.
- Long-term effectiveness including degree of certainty that the alternative will be successful, long-term reliability, magnitude of residual risk, and effectiveness of controls required to manage treatment resides or remaining wastes.
- Short-term effectiveness including protection of human health and the environment during construction and implementation of the alternative, and the degree of risk to human health and the environment prior to attainment of cleanup standards.

- Permanent reduction of toxicity, mobility and volume of the hazardous substance including adequacy of the alternative in destroying the hazardous substances, reduction or elimination of hazardous substances releases and sources of releases, degree of irreversibility of waste treatment process, and the characteristics and quantity of treatment residuals generated.
- Implementability including consideration of whether the alternative is technically possible, availability of necessary off-site facilities, services and materials, administrative and regulatory requirements, scheduling, size complexity, monitoring requirements, access for construction, operations and monitoring, and integration with existing facility operations and other current or potential remedial actions.
- Cleanup costs including capital costs and operation and maintenance costs. If the cost of an action is substantial and disproportionate to the incremental degree of protection it would achieve over a lower preference action is will not be considered practicable.
- The degree to which community concerns are addressed.

10.3 Restoration Time Frame Criteria

WAC 173-340-360(6)(a) requires that cleanup actions shall be completed in a reasonable time frame. The factors to consider when establishing if a time frame is "reasonable" include:

- Potential risks posed by the site to human health and the environment
- Practicability of achieving a shorter restoration time frame
- Current use of the site, surrounding areas, and associated resources that are or may be affected by releases from the site
- Potential future use of the site, surrounding areas and associated resources that are or may be affected by releases from the site
- Likely effectiveness and reliability of institutional controls
- Ability to control and monitor migration of hazardous substances from the site
- Toxicity of the hazardous substances at the site.

10.4 Consider Public Concerns

Consideration of public concerns is an inherent part of the site cleanup process under MTCA. After addressing public and stakeholder comments received on this RI/FS report, the City and Ecology anticipate entering into a MTCA Consent Decree to develop and implement a Cleanup Action Plan (CAP). Ecology's selected remedy will be articulated in a draft CAP and drafts of both the Consent Decree and CAP will be provided for public review. A draft public participation plan (PPP) that includes the elements listed in WAC 173-340-600(8) will also be included with the draft Consent Decree and CAP for public review. These draft documents will move from draft to final form through addressing public comment.

10.5 Net Environmental Benefits – Consistency with Comprehensive Strategy

This criterion evaluates overall benefits to the natural environment that result from the alternative, such as restoration of habitat, improved public access, land use/redevelopment, and other values as generally outlined in the Comprehensive Strategy (Ecology 2000). The Bellingham Bay Comprehensive Strategy EIS provided a broad evaluation of these factors, and provides the context to assess net environmental benefits of alternative actions at the Holly Street Landfill

Site. The Comprehensive Strategy EIS also includes additional sites, actions, and evaluation criteria to address baywide strategic environmental planning and project integration to incorporate cleanup, source control, habitat restoration, and shoreline property management components.

10.6 Comparative MTCA Analysis of Cleanup Alternatives

This section compares each of the alternatives to the MTCA criteria discussed above.

10.6.1 Alternative 1 – No Action

Alternative 1 would not implement any remedial actions.

10.6.1.1 Threshold Requirements

The No Action alternative does not meet MTCA threshold requirements. It would not meet MTCA cleanup standards for soil and surface water (seeps), and would not be protective of the environment, as contaminated seeps from the landfill would continue to discharge into Whatcom Creek. The seeps would also not comply with other applicable state and federal laws (e.g., Surface Water Quality Standards). There would be no compliance monitoring under this alternative.

10.6.1.2 Permanence Criteria

Since it is not protective of human health and the environment, and is not considered effective over the long-term, the No Action Alternative does not meet the MTCA permanence criterion (Section 10.2).

10.6.1.3 Restoration Time Frame

As discussed in Section 7.3, preliminary calculations of mass loading leaving the landfill site suggest that natural attenuation would require at least another 100 years before reductions in concentrations in soil or seepage could be reasonably detected. This time frame does not meet the "reasonableness" criterion defined under MTCA.

10.6.1.4 Net Environmental Benefits

The No Action alternative does not provide net environmental benefits.

10.6.2 Alternative 2 – Capping with Upland Development

10.6.2.1 Threshold Requirements

Alternative 2 would comply with MTCA and with other applicable cleanup standards and laws through capping of upland and shoreline areas of the Site. The conceptual design of this alternative includes localized excavation and off-site disposal of approximately 640 cy of refuse along the Whatcom Creek shoreline, in order to achieve the requirement of no net loss of aquatic habitat area or function. Alternative 2 would also provide overall protection of human health and the environment through use of upland and shoreline containment technologies that would be designed to attain water quality standards (Section 8.1). This alternative would continue to isolate upland refuse, consistent with EPA's CERCLA Presumptive Remedy for landfills. The minor amount of material removed would be disposed of at an offsite landfill. Periodic monitoring would be required and will be defined in the CAP and during remedial design.

10.6.2.2 Permanence Criteria

Under this alternative, a minor amount (640 cy) of soil and refuse would be excavated from the site and disposed at an engineered containment facility. However, the vast majority of waste materials (approx. 350,000 cy) would be contained *in situ*.

Ecology's evaluation criteria for determining whether a cleanup action is "permanent to the maximum extent practicable" are summarized below:

- **Overall protectiveness of human health and the environment.** Alternative 2 would be protective of human health and the environment by eliminating contaminant migration through seeps to Whatcom Creek, and through upland waste isolation.
- **Long-term effectiveness.** The long-term effectiveness of Alternative 2 in achieving surface water standards was predicted using the 3-dimensional computer model MODFLOW (Section 8.1). Construction of passive methane venting systems as part of future upland development will also ensure the long-term effectiveness of this alternative.
- **Short-term effectiveness.** During the construction period for this alternative, care would need to be taken to ensure there would be no releases of contaminants or turbidity into Whatcom Creek. This could include the use of silt curtains or limiting construction activities such that the newly exposed surface is backfilled with the capping material prior to being inundated by the incoming tide.
- **Permanent reduction of toxicity, mobility and volume.** Alternative 2 does not destroy hazardous substances, or reduce or eliminate hazardous substances releases and sources of releases. However, Alternative 2 would be effective in reducing the mobility of contaminants by placing a 3- to 5-foot thick cap along the northern bank of Whatcom Creek. This would also reduce the toxicity of contaminants by attenuating contaminant transport within the ground water such that there would be no exceedances of surface water quality standards. There would be a negligible reduction in the volume of contaminants with the minimal removal of material along the bank; some refuse may be included in that removal.
- **Implementability.** Alternative 2 is technically implementable. No special equipment would be required to construct the remedial option. The needed construction equipment is readily available, including backhoes, excavators, dump trucks, and bulldozers. Excavated material would either be hauled directly by trucks to an approved landfill or would be hauled to a railhead where the material could be transported by rail car to an approved landfill. Potential landfills that could take the excavated material include Columbia Ridge Landfill and Recycling Center (Waste Management), Arlington, Oregon, and the Regional Disposal Company Landfill (RABANCO), Roosevelt, Washington. If excess water is encountered in the excavated material it may need to be dewatered prior to transport. There are sources of clean capping material that are locally available. This alternative is expected to be administratively feasibility since permits are routinely issued for the actions associated with this alternative. All permit requirements would be adhered to.
- **Cost.** The estimated construction and long-term operation and maintenance cost of this alternative (present worth basis) is approximately $190,000, as summarized in Table 10-1. This estimate includes the cost of constructing supplemental upland caps within the Maritime Heritage Center, but does not include passive gas venting controls, which are likely to be

integrated (as necessary) with future development at a relatively low marginal cost to the developer. If the remedial action were performed under a Consent Decree with Ecology, MTCA Remedial Action Grant assistance of up to 50 percent of the total construction cost may potentially be available for implementation of this alternative. Under this scenario, the local share of the cleanup costs would be approximately $100,000.

10.6.2.3 Restoration Time Frame

The restoration time frame for construction of the upland and shoreline caps under Alternative 2 is estimated at approximately 2 years or less, given typical design and construction schedules. Completion of soil gas venting controls (as necessary) would be tied to upland redevelopment schedules.

10.6.2.4 Net Environmental Benefits

In addition to providing cleanup, Alternative 2 provides additional benefits to the environment, including land use/redevelopment in the project area. That is, the level of certainty provided by an in-place area-wide Cleanup Action Plan approved by Ecology would minimize barriers to further redevelopment of properties within the study area, consistent with the broad goals outlined in the Comprehensive Strategy (Ecology 2000) and in various strategic plans for the Holly Street redevelopment area (Section 8.5).

However, Alternative 2 would provide little net benefit to habitat restoration or public access goals of the Comprehensive Strategy.

10.6.3 Alternative 3 – Limited Removal/Capping with Habitat Restoration and Upland Development

10.6.3.1 Threshold Requirements

Alternative 3 would comply with MTCA and with other applicable cleanup standards and laws through capping of upland and shoreline areas of the Site. The conceptual design of this alternative includes excavation and off-site disposal of approximately 5,700 cy of refuse within the B Street ROW or alternate location, concurrently accomplishing habitat restoration and (potentially) public access objectives. Alternative 3 would provide overall protection of human health and the environment through use of upland and shoreline containment technologies that would be designed to attain water quality standards (Section 8.1). This alternative would continue to isolate upland refuse, consistent with EPA's CERCLA Presumptive Remedy for landfills. Excavated landfill refuse materials from the B Street ROW (or other shoreline excavation areas) would be disposed of at an offsite landfill. Periodic monitoring would be required and will be defined in the CAP and during remedial design.

10.6.3.2 Permanence Criteria

Under this alternative, 5,700 cy of soil and refuse would be excavated from the site and disposed at an engineered containment facility. However, the majority (98 percent) of waste materials at the Site (approx. 340,000 cy) would be contained *in situ*.

Ecology's evaluation criteria for determining whether a cleanup action is "permanent to the maximum extent practicable" are summarized below:

- **Overall protectiveness of human health and the environment.** Alternative 3 would be protective of human health and the environment by eliminating contaminant migration through seeps to Whatcom Creek, and through upland waste isolation.
- **Long-term effectiveness.** The long-term effectiveness of Alternative 3 in achieving surface water standards was predicted using the 3-dimensional computer model MODFLOW (Section 8.1). Relative to Alternative 2, the thicker cap sections included in Alternative 3 (10 versus 5 feet) provide a higher degree of protection of surface water. Construction of passive methane venting systems as part of future upland development will also ensure the long-term effectiveness of this alternative.
- **Short-term effectiveness.** During the construction period for this alternative, care would need to be taken to ensure there would be no releases of contaminants or turbidity into Whatcom Creek. This could include the use of silt curtains or limiting construction activities such that the newly exposed surface is backfilled with the capping material prior to being inundated by the incoming tide.
- **Permanent reduction of toxicity, mobility and volume.** Alternative 3 does not destroy hazardous substances, or reduce or eliminate hazardous substances releases and sources of releases. However, Alternative 3 would be effective in reducing the mobility of contaminants by placing a minimum 10-foot thick cap along the northern bank of Whatcom Creek. This would also reduce the toxicity of contaminants by attenuating contaminant transport within the ground water such that there would be no exceedances of surface water quality standards. There would be a small (approximately 2 percent) reduction in the volume of contaminants with the removal of material from the B Street right-of-way.
- **Implementability.** Alternative 3 is technically implementable. No special equipment would be required to construct the remedial option. The needed construction equipment is readily available, including backhoes, excavators, dump trucks, and bulldozers. Excavated material would either be hauled directly by trucks to an approved landfill or would be hauled to a railhead where the material could be transported by rail car to an approved landfill. Potential landfills that could take the excavated material include Columbia Ridge Landfill and Recycling Center (Waste Management), Arlington, Oregon, and the Regional Disposal Company Landfill (RABANCO), Roosevelt, Washington. If excess water is encountered in the excavated material it may need to be dewatered prior to transport. There are sources of clean capping material that are locally available. This alternative is expected to be administratively feasibility since permits are routinely issued for the actions associated with this alternative. All permit requirements would be adhered to.
- **Cost.** The estimated construction and long-term operation and maintenance cost of this alternative (present worth basis) is approximately $1,700,000, as summarized in Table 10-2. This estimate includes the cost of constructing upland caps, but does not include the cost of passive gas venting controls, which are assumed to be integrated with future development at relatively low marginal cost to the developer. This cost estimate also does not include the value of uplands (e.g., within the ROW) converted to aquatic habitat.

  The conversion of uplands into aquatic habitat, along with upland/shoreline cleanup and trail access, could be undertaken as a single combined remediation/restoration/ public access project. In this event, potential funding may be available from federal (Corps) ecosystem restoration authorities, with prospective funding of up to 75 percent of the marginal cost of Alternative 3, relative to the "minimum MTCA cleanup" Alternative 2. Depending on how the land value of the B Street ROW is calculated and other factors, potential Corps funding of Alternative 3 could likely exceed $800,000. In addition, if the action were performed under a Consent Decree with Ecology, MTCA Remedial Action Grant assistance of up to 50 percent of the total construction cost may potentially be available for implementation of this alternative (up to roughly $800,000). Thus, under this scenario, the local share of cleanup costs could potentially be less than $100,000.

10.6.3.3 Restoration Time Frame

Given typical design and construction schedules, the restoration time frame for construction of the upland and shoreline caps under Alternative 3 is estimated at approximately 2 years or less, equivalent to Alternative 2. Completion of associated soil gas venting controls (as necessary) would be tied to upland redevelopment schedules.

10.6.3.4 Net Environmental Benefits

In addition to providing cleanup, Alternative 3 provides additional benefits to the environment, including land use/redevelopment in the project area, habitat restoration, and public access. The level of certainty provided by an in-place Cleanup Action Plan approved by Ecology would minimize barriers to further redevelopment of properties within the study area, consistent with the broad goals outlined in the Comprehensive Strategy (Ecology 2000).

Moreover, because of the expected benefit to endangered salmon recovery efforts and other ecosystem restoration objectives, one of the highest-ranking habitat restoration opportunities identified by the Comprehensive Strategy was the removal/restoration of estuarine habitat at the Holly Street Landfill Site, which is an element of Alternative 3. Integration of this habitat restoration action into the Holly Street Landfill cleanup may provide an opportunity to achieve substantial overall environmental enhancements, consistent with the Comprehensive Strategy.

Incorporating public access design with cleanup and habitat restoration would meet additional community open space goals and planning objectives, leverage additional community support and funding, and provide an opportunity to educate the public about critical estuarine environments. Integration of public access and redevelopment actions into the Holly Street Landfill cleanup may provide an opportunity to achieve substantial overall enhancements of the Lettered Streets Neighborhood, consistent with the Comprehensive Strategy.

10.6.4 Alternative 4 – Maximum Removal and Habitat Restoration

10.6.4.1 Threshold Requirements

Alternative 4 would comply with MTCA and with other applicable cleanup standards and laws through removal and off-site disposal of all 350,000 cy of solid waste from the Site. The excavated area could either be completed as aquatic habitat, or backfilled with clean materials to restore upland development to the area. Alternative 4 would provide overall protection of human health and the environment through use of removal and off-site disposal technologies. Periodic monitoring would not be required since all landfill refuse would be removed; however compliance monitoring would be performed during the implementation of the remedy.

10.6.4.2 Permanence Criteria

Under this alternative, 350,000 cy of soil and refuse would be excavated from the site and disposed at an engineered containment facility. No solid waste would remain on-site. Ecology's evaluation criteria for determining whether a cleanup action is "permanent to the maximum extent practicable" are summarized below:

- **Overall protectiveness of human health and the environment.** Alternative 4 would be protective of human health and the environment by eliminating contaminant sources and all transport pathways.
- **Long-term effectiveness.** Since no waste materials would remain on-site under this alternative, the long-term effectiveness of Alternative 4 is assured.
- **Short-term effectiveness.** During the extended construction period for this alternative, care would need to be taken to minimize releases of contaminants or turbidity into Whatcom Creek. While silt curtains or other controls could potentially be applied in this case, the large volume of wastes removed under this alternative results in a lower short-term effectiveness, relative to Alternatives 2 and 3. Under Alternative 4, areas furthest from Whatcom Creek would likely be excavated first, breaking through the remaining berm to the Creek towards the end of the construction period, in order to minimize the potential for releases. The large volume of material removed also increases the likelihood for releases during transport (e.g., highway and/or rail systems), relative to the other alternatives evaluated.
- **Permanent reduction of toxicity, mobility and volume.** Alternative 4 does not destroy hazardous substances, but would reduce or eliminate long-term hazardous substance releases and sources of releases.
- **Implementability.** Although Alternative 4 is technically implementable, the size of the excavation and associated displacement of a substantial number of existing businesses and facilities renders this alternative impracticable. For example, administrative and legal requirements associated with obtaining access to existing private lands for construction and other operations, including anticipated displacement and compensation agreements with these property owners, greatly complicates the implementation of this alternative. Thus, implementation of Alternative 4 is considered impracticable.
- **Cost.** The estimated construction cost of this alternative (present worth basis) is approximately $35,000,000, as summarized in Table 10-3. If the remedial action were performed under a Consent Decree with Ecology, MTCA Remedial Action Grant assistance of up to 50 percent of the total construction cost may potentially be available for implementation of this alternative. Under this scenario, the local share of the cleanup costs would be approximately $18,000,000, subject to the availability of MTCA matching funds at this level.

10.6.4.3 Restoration Time Frame

Given anticipated administrative, legal, design and construction schedules, the potential restoration time frame for construction of Alternative 4 is estimated at approximately 10 to 20 years, longer than that of Alternatives 2 or 3.

10.6.4.4 Net Environmental Benefits

In addition to providing cleanup, Alternative 4 provides considerable additional habitat restoration benefits, inasmuch as the alternative (if completed at or below tidal elevations) could restore approximately 13 acres of aquatic habitat to the Whatcom Creek estuary. Such an action would provide substantial benefits to endangered salmon recovery efforts and other ecosystem restoration objectives, consistent with the Comprehensive Strategy.

However, implementation of Alternative 4 (aquatic habitat option) would also likely lead to significant impacts to redevelopment of properties within the study area, since such properties would be removed from upland use, at least temporarily. In addition, removal of park facilities on both sides of Whatcom Creek would considerably impact public access and recreational amenities. Such actions would not be consistent with the broad goals outlined in the Comprehensive Strategy (Ecology 2000).

Table 10-1. Estimated Costs for Alternative 2 - Capping with Upland Development

			Alternative 2	
Item	Unit	Unit Cost	Quantity	Cost
Mobilization/Demobilization	LS	$ 10,000	1	$ 10,000
Site Preparation/Demo	LS	$ 5,000	1	$ 5,000
Upland Staging Area	LS	$ 10,000	1	$ 10,000
Excavate Bank	Ton	$ 7.00	900	$ 6,300
Haul and Disposal	Ton	$ 34.00	900	$ 30,600
Purchase and Deliver Cap Material	Ton	$ 5.00	1,800	$ 9,000
Place Cap	Ton	$ 15.00	1,800	$ 27,000
Subtotal				$ 97,900
Engineering Design	Percent	10%		$ 9,790
Const. Monitoring/Mgmt.	Percent	5%		$ 4,895
Long Term Monitoring	LS	$ 50,000	1	$ 50,000
Contingency	Percent	30%		$ 29,370
Total				**$ 190,000**

Assumptions: Unit conversion for sand between CY and Ton: CY * 1.3 = Ton
Unit conversion for bank material between CY and Ton: CY * 1.4 = Ton
Dewatering of the excavated material is not required.
Haul and Disposal costs from Rabanco (telecon 3/23/01)
Long-term monitoring based on 4 seep and 1 QA/QC samples each year for years 0 - 5.
Excavation cost from Wilder Construction (telecon with Bert 3/26/01)
Purchase and deliver Cap Material cost from Wilder Construction (telecon with Bert 3/26/01)

Table 10-2. Estimated Costs for Alternative 3 - Limited Removal/Capping with Habitat

			Alternative 3	
Item	Unit	Unit Cost	Quantity	Cost
Mobilization/Demobilization	LS	$ 10,000	1	$ 10,000
Site Preparation/Demo	LS	$ 5,000	1	$ 5,000
Upland Staging Area	LS	$ 10,000	1	$ 10,000
Excavate Bank	Ton	$ 7.00	8,000	$ 56,000
Haul and Disposal	Ton	$ 34.00	8,000	$ 272,000
Purchase and Deliver Cap Material	Ton	$ 5.00	1,755	$ 8,775
Place Cap	Ton	$ 15.00	1,755	$ 26,325
Purchase and Install Topsoil	CY	$ 30.00	1,350	$ 40,500
Shoreline Trail Boardwalk	SF	$ 65.00	9,400	$ 611,000
Planting and Erosion Control	LS	$ 87,000	1	$ 87,000
Subtotal				$ 1,126,600
Engineering Design	Percent	10%		$ 112,660
Const. Monitoring/Mgmt.	Percent	5%		$ 56,330
Long Term Monitoring	LS	$ 50,000	1	$ 50,000
Contingency	Percent	30%		$ 337,980
Total				**$ 1,700,000**

Assumptions: Unit conversion for sand between CY and Ton: CY * 1.3 = Ton

Unit conversion for bank material between CY and Ton: CY * 1.4 = Ton

Dewatering of the excavated material is not required.

Haul and Disposal costs from Rabanco (telecon 3/23/01)

Long-term monitoring based on 4 seep and 1 QA/QC samples each year for years 0 - 5.

Excavation cost from Wilder Construction (telecon with Bert 3/26/01)

Purchase and deliver Cap Material cost from Wilder Construction (telecon with Bert 3/26/01)

Planting and erosion control includes purchase and installation of coir biodegradable fabric, trees, shrubs, and wetland grasses and a goose exclosure

Note: Costs associated with loss of existing uplands (e.g., within B Street ROW) are not included.

Boardwalk

611,000

10% 61,100

5% 30,550

702,650

30% 183,300

[illegible] $885,950 900,000

Table 10-3. Estimated Costs for Alternative 4 - Maximum Removal and Habitat

			Alternative 4	
Item	Unit	Unit Cost	Quantity	Cost
Mobilization/Demobilization	LS	$ 10,000	1	$ 10,000
Site Preparation/Demo	LS	$ 5,000	1	$ 5,000
Upland Staging Area	LS	$ 10,000	1	$ 10,000
Excavate Site	Ton	$ 7.00	590,000	$ 4,130,000
Haul and Disposal	Ton	$ 34.00	590,000	$ 20,060,000
Purchase and Deliver Cap Material	Ton	$ 5.00	0	$ -
Place Cap	Ton	$ 15.00	0	$ -
Subtotal				$ 24,215,000
Engineering Design	Percent	10%		$ 2,421,500
Const. Monitoring/Mgmt.	Percent	5%		$ 1,210,750
Long Term Monitoring	LS	$ -	0	$ -
Contingency	Percent	30%		$ 7,264,500
Total				**$ 35,000,000**

Assumptions: Unit conversion for sand between CY and Ton: CY * 1.3 = Ton
Unit conversion for bank material between CY and Ton: CY * 1.4 = Ton
Dewatering of the excavated material is not required.
Haul and Disposal costs from Rabanco (telecon 3/23/01)
Excavation cost from Wilder Construction (telecon with Bert 3/26/01)
Purchase and deliver Cap Material cost from Wilder Construction (telecon with Bert 3/26/01)

Note: Costs associated with loss of 13 acres of existing uplands and improvements not included.

11.0 Next Steps

This RI/FS report presents information relevant to the weighing of alternative cleanup actions for the Holly Street Landfill Site, considering net environmental benefits, permanence, implementability, cost, and other MTCA criteria. The report is intended to facilitate agency, landowner, and public review, and to enable Ecology to select a cleanup action alternative for the Site. The cleanup alternatives described in this document also address the overall objectives of both the EPA Brownfields Assessment Demonstration Pilot Program, as well as the Bellingham Bay Comprehensive Strategy. Cleanup alternatives have been integrated with related redevelopment, public access, and habitat restoration elements, to examine opportunities for a coordinated approach.

The City solicited public comments on the draft RI/FS report in June and July, 2001, including at a public meeting held on June 13, 2001. Public and stakeholder comments received on the draft RI/FS report have been incorporated into this document.

The City and Ecology anticipate entering into a MTCA Consent Decree in early 2002 to develop and implement a Cleanup Action Plan (CAP) for the Holly Street Landfill Site. Ecology's selected remedy will be articulated in a draft CAP and drafts of the Consent Decree and CAP will be provided for public review, consistent with MTCA requirements. Design and permitting tasks associated with the shoreline remedy will likely be funded in part through a Supplemental Assistance Grant to the City from EPA for the Holly Street Landfill Brownfields Redevelopment Project. The design would be coordinated with other actions within the area. Construction of the selected remedy (e.g., shoreline cleanup) could begin in fall 2003.

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APPENDIX A

Remedial Investigation Boring Logs, Tidal Monitoring and Aquifer Characterization

A.1 Boring Logs

Boring logs for the three monitoring wells installed as part of this Remedial Investigation are presented in Figures A-1 through A-4.

A.2 Tidal Monitoring

After completing rising-head slug tests in each of the monitoring wells (discussed below), 30-psi pressure transducers were set near the bottom of the wells and programmed to record water pressure every five minutes for a minimum of 72 hours (the minimum time needed to accurately evaluate tidal effects). The resulting data were converted to ground water elevations using the surveyed well casings and the Bellingham datum. Water level data were also converted to USC&G Mean Lower Low Water (MLLW) to compare with tidal data compiled by NOAA.

The tidal data were filtered using a method described in Serfes (1991) to obtain a mean elevation over the three-day period for each well. The mean elevations were then used to determine the horizontal hydraulic gradient. The filtering removes lunar and solar harmonics, and requires 71 consecutive, hourly water-level measurements. The five-minute measurements were sub-sampled to obtain hourly values, then the mean elevation in the middle (hour 36) of the 71 measurements was determined by

$$h_{mean} = \sum_{j=1}^{25} \frac{y_j}{25}$$

where

$$y_j = \sum_{i=0}^{23} \frac{x_j + j}{24}$$

and

$$x_i = \sum_{k=0}^{23} \frac{h_{k+i}}{24}$$

where

h = measured, hourly elevation, L
h_{mean} = mean elevation at hour 36, L
x_j = first set of filtered means, L
y_j = second set of filtered means, L
i = 1, 2, 3, … , 48
j = 1, 2, 3, … , 25

The mean elevation is calculated for each successive set of 71-hour measurements. Each set of filtered means and the mean elevation are shown graphically in Figures A-5 through A-7. Note that the tidal fluctuations for MW-1 and MW-2 are very small compared to those measured at MW-3, but that some tidal influence can be inferred.

A.3 Aquifer Characterization

Hydraulic properties of the water table aquifer were evaluated by rising-head slug tests conducted on October 6, 2000, on each of the three monitoring wells (MW-1, MW-2, and MW-3). The water level was measured prior to the test, a dedicated, 30-psi pressure transducer was set near the bottom of the well (the transducers were later used for tidal monitoring), and a disposable bailer was used to remove a volume of water for the test. Water pressures were recorded with a logarithmic recording interval (up to four seconds, after which a linear interval was used) until sufficient recovery had occurred and the test deemed completed.

The Bouwer and Rice (1976) method was used to estimate hydraulic conductivity. This analysis method best fits the aquifer type, and the method can compensate for partial well penetration. The method uses a semi-logarithmic correlation of displacement and time to determine the valid portion of the data (data not influenced by the filter pack or vertical flow near the well). The initial response in the test is reasonable for the fine-grained filter pack used for these wells (Colorado 20/40 sand), and yields a hydraulic conductivity that is reasonable for a fine sand. Where a filter-pack response was inferred, the subsequent data were was used to determine hydraulic conductivity. The data are plotted in Figures A-8 through A-10.

Hydraulic conductivity is estimated as

$$K = \frac{r_c^2 \ln(R_e / r_w)}{2L} \frac{1}{t} \ln \frac{y_0}{y_t}$$

where

K = hydraulic conductivity, LT^{-1}
r_c = casing radius, L
R_e = effective radius over which head loss is dissipated, L
r_w = boring radius, L
t = time, T
L = screened length of well, L
y_0 = extrapolated displacement at time zero, L
y_t = displacement at time t, L.

$\ln R_e/r_w$ is determined from well-geometry parameters and y_0 is estimated by extrapolating the valid portion of the data back to time zero.

Hydraulic conductivity was also estimated by using the tidal monitoring data and the method described in Ferris (1963). The method relates the ground water fluctuation and tidal stage ranges to transmissivity and storativity by

$$\frac{s_r}{2s_0} = e^{-x\sqrt{\frac{\pi S}{t_0 T}}}$$

where

s_r = ground water elevation range during tidal influence, L
$2s_0$ = tidal elevation range, L
$s_r/2s_0$ = stage ratio, L^0
x = inland distance from tide water, L
t_0 = tidal period, T
S = storativity, L^0
T = transmissivity, L^2T^{-1}

A semi-logarithmic plot correlating stage ratio and distance is used to calculate transmissivity (Figure A-11). For transmissivity in gallons per day per foot, distance in feet, and tidal period in days,

$$T = \frac{4.4\Delta x^2 S}{t_0}$$

where Δx is the change in distance over one log cycle. Because some tidal response was inferred in MW-1 and MW-2, each of the wells was used to determine the regressed line shown in Figure A-11. The resulting equation that relates distance to stage ratio was then used to calculate the ground water fluctuation range shown in the conceptual hydrogeologic model (Figure 4-4). An estimated value of 0.1 was used for storativity, which is reasonable for the types of subsurface materials comprising the aquifer. A storativity of 0.04 yields results that match the slug test analyses from MW-2 and MW-3 (the wells completed in the refuse).When using the saturated thickness to estimate hydraulic conductivity (discussed below), the estimated storativity value also yields a transmissivity that generally matches those obtained from the slug test analyses.

Transmissivity and hydraulic conductivity are related by

$$T = Kb$$

where

K = hydraulic conductivity, LT^{-1}
b = aquifer thickness, L.

An unconfined saturated thickness was used at each well, based on static water elevations and the inferred base of the aquifer, assumed to be the top of the Bellingham Drift. The estimated saturated thickness yields a reasonable result when converting the transmissivity determined using the Ferris method to hydraulic conductivity.

Ground water flow velocity is obtained from

$$v = \frac{Ki}{n}$$

where

v = average interstitial ground water velocity, LT^{-1}
i = horizontal hydraulic gradient, L^0
n = effective porosity, L^0.

A velocity at each well was calculated using a the hydraulic gradient determined from the October 2000 water-level measurements and reasonable values for effective porosity (Fetter, 1988).

Table A-1 provides a summary of the transmissivity, hydraulic conductivity, and ground water velocity values estimated from the test data.

A.3 Estimated Landward Extent of Tidal Mixing

The lateral extent of tidal mixing was evaluated by using the aquifer parameters estimated in this investigation and water levels obtained during the tidal monitoring conducted in October 2000. The following procedure was used to estimate the lateral, inland movement of ground water as a result of tidal influences:

1. For every 30 minutes during the tidal monitoring, determine the horizontal hydraulic gradient between tide water in Whatcom Creek (using the NOAA tide data from Cherry Point, Washington) and ground water in monitoring well MW-3. The mean, shoreline-to-well distance between MW-3 and tide water is assumed to be 14 feet.
2. For each time when the gradient is landward (tide water is higher than the ground water in MW-3), calculate the corresponding ground water velocity using the hydraulic conductivity and porosity. Hydraulic conductivities of 42 feet per day (from the slug-test analysis for MW-2, screened in the refuse) and 100 feet per day (from the Ferris analysis), and porosities of 0.15 (the minimum anticipated porosity) and 0.30 (the maximum anticipated porosity) were used to calculate a minimum and maximum velocity.
3. Use the calculated velocity to calculate the distance traveled for each 30-minute interval.
4. Sum the distances for every time interval for which a landward gradient exists. The resulting value is the farthest inland point to which ground water flows by advection.

The procedure is summarized as

$$d_{\max} = \sum_{j=1}^{m} \frac{Ki_j}{n} t_j$$

d_{max} = maximum inland distance traveled by ground water, L
K = horizontal hydraulic conductivity, LT^{-1}
i = horizontal hydraulic gradient, L^0
n = effective porosity, L^0
t = time interval j (30 minutes), T
m = number of time intervals for which the gradient is landward.

In order to evaluate a maximum inland extent of tidal mixing, a tidal period when the high-to-low tidal fluctuation is relatively low (resulting in a tidal period dominated by relatively high tide) was used in place of the NOAA tide data in Step 1 above. Tidal data from the NOAA database were reviewed to select a period near the tidal monitoring conducted between October 6 and 9, 2000. The NOAA tidal elevations on October 17, 2000, were selected to represent this high-tide maximum.

The minimum extent of tidal mixing was calculated using the minimum hydraulic conductivity, the maximum anticipated porosity, and the NOAA tidal data for the tidal monitoring conducted between October 6 and 9, 2000. The maximum extent was calculated using the maximum hydraulic conductivity, the minimum anticipated porosity, and the NOAA tidal data for October 17, 2000.

A.4 Ground Water Flux

The amount of ground water discharging to Whatcom Creek from the site can be estimated using Darcy's Law:

$$q = Ki$$

where

q = specific discharge, LT^{-1}
K = hydraulic conductivity, LT^{-1}
i = horizontal hydraulic gradient, L^0

The discharge to Whatcom Creek is then

$$Q = qA$$

where

Q = discharge, L^3T^{-1}
A = discharge area, L^2

The parameters used to estimate the ground water flux are discussed in Section 4.4.5.

Table A-1
Summary of Aquifer Parameters
Holly Street Landfill

	Aquifer Material Screened	Type of Test	Analysis	b	T	K		Grad	Porosity	Velocity	
				ft	gpd/ft	ft/day	cm/sec	L^0	L^0	ft/day	ft/year
MW-1	Silt	Slug	Bouwer & Rice	6.6	4.3E+01	8.7E-01	3.1E-04	0.014	0.15	8.2E-02	3.0E+01
MW-2	Sandy, gravelly, refuse	Slug	Bouwer & Rice	3.8	1.2E+03	4.2E+01	1.5E-02	0.014	0.30	2.0E+00	7.2E+02
MW-3	Silty sand	Slug	Bouwer & Rice	29	2.2E+03	9.9E+00	3.5E-03	0.014	0.25	5.5E-01	2.0E+02
All	Primarily sandy refuse	Tidal	Ferris	17	1.4E+04	1.0E+02	3.7E-02	0.014	0.30	4.9E+00	1.8E+03

Notes

1 b, T, K, and Grad stand for saturated thickness, transmissivity, hydraulic conductivity, and horizontal hydraulic gradient, respectively.
2 Saturated thickness is the distance from the water table to the top of the Bellingham Drift at the time of testing.
3 The saturated thickness that represents all wells is the average of the saturated thickness at MW-3 (where the Bellingham Drift is inferred to be eroded) and the average of the saturated thicknesses at MW-1 and MW-2, where the glacio-marine deposit is approximately 30 feet higher.
4 The slug tests yield K (T is calculated from b), and the tidal test yields T (K is caculated from b).
5 The calculations for T for the Ferris analysis uses 0.15 for storativity, and a measured tidal period of 1.02 days.
6 The gradient is based on static water levels for 10/8/00, corrected for tidal fluctuation.
7 Estimated porosities (Fetter, Figure 4.11) are based on the types of deposits surrounding the well screen.
8 Aquifer Material Screened refers to the saturated portion of the material surrounding the well screen at the time of testing.

Coarse-Grained Soils - More than 50%(1) Retained on No. 200 Sieve	Gravels - More than 50%(1) of Coarse Fraction Retained on No. 4 Sieve	≤5% Fines(5)	**GW**	Well-graded gravel and gravel with sand, little to no fines
			GP	Poorly-graded gravel and gravel with sand, little to no fines
		≥15% Fines(5)	**GM**	Silty gravel and silty gravel with sand
			GC	Clayey gravel and clayey gravel with sand
	Sands - 50%(1) or More of Coarse Fraction Passes No. 4 Sieve	≤5% Fines(5)	**SW**	Well-graded sand and sand with gravel, little to no fines
			SP	Poorly-graded sand and sand with gravel, little to no fines
		≥15% Fines(5)	**SM**	Silty sand and silty sand with gravel
			SC	Clayey sand and clayey sand with gravel
Fine-Grained Soils - 50%(1) or More Passes No. 200 Sieve	Silts and Clays Liquid Limit Less than 50		**ML**	Silt, sandy silt, gravelly silt, silt with sand or gravel
			CL	Clay of low to medium plasticity; silty, sandy, or gravelly clay, lean clay
			OL	Organic clay or silt of low plasticity
	Silts and Clays Liquid Limit 50 or More		**MH**	Elastic silt, clayey silt, silt with micaceous or diatomaceous fine sand or silt
			CH	Clay of high plasticity, sandy or gravelly clay, fat clay with sand or gravel
			OH	Organic clay or silt of medium to high plasticity
Highly Organic Soils			**PT**	Peat, muck and other highly organic soils

Terms Describing Relative Density and Consistency

	Density	SPT(2) blows/foot
Coarse-Grained Soils	Very Loose	0 to 4
	Loose	4 to 10
	Medium Dense	10 to 30
	Dense	30 to 50
	Very Dense	>50

	Consistency	SPT(2) blows/foot
Fine-Grained Soils	Very Soft	0 to 2
	Soft	2 to 4
	Medium Stiff	4 to 8
	Stiff	8 to 15
	Very Stiff	15 to 30
	Hard	>30

Test Symbols

G = Grain Size
M = Moisture Content
A = Atterberg Limits
C = Chemical
DD = Dry Density
K = Permeability

Component Definitions

Descriptive Term	Size Range and Sieve Number
Boulders	Larger than 12"
Cobbles	3" to 12"
Gravel	3" to No. 4 (4.75 mm)
Coarse Gravel	3" to 3/4"
Fine Gravel	3/4" to No. 4 (4.75 mm)
Sand	No. 4 (4.75 mm) to No. 200 (0.075 mm)
Coarse Sand	No. 4 (4.75 mm) to No. 10 (2.00 mm)
Medium Sand	No. 10 (2.00 mm) to No. 40 (0.425 mm)
Fine Sand	No. 40 (0.425 mm) to No. 200 (0.075 mm)
Silt and Clay	Smaller than No. 200 (0.075 mm)

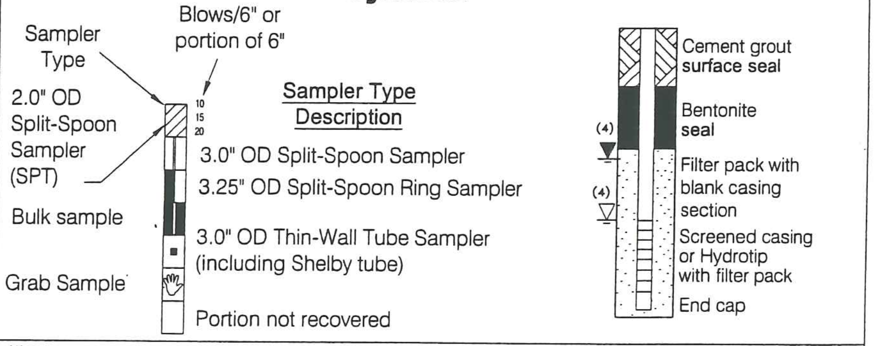
(3) Estimated Percentage

Component	Percentage by Weight
Trace	<5
Few	5 to 10
Little	15 to 25
With	- Non-primary coarse constituents: ≥ 15% - Fines content between 5% and 15%

Moisture Content

Dry - Absence of moisture, dusty, dry to the touch
Slightly Moist - Perceptible moisture
Moist - Damp but no visible water
Very Moist - Water visible but not free draining
Wet - Visible free water, usually from below water table

Symbols



(1) Percentage by dry weight
(2) (SPT) Standard Penetration Test (ASTM D-1586)
(3) In General Accordance with Standard Practice for Description and Identification of Soils (ASTM D-2488)
(4) Depth of groundwater
▼ ATD = At time of drilling
▽ Static water level (date)
(5) Combined USCS symbols used for fines between 5% and 15%

Classifications of soils in this report are based on visual field and/or laboratory observations, which include density/consistency, moisture condition, grain size, and plasticity estimates and should not be construed to imply field or laboratory testing unless presented herein. Visual-manual and/or laboratory classification methods of ASTM D-2487 and D-2488 were used as an identification guide for the Unified Soil Classification System.

log_key.dwg 03/29/00 1:1

ASSOCIATED EARTH SCIENCES, INC

Exploration Log Key

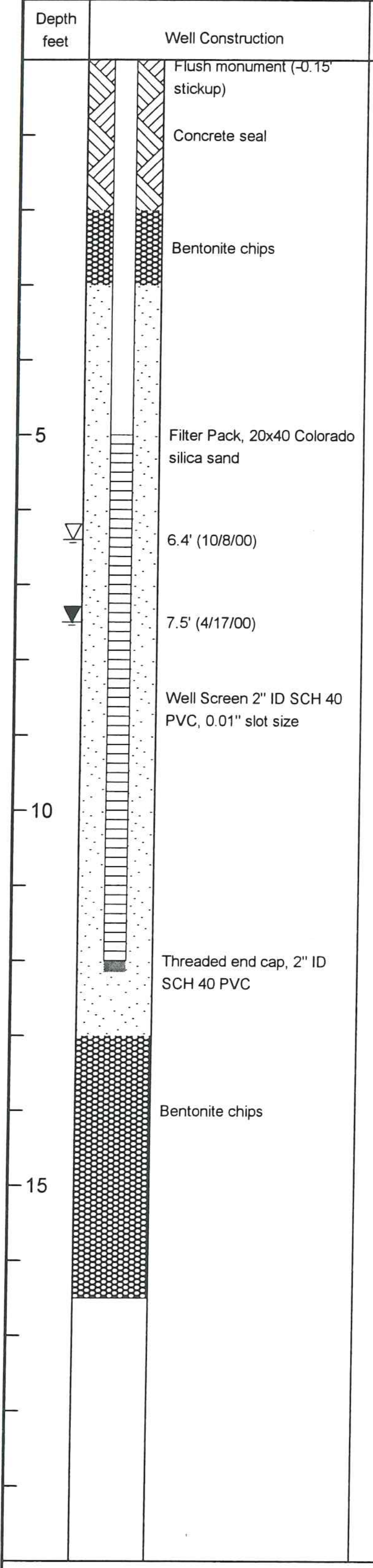
FIGURE
A-1

ASSOCIATED EARTH SCIENCES, INC

Geologic & Monitoring Well Construction Log

Project Number	Well Number	Sheet
BV99139	A-MW-1	1 of 1

Project Name: Holly Street Landfill
Location: Bellingham, Washington
Drilling Method: Hollow Stem Auger 8" OD/ 4.5"ID
Sampling Method: 2" diameter, Split Spoon Sampler
Surface Elevation: 21.51
Water Depth (ft bgs): 6.4
Start Date: April 17, 2000
Finish Date: April 17, 2000



Methane %	ST	Blows/ 6"	Sample ID
0	▨ ○	2 3 3	S-1
0.2	▨ ○	1 1 4	S-2
0	▨	2 4 4	S-3
	▨	2 4 5	S-4

Description

Asphalt

FILL

Moist, brown SILT with GRAVEL including steel and glass debris

Stiff, moist, brown and tan mottled SILT; trace sand, trace gravel, trace wood and glass

MUDFLAT DEPOSITS

Soft to medium stiff, wet, gray SILT over SILTY SAND; trace gravel, trace wood; sand fine to medium

-cobble

GLACIAL MARINE DRIFT

Stiff, wet, gray CLAYEY SILT

Bottom of boring at 16.5 feet.

Sampler Type (ST):
B Bag Sample
○ No Recovery
▨ 2" OD Split-Spoon Sampler

Lab Tests:
G - Grain Size
P - Permeability
M - Moisture Content

▼ Water Level (ATD) ▽ Static Water Level

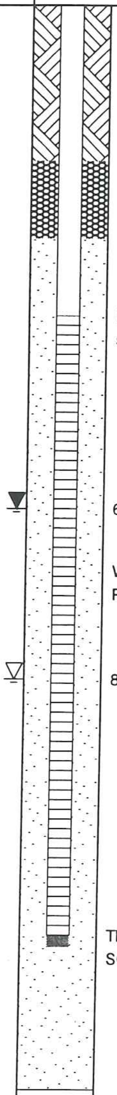
Logged by: RRH
Approved by: TJF
Figure No. A - 2

ASSOCIATED EARTH SCIENCES, INC

Geologic & Monitoring Well Construction Log

Project Number	Well Number	Sheet
BV99139	A-MW-2	1 of 1

Project Name: Holly Street Landfill
Location: Bellingham, Washington
Drilling Method: Hollow Stem Auger 8" OD/ 4.5"ID
Sampling Method: 2" diameter, Split Spoon Sampler
Surface Elevation: 19.57
Water Depth (ft bgs): 8.7
Start Date: April 18, 2000
Finish Date: April 18, 2000



Depth feet	Well Construction	Methane %		S T	Blows/ 6"	Sample ID	Description
	Flush monument (-0.02' stickup)						Asphalt
	Concrete seal						**FILL** Dark brown SILTY SAND with GRAVEL
							LANDFILL DEBRIS Medium dense, moist to wet, brown SANDY GRAVEL with glass, rusted metal, and ash-like material
	Bentonite chips	0.2		▨ ○	5 6 14	S-1	
	Filter Pack, 20x40 Colorado silica sand						-cobble or large piece of debris
5		0.4		○	14 15 7	S-2	
	▼ 6.5' (4/18/00)						
	Well Screen 2" ID SCH 40 PVC, 0.01" slot size	0.4		▨ ○	1 0.5 0.5	S-3	-grades loose, wet and gray
	▽ 8.7' (10/8/00)						
10		0.4		▨ ○	1 1 1	S-4	-grades black; debris includes glass and metal
	Threaded end cap, 2" ID SCH 40 PVC						
		0.2		▨ ○	4 5 7	S-5	**MUDFLAT DEPOSITS** Medium dense, wet, dark gray to brown SILTY SAND with SILT interbeds; sand predominantly fine
15							Bottom of boring at 14 feet.

Sampler Type (ST):
- B Bag Sample
- ○ No Recovery
- ▨ 2" OD Split-Spoon Sampler

▼ Water Level (ATD) ▽ Static Water Level

Lab Tests:
G - Grain Size
P - Permeability
M - Moisture Content

Logged by: RRH
Approved by: TJF
Figure No. A - 3

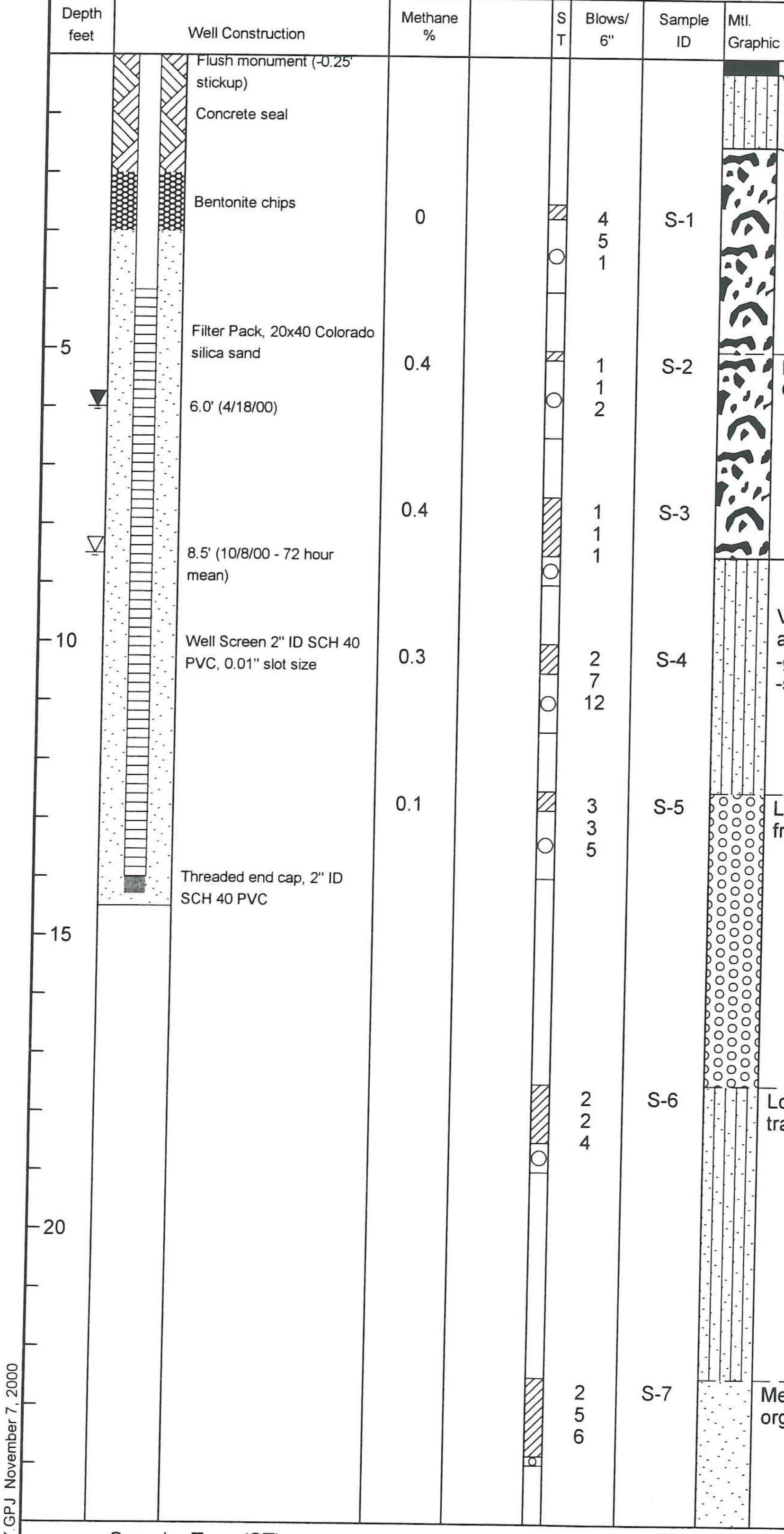
ASSOCIATED EARTH SCIENCES, INC

Geologic & Monitoring Well Construction Log

Project Number	Well Number	Sheet
BV99139	A-MW-3	1 of 2

Project Name Holly Street Landfill
Location Bellingham, Washington
Drilling Method Hollow Stem Auger 8" OD/ 4.5"ID
Sampling Method 2" diameter, Split Spoon Sampler

Surface Elevation 15.29
Water Depth (ft bgs) 8.5
Start Date April 18, 2000
Finish Date April 18, 2000



Methane %	Blows/ 6"	Sample ID
0	4 5 1	S-1
0.4	1 1 2	S-2
0.4	1 1 1	S-3
0.3	2 7 12	S-4
0.1	3 3 5	S-5
	2 2 4	S-6
	2 5 6	S-7

Description

Asphalt

FILL

Medium dense, moist, brown SILTY SAND with GRAVEL

LANDFILL DEBRIS

Loose, moist, dark brown SILT with SAND; with ash-like material, brick, and wood

Loose, moist to wet, dark brown to brown SILTY SAND with GRAVEL; trace glass, wood and ash-like material

MUDFLAT DEPOSITS

Very loose, wet, dark brown to black SILTY SAND; trace organics and shell fragments
-grades medium dense, dark gray; trace wood and gravel
-silt interbed

Loose, wet, dark gray GRAVEL with SAND; trace silt and shell fragments

Loose, wet, dark gray SILTY SAND with SILT interbeds to 2" thick; trace wood, organics and shell fragments

Medium dense, wet, gray SAND; few silt; silt interbeds; trace organics; sand predominantly fine to medium

Sampler Type (ST):
B Bag Sample
○ No Recovery
▨ 2" OD Split-Spoon Sampler

Lab Tests:
G - Grain Size
P - Permeability
M - Moisture Content

▼ Water Level (ATD) ▽ Static Water Level

Logged by: RRH
Approved by: TJF

Figure No. A - 4

ASSOCIATED EARTH SCIENCES, INC

Geologic & Monitoring Well Construction Log

Project Number	Well Number	Sheet
BV99139	A-MW-3	2 of 2

Project Name: Holly Street Landfill
Location: Bellingham, Washington
Drilling Method: Hollow Stem Auger 8" OD/ 4.5"ID
Sampling Method: 2" diameter, Split Spoon Sampler

Surface Elevation: 15.29
Water Depth (ft bgs): 8.5
Start Date: April 18, 2000
Finish Date: April 18, 2000

Depth feet	Well Construction	Methane %		S T	Blows/ 6"	Sample ID	Mtl. Graphic	Description
				▨ ○	4 5 7	S-8		-silty sand interbeds
30								
				▨ ○	4 5 8	S-9		-predominantly medium sand
35								
								GLACIAL MARINE DRIFT
				▨ ○	3 11 9	S-10		Very stiff, wet, gray CLAYEY SILT with 2" sand interbed
40								Bottom of boring at 39.5 feet. Original boring grouted with bentonite and cement. Moved 5 ft toward the creek and drilled to 14.5' with plug in auger then installed monitoring well
45								

Sampler Type (ST):
- B Bag Sample
- ○ No Recovery
- ▨ 2" OD Split-Spoon Sampler

Lab Tests:
- G - Grain Size
- P - Permeability
- M - Moisture Content

▼ Water Level (ATD) ▽ Static Water Level

Logged by: RRH
Approved by: TJF

Figure No. A - 4

Figure A-5
MW-1
Tidal Monitoring and Filtering

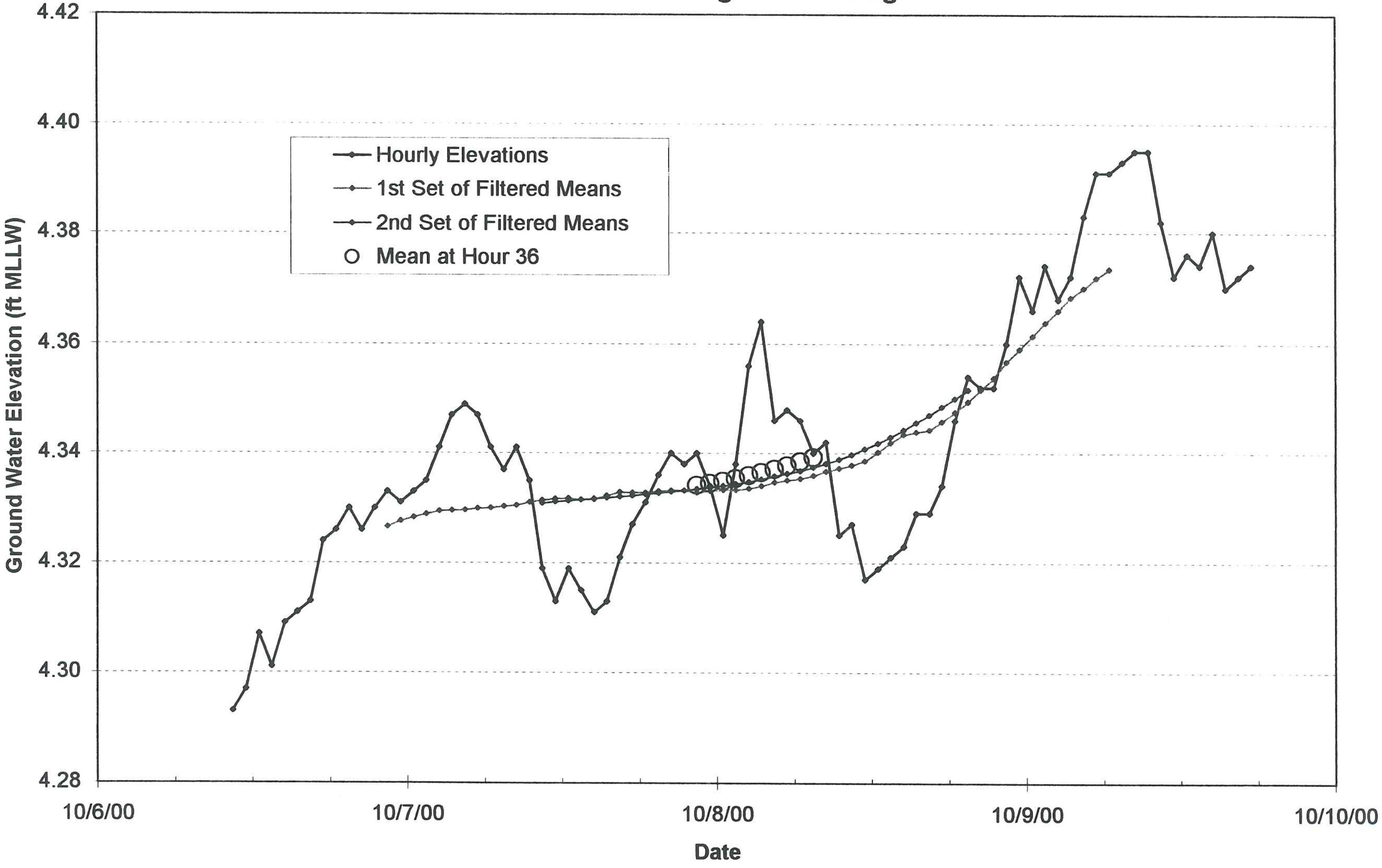


Figure A-6
MW-2
Tidal Monitoring and Filtering

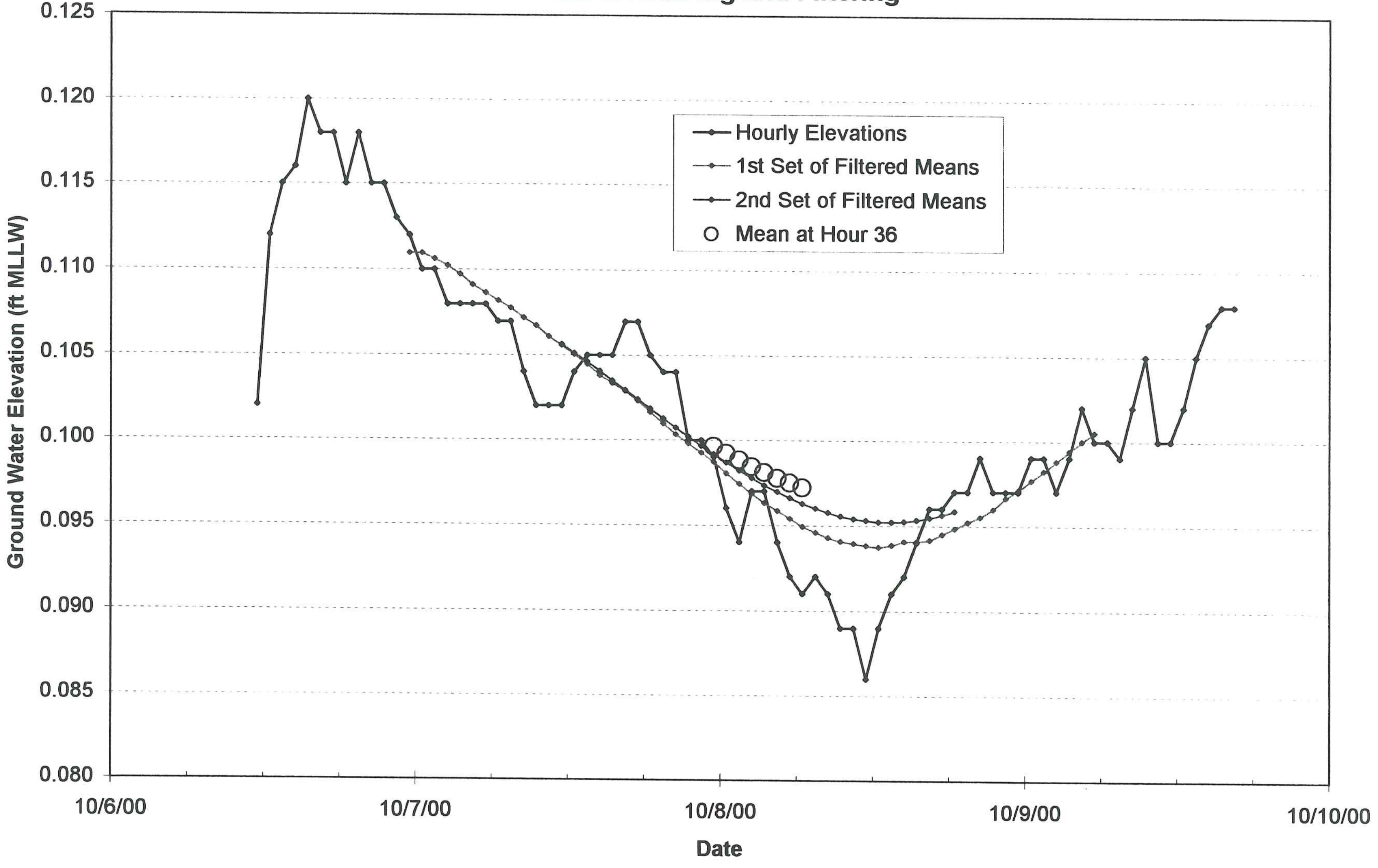
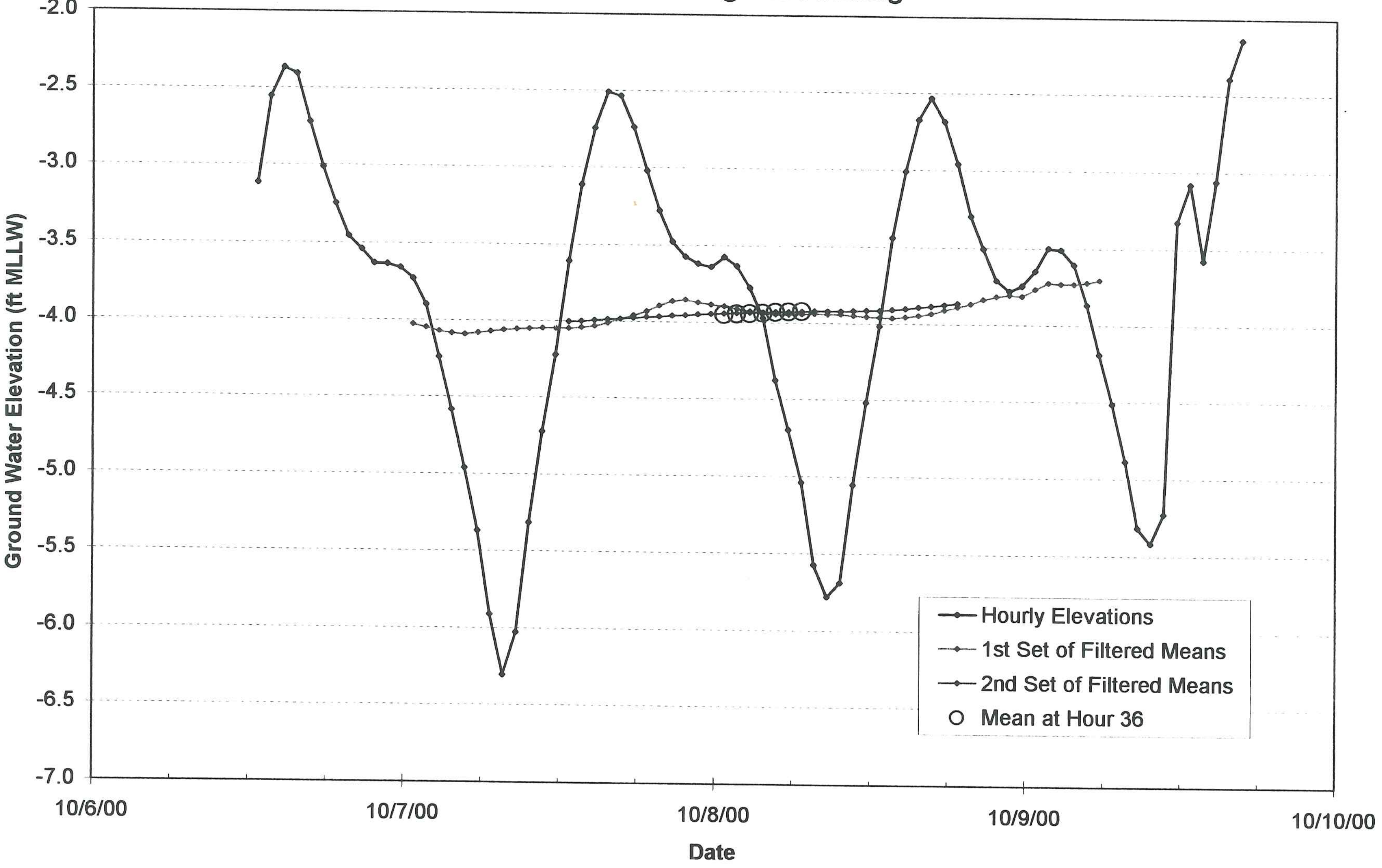
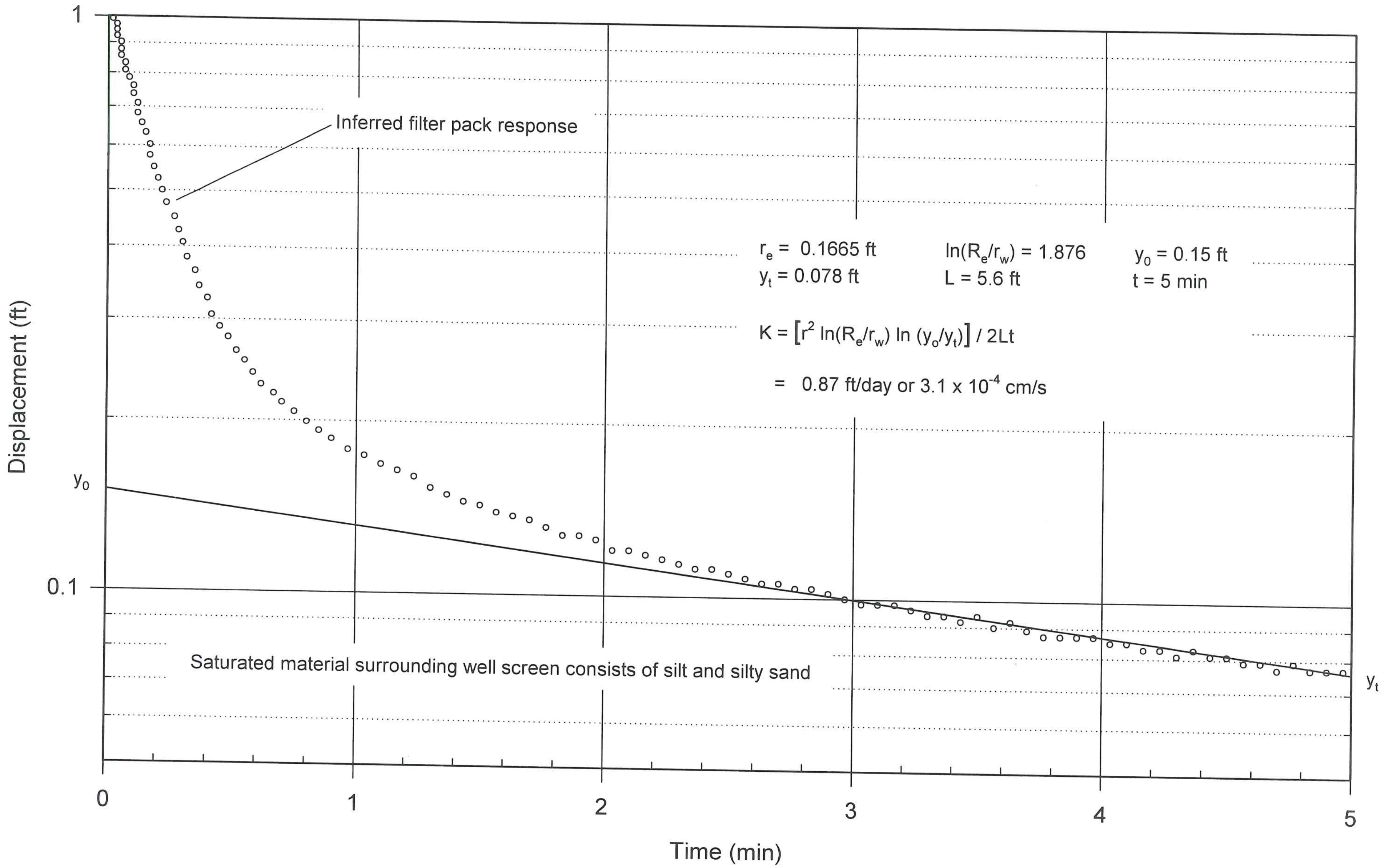


Figure A-7
MW-3
Tidal Monitoring and Filtering

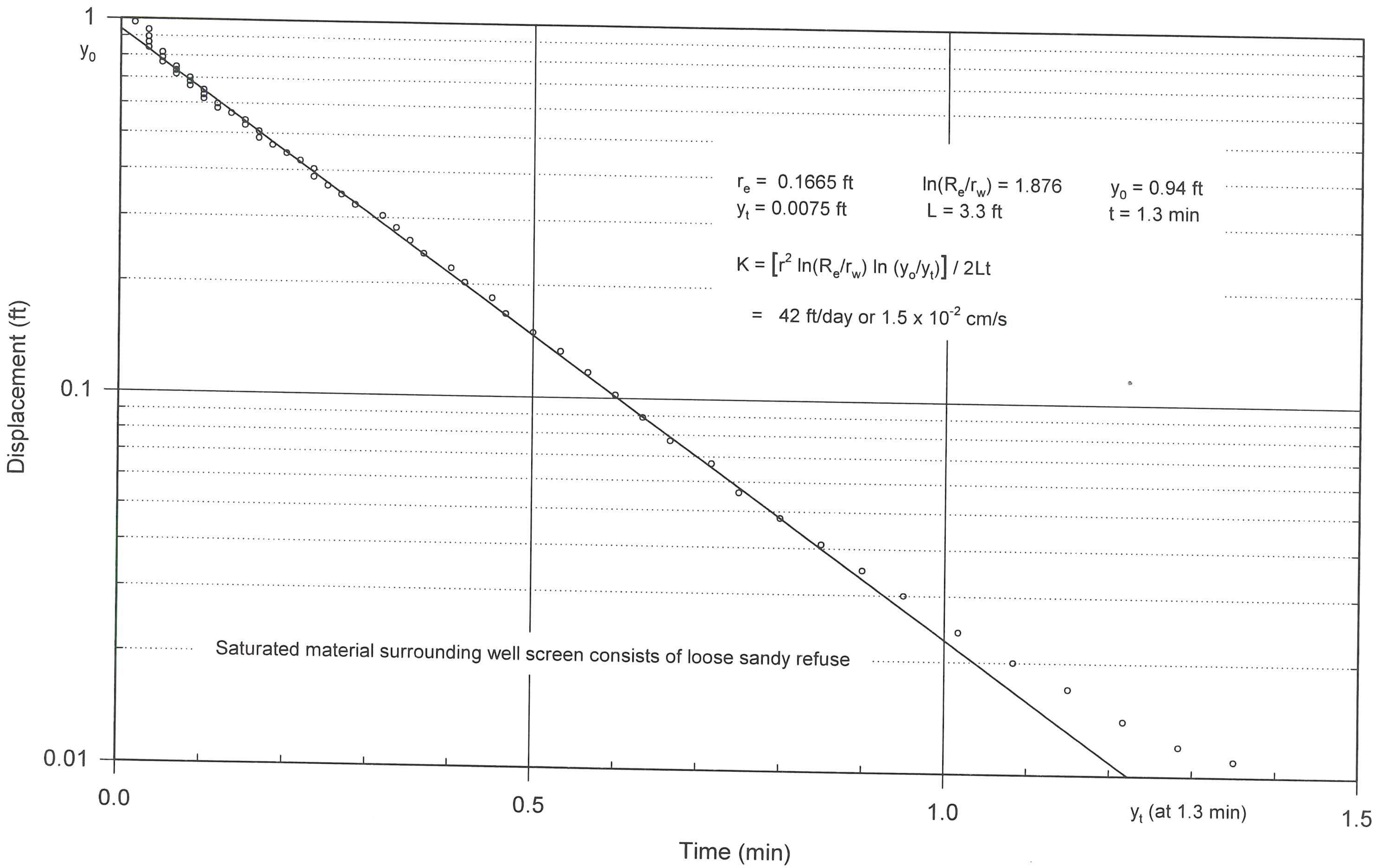




Associated Earth Sciences, Inc.

MW-1
Holly Street Landfill
Rising-Head Slug Test
Bouwer & Rice Analysis

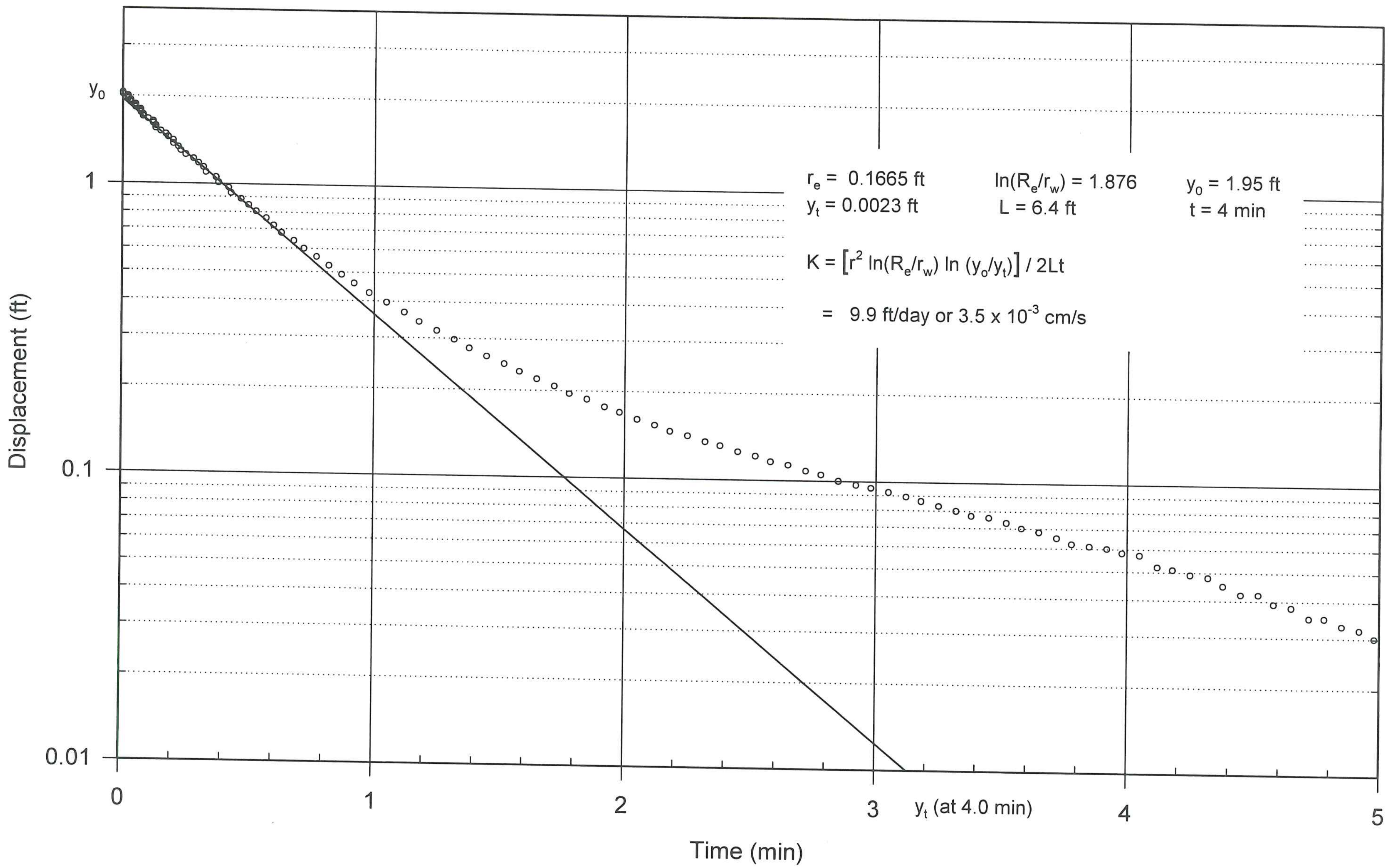
Figure
A-8



Associated Earth Sciences, Inc.

A-MW-2
Holly Street Landfill
Rising-Head Slug Test
Bouwer & Rice Analysis

Figure
A-9



r_e = 0.1665 ft
y_t = 0.0023 ft
$\ln(R_e/r_w)$ = 1.876
L = 6.4 ft
y_0 = 1.95 ft
t = 4 min

$K = \left[r^2 \ln(R_e/r_w) \ln(y_o/y_t)\right] / 2Lt$

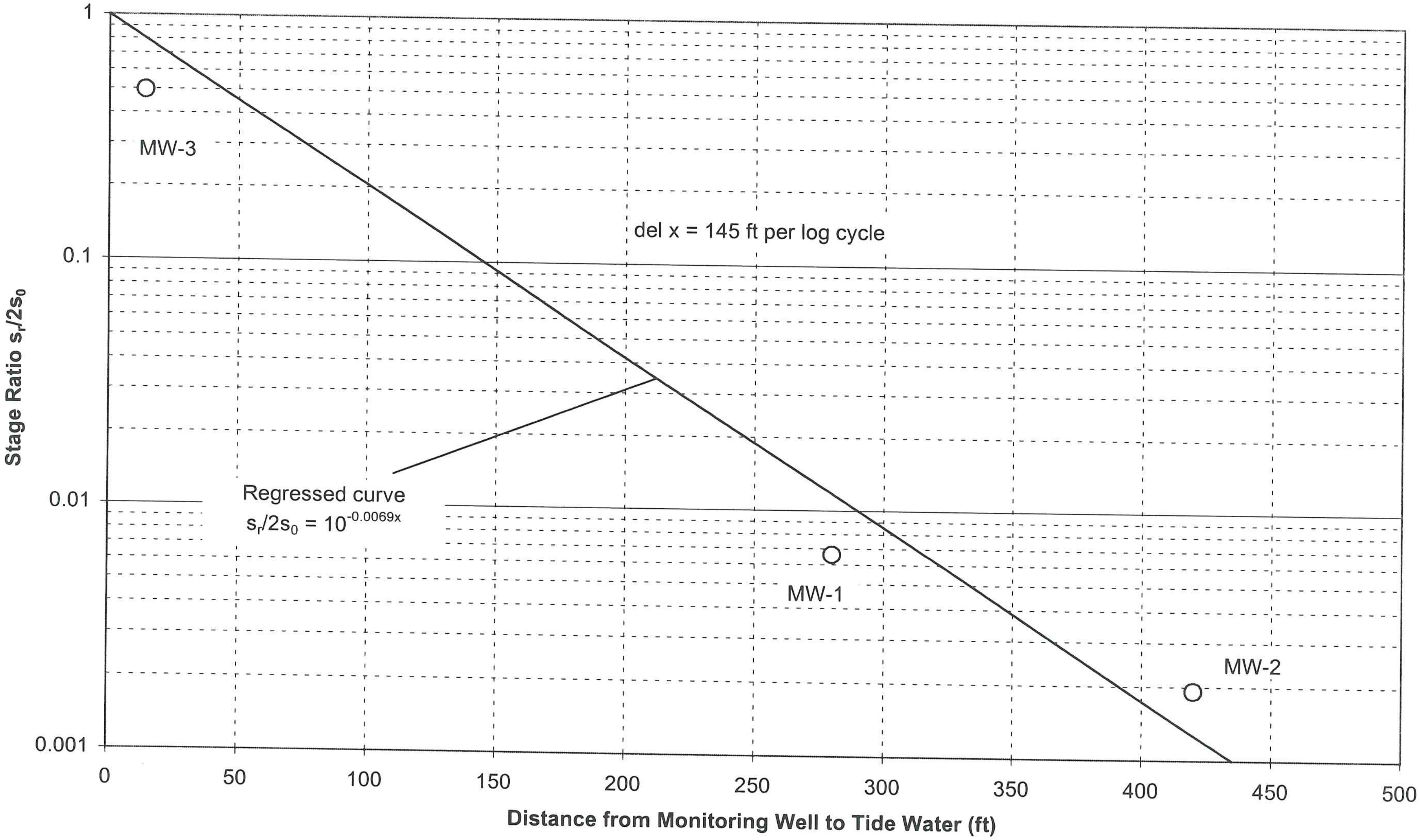
= 9.9 ft/day or 3.5 x 10^{-3} cm/s

Associated Earth Sciences, Inc.

A-MW-3
Holly Street Landfill
Rising-Head Slug Test
Bouwer & Rice Analysis

Figure
A-10

Figure A-11
Stage-Ratio Evaluation



ASSOCIATED EARTH SCIENCES, INC.

HollyStreetAquiferTest 11/7/00

FIELD REPORT

BEK ENGINEERING & ENVIRONMENTAL
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FAX: (360) 676-4625

BEK ENGINERING & ENVIRONMENTAL
2733 Colby Avenue
Everett, WA 98201
PH: (425) 258-2059
(800) 835-4971
FAX: (425) 258-5046

CLIENT: Anchor Environmental
PROJECT: Maritime Heritage Park
LOCATION: Bellingham, WA
FIELD REP: Ken Koenig

BEK JOB: 200195
REPORT: #1
DATE: 03-08-01
PAGE: 1 of 1

Weather Conditions: 50 degrees F, Rain, Slight Breeze, Barometric Pressure 30.16 in. Hg at Bellingham Airport.
On-Site: 1115
Off-Site: 1245

FIELD OBSERVATIONS / NOTES:

Onsite on March 8, 2001 to perform gas monitoring for methane in ground water monitoring wells AMW-4, AMW-5, and AMW-6. Depth to ground water, gas pressure, and percent methane were measured. Each well was equipped with a special 2-inch PVC expansion cap containing a 1/4-inch drilled hole prior to gas pressure and methane measurements. Gas pressure at the top of each monitoring well casing was measured by inserting the manometer tubing through the hole in the expansion cap, waiting for the gas pressure in the well to equilibrate, and recording the measurement. Methane gas concentrations were recorded in the same manner, except that the tubing was lowered to within 2 feet of the water table. A GMI Gas Surveyor Model 422 calibrated with 25% of the Lower Explosive Level (LEL) methane was used for gas measurements. Methane gas concentrations stabilized in less than one minute in each well. The combustibility meter was monitored for a period of approximately five minutes at each well, with no notable change in methane concentrations. The results are tabulated below.

Well	Casing (feet MSL)	DTW (feet BGS)	Elevation (feet MSL)	Pressure (in. water)	Methane Concentration
AMW-4	19.90	13.86	6.04	0.0	15% by volume (300% of the LEL)
AMW-5	20.00	14.47	5.53	0.0	58% LEL
AMW-6	32.53	23.94	8.59	0.0	35% LEL

Field Technician: Ken Koenig

Project Manager: Jon Einarsen

UNIFIED SOIL CLASSIFICATION CHART (USCS)

MAJOR DIVISIONS			LETTER SYMBOL	TYPICAL DESCRIPTIONS
COARSE GRAINED SOILS MORE THAN 50% OF MATERIAL IS LARGER THAN NO. 200 SIEVE SIZE	GRAVEL AND GRAVELLY SOILS MORE THAN 50% OF COARSE FRACTION RETAINED ON NO. 4 SIEVE	CLEAN GRAVELS (LITTLE OR NO FINES) <5%	GW	WELL-GRADED GRAVELS, GRAVEL-SAND MIXTURES, LITTLE OR NO FINES
			GP	POORLY-GRADED GRAVELS, GRAVEL-SAND MIXTURES, LITTLE OR NO FINES
		GRAVELS WITH FINES (APPRECIABLE AMOUNT OF FINES) >12%	GM	SILTY GRAVELS, GRAVEL-SAND-SILT MIXTURES
			GC	CLAYEY GRAVELS, GRAVEL-SAND-CLAY MIXTURES
	SAND AND SANDY SOILS MORE THAN 50% OF COARSE FRACTION PASSING NO. 4 SIEVE	CLEAN SANDS (LITTLE OR NO FINES) <5%	SW	WELL-GRADED SANDS, GRAVELLY SANDS, LITTLE OR NO FINES
			SP	POORLY-GRADED SANDS, GRAVELLY SANDS, LITTLE OR NO FINES
		SANDS WITH FINES (APPRECIABLE AMOUNT OF FINES) >12%	SM	SILTY SANDS, SAND-SILT MIXTURES
			SC	CLAYEY SANDS, SAND-CLAY MIXTURES
FINE GRAINED SOILS MORE THAN 50% OF MATERIAL IS SMALLER THAN NO. 200 SIEVE SIZE	SILTS AND CLAYS	LIQUID LIMIT LESS THAN 50	ML	INORGANIC SILTS AND VERY FINE SANDS, ROCK FLOUR, SILTY OR CLAYEY FINE SANDS OR CLAYEY SILTS WITH SLIGHT PLASTICITY
			CL	INORGANIC CLAYS OF LOW TO MEDIUM PLASTICITY, GRAVELLY CLAYS, SANDY CLAYS, SILTY CLAYS, LEAN CLAYS
			OL	ORGANIC SILTS AND ORGANIC SILTY CLAYS OF LOW PLASTICITY
	SILTS AND CLAYS	LIQUID LIMIT GREATER THAN 50	MH	INORGANIC SILTS, MICACEOUS OR DIATOMACEOUS FINE SAND OR SILTY SOILS
			CH	INORGANIC CLAYS OF HIGH PLASTICITY, FAT CLAYS
			OH	ORGANIC CLAYS OF MEDIUM TO HIGH PLASTICITY, ORGANIC SILTS
HIGHLY ORGANIC SOILS			PT	PEAT, HUMUS, SWAMP SOILS WITH HIGH ORGANIC CONTENTS

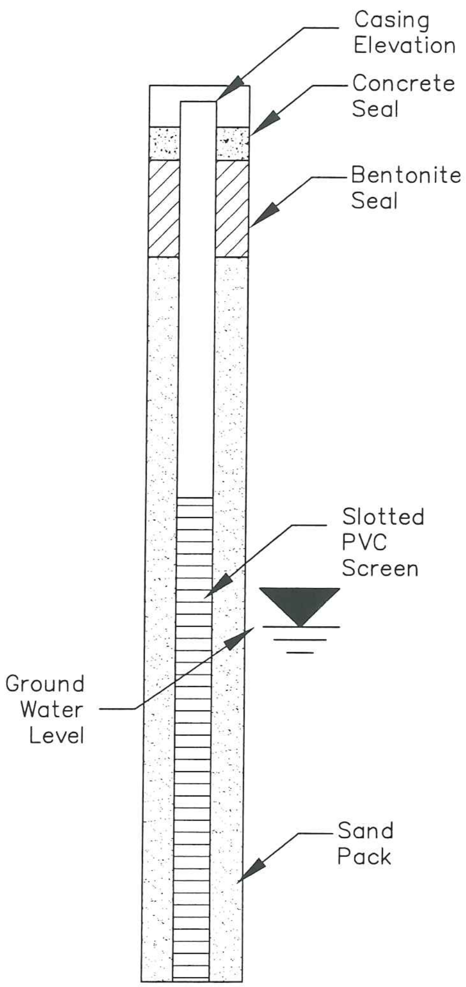
SOIL DESCRIPTIONS

Trace = 0–5%

Some = 5–12%

Gravelly
Sandy
Silty
Clayey } = 12–49%

KEY TO LOG OF WELLS



KEY TO LOG OF BORINGS

▯ SPT No recovery
☒ SPT Disturbed
▮ SPT Undisturbed
■ D&M Undisturbed
☒ D&M Disturbed
☐ D&M No recovery
● % Moisture
■ D&M 300# Hammer Blows/Ft.
▲ SPT 140# Hammer Blows/Ft.
▼ Static Water Level

JOB NO.: N/A
DESIGNED BY/DRAWN BY: KRK
CHECKED BY: TEB
DWG FILE: USCS KEY TO WELLS

BEK ENGINEERING &
ENVIRONMENTAL, INC.

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Bellingham, WA 98225
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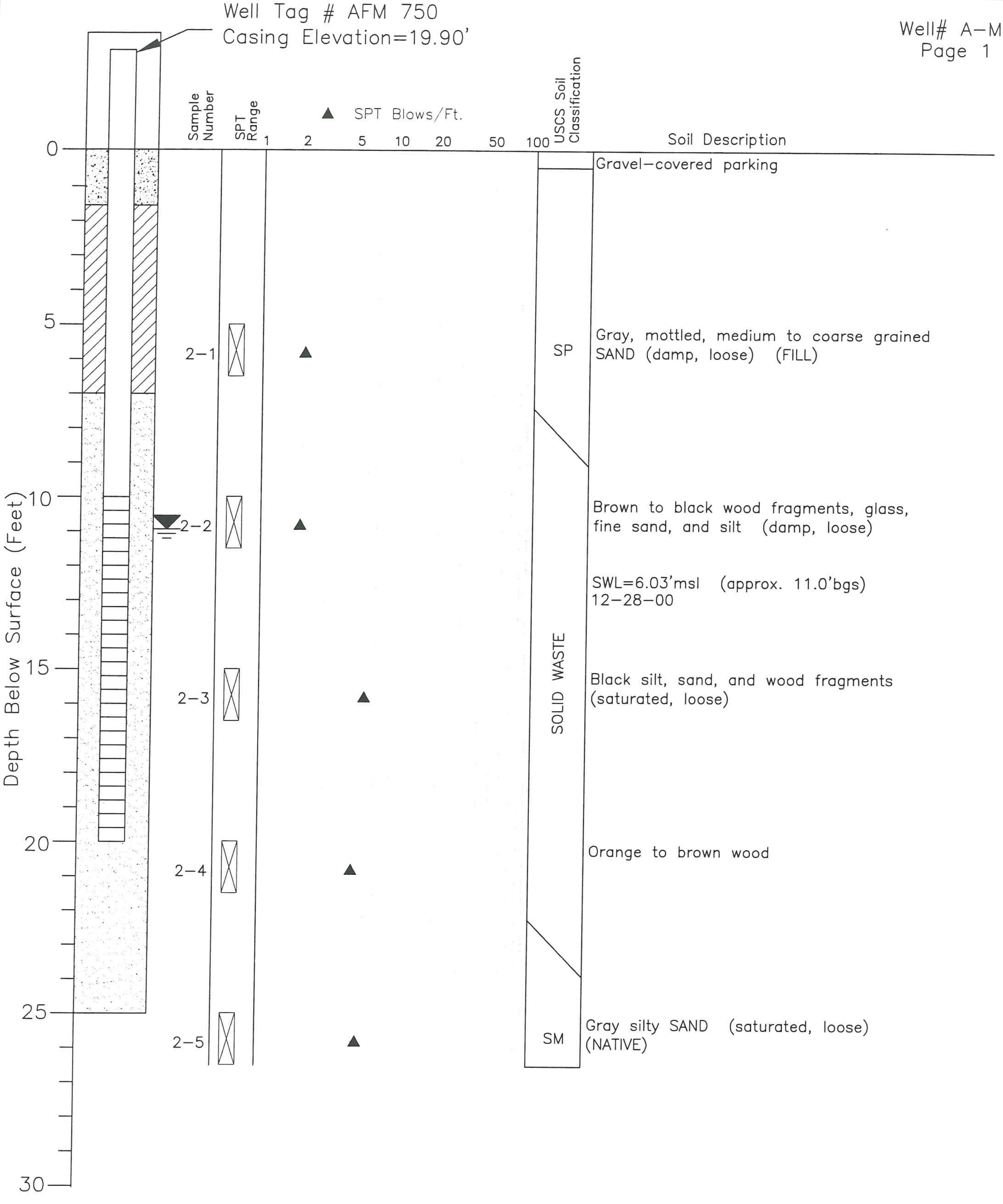
Ph: (800) 859-5597
Fax: (360) 676-4625

KEY TO WELL LOGS & UNIFIED SOILS CLASSIFICATION SYSTEM

DATE: N/A
SCALE: H: N/A V: N/A

Well# A-MW-4
Page 1 of 1



Gravel-covered parking

Gray, mottled, medium to coarse grained SAND (damp, loose) (FILL)

Brown to black wood fragments, glass, fine sand, and silt (damp, loose)

SWL=6.03'msl (approx. 11.0'bgs)
12-28-00

Black silt, sand, and wood fragments (saturated, loose)

Orange to brown wood

Gray silty SAND (saturated, loose) (NATIVE)

LOGGED BY: KRK
DRILLER: Gregory Drilling
DRILLING METHOD: HSA
SAMPLING METHOD: STP
CASING TYPE: PVC
ANNULAR PACK: 10/20 Sand
SLOT SIZE: 10 slot

HAMMER SIZE: 140 lb. /30" drop AutoHammer
DATE DRILLED: December 28, 2000
HOLE DIAMETER: 6.25-Inch
HOLE DEPTH: 25'
WELL DIAMETER: 2"
WELL DEPTH: 20'
LOCATION: see drawing

See Site Plan for actual location

Soils classified visually using the Unified Soils Classification System

JOB NO.: 200195
DESIGNED BY/DRAWN BY: KRK
CHECKED BY: JME
DWG FILE: WELL LOGS.DWG

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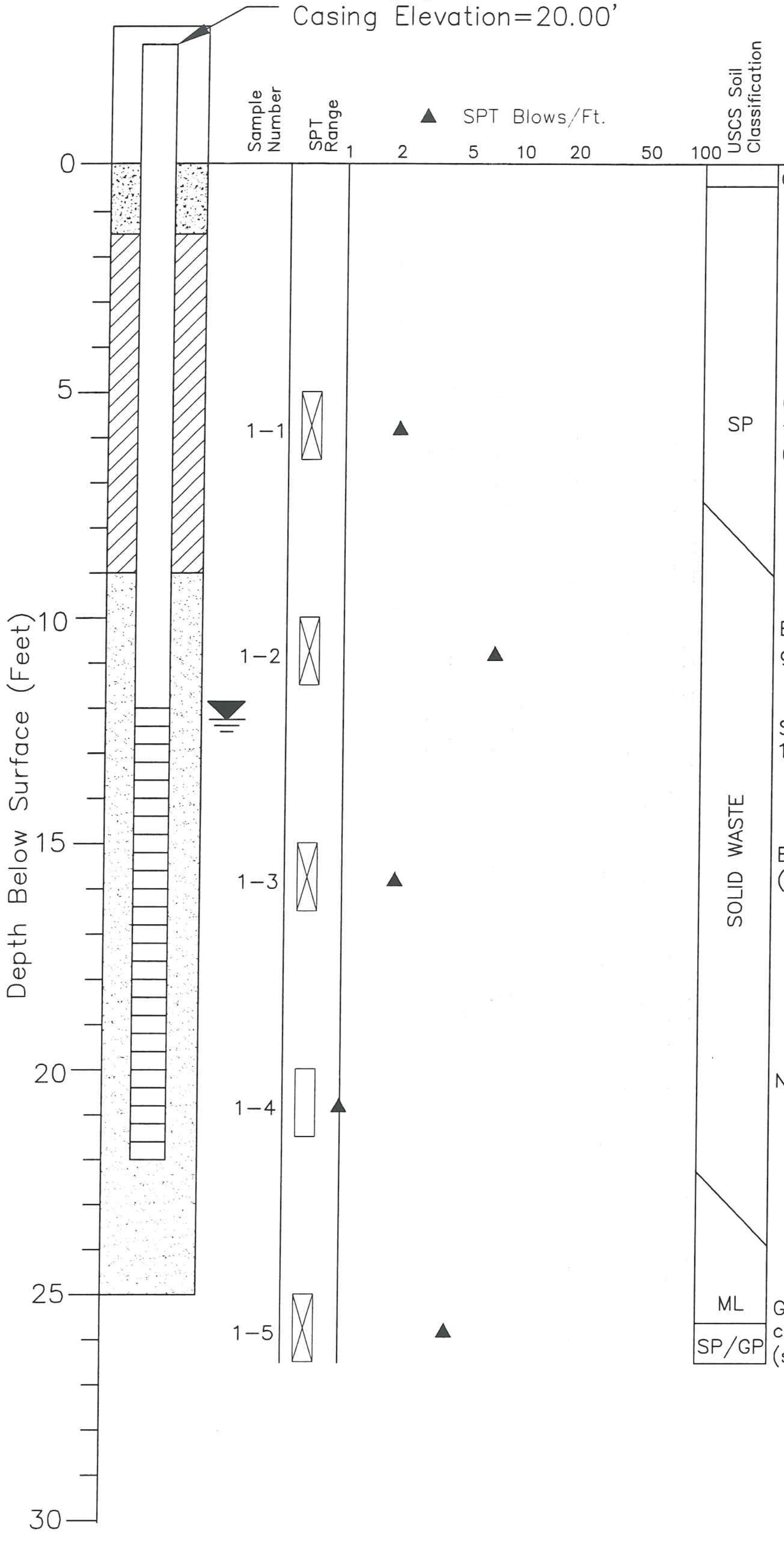
Ph: (800) 859-5597
Fax: (360) 676-4625

MONITORING WELL # A-MW-4
MARITIME HERITAGE PARK
BELLINGHAM, WASHINGTON

DATE: DECEMBER 28, 2000
SCALE: H: N/A V: N/A

Well# A-MW-5
Page 1 of 1

Well Tag # AFM 749
Casing Elevation=20.00'



Soil Description

Gravel-covered parking

Gray medium to coarse grained SAND with trace wood fragments (damp, loose) (FILL)

Brown to black wood, fine sand, silt, and glass fragments (damp, loose)

SWL=5.02'msl (approx. 12.2'bgs)
12-28-00

Black silt, sand and wood fragments (saturated, loose)

No recovery

Gray SILT w/ trace sand, grades to coarse sand to poorly-graded gravel (saturated, loose) (NATIVE)

LOGGED BY: JME	HAMMER SIZE: 140 lb. /30" drop AutoHammer
DRILLER: Gregory Drilling	DATE DRILLED: December 28, 2000
DRILLING METHOD: HSA	HOLE DIAMETER: 6.25-Inch
SAMPLING METHOD: STP	HOLE DEPTH: 25'
CASING TYPE: PVC	WELL DIAMETER: 2"
ANNULAR PACK: 10/20 Sand	WELL DEPTH: 22'
SLOT SIZE: 10 slot	LOCATION: see drawing

See Site Plan for actual location

Soils classified visually using the Unified Soils Classification System

JOB NO.:	200195
DESIGNED BY/DRAWN BY:	KRK
CHECKED BY:	JME
DWG FILE:	WELL LOGS.DWG

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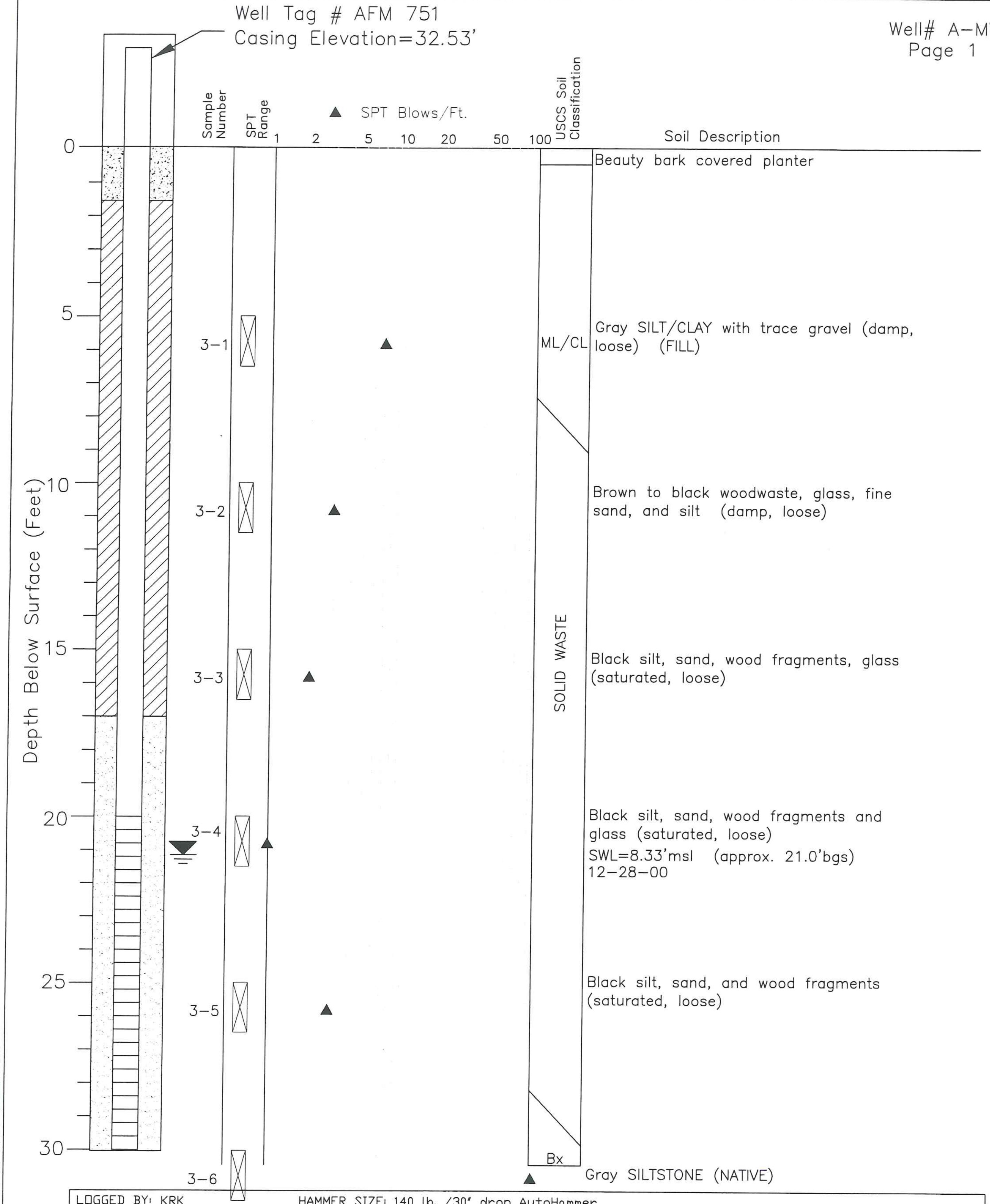
MONITORING WELL # A-MW-5
MARITIME HERITAGE PARK
BELLINGHAM, WASHINGTON

DATE: DECEMBER 28, 2000 SCALE: H: N/A V: N/A

Well# A-MW-6
Page 1 of 1



Beauty bark covered planter

Gray SILT/CLAY with trace gravel (damp, loose) (FILL)

Brown to black woodwaste, glass, fine sand, and silt (damp, loose)

Black silt, sand, wood fragments, glass (saturated, loose)

Black silt, sand, wood fragments and glass (saturated, loose)
SWL=8.33'msl (approx. 21.0'bgs)
12-28-00

Black silt, sand, and wood fragments (saturated, loose)

Gray SILTSTONE (NATIVE)

LOGGED BY: KRK
DRILLER: Gregory Drilling
DRILLING METHOD: HSA
SAMPLING METHOD: STP
CASING TYPE: PVC
ANNULAR PACK: 10/20 Sand
SLOT SIZE: 10 slot

HAMMER SIZE: 140 lb. /30" drop AutoHammer
DATE DRILLED: December 28, 2000
HOLE DIAMETER: 6.25-Inch
HOLE DEPTH: 30'
WELL DIAMETER: 2"
WELL DEPTH: 30'
LOCATION: see drawing

See Site Plan for actual location

Soils classified visually using the Unified Soils Classification System

JOB NO.: 200195
DESIGNED BY/DRAWN BY: KRK
CHECKED BY: JME
DWG FILE: WELL LOGS.DWG

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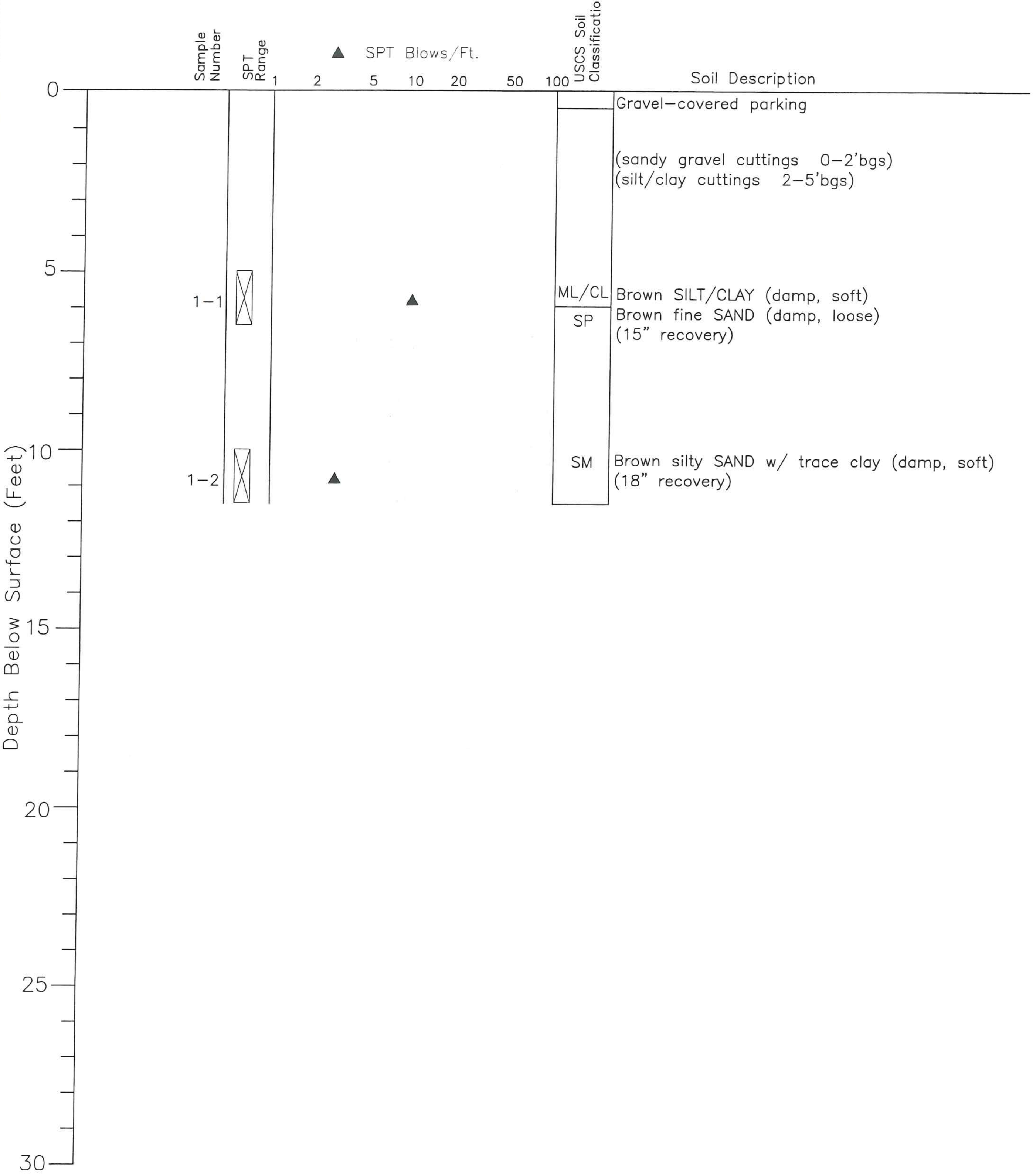
Ph: (800) 859-5597
Fax: (360) 676-4625

MONITORING WELL # A-MW-6
MARITIME HERITAGE PARK
BELLINGHAM, WASHINGTON

DATE: DECEMBER 28, 2000
SCALE: H: N/A V: N/A

Boring# B–1
Page 1 of 1



LOGGED BY: JME
DRILLER: Gregory Drilling
DRILLING METHOD: HSA
SAMPLING METHOD: STP
CASING TYPE: n/a
ANNULAR PACK: n/a
SLOT SIZE: n/a

HAMMER SIZE: 140 lb. /30" drop AutoHammer
DATE DRILLED: December 29, 2000
HOLE DIAMETER: 6.25-Inch
HOLE DEPTH: 10.0'
WELL DIAMETER: n/a
WELL DEPTH: n/a
LOCATION: see drawing

See Site Plan for actual location

Soils classified visually using the Unified Soils Classification System

JOB NO.:	200195
DESIGNED BY/DRAWN BY:	KRK
CHECKED BY:	JME
DWG FILE:	WELL LOGS.DWG

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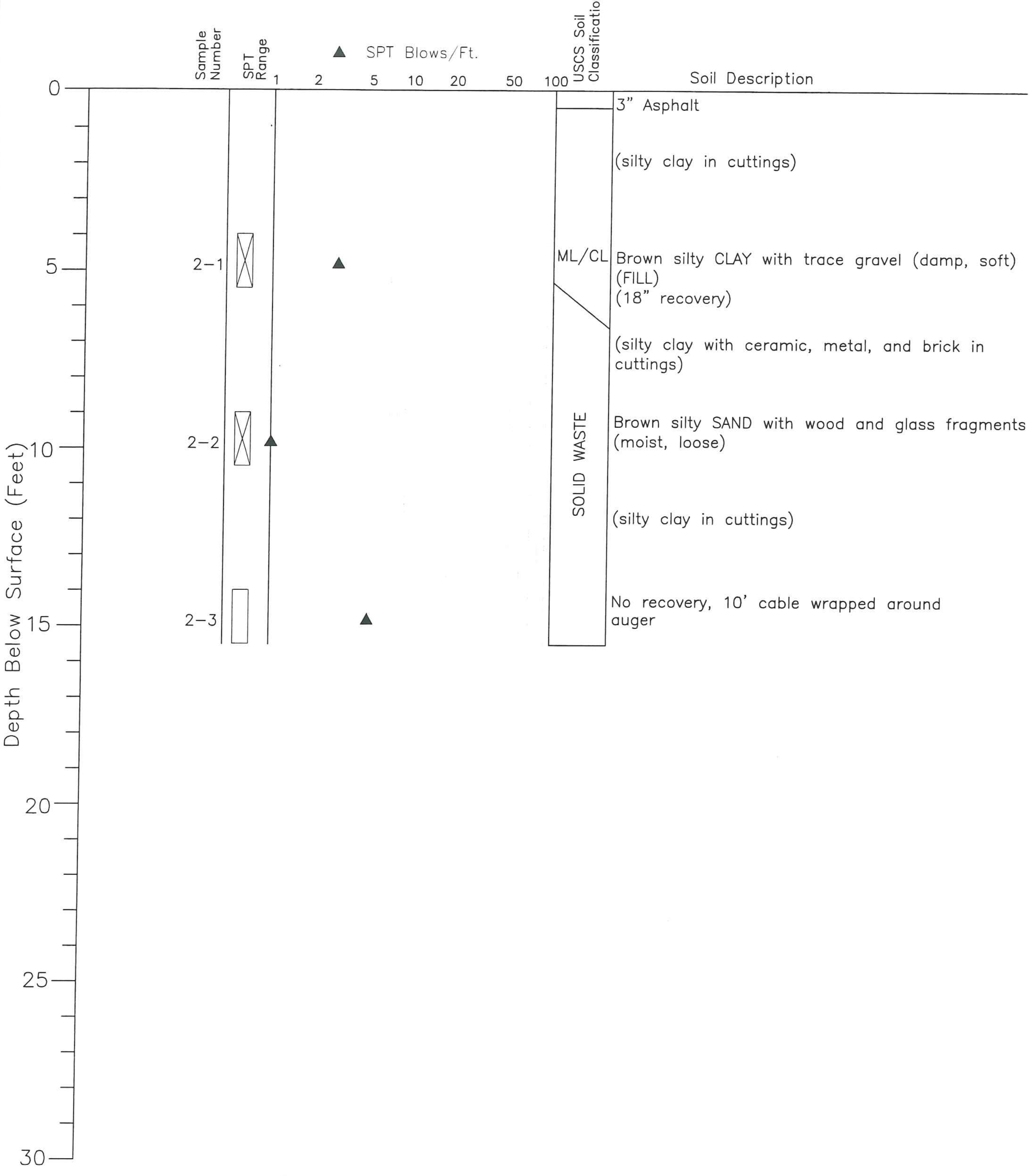
Fax: (360) 676-4625

EXPLORATORY BORING # A-BI
MARITIME HERITAGE PARK
BELLINGHAM, WASHINGTON

DATE: DECEMBER 29, 2000 SCALE: H: N/A V: N/A

Boring# B-2
Page 1 of 1



3" Asphalt

(silty clay in cuttings)

Brown silty CLAY with trace gravel (damp, soft) (FILL)
(18" recovery)

(silty clay with ceramic, metal, and brick in cuttings)

Brown silty SAND with wood and glass fragments (moist, loose)

(silty clay in cuttings)

No recovery, 10' cable wrapped around auger

LOGGED BY: JME
DRILLER: Gregory Drilling
DRILLING METHOD: HSA
SAMPLING METHOD: STP
CASING TYPE: n/a
ANNULAR PACK: n/a
SLOT SIZE: n/a

HAMMER SIZE: 140 lb. /30" drop AutoHammer
DATE DRILLED: December 29, 2000
HOLE DIAMETER: 6.25-inch
HOLE DEPTH: 14.0'
WELL DIAMETER: n/a
WELL DEPTH: n/a
LOCATION: see drawing

See Site Plan for actual location

Soils classified visually using the Unified Soils Classification System

JOB NO.:	200195
DESIGNED BY/DRAWN BY:	KRK
CHECKED BY:	JME
DWG FILE:	WELL LOGS.DWG

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ENVIRONMENTAL
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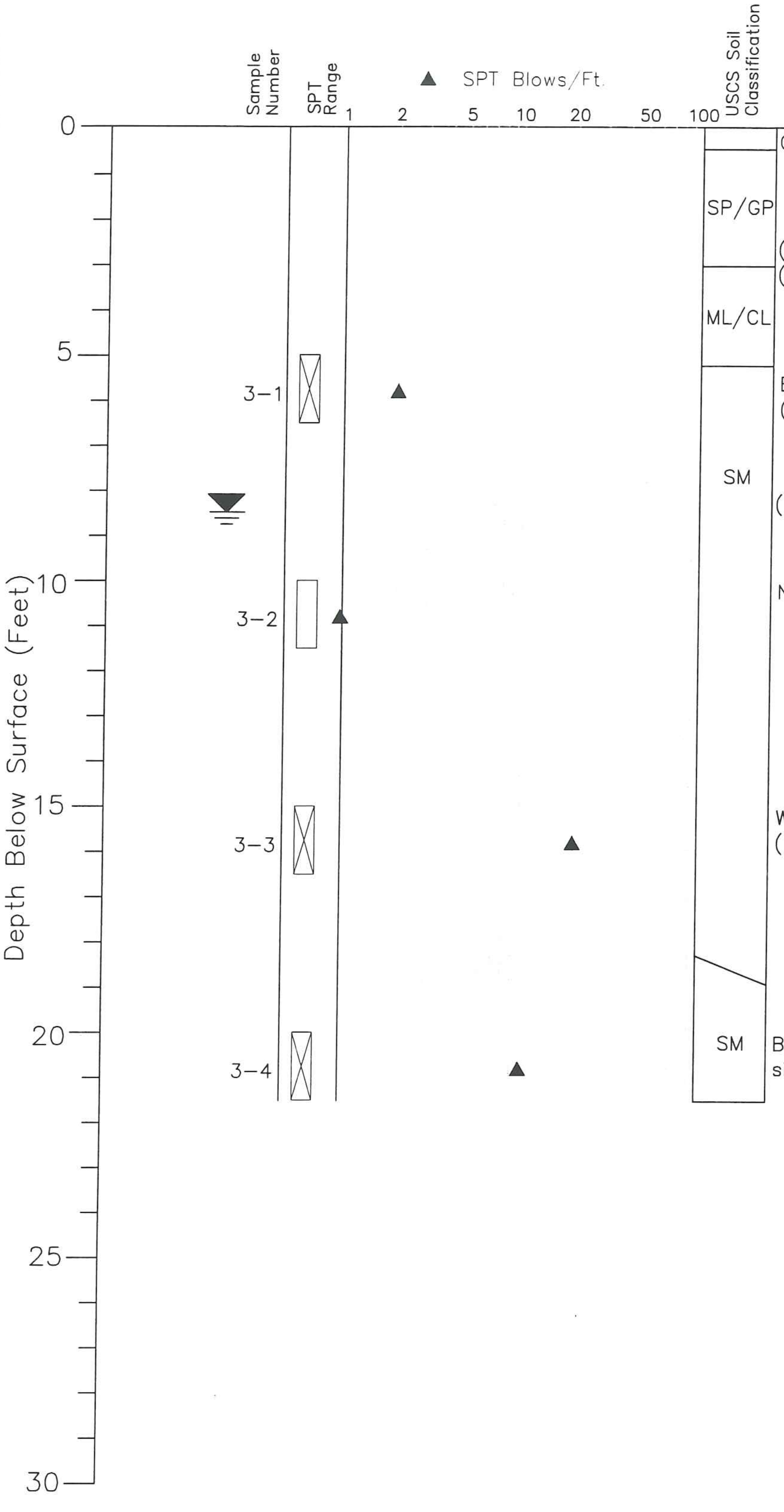
EXPLORATORY BORING # A-B2
MARITIME HERITAGE PARK
BELLINGHAM, WASHINGTON

DATE: DECEMBER 29, 2000
SCALE: H: N/A V: N/A

Boring# B-3
Page 1 of 1



Soil Description

Gravel-covered parking

(sand & gravel in cuttings from 0-3'bgs)
(brown silty clay in cuttings from 3-5'bgs)

Brown grading to blue gray silty SAND (moist, loose)
(18" recovery)

(Blue-gray silty sand in cuttings, groundwater at 8.5'bgs)

No recovery

WOOD
(Buried piling or driftwood?)

Blue-gray fine grained SAND with trace
silt and gravel (medium dense, saturated)

LOGGED BY: JME
DRILLER: Gregory Drilling
DRILLING METHOD: HSA
SAMPLING METHOD: STP
CASING TYPE: n/a
ANNULAR PACK: n/a
SLOT SIZE: n/a

HAMMER SIZE: 140 lb. /30" drop AutoHammer
DATE DRILLED: December 29, 2000
HOLE DIAMETER: 6.25-inch
HOLE DEPTH: 20.0'
WELL DIAMETER: n/a
WELL DEPTH: n/a
LOCATION: see drawing

See Site Plan for actual location

Soils classified visually using the Unified Soils Classification System

JOB NO.: 200195
DESIGNED BY/DRAWN BY: KRK
CHECKED BY: JME
DWG FILE: WELL LOGS.DWG

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EXPLORATORY BORING # A-B3
MARITIME HERITAGE PARK
BELLINGHAM, WASHINGTON

DATE: DECEMBER 29, 2000
SCALE: H: N/A V: N/A

Report

Geotechnical and Environmental Services Proposed Parking Lot Development Bellingham, Washington

August 30, 2001

For

City of Bellingham Parks Department

SOIL CLASSIFICATION SYSTEM

MAJOR DIVISIONS			GROUP SYMBOL	GROUP NAME
COARSE GRAINED SOILS More Than 50% Retained on No. 200 Sieve	GRAVEL More Than 50% of Coarse Fraction Retained on No. 4 Sieve	CLEAN GRAVEL	GW	WELL-GRADED GRAVEL, FINE TO COARSE GRAVEL
			GP	POORLY-GRADED GRAVEL
		GRAVEL WITH FINES	GM	SILTY GRAVEL
			GC	CLAYEY GRAVEL
	SAND More Than 50% of Coarse Fraction Passes No. 4 Sieve	CLEAN SAND	SW	WELL-GRADED SAND, FINE TO COARSE SAND
			SP	POORLY-GRADED SAND
		SAND WITH FINES	SM	SILTY SAND
			SC	CLAYEY SAND
FINE GRAINED SOILS More Than 50% Passes No. 200 Sieve	SILT AND CLAY Liquid Limit Less Than 50	INORGANIC	ML	SILT
			CL	CLAY
		ORGANIC	OL	ORGANIC SILT, ORGANIC CLAY
	SILT AND CLAY Liquid Limit 50 or More	INORGANIC	MH	SILT OF HIGH PLASTICITY, ELASTIC SILT
			CH	CLAY OF HIGH PLASTICITY, FAT CLAY
		ORGANIC	OH	ORGANIC CLAY, ORGANIC SILT
HIGHLY ORGANIC SOILS			PT	PEAT

NOTES:

1. Field classification is based on visual examination of soil in general accordance with ASTM D2488-90.
2. Soil classification using laboratory tests is based on ASTM D2487-90.
3. Descriptions of soil density or consistency are based on interpretation of blow count data, visual appearance of soils, and/or test data.

SOIL MOISTURE MODIFIERS:

Dry -	Absence of moisture, dusty, dry to the touch
Moist -	Damp, but no visible water
Wet -	Visible free water or saturated, usually soil is obtained from below water table

GeoEngineers

SOIL CLASSIFICATION SYSTEM

FIGURE A-1

LABORATORY TESTS:

CA	Chemical Analysis

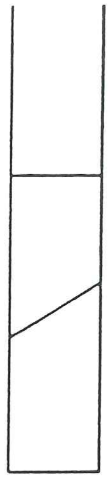
FIELD SCREENING TESTS:

Headspace vapor concentration data given in parts per million

Sheen classification system:

NS	No Visible Sheen
SS	Slight Sheen
MS	Moderate Sheen
HS	Heavy Sheen
NT	Not Tested

SOIL GRAPH:



SM	Soil Group Symbol (See Note 2)
	Distinct Contact Between Soil Strata
	Gradual or Approximate Location of Change Between Soil Strata
∇	Water Level
	Bottom of Boring

BLOW COUNT/SAMPLE DATA:

Blows required to drive a 2.4-inch I.D. split-barrel sampler 12 inches or other indicated distances using a 300-pound hammer falling 30 inches.

22 ■	Location of relatively undisturbed sample
12 ☒	Location of disturbed sample
17 ☐	Location of sampling attempt with no recovery

Blows required to drive a 1.5-inch I.D. (SPT) split-barrel sampler 12 inches or other indicated distances using a 140-pound hammer falling 30 inches.

10 ◧	Location of sample obtained in general accordance with Standard Penetration Test (ASTM D 1586) procedures
26 ◫	Location of SPT sampling attempt with no recovery
▤	Location of grab sample

"P" indicates sampler pushed with weight of hammer or against weight of drill rig.

NOTES:

1. The reader must refer to the discussion in the report text, the Key to Boring Log Symbols and the exploration logs for a proper understanding of subsurface conditions.
2. Soil classification system is summarized in Figure A-1.

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KEY TO BORING LOG SYMBOLS

FIGURE A-2

Project City of Bellingham Parks	Job Number 3125-010-00	Location Bellingham, Washington

Date Drilled	04/19/01	Logged By	MRS	Contractor	Holt
Drill Method	Hollow Stem Auger	Equipment	Mobile Drill B-61	Drill Bit	
Sample Method	D&M	Hammer Data	300lb hammer, 30" drop	X-coordinate: Y-coordinate:	Not Determined Not Determined
Total Depth (ft)	14	Elevation (ft)	Not Measured	Datum: System:	

DEPTH IN FEET	% Recovery	Sample No.	Blow Count	Sample	Graphic Log	USCS Group Symbol	Material Description	Moisture Content (%)	Dry Unit Weight (pcf)	Other Tests And Notes	DEPTH IN FEET
0						AC	1.5 inches asphalt concrete				0
						SP	2 inches brown fine to medium sand with gravel (dense, moist) (fill)				
						ML	Brown fine sandy silt with occasional gravel (soft, moist) (fill)				
	44	1	4	☒				23			
5											5
	67	2	6	☒			Sandstone fragment in sample	27			
	67	3	4	☒			Wood debris in sample	19			
10						ML	Brown fine sandy silt with coarse sand and gravel (soft, moist) (fill?)				10
	100	4	4	☒				37			
						CL	Gray fine sandy clay with occasional gravel and root hairs (soft, moist)				
	100	5	4	☒				29			
							Boring completed at 14.0 feet below ground surface on 04/19/01 No ground water encountered during drilling				
15											15
20											20
25											25
30											30
35											35

Note: See Figure A-2 for explanation of symbols

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LOG OF BORING PL-1

FIGURE A-3

Project City of Bellingham Parks	Job Number 3125-010-00	Location Bellingham, Washington

Date Drilled	04/19/01	Logged By	MRS	Contractor	Holt
Drill Method	Hollow Stem Auger	Equipment	Mobile Drill B-61	Drill Bit	
Sample Method	D&M	Hammer Data	300lb hammer, 30" drop	X-coordinate: Y-coordinate:	Not Determined Not Determined
Total Depth (ft)	9	Elevation (ft)	Not Measured	Datum: System:	

DEPTH IN FEET	% Recovery	Sample No.	Blow Count	Sample	USCS Group Symbol	Material Description	Moisture Content (%)	Dry Unit Weight (pcf)	Other Tests And Notes	DEPTH IN FEET
0					AC	2 inches asphalt concrete				0
					SP	Brown fine to medium sand with gravel (dense, moist) (fill)				
	100	1	5	■	CL	Gray and brown fine sandy clay with coarse sand and gravel (soft to medium stiff, moist) (fill) Note: piece of rubber material in sample	25			
5	67	2	5	■	ML	Brown and gray fine to medium sandy silt with coarse sand and occasional gravel (soft to medium stiff, moist) (fill)	22			5
	67	3	3	■	CL	Gray fine sandy clay with medium sand and gravel (soft, moist)	23			
						Boring completed at 9.0 feet below ground surface on 04/19/01 No ground water encountered during drilling				
10										10
15										15
20										20
25										25
30										30
35										35

Note: See Figure A-2 for explanation of symbols

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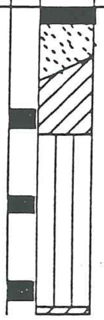
LOG OF BORING PL-2

FIGURE A-4

Project City of Bellingham Parks	Job Number 3125-010-00	Location Bellingham, Washington

Date Drilled	04/19/01	Logged By	MRS	Contractor	Holt
Drill Method	Hollow Stem Auger	Equipment	Mobile Drill B-61	Drill Bit	
Sample Method	D&M	Hammer Data	300lb hammer, 30" drop	X-coordinate: Y-coordinate:	Not Determined Not Determined
Total Depth (ft)	9	Elevation (ft)	Not Measured	Datum: System:	



DEPTH IN FEET	% Recovery	Sample No.	Blow Count	USCS Group Symbol	Material Description	Moisture Content (%)	Dry Unit Weight (pcf)	Other Tests And Notes
0				AC	4 inches asphalt concrete			
				SP	Brown fine to medium sand with coarse sand and gravel (dense, moist) (fill)			
				CL	Gray fine sandy clay with sand and occasional organic matter (medium stiff, moist) (fill)			
	89	1	6					Slight petroleum odor
				ML	Brown, dark brown and gray fine sandy silt with occasional sand (medium stiff, moist) (fill) Wood and ash debris at 4.0 feet			
5	56	2	8					
	78	3	8					
				CL	Gray fine sandy clay with occasional small burnt and unburnt wood fragments and fine gravel (medium stiff, moist) (fill) Concrete pieces at 9.0 feet			
10					Boring completed at 9.0 feet below ground surface on 04/19/01 No ground water encountered during drilling			
15								
20								
25								
30								
35								

Note: See Figure A-2 for explanation of symbols

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LOG OF BORING PL-3

FIGURE A-5

Project	City of Bellingham Parks	Job Number	3125-010-00	Location	Bellingham, Washington
Date Drilled	04/19/01	Logged By	MRS	Contractor	Holt
Drill Method	Hollow Stem Auger	Equipment	Mobile Drill B-61	Drill Bit	
Sample Method	D&M	Hammer Data	300lb hammer, 30" drop	X-coordinate: Y-coordinate:	Not Determined Not Determined
Total Depth (ft)	14	Elevation (ft)	Not Measured	Datum: System:	

DEPTH IN FEET	% Recovery	Sample No.	Blow Count	Sample	Graphic Log	USCS Group Symbol	Material Description	Moisture Content (%)	Dry Unit Weight (pcf)	Other Tests And Notes	DEPTH IN FEET
0						AC	2 inches asphalt concrete				0
						SP	Brown fine to medium sand with coarse sand and gravel and occasional cobbles (dense, moist) (fill)				
	00		14	☐		SM	No recovery at 3.0 feet due to obstruction				
	39	1	5	☒			Gray silty fine to medium sand with coarse sand and wood debris (loose, moist) (fill)	10			
5	67	2	3	■		CL	Gray, brown and dark brown silty clay with fine sand and brown silt with organic matter (soft, moist) (fill)	22			5
	67	3	4	■				24			
10											10
	67	4	7	■				23			
15							Boring completed at 14.0 feet below ground surface on 04/19/01 No ground water encountered during drilling				15
20											20
25											25
30											30
35											35

Note: See Figure A-2 for explanation of symbols

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LOG OF BORING PL-4

FIGURE A-6

Project	City of Bellingham Parks	Job Number	3125-010-00	Location	Bellingham, Washington
Date Drilled	04/19/01	Logged By	MRS	Contractor	Holt
Drill Method	Hollow Stem Auger	Equipment	Mobile Drill B-61	Drill Bit	
Sample Method	D&M	Hammer Data	300lb hammer, 30" drop	X-coordinate: Y-coordinate:	Not Determined Not Determined
Total Depth (ft)	14	Elevation (ft)	Not Measured	Datum: System:	

DEPTH IN FEET	% Recovery	Sample No.	Blow Count	Sample	Graphic Log	USCS Group Symbol	Material Description	Moisture Content (%)	Dry Unit Weight (pcf)	Other Tests And Notes	DEPTH IN FEET
0							3 inches mulch				0
						ML	Brown fine sandy silt with coarse sand and gravel (soft, moist) (fill)				
						CL	Gray silty clay with fine sand and occaional wood fragments (soft to medium stiff, moist) (fill)				
	50	1	5	■							
						ML	Dark gray, brown and black fine sandy silt with organic matter, glass and gravel (medium stiff, moist) (fill)			Slight petroleum odor	
5	100	2	6	■						Likely landfill debris	5
	00		6	☐			No recovery				
10	00			☐			No recovery, metal debris, wire and glass in cuttings				10
	40	3	5	■							
15							Boring completed at 14.0 feet below ground surface on 04/19/01 No ground water encountered during drilling				15
20											20
25											25
30											30
35											35

Note: See Figure A-2 for explanation of symbols

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LOG OF BORING PL-5

FIGURE A-7

Project City of Bellingham Parks	Job Number 3125-010-00	Location Bellingham, Washington

Date Drilled	04/19/01	Logged By	MRS	Contractor	Holt
Drill Method	Hollow Stem Auger	Equipment	Mobile Drill B-61	Drill Bit	
Sample Method	D&M	Hammer Data	300lb hammer, 30" drop	X-coordinate: Y-coordinate:	Not Determined Not Determined
Total Depth (ft)	9	Elevation (ft)	Not Measured	Datum: System:	

DEPTH IN FEET	% Recovery	Sample No.	Blow Count	Sample	Graphic Log	USCS Group Symbol	Material Description	Moisture Content (%)	Dry Unit Weight (pcf)	Other Tests And Notes	DEPTH IN FEET
0						AC	2 inches asphalt concrete				0
						SP	Brown fine to medium sand with gravel (dense, moist) (fill)				
						CL	Gray and brown fine sandy clay with sand and fine gravel (very soft, moist) (fill)				
	78	1	1	■				24			
5											5
	70	2	3	■			Grades to dark brown, piece of glass in sample	17			
	56	3	50 for 6"	■			Note: concrete chips in sample, blow counts inflated by obstruction	26			
							Boring completed at 9.0 feet below ground surface on 04/19/01 No ground water encountered during drilling				
10											10
15											15
20											20
25											25
30											30
35											35

Note: See Figure A-2 for explanation of symbols

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LOG OF BORING PL-6

FIGURE A-8

Project	City of Bellingham Parks	Job Number	3125-010-00	Location	Bellingham, Washington
Date Drilled	04/19/01	Logged By	MRS	Contractor	Holt
Drill Method	Hollow Stem Auger	Equipment	Mobile Drill B-61	Drill Bit	
Sample Method	D&M	Hammer Data	300lb hammer, 30" drop	X-coordinate: Y-coordinate:	Not Determined Not Determined
Total Depth (ft)	14	Elevation (ft)	Not Measured	Datum: System:	

DEPTH IN FEET	% Recovery	Sample No.	Blow Count	Sample	Graphic Log	USCS Group Symbol	Material Description	Moisture Content (%)	Dry Unit Weight (pcf)	Other Tests And Notes	DEPTH IN FEET
0						SP	2 inches grass root mat Brown fine to medium sand with gravel (dense grading to loose, moist) (fill)				0
	89	1	7	■							
5						SP	Brown fine to medium sand (loose, moist) (fill)				5
	100	2	5	■				29			
	67	3	9	■		CL	Note: concrete gravel/rubble at 8.0 feet Gray silty clay with fine sand (medium stiff, moist)				
10							Grades to medium stiff				10
	78	4	6	■				32			
15							Boring completed at 14.0 feet below ground surface on 04/19/01 No ground water encountered during drilling				15
20											20
25											25
30											30
35											35

Note: See Figure A-2 for explanation of symbols

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LOG OF BORING PL-7

FIGURE A-9

Data Validation and Data Quality Assessment Report

Focused Site Characterization
Holly Street Landfill Redevelopment Project
Bellingham, Washington
Project Number: 99-062-04(2)

Prepared for:

Anchor Environmental, L.L.C.
1411 Fourth Avenue
Suite 1210
Seattle, Washington 98101

Prepared by:

Kathy J. Gunderson
981 State Street
Raymond, Washington 98577

July 19, 2000

Approved for Release: ______________________________
Kathy J. Gunderson
Owner, Validation Chemist

1.0 Introduction

The Functional Guidelines data validation of the samples listed in Table 1 has been completed. The bulk of the analyses were performed by Analytical Resources, Incorporated (ARI), located in Seattle Washington. The porewater extractions and grain size analyses were performed by Rosa Environmental and Geotechnical Laboratory (REGL), located in Seattle, Washington.

The validation was performed in accordance with the procedures established in the *Contract Laboratory Program National Functional Guidelines for Inorganic and Organic Data Review* (Functional Guidelines) (USEPA 1994 and 1994a). Project detection limits, quality control (QC) sample frequencies, and data quality objectives (DQOs) were taken from the *Work Plan/Sampling and Analysis Plan, Focused Site Characterization Holly Street Landfill Redevelopment Project* (SAP) (Anchor & AESI 2000). The criteria used to qualify data are taken from Functional Guidelines, the SAP, the analytical methods, or the professional judgment of the validation chemist.

Sections 2 through 8 present the validation findings and Section 10 defines the data qualifiers. Section 9 evaluates the project data against the data quality objectives set forth in the SAP. Table 2 presents an evaluation of field duplicate precision and Table 3 is a summary of the qualified data. Copies of laboratory communications are provided in Appendix A. The original laboratory resubmissions have been placed in the data package. Validation qualifier flags have been added to the sample data sheets in the Data Summary section of the original data package.

The laboratory electronic data deliverable (EDD) files in the Washington State Department of Ecology SEDQUAL format were reviewed and compared to the hardcopy report. Corrections were made as specified in this report and validation qualifiers were added to the SEDQUAL EDD files.

The laboratory EDD file for non-soil/sediment samples in the Environmental Information Management (EIM) System format was not reviewed and data qualifiers were not added.

Table 1
Sample Data Reviewed

Sample ID	Matrix	Laboratory Sample ID	VOA	SVOA	P/PCB	TPH-Dx	TPH-HCID	Metals	Conventionals	Porewater
A-MW-3-S-1	Soil	BN72A		X	X	X	X	X	X	
A-MW-2-S-1	Soil	BN72B		X	X	X	X	X	X	
AMW1	Water	BN94A & BN95G	X	X			X	X	X	
AMW2	Water	BN94B & BN95H	X	X			X	X	X	
AMW3	Water	BN94C & BN95I	X	X			X	X	X	
WP5	Water	BN94D & BN95J	X	X			X	X	X	
WP1	Water	BN94E & BN95K	X	X			X	X	X	
AMW4	Water	BN94F & BN95L	X	X			X	X	X	
AN-SD-6	Sediment	BO07A	X	X	X			X	X	X
AN-SD-4	Sediment	BO07B	X	X	X			X	X	X
AN-SD-5	Sediment	BO07C	X	X	X			X	X	X
AN-SD-1	Sediment	BO07D	X	X	X			X	X	X
AN-SD-2	Sediment	BO07E	X	X	X			X	X	X
Trip Blank	Water	BO07G	X							
AN-SD-3	Sediment	BO07F	X	X	X			X	X	X
WP-2	Water	BO02A & BO02C	X	X	X		X	X	X	
WP-3	Water	BO02B & BO02D	X	X	X		X	X	X	
Trip Blank	Water	BO02E	X							

VOA: Volatile organics by Method 8260
SVOA: Semivolatile organics by Method 8270
P/PCB: Pesticides and polychlorinated biphenyls by Method 8081
TPH-Dx: Diesel range and heavier petroleum hydrocarbons by Method NWTPH-Dx (WDOE 1997)
TPH-HCID: Petroleum hydrocarbon identification by Method NWTPH-HCID (WDOE 1997)
Metals: Arsenic, cadmium, chromium, copper, lead, silver and zinc in soil/sediment by Method 6010; arsenic, cadmium, lead, and silver in water by Method 200.8; chromium, copper, iron, manganese, and zinc in water by Method 6010; and mercury by Method 7470 in water and Method 7471 in soil
Conventionals: Total solids by Method 160.3, total dissolved solids by Method 160.1, total suspended solids by Method 160.2, alkalinity by Method 2320, ammonia by Method 350.1, chloride by Method 325.2, nitrite by Method 354.1, nitrate and nitrite by Method 353.2, sulfide by Methods 375.2 and 210C, total organic carbon by the Methods Plumb (Plumb 1981) and 415.1 and conductivity by Method 2520B
Porewater: Salinity by Method 210C and pH by Method 150.1 analyses of interstitial water

2.0 Data Validation of Volatile Organics Analyses

2.1 Custody, Preservation, Holding Times, and Completeness – Acceptable with Discussion

All samples were analyzed within the required holding times and all samples were received intact and were properly preserved. Except as noted below, the data package is complete and contains all the information necessary to recreate the sample results.

The raw data for the 4-25-00 method blank and laboratory control sample (LCS) analyzed on instrument Finn 3 were missing from the data package. The laboratory resubmitted the missing information.

The Continuing Calibration Check Form 7 for 4-25-00 on instrument Finn 3 was missing from the standards raw data section of the data pack. The missing form was located in the QC summary section of the pack and a copy was added to the standards raw data section.

2.2 Instrument Tuning and Mass Calibration – Acceptable

The tuning compound bromofluorobenzene was analyzed at the required frequency and all Functional Guidelines criteria were met.

2.3 Initial Calibration – Acceptable

Initial calibrations were analyzed at the required frequency and are calculated correctly. The Functional Guidelines criteria of relative standard deviation (RSD) values less than or equal to 30% and relative response factors greater than 0.05 were met for all target compounds.

2.4 Continuing Calibration – Acceptable with Discussion

Continuing calibrations were analyzed at the required frequency and are calculated correctly. The Functional Guidelines criteria of percent difference values less than or equal to 25 and relative response factors (RRFs) greater than 0.05 were met.

The percent difference values of toluene-d_8, 4-bromofluorobenzene, and 1,2-dichlorobenzene-d_4 in the continuing calibration analyzed on 4-28-00 on instrument Finn 3 are 27.3%, 28.3%, and 26.4%, respectively Data qualifiers are not required for surrogate compounds.

The RRFs on the Form VII for the 4-25-00 CCV on Finn3 are incorrectly calculated. However, an instrument generated Form VII is correctly calculated. Data qualifiers are not required.

2.5 Blank Analyses – Acceptable

2.5.1 Method Blanks

Method blanks were analyzed at the required frequency and target analytes were not detected above the reporting limits.

2.5.2 Field Blanks

Two trip blanks are associated with the samples. Target analytes were not detected above the reporting limits in either of the trip blanks.

2.6 Surrogate Analyses – Acceptable

Surrogate compounds were added to all samples, blanks and QC samples as required. All percent recovery values are correctly calculated and all are within the SAP criteria.

2.7 Matrix Spike/Matrix Spike Duplicate Analyses – Acceptable with Qualifications

Matrix spike/matrix spike duplicates (MS/MSD) were analyzed at the required frequency and are correctly calculated. Except as noted below, all percent recovery and relative percent difference (RPD) values are within the SAP criteria (50 to 140% recovery and RPD values less than 40% for sediments and 60 to 140% recovery and RPD values less than 35% for waters).

The 1,2,4-trichlorobenzene recovery values in the MS and MSD analyses of sample AN-SD-6 are below the SAP criteria at 37.4% and 39.6%. Since the recovery of the LCS is acceptable, only sample AN-SD-6 has been qualified as estimated detection limit (UJ).

Sample ID	Analyte	Quality Control Exceedance	Qualification
AN-SD-6	1,2,4-trichlorobenzene	MS and MSD recovery < 50%	UJ

2.8 Laboratory Control Sample Analyses – Acceptable

Laboratory control samples (LCSs) were analyzed as required and are correctly calculated. All percent recovery values are within the SAP criteria.

2.9 Standard Reference Material Analyses

The SAP does not require standard reference material (SRM) analyses for volatile organics.

2.10 Internal Standard Evaluation – Acceptable with Qualifications

Internal standards were added to all samples, blanks and QC samples as required. Except as noted below, the internal standard recovery and retention time criteria of Functional Guidelines were met.

The internal standard recovery values of chlorobenzene-d_5 and 1,4-dichlorobenzene-d_4 in the original analysis of sample AN-SD-4 are below the Functional Guidelines criteria of greater than 50% of the associated continuing calibration internal standard area. The results for the original analysis of sample AN-SD-4 have been rejected in favor of the re-analysis.

The internal standard recovery of 1,4-dichlorobenzene-d_4 in the original analysis of sample AN-SD-6 is below the Functional Guidelines criteria. The results for the original analysis of sample AN-SD-6 have been rejected in favor of the re-analysis.

The internal standard recovery of 1,4-dichlorobenzene-d_4 in the reanalysis of sample AN-SD-4 is below the Functional Guidelines criteria. The results of the associated analytes have been qualified as estimated detection limit (UJ) as shown in the following table.

Sample ID	Analyte	Quality Control Exceedance	Qualification
AN-SD-4	All	Internal standard recovery below Functional Guidelines criteria	R (in favor of re-analysis)
AN-SD-6	All	Internal standard recovery below Functional Guidelines criteria	R (in favor of re-analysis)
AN-SD-4 Reanalysis	1,4-dichlorobenzene 1,2-dichlorobenzene 1,2,4-trichlorobenzene	Internal standard recovery below Functional Guidelines criteria	UJ

2.11 Compound Quantitation and Laboratory Reporting Limits – Acceptable with Discussion

The final results are correctly calculated including percent moisture, amount analyzed and dilution factors. Positive results meet the Functional Guidelines criteria for retention time and mass spectra.

The SAP target detection limits were met with one exception. The 1,2,4-trichlorobenzene reporting limit in the reanalysis of sample AN-SD-4 (12 ug/kg) is above the SAP target detection limit (10 ug/kg).

The original total xylene results of samples WP1 and WP5 were reported as non-detected at an elevated detection limit (laboratory Y flag). Since the spectra meet the Functional Guidelines criteria for positive results, the laboratory was contacted for verification of the results. The laboratory resubmitted the results sheets with total xylenes reported as positive results. A corrected EIM EDD file was resubmitted by the laboratory.

2.12 Field Duplicates – Acceptable

Sample AMW4 was identified as a field duplicate of sample AMW3. RPD values could not be calculated since positive results were not detected in either sample.

2.13 Overall Assessment of Data Useability

The useability of the data is based on the guidance documents listed above. Upon consideration of the information presented here, the data are acceptable except where flagged with data qualifiers that modify the usefulness of the individual values.

3.0 Data Validation of Semivolatile Organics Analyses

3.1 Custody, Preservation, Holding Times, and Completeness – Acceptable with Discussion

All samples were extracted and analyzed within the required holding times. All samples were received intact and were properly preserved. The data package is complete and contains all the information necessary to recreate the sample results.

The BO07 sediment extraction benchsheet was missing from the data package. The laboratory resubmitted the missing information.

The raw data for the BN95 water LCSD was missing from the data package. The laboratory resubmitted the missing information.

3.2 Instrument Tuning and Mass Calibration – Acceptable

The tuning compound decafluorotriphenylphosphine was analyzed at the required frequency and all relative abundance values are within Functional Guidelines criteria.

3.3 Initial Calibration – Acceptable

Initial calibrations were analyzed at the required frequency and are correctly calculated. The Functional Guidelines criteria of RSD values less than 30 and relative response factors greater than 0.05 were met for target analytes.

3.4 Continuing Calibration – Acceptable with Qualifications

Continuing calibration verifications (CCVs) were analyzed at the required frequency and are correctly calculated. Except as noted below, all percent difference values and relative response factors met the Functional Guidelines criteria of less than 25% and greater than 0.05, respectively.

The percent difference values of 1,2-dichlorobenzene-d_4 in the CCVs analyzed on 4-26-00 and 4-27-00 are above the Functional Guidelines criteria at 38.2% and 39.8%, respectively. Data qualifiers are not required for surrogate compounds.

The percent difference value of dibenz(a,h)anthracene in the CCV analyzed on 4-28-00 is above the Functional Guidelines criteria at 25.6%. Since the response increased, only positive results in the associated samples were qualified as estimated (J) as shown in the following table.

The percent difference values of indeno(1,2,3-cd)pyrene and benzo(g,h,i)perylene in the CCV analyzed on 5-1-00 are 31.1% and 25.7%, respectively. Since the response increased, only positive results in the associated samples were qualified as estimated (J) as shown in the following table.

Sample ID	Analyte	Quality Control Exceedance	Qualification
AN-SD-4	Dibenz(a,h)anthracene	Percent difference > 25 (response increased)	J
AN-SD-6 AN-SD-5 AN-SD-2 AN-SD-3	Indeno(1,2,3-cd)pyrene Benzo(g,h,i)perylene	Percent difference > 25 (response increased)	J

3.5 Blank Analyses – Acceptable

3.5.1 Method Blanks

Method blanks were analyzed at the required frequency and target analytes were not detected above the reporting limit.

3.5.2 Field Blanks

Field blanks are not associated with this set of samples.

3.6 Surrogate Analyses – Acceptable with Qualifications

Surrogate compounds were added to all samples, blanks and QC samples as required and are correctly calculated. Except as noted below, all surrogate recovery values are within the SAP criteria (60 to 140% for waters, 50 to 140% for soils and sediments).

The 2-fluorobiphenyl and 1,2-dichlorobenzene-d_4 surrogate recovery values from sample A-MW-2-S-1 are 146% and 48.6%, respectively. Functional Guidelines requires qualifying data when two or more surrogate recovery values in the same fraction (base/neutral or acid) are outside criteria. Therefore, base/neutral analytes in sample A-MW-2-S-1 were qualified as estimated (J) or estimated detection limit (UJ) as shown in the following table.

The 1,2-dichlorobenzene-d_4 surrogate recovery values from samples AMW1, AMW2, AMW3, AMW4, WP5, WP1, WP-2, and WP-3 are below the SAP criteria. Data were not qualified because Functional Guidelines allows one surrogate per fraction to exceed criteria without qualification.

The 2-fluorophenol surrogate recovery value from sample AN-SD-1 is below the SAP criteria at 41.8%. Data were not qualified because Functional Guidelines allows one surrogate per fraction to exceed criteria without qualification.

The 1,2-dichlorobenzene-d_4 surrogate recovery values from the water LCS and LCSD are below the SAP criteria at 55.0% and 54.9%, respectively. Data qualifiers are not required for QC samples.

The 2-fluorophenol surrogate recovery value from sample AN-SD-5MSD is below the SAP criteria at 17.6%. Data qualifiers are not required for QC samples.

Sample ID	Analyte	Qualification	Quality Control Exceedance
A-MW-2-S-1	Base/neutral analytes	J positive results UJ detection limits	Surrogate recovery outside SAP criteria

3.7 Matrix Spike/Matrix Spike Duplicate Analyses – Acceptable with Qualifications

Except as noted below, MS/MSD analyses were performed at the required frequency and are correctly calculated. All percent recovery and RPD values are within the SAP criteria (50 to 150% recovery for soils and sediment, 60 to 140% recovery for waters, and RPD values are less than 40 for soils and sediment, and less than 35 for waters).

The laboratory did not perform water MS/MSD analyses due to insufficient sample volume. Data qualifiers are not required because the acceptable laboratory control sample/laboratory control sample duplicate (LCS/LCSD) demonstrates the analytical system is in control.

The percent recovery values of pyrene in the MS and MSD analyses of sample A-MW-3-S-1 are reported by the laboratory as NA (no recovery due to high concentration of analyte in original sample). The calculated recovery values are zero percent. Data qualifiers are not required because the pyrene result in the original sample is above the calibration range. Ideally, the laboratory should have analyzed the MS and MSD at a dilution.

The pentachlorophenol recovery in the MS and MSD analyses of sample AN-SD-5 are below SAP criteria at 43.0% and 46.0%, respectively. The pentachlorophenol result in sample AN-SD-5 has been qualified as estimated detection limit (UJ).

The pyrene percent recovery in the MS analysis of sample AN-SD-5 is below the SAP criteria at 46.1%. Data qualifiers are not required because the MSD recovery is acceptable.

Sample ID	Analyte	QC Exceedance	Qualification
AN-SD-5	Pentachlorophenol	MS and MSD recovery < 50%	UJ

3.8 Laboratory Control Sample Analyses – Acceptable with Qualifications

Laboratory control samples were analyzed with each batch and the results are correctly calculated. Except as noted below, all percent recovery values are within the SAP criteria (60 to 140% for water and 50 to 140% for soil and sediment).

The pentachlorophenol percent recovery in the sediment LCS is below the SAP criteria at 48.0%. The pentachlorophenol results in all sediment samples have been qualified as estimated (J) or estimated detection limit (UJ).

Sample ID	Analyte	QC Exceedance	Qualification
All sediment samples	Pentachlorophenol	LCS recovery < 50%	J positive results UJ detection limits

3.9 Standard Reference Material Analyses – Acceptable with Discussion

The Sequim Bay Fortified Reference Sediment was analyzed as the SRM. One SRM was analyzed with each soil and sediment extraction batch as required by the SAP. The results are correctly calculated. Since the Sequim Bay Fortified Reference Sediment is not truly certified, the SAP accuracy criteria were not used. All results are within the 95% confidence interval, with one exception. The benzo(g,h,i)perylene result in the soil SRM (BN72 SQ-1) is above the 95% confidence interval. Data qualifiers are not required based on SRM results alone.

3.10 Internal Standard Evaluation – Acceptable with Discussion

Internal standards were added to all samples, blanks and QC samples as required. Except as noted below, the recovery and retention time criteria of Functional Guidelines were met.

The internal standard recovery of chrysene-d_{12} and perylene-d_{12} in the MSD analysis of sample A-MW-3-S-1 are below the Functional Guidelines criteria of greater than 50% of the associated continuing calibration internal standard area. Data qualifiers are not required for QC samples.

3.11 Compound Quantitation and Laboratory Reporting Limits – Acceptable with Qualifications

The final results were correctly calculated including percent moisture, amount extracted, and dilution factors. Positive results meet the Functional Guidelines criteria for retention time and mass spectra.

The SAP target detection limits were not met in all cases. The water target detection limits were not met for hexachlorobutadiene, phenol, 2-methylphenol, 2,4-dimethylphenol, benzyl alcohol, pentachlorophenol, and benzoic acid. The soil and sediment target detection limit for pentachlorophenol was not met by any samples. Soil and sediment samples with high percent moisture content, or that required diluted analysis, did not meet the target detection limits.

The indeno(1,2,3-cd)pyrene reference spectra on instrument Finn4 was incorrect. The laboratory was contacted and resubmitted the corrected reference spectra with one sample (AN-SD-6). Data qualifiers are not required because indeno(1,2,3-cd)pyrene was correctly identified in the samples.

Several results in the soil and sediment samples were flagged M by the laboratory. The M flag is defined as "indicates as estimated value of analyte found and confirmed by analyst but with low spectral match". The spectra was reviewed and in most cases meet the Functional Guidelines criteria. In samples AN-SD-4 and A-MW-2-S-1, the dibenz(a,h)anthracene and anthracene spectra, respectively, do not meet the Functional Guidelines criteria and were qualified as N, presumptive evidence for a tentative identification.

Samples A-MW-3-S-1 and AN-SD-4 were diluted due to high levels of target compounds. In these instances the laboratory reported one analysis data sheet for the original analysis and one for the dilution. To condense the results to one result per analyte per sample, results that are above the calibration range (laboratory E flag) have been rejected (qualified R). Results and elevated detection limits from the diluted analyses that are not necessary have also been rejected (qualified R).

Sample ID	Analyte	Qualification	Quality Control Exceedance
AN-SD-4	Dibenz(a,h)anthracene	N	Spectra does not Functional Guidelines criteria
A-MW-2-S-1	Anthracene	N	Spectra does not Functional Guidelines criteria
A-MW-3-S-1 AN-SD-4	All analytes flagged E by the laboratory	R	Result above the calibration range
A-MW-3-S-1 Dilution AN-SD-4 Dilution	All analytes for which the dilution was not required	R	Unnecessary result or elevated detection limit

3.12 Field Duplicates – Acceptable with Discussion

Sample AMW4 was identified as a field duplicate of sample AMW3. An RPD values could not be calculated because bis(2-ethylhexyl)phthalate was detected in sample AMW3 (2.2 ug/L), but was not detected in sample AMW4 (1 ug/L detection limit).

3.13 Overall Assessment of Data Useability

The useability of the data is based on the guidance documents listed above. Upon consideration of the information presented here, the data are acceptable except where flagged with data qualifiers that modify the usefulness of the individual values.

4.0 Data Validation of Pesticides and Polychlorinated Biphenyls

4.1 Custody, Preservation, Holding Times, and Completeness – Acceptable with Discussion

All samples were extracted and analyzed within the required holding times. All samples were received intact and were properly preserved. The data package is complete and contains all the information necessary to recreate the sample results.

The soil extraction benchsheet was missing from the pesticide/PCB section of the data package. It was misplaced in the package and a copy was added to the pesticide/PCB section.

The SRM surrogate recovery values were missing from the BO07 Form II. The laboratory resubmitted a corrected Form II.

4.2 Initial Calibration and Performance Evaluation Checks – Acceptable with Qualifications

Initial calibrations and performance evaluation checks were analyzed at the required frequency and are correctly calculated. Except as noted below, the Functional Guidelines linearity criteria (pesticide RSD < 20% and multicomponent RSD < 30%) and performance evaluation criteria were met.

The RSD of 4,4'-DDD on the RTX-CLP1 column in the initial calibration is above the Functional Guidelines criteria at 24.6%. Results in the associated samples were qualified as estimated (J) or estimated detection limit (UJ) as shown in the following table.

Sample ID	Analyte	Quality Control Exceedance	Qualification
A-MW-3-S-1 A-MW-2-S-1	4,4'-DDD	Initial calibration RSD > 20%	J positive results UJ detection limits

4.3 Calibration Verifications – Acceptable

Continue calibration verifications were analyzed at the required frequency and are correctly calculated. The Functional Guidelines criteria of percent difference values less than or equal to 25% was met.

4.4 Blank Analyses – Acceptable

4.4.1 Method Blanks

Method blanks were analyzed at the required frequency and target analytes were not detected above the reporting limit.

4.4.2 Field Blanks

Field blanks are not associated with this set of samples.

4.5 Surrogate Analyses – Acceptable with Discussion

Surrogate compounds were added to all samples, blanks and QC samples as required and are correctly calculated. Except as noted below, all percent recovery values are within SAP criteria of 50 to 140%.

The decachlorobiphenyl (DCBP) surrogate recovery is above the SAP criteria at 750% for sample A-MW-3-S-1. Data qualifiers are not required because positive chromatographic interference is present on both columns and the recovery of the surrogate tetrachlorometaxylene (TCMX) is acceptable.

The TCMX surrogate recovery is below the SAP criteria at 48.8%, 47.0%, and 46.5% for samples A-MW-2-S-1, A-MW-2-S-1MS, and A-MW-2-S-1MSD, respectively. Data qualifiers are not required because the recovery of the surrogate DCBP is acceptable.

4.6 Matrix Spike/Matrix Spike Duplicate Analyses – Acceptable with Qualifications

MS/MSD analyses were performed as required and are correctly calculated. Except as noted below, all percent recovery and relative percent difference values are within the SAP criteria of 50 to 140% recovery and RPD values less than 40.

The aldrin recovery in the MS and MSD analyses of sample A-MW-2-S-1 are below the SAP criteria at 45.2% each. Since the recovery of the LCS is acceptable, only the aldrin result in sample A-MW-2-S-1 has been qualified as estimated detection limit (UJ).

Sample ID	Analyte	Quality Control Exceedance	Qualification
A-MW-2-S-1	Aldrin	MS and MSD recovery < 50%	UJ

4.7 Laboratory Control Sample Analysis – Acceptable

Laboratory control samples were analyzed as required and are correctly calculated. All percent recovery values are within the SAP criteria of 50 to 140%.

4.8 Standard Reference Material Analyses – Acceptable with Discussion

The laboratory analyzed the Sequim Bay Fortified Reference Sediment as the SRM for the pesticides and PCB analyses. Since the Sequim Bay Fortified Reference Sediment is not truly certified, the SAP accuracy criteria were not used. All results are within the 95% confidence interval.

4.9 Compound Quantitation and Laboratory Reporting Limits – Acceptable with Discussion

The final results are correctly calculated, including the amount extracted, percent moisture content, and dilution factors. The retention time criteria and percent difference between column results meet the requirements of Method 8081A (USEPA 1995).

The SAP target detection limits were not met for all analytes. The total PCB target detection limit was not met by any samples. The soil pesticide target detection limit of 2 ug/kg was met for samples that were analyzed undiluted without interferences. The hexachlorobenzene and hexachlorobutadiene target detection limits were met by all samples.

The validation chemist reviewed the chromatograms for multicomponent analytes, i.e., Aroclors. Due to the complex nature of the samples, the amount of non-target-analyte material present in the chromatograms, and the small size of the hard copy chromatograms, it is difficult to absolutely verify what, if any, Aroclor patterns are present in the samples. For samples with high levels of Aroclors, the patterns are apparent and the correct Aroclors were reported. In the opinion of the validation chemist, the expertise of the laboratory staff and their ability to electronically manipulate the chromatograms (overlay, expand, etc.), should be relied upon for the determination of Aroclor results.

4.10 Field Duplicates

Field duplicates are not associated with this set of samples.

4.11 Overall Assessment of Data Useability

The useability of the data is based on the guidance documents listed above. Upon consideration of the information presented here, the data are acceptable except where flagged with data qualifiers that modify the usefulness of the individual values.

5.0 Data Validation of Petroleum Hydrocarbons by Methods NWTPH-HCID and NWTPH-Dx

5.1 Custody, Preservation, Holding Times, and Completeness – Acceptable with Discussion

All samples were extracted and analyzed within the required holding times. All samples were received intact and were properly preserved. The data package is complete and contains all the information necessary to recreate the sample results.

The laboratory did not use Method NWTPH-HCID for the water HCID analyses as required by the SAP. The laboratory used an in-house method that uses smaller sample volumes and extraction solvent volumes. The resulting reporting limit for diesel (10 mg/L) is much higher than the SAP target detection limit (0.25 mg/L).

The HCID surrogate summary form (Form II) for SDG BO03 was missing from the data package. The laboratory resubmitted the missing form.

5.2 Initial Calibration – Acceptable

Initial calibrations were analyzed at the required frequency and are correctly calculated. The Functional Guidelines linearity criteria (for GC pesticides) of RSD values less than 20% was met.

5.3 Calibration Verifications – Acceptable

Continuing calibration verifications were analyzed at the required frequency and are correctly calculated. The method criteria of percent difference values less than or equal to 15% was met.

5.4 Blank Analyses – Acceptable

5.4.1 Method Blanks

Method blanks were analyzed at the required frequency and target analytes were not detected above the reporting limit.

5.4.2 Field Blanks

Field blanks are not associated with this set of samples.

5.5 Surrogate Analyses – Acceptable with Qualifications

Surrogate compounds were added to all samples, blanks and QC samples as required and are correctly calculated. Except as noted below, all percent recovery values are within SAP criteria of 70 to 130% for waters and 65 to 135% for soils.

The methylaracidate surrogate recovery values in the TPH-D analyses of samples A-MW-3-S-1 and A-MW-2-S-1 below the SAP criteria at 60% each. Diesel range and motor oil range hydrocarbons in both samples have been qualified as estimated (J) or estimated detection limit (UJ).

The methylaracidate surrogate recovery values in the TPH-D analyses of samples A-MW-3-S-1MS, A-MW-3-S-1MSD, and A-MW-2-S-1 duplicate are below the SAP criteria at 50%, 60%, and 60%, respectively. Data qualifiers are not required for QC samples.

Sample ID	Analyte	Qualifier	Quality Control Exceedance
A-MW-3-S-1 A-MW-2-S-1	Diesel range hydrocarbons Motor oil range hydrocarbons	J positive results UJ detection limits	Surrogate recovery < 65%

5.6 Matrix Spike/Matrix Spike Duplicate Analyses – Acceptable with Discussion

MS/MSD analyses were performed as required and are correctly calculated. Except as noted below, all percent recovery and relative percent difference values are within the SAP criteria of 65 to 135% recovery and RPD values less than 35.

MS/MSD analyses are not required by Method NWTPH-HCID (WDOE 1997).

The diesel recovery in the MS analysis of sample A-MW-3-S-1 is above the SAP criteria at 145%. Since the recovery of the MSD is acceptable (81.2%), data qualifiers are not required.

The RPD value reported by the laboratory for the TPH-D analyses of sample A-MW-3-S-1 is 56.2%. This value is calculated using the percent recovery values and not the MS and MSD results. Data qualifiers are not required because the RPD value, calculated on the results, is within the SAP criterion at 12.6%.

5.7 Laboratory Control Sample Analysis – Acceptable

Laboratory control samples were analyzed as required and are correctly calculated. All percent recovery values are within the SAP criteria.

5.8 Standard Reference Material Analyses

The SAP does not require SRM analyses for petroleum hydrocarbons.

5.9 Compound Quantitation and Laboratory Reporting Limits – Acceptable with Discussion

The final results are correctly calculated, including the amount extracted, percent moisture content, and dilution factors.

For soil samples, the NWTPH-HCID reporting limits meet the SAP target detection limits. The HCID water reporting limits do not meet the SAP target detection limits. The laboratory reporting limits of 25 mg/L for oil range hydrocarbons and 10 mg/L for gasoline and diesel are above the SAP detection limit of 0.25 mg/L.

5.10 Field Duplicates – Acceptable

Sample AMW4 was identified as a field duplicate of sample AMW3. An RPD value could not be calculated because positive results were not detected in either sample.

5.11 Overall Assessment of Data Useability

The useability of the data is based on the guidance documents listed above. Upon consideration of the information presented here, the data are acceptable except where flagged with data qualifiers that modify the usefulness of the individual values.

6.0 Data Validation of Metals by Method 6010 and Mercury by Methods 7470 and 7471

6.1 Custody, Preservation, Holding Times, and Completeness – Acceptable

All samples were analyzed within the required holding times. All samples were received intact and were properly preserved. The data package is complete and contains all the information necessary to recreate the sample results.

6.2 Initial Calibration – Acceptable with Discussion

Initial calibrations were analyzed as required and all quality control checks met Functional Guidelines requirements.

The zinc recovery is the ending detection limit standard analyzed on 5-2-00 is 212.6%. Criteria have not been established for this parameter. The data are not impacted because the zinc concentrations is the associated samples are much greater than the detection limit standard spike concentration (12 ug/L or 0.6 mg/kg).

6.3 Calibration Verifications – Acceptable

Initial calibration verifications and continuing calibration verifications were analyzed at the required frequency and are correctly calculated. All Functional Guidelines criteria were met.

6.4 Blank Analyses – Acceptable with Discussion

6.4.1 Method Blanks

Instrument and method blanks were analyzed at the required frequency. Except as noted below, target analytes were not detected above the reporting limit.

Zinc was detected in the soil method blank at 0.3 mg/kg. As specified in Functional Guidelines, data qualifiers are not required because the zinc concentrations in the associated samples are all greater than 5 times the method blank concentration.

6.4.2 Field Blanks

Field blanks are not associated with this set of samples.

6.5 ICP Interference Check – Acceptable with Qualifications

ICP interference check samples (ICS) were analyzed at the required frequency and are correctly calculated. All percent recovery values are within Functional Guidelines criteria and, except as noted below, all non-spiked analytes have absolute values less than the instrument detection limit (IDL).

The copper and silver results in first ICS analyzed on 5-2-00 have negative values greater than the IDL. Because negative values greater than the IDL indicate the potential for false negative results when the associated samples contain comparable levels of interfering elements (calcium, aluminum, magnesium, and iron), non-detected results in the associated samples are qualified as estimated detection limits (UJ). Since the associated samples contain comparable levels of iron they were qualified as shown in the following table.

Arsenic, lead, and zinc have positive results greater than the IDL in the second ICS analyzed on 5-2-00. Because positive results in the ICS indicate a potential high bias when the samples contain comparable levels of interfering elements, positive results are qualified as estimated (J) when the concentration in the sample is comparable to the level in the ICS. Since the associated samples contained comparable levels of iron they were qualified as shown in the following table.

Arsenic, copper, lead, and silver results in the four ICS analyses analyzed on 5-4-00 have negative values greater than the IDL. Data qualifiers are not required because the water samples associated with these ICS analyses do not contain the interfering elements at comparable concentrations.

Sample ID	Analyte	Qualification	Quality Control Exceedance
AN-SD-6 AN-SD-4 AN-SD-5	Silver	UJ detection limits	Negative ICS concentration and comparable levels of interfering elements present in the samples
AN-SD-3 AN-SD-5	Arsenic	J positive results	ICS concentration > IDL and sample concentration comparable to the ICS and comparable levels of interfering elements present

6.6 Duplicate Sample Analysis – Acceptable with Qualifications

Sample duplicate analyses were performed at the required frequency and are correctly calculated. Except as noted below, all RPD values are within the SAP criteria of less than 20% for waters and sediments and less than 35% for soils.

The RPD value for mercury in the duplicate analysis of soil sample A-MW-2-S-1 is above the SAP criteria at 46.8%. As directed by Functional Guidelines, positive mercury results in all associated soil samples have been qualified as estimated (J).

The RPD values for lead, zinc, and mercury in the duplicate analysis of sediment sample AN-SD-6 are above the SAP criteria at 54.6%, 39.2%, and 145%, respectively. Positive lead, zinc, and mercury results in all associated sediment samples have been qualified as estimated (J).

Sample ID	Analyte	Qualification	Quality Control Exceedance
All soil samples	Mercury	J	Laboratory duplicate RPD > 35
All sediment samples	Lead Zinc Mercury	J	Laboratory duplicate RPD > 20

6.7 Spike Sample Analysis – Acceptable with Qualifications

Matrix spike analyses were performed at the required frequency and are correctly calculated. Except as noted below, all percent recovery values are within the SAP criteria of 75 to 125% for waters and 60 to 135% for soils and sediments.

The lead, silver, and zinc recovery values in the spiked analysis of soil sample A-MW-2-S-1 are outside the SAP criteria. Lead and silver recovery values are 388% and 138%, respectively. The zinc recovery value was reported as -288%, which realistically is zero percent recovery. As specified in Functional Guidelines, data qualifiers are not required when the sample concentration is greater than 4 times the spike concentration. Therefore, data qualifiers are not required for lead and zinc because the sample concentrations are 18 and 20 times the spike concentration. Since the silver sample concentration is less than 4 times the spike concentration, positive silver results in all soil samples have been qualified as estimated (J).

The iron and manganese recovery values in the total metals spiked analysis of water sample AMW1 are below the SAP criteria at 65.0% and 56.0%, respectively. Data qualifiers are not required for manganese because the sample concentration is greater than 4 times the spike concentration. Total iron results in all water samples have been qualified as estimated (J) or estimated detection limit (UJ).

The copper, lead, and zinc recovery values in the spiked analysis of sediment sample AN-SD-6 are outside the SAP criteria. The copper recovery value is 189%. The lead and zinc recovery values were reported as -199% and -2.6%, which are zero percent recovery. Data qualifiers are not required for lead because the sample concentration is greater than 4 times the spike concentration. Since all the copper and zinc results in the sediment samples are positive, they have been qualified as estimated (J).

Sample ID	Analyte	Quality Control Exceedance	Qualification
All soil samples	Silver	Matrix spike recovery > 135%	J positive results
All water samples	Total Iron	Matrix spike recovery < 75%	J positive results UJ detection limits
All sediment samples	Copper	Matrix spike recovery > 135%	J positive results
All sediment samples	Zinc	Matrix spike recovery < 65%	J positive results

6.8 ICP Serial Dilution Analysis – Acceptable

Serial dilutions were performed as required and are correctly calculated. The Functional Guidelines criteria of percent difference values less than 10% for results greater than 50 times the IDL were met.

6.9 Standard Reference Material Analyses – Acceptable

Certified reference materials were analyzed as required by the SAP and are correctly calculated. All percent recovery values are within the SAP criteria.

6.10 Compound Quantitation and Laboratory Reporting Limits – Acceptable with Discussion

The final results are correctly calculated including percent moisture, amount digested, and dilution factors.

The SAP specified target detection limits were met for the water samples and the sediment samples with one exception. The laboratory reporting limits for sediment sample AN-SD-4 are above the SAP target detection limits due to the high percent moisture content of the sample (59.9% moisture).

The SAP does not list target detection limits soils or for iron and manganese in water. Kim Magruder, of Anchor Environmental, provided the following target detection limits. Of these target detection limits, all were met, with the exception of silver.

Element	Target Detection Limit
Arsenic	20 mg/kg dry
Cadmium	2 mg/kg dry
Chromium	100 mg/kg dry
Copper	17 mg/kg dry
Lead	250 mg/kg dry
Mercury	1 mg/kg dry
Silver	0.5 mg/kg dry
Zinc	7 mg/kg dry
Iron	300 ug/L
Manganese	50 ug/L

6.11 Field Duplicates – Acceptable with Qualifications

Sample AMW4 was identified as a field duplicate of sample AMW3. The SAP criterion for field duplicate precision is RPD values less than 20. The RPD values of total copper, total iron, and dissolved iron are above the SAP criterion (RPD values range from 28 to 82). Total copper, total iron, and dissolved iron results in samples AMW3 and AMW4 were qualified as estimated (J). The precision of the field duplicate set is presented Table 2.

Sample ID	Analyte	Quality Control Exceedance	Qualification
AMW4 AMW3	Total copper Total iron Dissolved iron	Field duplicate RPD > 20	J

6.12 Overall Assessment of Data Useability

The useability of the data is based on the guidance documents listed above. Upon consideration of the information presented here, the data are acceptable except where flagged with data qualifiers that modify the usefulness of the individual values.

7.0 Data Validation of Metals by ICP/MS Method 200.8

7.1 Custody, Preservation, Holding Times, and Completeness – Acceptable

All samples were analyzed within the required holding times and all samples were received intact and were properly preserved. The data package is complete and contains all the information necessary to recreate the sample results.

7.2 Initial Calibration – Acceptable

Initial calibrations were analyzed as required and all quality control checks met Functional Guidelines requirements.

7.3 Calibration Verifications – Acceptable

Initial calibration verifications and continuing calibration verifications were analyzed at the required frequency and are correctly calculated. All Functional Guidelines criteria were met.

7.4 Blank Analyses – Acceptable

7.4.1 Method Blanks

Instrument and method blanks were analyzed at the required frequency and target analytes were not detected above the reporting limit.

7.4.2 Field Blanks

Field blanks are not associated with this set of samples.

7.5 ICP Interference Check – Acceptable

ICP interference check samples (ICS) were analyzed at the required frequency and are correctly calculated. All percent recovery values are within Functional Guidelines criteria and all non-spiked analytes have absolute values less than the IDL.

7.6 Internal Standard Evaluation – Acceptable

Internal standards were added to all samples, blanks and QC samples as required and all method criteria were met.

7.7 Duplicate Sample Analysis – Acceptable

Sample duplicate analyses were performed at the required frequency and are correctly calculated. All RPD values are within the SAP criterion of less than 20%.

7.8 Spike Sample Analysis – Acceptable with Qualifications

Matrix spike analyses were performed at the required frequency and are correctly calculated. Except as noted below, all percent recovery values are within the SAP criteria of 75 to 125%.

The silver recovery value in the total metals spiked analysis of water sample AMW1 is below the SAP criteria at 55.2%. The total silver results in all water samples have been qualified as estimated (J) or estimated detection limit (UJ).

Sample ID	Analyte	Quality Control Exceedance	Qualification
All water samples	Total Silver	Matrix spike recovery < 75%	J positive results UJ detection limits

7.9 Standard Reference Material Analyses – Acceptable

Standard reference materials were analyzed as required by the SAP and are correctly calculated. All percent recovery values are within the SAP criteria.

7.10 Compound Quantitation and Laboratory Reporting Limits – Acceptable

The final results are correctly calculated including amount digested and dilution factors. The SAP specified target detection limits were met for the water samples.

7.11 Field Duplicates – Acceptable with Qualifications

Sample AMW4 was identified as a field duplicate of sample AMW3. The SAP criterion for field duplicate precision is RPD values less than 20. The RPD values of total arsenic, total lead, and dissolved arsenic are above the SAP criterion at 22, 100, and 67, respectively. As prescribed by Functional Guidelines, data qualifiers are not required when the results are less than 5 times the reporting limit. Therefore, total arsenic and dissolved arsenic results in samples AMW3 and

AMW4 were qualified as estimated (J). The precision of the field duplicate set is presented Table 2.

Sample ID	Analyte	Quality Control Exceedance	Qualification
AMW4 AMW3	Total arsenic Dissolved arsenic	Field duplicate RPD > 20	J

7.12 Overall Assessment of Data Useability

The useability of the data is based on the guidance documents listed above. Upon consideration of the information presented here, the data are acceptable except where flagged with data qualifiers that modify the usefulness of the individual values.

8.0 Data Validation of Conventional Chemistry Analyses

8.1 Custody, Preservation, Holding Times, and Completeness – Acceptable with Discussion

All samples were analyzed within the required holding times and all samples were received intact and were properly preserved. The data package is complete and contains all the information necessary to recreate the sample results.

The interlaboratory COC for SDG BO07 indicates a 2 day custody gap. Sample custody was relinquished by ARI on 4-25-00 and the samples were received by REGL on 4-27-00. ARI states that sample custody was maintained (the samples were stored in a refrigerator).

For SDG BO07, the porewater extractions for salinity and pH analyses were performed 11 days past sample collection. A porewater extraction holding time for these tests has not been established. Data qualifiers are not required.

The pH raw data was missing from the data package. The laboratory resubmitted the missing documentation.

8.2 Initial Calibration – Acceptable

Initial calibrations were performed as required and are correctly calculated. All quality control criteria were met.

8.3 Calibration Verifications – Acceptable

Initial calibration verifications and continuing calibration verifications were analyzed as required and are correctly calculated. All quality control criteria were met.

8.4 Blank Analyses – Acceptable

8.4.1 Method Blanks

Method blanks were analyzed at the required frequency and target species were not detected above the reporting limits.

8.4.2 Field Blanks

Field blanks are not associated with this set of samples.

8.5 Replicate Sample Analyses – Acceptable with Qualifications

Sample duplicates/triplicates were analyzed at the required frequency and are correctly calculated. Except as noted below, all RPD or relative standard deviation (RSD) values are within the SAP criteria (less than 20%, except for total solids less than 10%).

The total suspended solids RSD value of water sample WP1 is above the SAP criterion at 23.8%. The total suspended solids result of sample WP1 was qualified as estimated (J).

The TOC RPD value of the duplicate analyses of water sample WP-3 is above the SAP criterion at 20.4%. The positive TOC result in sample WP-3 has been qualified as estimated (J).

Sample ID	Analyte	Quality Control Exceedance	Qualification
WP1	Total suspended solids	Triplicate RSD > 20	J
WP-3	Total organic carbon	Duplicate RPD > 20	J

8.6 Spike Sample Analyses – Acceptable

Matrix spike analyses were performed as required and are correctly calculated. All percent recovery values are within the SAP criteria of 75 to 125% for waters and 65 to 135% for soils and sediments.

8.7 Laboratory Control Sample Analyses – Acceptable

Laboratory control sample analyses were performed are required and are correctly calculated. All percent recovery values are within the SAP criteria.

8.8 Standard Reference Material Analyses – Acceptable

Standard reference materials were analyzed for TOC as required by the SAP and are correctly calculated. All percent recovery values are meet the SAP criteria of 65 to 135%.

8.9 Laboratory Reporting Limits – Acceptable with Discussion

The SAP required target detection limits were met by the soil and sediment samples. The water reporting limits meet the SAP target detection limits, except when samples were analyzed at a dilution.

8.10 Field Duplicates – Acceptable

Sample AMW4 was identified as a field duplicate of sample AMW3. The SAP criterion for field duplicate precision is RPD values less than 20. The precision of the field duplicate is acceptable as shown in Table 2.

8.11 Overall Assessment of Data Useability

The useability of the data is based on the guidance documents listed above. Upon consideration of the information presented here, the data are acceptable except where flagged with data qualifiers that modify the usefulness of the individual values.

9.0 Assessment of Data Quality Objectives

9.1 Precision

Precision is a measure of the mutual agreement among individual measurements of the same property, under prescribed similar conditions. Precision is determined through analysis of matrix spike/matrix spike duplicates, sample duplicates, sample triplicates, and field duplicate samples. Duplicate samples are evaluated for precision in terms of relative percent difference and triplicate samples are evaluated in term of relative standard deviation. Relative percent difference is defined as the difference between the duplicate results divided by the mean and expressed as a percent. Relative standard deviation is the standard deviation divided by the average result and expressed as a percent.

The precision of the volatile, semivolatile, and pesticide/PCB data is good and meets the DQO requirements of the SAP. Laboratory precision as shown by the MS/MSD RPDs and field duplicate precision as demonstrated by the acceptable RPD values are acceptable.

The precision of the petroleum hydrocarbon data set meets the DQO even though the reported diesel RPD value is above the SAP criteria. When the diesel RPD is calculated on the MS and MSD results the RPD is acceptable. Field duplicate precision is acceptable as well.

The precision of the metals data meets the DQO, with several exceptions. The laboratory duplicate RPD value of mercury in soil and lead, zinc, and mercury in sediment are above the SAP criteria. The RPD values of total and dissolved arsenic in the field duplicate are also above the SAP criteria.

The precision of the conventional chemistry data meets the DQO, with two exceptions. The total suspended solids water triplicate RSD value and the water TOC duplicate RPD value are above the SAP criterion indicating poor precision for these results. Field duplicate precision is acceptable.

9.2 Accuracy

Accuracy is the degree of agreement between a measurement and the accepted reference or true value. The level of accuracy is determined by examination of surrogates, matrix spikes, matrix spike duplicates, laboratory control samples, SRMs, method blanks, and field blanks. The surrogate, matrix spike, matrix spike duplicate, SRMs, and laboratory control sample recovery values were compared to the criteria set forth in the SAP, Functional Guidelines, or the analytical method. Method and field blanks are analyzed to identify compounds that could be introduced during the sampling, laboratory extraction, or analysis phase (i.e., laboratory contaminates) and lead to inaccurate results.

The accuracy of the volatile organics data meet the DQO, with one exception. The recovery values of 1,2,4-trichlorobenzene in the MS and MSD analysis of sediment sample AN-SD-6 are below the SAP DQO indicating a potential low bias to the 1,2,4-trichlorobenzene sediment results. All LCSs, surrogates, method blanks, and trip blanks are acceptable.

The accuracy of the semivolatile organic data meets the DQO, with the following exceptions. The low LCS, MS, and MSD recovery values of pentachlorophenol from the sediment matrix indicate a low bias for pentachlorophenol sediment results. The base/neutral analyte results of sample
A-MW-2-S-1 may be inaccurate as shown by the out-of-criteria surrogate recovery values. Several other samples have out-of-criteria surrogate recoveries. However, accuracy is not impacted because a pattern of two or more recovery values per fraction out-of-criteria is not present. The SRM results are acceptable, even though the benzo(g,h,i)perylene soil result is above the 95% confidence interval. The accuracy of the benzo(g,h,i)perylene soil results are considered acceptable because bias is not judged on SRM results alone. The method blanks are acceptable.

The accuracy of the pesticide/PCB data meets the DQO, with one exception. The accuracy of the aldrin result in soil sample A-MW-2-S-1 is biased low as shown by the low MS and MSD recovery values. Several samples have out-of-criteria surrogate recovery values. However, the accuracy of the data set is not impacted since the recovery of the second surrogate is acceptable. The LCSs, SRMs, and method blanks are acceptable.

The accuracy of the petroleum hydrocarbon data meets the DQO, with one exception. The accuracy of the soil results maybe bias low as shown by the low surrogate recovery values of both soil samples. The diesel recovery from the MS is high, however, the accuracy is not impacted because the MSD recovery is with the SAP criteria. The LCS is acceptable and the method blanks are free of contamination.

The accuracy of the metals data meets the DQO, with several exceptions. As illustrated by the matrix spike recovery results, the soil silver results maybe biased high, the sediment copper results maybe biased high, the sediment zinc results maybe biased low, the total iron water results maybe biased low, and the total silver water results maybe biased low. Zinc was detected in the soil method blank. Since the blank concentration is less than 5 times the sample concentrations, the impact of the zinc contamination on the soil sample results is minimal. The SRM recovery values are within the SAP criteria.

The accuracy of the conventional chemistry data meet the DQO specified by the SAP. All matrix spikes, LCSs, SRMs, and method blanks are acceptable.

9.3 Representativeness

Representativeness is the extent to which the data reflect the actual contaminate levels present in the samples. Representativeness is assessed through method and field blanks, and proper preservation and handling. Method and field blank analyses allow for the detection of artifacts that may be reported as false positive results. Proper sample preservation and handling ensure that sample results reflect the actual sample concentrations.

The data are assumed to be representative since all samples were analyzed within the required holding time, the samples were properly preserved and handled and trip blank contamination was not present. The zinc detected in the method blank does not impact the data because the associated sample results are greater than 5 times the method blank concentration.

9.4 Comparability

Comparability is a measure of how easily the data set can be compared and combined with other data sets.

With the exception of the HCID water analyses, the data are assumed to be comparable since standard EPA methods were used to analyze the samples, the method QC criteria were met, and routine detection limits were reported.

9.5 Completeness

Completeness is expressed as the ratio of valid results to the amount of data expected to be obtained under normal conditions. Completeness is determined by assessing the number of samples for which valid results were obtained versus the number of samples that were submitted to the laboratory for analysis. Valid results are results that are determined to be usable during the data validation review process.

The 100% completeness goal was met. The completeness of this data set is 100% because all the samples were analyzed and all the results are valid.

10.0 Definition of Data Qualifiers

10.1 Inorganic Data Qualifiers

The following data validation qualifiers were used in the review of this data set. These qualifiers are taken from Contract Laboratory Program National Functional Guidelines for Inorganic Data Review (USEPA 1994).

U The material was analyzed for, but was not detected above the level of the associated value. The associated value is either the sample quantitation limit or the sample detection limit.

J The associated value is an estimated quantity.

UJ The material was analyzed for, but was not detected. The associated value is an estimate and may be inaccurate or imprecise.

R The data are unusable. (Note: Analyte may or may not be present.)

10.2 Organic Data Qualifiers

The following data validation qualifiers were used in the review of this data set. These qualifiers are taken from Contract Laboratory Program National Functional Guidelines for Organic Data Review (EPA 1994a).

U The analyte was analyzed for but not detected above the reported sample quantitation limit.

J The analyte was positively identified; the associated numerical value is the approximate concentration of the analyte in the sample.

UJ The analyte was not detected above the reported sample quantitation limit. However, the reported quantitation limit is approximate and may or may not represent the actual limit of quantitation necessary to accurately and precisely measure the analyte in the sample.

N The analysis indicates the presence of an analyte for which there is presumptive evidence to make a "tentative identification".

NJ The analysis indicates the presence of an analyte that has been "tentatively identified" and the associated numerical value represents its approximate concentration.

R The sample results are rejected due to serious deficiencies in the ability to analyze the samples and meet quality control criteria. The presence or absence of the analyte cannot be verified.

11.0 References

Anchor Environmental & AESI. 2000. Work Plan/Sampling and Analysis Plan, Focused Site Characterization Holly Street Landfill Redevelopment Project. Anchor Environmental, L.L.C. and AESI, Inc. March 23, 2000

Plumb. 1981 Procedures for Handling and Chemical Analysis of Sediment and Water Samples. Technical Report EPA/CE-81-1. U.S. Army Corps of Engineers, Vicksburg, MS.

USEPA. 1994a. Contract Laboratory Program National Functional Guidelines For Inorganic Data Review. Office of Solid Waste and Emergence Response.

USEPA. 1994b. Contract Laboratory Program National Functional Guidelines For Organic Data Review. Office of Solid Waste and Emergence Response.

USEPA. 1995. Test Methods for Evaluating Solid Waste, Physical/Chemical Methods (SW-846) Third Edition, Updates I, II, IIA and IIB.

WDOE. 1997. Analytical Methods for Petroleum Hydrocarbons. Prepared by the Washington State Department of Ecology Toxics Cleanup Program and the Ecology Environmental Laboratory. June 1997

Table 2
Field Duplicate Precision

Sample ID	Duplicate ID	Analyte	Sample Value	Duplicate Value	RPD
AMW3	AMW4	Bis(2-ethylhexyl)phthalate	2.2	1 U	NC
		Total Arsenic	1.5	1.2	22
		Total Cadmium	0.3	0.3	0
		Total Copper	12	5	82
		Total Iron	1640	1240	28
		Total Lead	3	1	100
		Total Manganese	350	297	16
		Total Zinc	80	67	18
		Dissolved Arsenic	1.4	0.7	67
		Dissolved Cadmium	0.3	0.3	0
		Dissolved Copper	3	3	0
		Dissolved Iron	350	250	33
		Dissolved Manganese	354	356	0.6
		Dissolved Zinc	76	78	2.6
		Hardness	610	530	14
		Alkalinity	160	160	0
		Total Dissolved Solids	3,400	3,400	0
		Total Suspended Solids	7.5	7.1	5.5
		Salinity	2.9	3.0	3.4
		Conductivity	5,600	5,700	1.8
		Chloride	2,000	2,100	9.8
		Ammonia	1.1	0.99	11
		Nitrate	0.30	0.32	6.5
		Nitrate + Nitrite	0.30	0.32	6.5
		Sulfate	260	260	0
		Total Organic Carbon	3.3	3.0	9.5

NC Not calculable
U Analyte not detected above the associated reporting limit
Alkalinity values are in mg/L $CaCO_3$
Total dissolved solids, total suspended solids, chloride, sulfate, and TOC values are in mg/L
Salinity values are in g/kg
Conductivity values are in uS/cm
Ammonia, nitrate, and nitrate + nitrite values are in mg-N/L
Metals and semivolatile organic values are in ug/L
Hardness values are in mg-$CaCO_3$/L

Table 3
Summary of Qualified Data

Sample ID	Analyte	Qualifier*	Reason for Qualification
AN-SD-6 re-analysis	1,2,4-trichlorobenzene	UJ	MS and MSD recovery < 50%
AN-SD-4	All	R (in favor of re-analysis)	Internal standard recovery below Functional Guidelines criteria
AN-SD-6	All	R (in favor of re-analysis)	Internal standard recovery below Functional Guidelines criteria
AN-SD-4 Reanalysis	1,4-dichlorobenzene 1,2-dichlorobenzene 1,2,4-trichlorobenzene	UJ UJ UJ	Internal standard recovery below Functional Guidelines criteria
AN-SD-4	Dibenz(a,h)anthracene	J	CCV Percent difference > 25 (response increased)
AN-SD-6 AN-SD-5 AN-SD-2 AN-SD-3	Indeno(1,2,3-cd)pyrene Benzo(g,h,i)perylene	J	CCV Percent difference > 25 (response increased)
A-MW-2-S-1	Benzyl Alcohol Naphthalene Hexachlorobutadiene 2-methylnaphthalene Dimethylphthalate Acenaphthylene Acenaphthene Dibenzofuran Diethylphthalate Fluorene N-nitrosodiphenylamine Hexachlorobenzene Phenanthrene Anthracene Di-n-butylphthalate Fluoranthene Pyrene Butylbenzylphthalate Benzo(a)anthracene Bis(2-ethylhexyl)phthalate Chrysene Di-n-octylphthalate Benzo(b)fluoranthene Benzo(k)fluroanthene Benzo(a)pyrene Indeno(1,2,3-cd)pyrene Dibenz(a,h)anthracene Benzo(g,h,i)perylene	J positive results UJ detection limits	Surrogate recovery outside SAP criteria
AN-SD-5	Pentachlorophenol	UJ	MS and MSD recovery < 50%
All sediment samples	Pentachlorophenol	UJ	LCS recovery < 50%

Table 3 Continued
Summary of Qualified Data

Sample ID	Analyte	Qualifier*	Reason for Qualification
AN-SD-4	Dibenz(a,h)anthracene	N	Spectra does not Functional Guidelines criteria
A-MW-2-S-1	Anthracene	N	Spectra does not Functional Guidelines criteria
A-MW-3-S-1 AN-SD-4	All analytes flagged E by the laboratory	R	Result above the calibration range
A-MW-3-S-1 Dilution AN-SD-4 Dilution	All analytes for which the dilution was not required	R	Unnecessary result or elevated detection limit
A-MW-3-S-1 A-MW-2-S-1	4,4'-DDD	J positive results UJ detection limits	Initial calibration RSD > 20%
A-MW-2-S-1	Aldrin	UJ	MS and MSD recovery < 50%
A-MW-3-S-1 A-MW-2-S-1	Diesel range hydrocarbons Motor oil range hydrocarbons	J positive results UJ detection limits	Surrogate recovery < 65%
AN-SD-6 AN-SD-4 AN-SD-5	Silver	UJ	Negative ICS concentration and comparable levels of interfering elements present in the samples
AN-SD-3 AN-SD-5	Arsenic	J	ICS concentration > IDL and sample concentration comparable to the ICS and comparable levels of interfering elements present
All soil samples	Mercury	J	Laboratory duplicate RPD > 35
All sediment samples	Lead Zinc Mercury	J	Laboratory duplicate RPD > 20
All soil samples	Silver	J positive results	Matrix spike recovery > 135%
All water samples	Total Iron	J positive results UJ detection limits	Matrix spike recovery < 75%
All sediment samples	Copper	J	Matrix spike recovery > 135%
All sediment samples	Zinc	J	Matrix spike recovery < 65%
AMW4 AMW3	Total copper Total iron Dissolved iron	J	Field duplicate RPD > 20
All water samples	Total Silver	J positive results UJ detection limits	Matrix spike recovery < 75%
AMW4 AMW3	Total arsenic Dissolved arsenic	J	Field duplicate RPD > 20
WP-3	Total organic carbon	J	Duplicate RPD > 20
WP1	Total suspended solids	J	Triplicate RSD > 20

* When the same qualifier applies to all associated samples it is listed only once.

Appendix A

Laboratory Communications

54 pages

Data Validation and Data Quality Assessment Report

Focused Site Characterization
Holly Street Landfill Redevelopment Project
Bellingham, Washington
Dry Season Sampling (August 2000)
Project Number: 990062-04(2)

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1.0 Introduction

This report describes the Functional Guidelines data validation of the samples listed in Table 1. The analyses were performed by Analytical Resources, Incorporated (ARI), located in Seattle Washington.

The validation was performed in accordance with the procedures established in the *Contract Laboratory Program National Functional Guidelines for Inorganic and Organic Data Review* (Functional Guidelines) (USEPA 1994 and 1994a). Project detection limits, quality control (QC) sample frequencies, and data quality objectives (DQOs) are from the *Work Plan/Sampling and Analysis Plan, Focused Site Characterization Holly Street Landfill Redevelopment Project* (SAP) (Anchor & AESI 2000). The criteria used to qualify data are taken from Functional Guidelines, the SAP, the analytical methods, or the professional judgment of the validation chemist.

Sections 2 through 7 present the validation findings and Section 9 defines the data qualifiers. Section 8 evaluates the project data against the data quality objectives set forth in the SAP. Table 2 presents an evaluation of field duplicate precision and Table 3 is a summary of the qualified data. Copies of laboratory communications are provided in Appendix A. The original laboratory resubmissions have been placed in the data packages. Validation qualifier flags have been added to the sample data sheets in the Data Summary section of the data packages.

The Anchor Data Tables were modified to reflect the data changes and qualifiers prescribed in this report. The validation qualifiers were added to the laboratory flag column of the Data Tables.

Table 1
Sample Data Reviewed

Sample ID	Matrix	Laboratory Sample ID	VOA	SVOA	TPH-HCID	Metals	Conventionals
A-MW-1	Water	CB46A & CB47A	X	X	X	X	X
A-MW-2	Water	CB46B & CB47B	X	X	X	X	X
A-MW-3	Water	CB46C & CB47C	X	X	X	X	X
A-MW-4	Water	CB46D & CB47D	X	X	X	X	X
WP-1	Water	CB46E & CB47E	X	X	X	X	X
WP-2	Water	CB46F & CB47F	X	X	X	X	X
WP-3	Water	CB46G & CB4G	X	X	X	X	X
WP-5	Water	CB46H & CB47H	X	X	X	X	X
RB-1	Water	CB46I & CB47I	X	X	X	X	X
Trip Blank	Water	CB47J	X				

VOA: Volatile organics by Method 8260

SVOA: Semivolatile organics by Method 8270

TPH-HCID: Petroleum hydrocarbon identification by Method NWTPH-HCID (WDOE 1997)

Metals: Total and dissolved arsenic, cadmium, lead, and silver by Method 200.8; total and dissolved calcium, chromium, copper, iron, manganese, magnesium, and zinc by Method 6010; and total and dissolved mercury by Method 7470

Conventionals: Total dissolved solids by Method 160.1, total suspended solids by Method 160.2, alkalinity by Method 2320, ammonia by Method 350.1, chloride by Method 325.2, nitrite by Method 353.2, nitrate and nitrite by Method 353.2, sulfate by Method 375.2, total organic carbon by Method 415.1, and conductivity and salinity by Method 2520B

2.0 Data Validation of Volatile Organics Analyses

2.1 Custody, Preservation, Holding Times, and Completeness – Acceptable

All samples were analyzed within the required holding times and all samples were received intact and were properly preserved. The data package is complete and contains all the information necessary to recreate the sample results.

2.2 Instrument Tuning and Mass Calibration – Acceptable

The tuning compound bromofluorobenzene was analyzed at the required frequency and all Functional Guidelines criteria were met.

2.3 Initial Calibration – Acceptable

Initial calibrations were analyzed at the required frequency and are calculated correctly. The Functional Guidelines criteria of relative standard deviation (RSD) values less than or equal to 30% and relative response factors greater than 0.05 were met for all target compounds.

2.4 Continuing Calibration – Acceptable with Qualifications

Continuing calibrations were analyzed at the required frequency and are calculated correctly. Except as noted below, the Functional Guidelines criteria of percent difference values less than or equal to 25 and relative response factors (RRFs) greater than 0.05 were met.

The percent difference values of 1,2-dichloroethane-d_4, toluene-d_8, 4-bromofluorobenzene, and 1,2-dichlorobenzene-d_4 are above the Functional Guidelines criteria (values range from 26.3% to 31.4%). Data qualifiers are not required for surrogate compounds.

The percent difference value of 1,2,4-trichlorobenzene is above the Functional Guidelines criteria at 27.9%. Since the response decreased and 1,2,4-trichlorobenzene was not detected in the associated samples, they were qualified as estimated detection limit (UJ).

Sample ID	Analyte	Quality Control Exceedance	Qualification
A-MW-1 A-MW-2 A-MW-3 A-MW-4 WP-1 WP-2 WP-3 WP-5 RB-1 Trip Blank	1,2,4-trichlorobenzene	CCV percent difference > 25%	UJ

2.5 Blank Analyses – Acceptable

2.5.1 Method Blanks

Method blanks were analyzed at the required frequency and target analytes were not detected above the reporting limits.

2.5.2 Field Blanks

One trip blank and one field blank (RB-1) are associated with the samples. Target analytes were not detected above the reporting limits in either blank.

2.6 Surrogate Analyses – Acceptable

Surrogate compounds were added to all samples, blanks and QC samples as required. The percent recovery values are correctly calculated and all are within the SAP criteria of 60 to 140%.

2.7 Matrix Spike/Matrix Spike Duplicate Analyses – Acceptable

Matrix spike/matrix spike duplicates (MS/MSD) were analyzed at the required frequency and are correctly calculated. All percent recovery and relative percent difference (RPD) values are within the SAP criteria (60 to 140% recovery and RPD values less than 35%).

2.8 Laboratory Control Sample Analyses – Acceptable

Laboratory control samples (LCSs) were analyzed as required and are correctly calculated. All percent recovery values are within the SAP criteria.

2.9 Standard Reference Material Analyses

The SAP does not require standard reference material (SRM) analyses for water samples.

2.10 Internal Standard Evaluation – Acceptable

Internal standards were added to all samples, blanks and QC samples as required. The internal standard recovery and retention time criteria of Functional Guidelines were met.

2.11 Compound Quantitation and Laboratory Reporting Limits – Acceptable

The final results are correctly calculated including the amount analyzed and dilution factors. Positive results meet the Functional Guidelines criteria for retention time and mass spectra.

The SAP target detection limits were met. The laboratory reporting limits are all less than or equal to the SAP target detection limits.

2.12 Field Duplicates – Acceptable

Sample A-MW-4 was identified as a field duplicate of sample A-MW-2. RPD values could not be calculated since positive results were not detected in either sample.

2.13 Overall Assessment of Data Useability

The useability of the data is based on the guidance documents listed above. Upon consideration of the information presented here, the data are acceptable except where flagged with data qualifiers that modify the usefulness of the individual values.

3.0 Data Validation of Semivolatile Organics Analyses

3.1 Custody, Preservation, Holding Times, and Completeness – Acceptable with Qualifications

All samples were extracted and analyzed within the required holding times. All samples were received intact and were properly preserved. The data package is complete and contains all the information necessary to recreate the sample results.

The QC summary Forms 4, 5, 7, and 8 for the re-extracted batch analyzed on 9-19-00 were missing from the data package. The laboratory resubmitted the missing forms.

The raw data for the laboratory control sample duplicate (LCSD) extracted on 9-4-00, and the tune and CCV analyzed on 9-19-00 were missing from the data package. The laboratory resubmitted the missing information.

The re-extraction of sample WP-3 was performed 6 days past the required 7 day holding time for extraction. Positive results have been qualified as estimated (J) and non-detected results have been qualified as estimated detection limit (UJ).

Sample ID	Analyte	Qualification	Quality Control Exceedance
WP-3	All	J positive results UJ detection limits	Extraction hold time exceeded

3.2 Instrument Tuning and Mass Calibration – Acceptable

The tuning compound decafluorotriphenylphosphine was analyzed at the required frequency and all relative abundance values are within Functional Guidelines criteria.

3.3 Initial Calibration – Acceptable with Discussion

Initial calibrations were analyzed at the required frequency and are correctly calculated. Except as noted below, the Functional Guidelines criteria of RSD values less than 30 and relative response factors greater than 0.05 were met for target analytes.

The RSD of dibenz(a,h)anthracene is above the Functional Guidelines criteria at 31.4%. Since the relative response factor is acceptable, and dibenz(a,h)anthracene was not detected in the associated samples, data qualifiers are not required.

3.4 Continuing Calibration – Acceptable with Qualifications

Continuing calibration verifications (CCVs) were analyzed at the required frequency and are correctly calculated. Except as noted below, all percent difference values and relative response factors met the Functional Guidelines criteria of less than 25% and greater than 0.05, respectively.

The percent difference values of benzyl alcohol, n-nitrosodiphenylamine, pyrene, chrysene, and di-n-octylphthalate in the CCV analyzed on 9-8-00 are above the Functional Guidelines criteria (values range from 25.5 to 39.2%). Data qualifiers are not required because the response increased and positive results were not detected in the associated samples.

The percent difference values of n-nitrosodiphenylamine, pyrene, and bis(2-ethylhexyl)phthalate in the CCV analyzed on 9-10-00 are above the Functional Guidelines criteria at 37.0%, 40.0%, and 30.5%, respectively. Since the response increased, positive results in the associated samples were qualified as estimated (J) as shown in the following table.

The percent difference values of hexachlorobenzene and pyrene in the CCV analyzed on 9-18-00 are above the Functional Guidelines criteria at 30.4% and 36.9%. Data qualifiers are not required for pyrene since the response increased and positive results were not detected in the associated sample (WP-3). The hexachlorobenzene result of sample WP-3 was qualified as estimated detection limit (UJ) because the response decreased.

The percent difference values of 2-fluorophenol and 2,4,6-tribromophenol in the CCVs analyzed on 9-10-00 and 9-19-00 are above the Functional Guidelines criteria (values range from 26.6% to 39.0%). Data qualifiers are not required for surrogate compounds.

Sample ID	Analyte	Quality Control Exceedance	Qualification
RB-1	Bis(2-ethylhexyl)phthalate	CCV Percent difference > 25 (response increased)	J
WP-3	Hexachlorobenzene	CCV Percent difference > 25 (response decreased)	UJ

3.5 Blank Analyses – Acceptable with Qualifications

3.5.1 Method Blanks

Method blanks were analyzed at the required frequency and target analytes were not detected above the reporting limit.

3.5.2 Field Blanks

Sample RB-1 was identified as a field blank. Bis(2-ethylhexyl)phthalate was detected in field blank at 1.7 ug/L. Functional Guidelines prescribes three qualifications schemes for blank contamination, (1) associated sample concentrations greater than the action level (10 times the blank concentration for phthalates) are not qualified, (2) associated sample concentrations less than the action level and greater than the reporting limit are qualified as undetected (U) at the reported value, and (3) associated sample concentrations less than the action level and less than the reporting limit are qualified as undetected (U) at the reporting limit. The associated samples were qualified as shown in the following table.

Sample ID	Analyte	Qualification	Quality Control Exceedance
A-MW-1 A-MW-2	Bis(2-ethylhexyl)phthalate	U at reported value	Result is greater than the reporting limit and less than 10 times the field blank level

3.6 Surrogate Analyses – Acceptable with Discussion

Surrogate compounds were added to all samples, blanks and QC samples as required and are correctly calculated. Except as noted below, all surrogate recovery values are within the SAP criteria of 60 to 140%.

The 1,2-dichlorobenzene-d_4 surrogate recovery values from samples A-MW-1, A-MW-2, A-MW-3, WP-1, WP-2, WP-5, and RB-1 are below the SAP criteria (values range from 51.7% to 54.0%). Data were not qualified because Functional Guidelines allows one surrogate per fraction (base/neutral or acid) to exceed criteria without qualification.

The 1,2-dichlorobenzene-d_4 and 2,4,6-tribromophenol surrogate recovery values from the method blank extracted 9-4-00 are below the SAP criteria at 47.2% and 56.1%, respectively. The 1,2-dichlorobenzene-d_4 surrogate recovery values from the laboratory control sample (LCS) and LCSD extracted 9-4-00 are below the SAP criteria at 56.5% and 52.0%, respectively. The 1,2-dichlorobenzene-d_4 surrogate recovery values from the LCS extracted 9-11-00 is below the SAP criteria at 59.0%. Data qualifiers are not required for QC samples.

3.7 Matrix Spike/Matrix Spike Duplicate Analyses – Acceptable with Discussion

Except as noted below, MS/MSD analyses were performed at the required frequency, are correctly calculated, and all percent recovery and RPD values are within the SAP criteria.

The laboratory did not perform MS/MSD analyses. Data qualifiers are not required.

3.8 Laboratory Control Sample Analyses – Acceptable with Qualifications

Laboratory control samples were analyzed with each batch and the results are correctly calculated. Except as noted below, all percent recovery and RPD values are within the SAP criteria of 60 to 140% and RPD values less than 35.

The pyrene percent recovery in the LCS and LCSD extracted on 9-4-00 and the LCS extracted on 9-11-00 are below the SAP criteria at 55.6%, 54.4%, and 54.4%, respectively. Due to the pattern of low recovery, the pyrene results in all samples have been qualified as estimated (J) or estimated detection limit (UJ).

The pentachlorophenol percent recovery in the 9-4-00 LCS is below the SAP criteria at 48.8%. The LCSD recovery is acceptable (69.9%), however, the RPD value is above the SAP criteria at 36%. Data qualifiers are not required due to the low LCS recovery because the LCSD is acceptable. Data qualifiers are not required due to the imprecision of the results, because positive pentachlorophenol results were not reported in the associated samples.

The pentachlorophenol percent recovery in the 9-11-00 LCS is below the SAP criteria at 59.5%. The pentachlorophenol result in the associated sample (WP-3) has have been qualified as estimated detection limit (UJ).

Sample ID	Analyte	QC Exceedance	Qualification
All samples	Pyrene	Pattern of low LCS & LCSD recovery	J positive results UJ detection limits
WP-3	Pentachlorophenol	LCS recovery < 50%	UJ

3.9 Standard Reference Material Analyses

The SAP does not require SRM analyses for water samples.

3.10 Internal Standard Evaluation – Acceptable

Internal standards were added to all samples, blanks and QC samples as required. The recovery and retention time criteria of Functional Guidelines were met.

3.11 Compound Quantitation and Laboratory Reporting Limits – Acceptable with Discussion

The final results are correctly calculated including the amount extracted and dilution factors. Positive results meet the Functional Guidelines criteria for retention time and mass spectra.

The SAP target detection limits were not met in all cases. The laboratory reporting limits for hexachlorobutadiene, phenol, 2-methylphenol, 2,4-dimethylphenol, benzyl alcohol, pentachlorophenol, and benzoic acid are above the SAP target detection limits.

3.12 Field Duplicates – Acceptable

Sample A-MW-4 was identified as a field duplicate of sample A-MW-2. An RPD value could not be calculated because di-n-butylphthalate was detected in sample A-MW-2 (1.1 ug/L), but was not detected in sample A-MW-4 (1 ug/L detection limit).

3.13 Overall Assessment of Data Useability

The useability of the data is based on the guidance documents listed above. Upon consideration of the information presented here, the data are acceptable except where flagged with data qualifiers that modify the usefulness of the individual values.

4.0 Data Validation of Petroleum Hydrocarbons by Method NWTPH-HCID

4.1 Custody, Preservation, Holding Times, and Completeness – Acceptable

All samples were extracted and analyzed within the required holding times. All samples were received intact and were properly preserved. The data package is complete and contains all the information necessary to recreate the sample results.

4.2 Initial Calibration – Acceptable

Initial calibrations were analyzed at the required frequency and are correctly calculated. The Functional Guidelines linearity criteria (for GC pesticides) of RSD values less than 20% was met.

4.3 Calibration Verifications – Acceptable

Continuing calibration verifications were analyzed at the required frequency and are correctly calculated. The method criteria of percent difference values less than or equal to 15% was met.

4.4 Blank Analyses – Acceptable

4.4.1 Method Blanks

Method blanks were analyzed at the required frequency and target analytes were not detected above the reporting limit.

4.4.2 Field Blanks

Sample RB-1 was identified as a field blank. Petroleum hydrocarbons were not detected above the reporting limit.

4.5 Surrogate Analyses – Acceptable

Surrogate compounds were added to all samples, blanks and QC samples as required and are correctly calculated. All percent recovery values are within SAP criteria of 70 to 130%.

4.6 Matrix Spike/Matrix Spike Duplicate Analyses – Acceptable with Discussion

Except as noted below, MS/MSD analyses were performed as required, are correctly calculated, and all percent recovery and relative percent difference values are within the SAP criteria.

The laboratory did not analyze MS/MSDs with the samples. MS/MSD analyses are not required by Method NWTPH-HCID (WDOE 1997). However, the SAP requires one MS/MSD pair per 20 samples. Data qualifiers are not required because the LCS is acceptable.

4.7 Laboratory Control Sample Analysis – Acceptable

Laboratory control samples were analyzed as required and are correctly calculated. All percent recovery values are within the SAP criteria of 70 to 130%.

4.8 Standard Reference Material Analyses

The SAP does not require SRM analyses for petroleum hydrocarbons.

4.9 Compound Quantitation and Laboratory Reporting Limits – Acceptable with Discussion

The final results are correctly calculated, including the amount extracted and dilution factors.

The SAP target detection limit was met for gasoline. The laboratory reporting limit of 0.50 mg/L for diesel range hydrocarbons and motor oil range hydrocarbons is above the SAP target detection limit of 0.25 mg/L.

4.10 Field Duplicates – Acceptable

Sample A-MW-4 was identified as a field duplicate of sample A-MW-2. An RPD value could not be calculated because positive results were not detected in either sample.

4.11 Overall Assessment of Data Useability

The useability of the data is based on the guidance documents listed above. Upon consideration of the information presented here, the data are acceptable.

5.0 Data Validation of Metals by Method 6010 and Mercury by Method 7470

5.1 Custody, Preservation, Holding Times, and Completeness – Acceptable

All samples were analyzed within the required holding times. All samples were received intact and were properly preserved. The data package is complete and contains all the information necessary to recreate the sample results.

5.2 Initial Calibration – Acceptable

Initial calibrations were analyzed as required and all quality control checks met Functional Guidelines requirements.

5.3 Calibration Verifications – Acceptable

Initial calibration verifications and continuing calibration verifications were analyzed at the required frequency and are correctly calculated. All Functional Guidelines criteria were met.

5.4 Blank Analyses – Acceptable with Qualifications

5.4.1 Method Blanks

Instrument and method blanks were analyzed at the required frequency. Target analytes were not detected above the reporting limit.

5.4.2 Field Blanks

Sample RB-1 was identified as a field blank. Total calcium, manganese, and zinc were detected in the field blank at 60 ug/L, 2 ug/L, and 11 ug/L, respectively. Functional Guidelines prescribes three qualifications schemes for blank contamination, (1) associated sample concentrations greater than the action level (5 times the blank concentration) are not qualified, (2) associated sample concentrations less than the action level and greater than the reporting limit are qualified as undetected (U) at the reported value, and (3) associated sample concentrations less than the action level and less than the reporting limit are qualified as undetected (U) at the reporting limit. The associated samples were qualified as shown in the following table.

Sample ID	Analyte	Qualification	Quality Control Exceedance
WP-1 WP-2	Total manganese	U at reported value	Result is greater than the reporting limit and less than 5 times the field blank level

5.5 ICP Interference Check – Acceptable with Qualifications

ICP interference check samples (ICS) were analyzed at the required frequency and are correctly calculated. All percent recovery values are within Functional Guidelines criteria and, except as noted below, all non-spiked analytes have absolute values less than the instrument detection limit (IDL).

The copper and manganese results in the opening and closing ICS analyses on 9-11-00 have negative values greater than the IDL. Functional Guidelines provides two qualifying schemes for negative results greater than the IDL: (1) when the negative value is greater than the IDL but less than 2 times the IDL, and the associated samples contain comparable levels of interfering elements (calcium, aluminum, magnesium, and iron), non-detected results are qualified as estimated detection limit (UE), and (2) when a negative value is greater than two times the IDL, and greater than 10% of the associated sample concentration, and when the associated samples contain comparable levels of interfering elements, positive results are qualified as estimated (J) and non-detected results are qualified as estimated detection limit (UJ). Since the associated samples contained comparable levels of magnesium they were qualified as shown in the following table.

Manganese has positive results greater than the IDL in the opening and closing ICS analyses on 9-12-00. Because positive results in the ICS indicate a potential high bias when the samples contain comparable levels of interfering elements, positive results are qualified as estimated (J) when the concentration in the sample is comparable to the level in the ICS. Data qualifiers are not required because manganese was not detected in the associated samples with comparable levels of interfering elements.

Sample ID	Analyte	Qualification	Quality Control Exceedance
WP-5	Dissolved copper	UJ	Negative ICS concentration and comparable levels of interfering elements present in the samples
WP-1	Dissolved copper	J	Negative ICS concentration > 2X IDL and > 10% of sample result and comparable levels of interfering elements present
WP-1	Dissolved manganese	UJ	Negative ICS concentration and comparable levels of interfering elements present in the samples

5.6 Duplicate Sample Analysis – Acceptable

Sample duplicate analyses were performed at the required frequency and are correctly calculated. All RPD values are within the SAP criteria of less than 20%.

5.7 Spike Sample Analyses – Acceptable

Matrix spike analyses were performed at the required frequency and are correctly calculated. All percent recovery values are within the SAP criteria of 75 to 125%.

5.8 ICP Serial Dilution Analyses – Acceptable

Serial dilutions were performed as required and are correctly calculated. The Functional Guidelines criteria of percent difference values less than 10% for results greater than 50 times the IDL were met.

5.9 Laboratory Control Sample/Standard Reference Material Analyses – Acceptable

Laboratory control samples or certified reference materials were analyzed as required and are correctly calculated. All percent recovery values are within the Functional Guidelines criteria of 80 to 120%.

5.10 Compound Quantitation and Laboratory Reporting Limits – Acceptable

The final results are correctly calculated including the amount digested and dilution factors.

The SAP specified target detection limits were met for samples that were analyzed undiluted. The laboratory reported total calcium and total magnesium, even though they were not required by the SAP.

5.11 Field Duplicates – Acceptable with Qualifications

Sample A-MW-4 was identified as a field duplicate of sample A-MW-2. The SAP criterion for field duplicate precision is RPD values less than 20. The RPD value of dissolved iron is above the SAP criterion at 156%. The dissolved iron results in samples A-MW-2 and A-MW-4 were qualified as estimated (J). The precision of the field duplicate set is presented in Table 2.

Sample ID	Analyte	Quality Control Exceedance	Qualification
A-MW-2 A-MW-4	Dissolved iron	Field duplicate RPD > 20	J

5.12 Overall Assessment of Data Useability

The useability of the data is based on the guidance documents listed above. Upon consideration of the information presented here, the data are acceptable except where flagged with data qualifiers that modify the usefulness of the individual values.

6.0 Data Validation of Metals by ICP/MS Method 200.8

6.1 Custody, Preservation, Holding Times, and Completeness – Acceptable

All samples were analyzed within the required holding times and all samples were received intact and were properly preserved. The data package is complete and contains all the information necessary to recreate the sample results.

6.2 Initial Calibration – Acceptable

Initial calibrations were analyzed as required and all quality control checks met Functional Guidelines requirements.

6.3 Calibration Verifications – Acceptable

Initial calibration verifications and continuing calibration verifications were analyzed at the required frequency and are correctly calculated. All Functional Guidelines criteria were met.

6.4 Blank Analyses – Acceptable with Qualifications

6.4.1 Method Blanks

Instrument and method blanks were analyzed at the required frequency and target analytes were not detected above the reporting limit.

6.4.2 Field Blanks

Sample RB-1 was identified as a field blank. Total cadmium and lead were detected in the field blank at 0.2 ug/L and 1 ug/L, respectively. Functional Guidelines prescribes three qualifications schemes for blank contamination, (1) associated sample concentrations greater than the action level (5 times the blank concentration) are not qualified, (2) associated sample concentrations less than the action level and greater than the reporting limit are qualified as undetected (U) at the reported value, and (3) associated sample concentrations less than the action level and less than the reporting limit are qualified as undetected (U) at the reporting limit. The associated samples were qualified as shown in the following table.

Sample ID	Analyte	Qualification	Quality Control Exceedance

Sample ID	Analyte	Qualification	Quality Control Exceedance
A-MW-2 A-MW-4	Total lead	U at reported value	Result is greater than the reporting limit and less than 5 times the field blank level

6.5 ICP Interference Check – Acceptable

ICP interference check samples (ICS) were analyzed at the required frequency and are correctly calculated. All percent recovery values are within Functional Guidelines criteria and all non-spiked analytes have absolute values less than the IDL.

6.6 Internal Standard Evaluation – Acceptable

Internal standards were added to all samples, blanks and QC samples as required and all method criteria were met.

6.7 Duplicate Sample Analysis – Acceptable with Discussion

Sample duplicate analyses were performed at the required frequency and are correctly calculated. Except as noted below, all RPD values are within the SAP criterion of less than 20%.

The RPD value of dissolved arsenic in the duplicate analysis of sample A-MW-2 is above the SAP criteria at 28.6%. Data qualifiers are not required because the results are less than 5 times the reporting limit, and are within one reporting limit of each other.

6.8 Spike Sample Analysis – Acceptable with Qualifications

Matrix spike analyses were performed at the required frequency and are correctly calculated. Except as noted below, all percent recovery values are within the SAP criteria of 75 to 125%.

The silver recovery value in the total metals spiked analysis of sample A-MW-1 is below the SAP criteria at 74.8%. Since the LCS is acceptable, only the total silver result in sample A-MW-1 has been qualified as estimated detection limit (UJ).

Sample ID	Analyte	Quality Control Exceedance	Qualification
A-MW-1	Total Silver	Matrix spike recovery < 75%	UJ

6.9 Laboratory Control Sample/Standard Reference Material Analyses – Acceptable

Laboratory control samples were analyzed as required and are correctly calculated. All percent recovery values are within the Functional Guidelines criteria of 80 to 120%.

6.10 Compound Quantitation and Laboratory Reporting Limits – Acceptable

The final results are correctly calculated including amount digested and dilution factors. The SAP specified target detection limits were met.

6.11 Field Duplicates – Acceptable with Discussion

Sample A-MW-4 was identified as a field duplicate of sample A-MW-2. The SAP criterion for field duplicate precision is RPD values less than 20. The RPD value of dissolved arsenic is above the SAP criterion at 29%. Data qualifiers are not required because the results are less than 5 times the reporting limit and within one reporting limit of each other. The precision of the field duplicate set is presented in Table 2.

6.12 Overall Assessment of Data Useability

The useability of the data is based on the guidance documents listed above. Upon consideration of the information presented here, the data are acceptable except where flagged with data qualifiers that modify the usefulness of the individual values.

7.0 Data Validation of Conventional Chemistry Analyses

7.1 Custody, Preservation, Holding Times, and Completeness – Acceptable with Discussion

All samples were analyzed within the required holding times and all samples were received intact and were properly preserved. The data package is complete and contains all the information necessary to recreate the sample results.

The chloride result reported for sample WP-3 was incorrect. The laboratory resubmitted the final data sheet with the correct result.

7.2 Initial Calibration – Acceptable

Initial calibrations were performed as required and are correctly calculated. All quality control criteria were met.

7.3 Calibration Verifications – Acceptable with Discussion

Except as noted below, initial calibration verifications and CCV were analyzed as required and are correctly calculated. All quality control criteria were met.

For the chloride analyses on 9-14-00, the sulfate analyses on 9-1-00, and the ammonia analyses on 9-8-00, more than 10 samples were analyzed between CCVs. Data qualifiers are not required because the all CCVs and matrix spikes analyzed during the analytical sequences are acceptable.

7.4 Blank Analyses – Acceptable with Qualifications

7.4.1 Method Blanks

Method blanks were analyzed at the required frequency and target species were not detected above the reporting limits.

7.4.2 Field Blanks

Sample RB-1 was identified as a field blank. Alkalinity, ammonia, nitrate, and nitrate plus nitrite were detected in the field blank at 1.6 mg/L, 0.020 mg-N/L, 0.015 mg-N/L, and 0.015 mg-N/L, respectively. Functional Guidelines prescribes three qualifications schemes for blank contamination, (1) associated sample concentrations greater than the action level (5 times the blank concentration) are not qualified, (2) associated sample concentrations less than the action level and greater than the reporting limit are qualified as undetected (U) at the reported value, and (3) associated sample concentrations less than the action level and less than the reporting limit are qualified as undetected (U) at the reporting limit. The associated samples were qualified as shown in the following table. Note that the nitrate plus nitrite results were reduced by the nitrate amount.

Sample ID	Analyte	Qualification	Quality Control Exceedance
A-MW-2 A-MW-3 A-MW-4	Nitrate	U at reported value	Result is greater than the reporting limit and less than 5 times the field blank level
WP-1 WP-2 WP-3	Ammonia	U at reported value	Result is greater than the reporting limit and less than 5 times the field blank level

7.5 Replicate Sample Analyses – Acceptable with Discussion

Sample duplicates/triplicates were analyzed at the required frequency and are correctly calculated. Except as noted below, all RPD or relative standard deviation (RSD) values are within the SAP criteria of less than 20%.

The RPD value for ammonia in the duplicate analysis of sample RB-1 is above the SAP criteria at 22.2%. Data qualifiers are not required because the results are less than 3 times the reporting limit, and are within one reporting limit of each other.

7.6 Spike Sample Analyses – Acceptable with Qualifications

Matrix spike analyses were performed as required and are correctly calculated. Except as noted below, all percent recovery values are within the SAP criteria of 75 to 125%.

The nitrate recovery values in the MS and MSD analysis of sample WP-5 are below the SAP criteria at 50.5% and 51.5%, respectively. Since the laboratory control samples are acceptable, only nitrate result of sample WP-5 has been qualified as estimated detection limit (UJ).

The nitrate plus nitrite recovery value in the spiked analysis of sample WP-5 is below the SAP criteria at 74.2. Since the laboratory control samples are acceptable, only the nitrate plus nitrite result of sample WP-5 has been qualified as estimated detection limit (UJ).

Sample ID	Analyte	QC Exceedance	Qualification
WP-5	Nitrate	Percent recovery < 75	UJ
WP-5	Nitrate + Nitrite	Percent recovery < 75	UJ

7.7 Laboratory Control Sample Analyses – Acceptable

Laboratory control sample analyses were performed are required and are correctly calculated. All percent recovery values are within the SAP criteria.

7.8 Standard Reference Material Analyses – Acceptable

Standard reference materials were analyzed as required and are correctly calculated. All percent recovery values are meet the SAP criteria.

7.9 Laboratory Reporting Limits – Acceptable with Discussion

The reporting limits meet the SAP target detection limits, except when samples were analyzed at a dilution.

The nitrate plus nitrite results of samples A-MW-2, A-MW-3, and A-MW-4 were reduced by subtracting the nitrate results that were determined to be undetected at the reported value, due to field blank contamination.

The salinity result of sample RB-1 was change by the validation chemist from 0.00 to < 0.10.

For samples WP-1, WP-2, WP-3, and WP-5, the laboratory reported the average chloride result from several analyses. For the samples listed in the following table, the RSD value of the averaged results is greater than 15. The chloride results for these samples have been qualified as estimated (J).

Sample ID	Analyte	QC Exceedance	Qualification

Sample ID	Analyte	QC Exceedance	Qualification
WP-2 WP-3 WP-5	Chloride	RSD of averaged results > 15	J

7.10 Field Duplicates – Acceptable with Qualifications

Sample A-MW-4 was identified as a field duplicate of sample A-MW-2. The SAP criterion for field duplicate precision is RPD values less than 20. The RPD value of sulfate is above the SAP criterion at 32%. The sulfate results in samples A-MW-2 and A-MW-4 were qualified as estimated (J). The precision of the field duplicate set is presented in Table 2.

Sample ID	Analyte	Quality Control Exceedance	Qualification
A-MW-2 A-MW-4	Sulfate	Field duplicate RPD > 20	J

7.11 Overall Assessment of Data Useability

The useability of the data is based on the guidance documents listed above. Upon consideration of the information presented here, the data are acceptable except where flagged with data qualifiers that modify the usefulness of the individual values.

8.0 Assessment of Data Quality Objectives

8.1 Precision

Precision is a measure of the mutual agreement among individual measurements of the same property, under prescribed similar conditions. Precision is determined through analysis of matrix spike/matrix spike duplicates, laboratory control sample/laboratory control sample duplicates, sample duplicates, sample triplicates, and field duplicate samples. Duplicate samples are evaluated for precision in terms of relative percent difference and triplicate samples are evaluated in term of relative standard deviation. Relative percent difference is defined as the difference between the duplicate results divided by the mean and expressed as a percent. Relative standard deviation is the standard deviation divided by the average result and expressed as a percent.

The precision of the volatile organic and petroleum hydrocarbon data is good and meets the DQO of the SAP. Laboratory precision as shown by the MS/MSD RPD values and field precision as shown by the field duplicate RPD values are acceptable.

The precision of the semivolatile organics data set meets the DQO. Since positive results were not detected for pentachlorophenol, the precision of the data set is not impacted by the high LCS/LCSD pentachlorophenol RPD value.

The precision of the metals data meets the DQO, with one exception. The field duplicate RPD value for dissolved iron is above the SAP criteria. Since the RPD value of the dissolved iron sample duplicate is acceptable, the imprecision may be due to field sampling techniques. The dissolved arsenic RPD value for the sample duplicate is above the SAP criteria, however, the data are not impacted because the arsenic results are within 5 times the reporting limit and within one reporting limit of each other.

The precision of the conventional chemistry data meets the SAP DQO, with the following exceptions. The chloride results of samples WP-2, WP-3, and WP-5 are imprecise as shown by the high RSD values of the averaged results. The sulfate field duplicate RPD value is above the SAP criterion. Since the sulfate sample duplicate is acceptable, field sampling techniques maybe the source of the imprecision.

8.2 Accuracy

Accuracy is the degree of agreement between a measurement and the accepted reference or true value. The level of accuracy is determined by examination of surrogates, matrix spikes, matrix spike duplicates, laboratory control samples, SRMs, method blanks, and field blanks. The surrogate, matrix spike, matrix spike duplicate, SRMs, and laboratory control sample recovery values were compared to the criteria set forth in the SAP. Method and field blanks are analyzed to identify compounds that could be introduced during the sampling, laboratory extraction, or analysis phase (i.e., laboratory contaminates) and lead to inaccurate results.

The accuracy of the volatile organics and petroleum hydrocarbon data meet the DQO of the SAP. The recovery values of the surrogates, MSs, MSDs, and LCSs are within the SAP criteria. The method blanks and field blanks are free of contamination.

The accuracy of the semivolatile organic data meets the DQO, with the following exceptions. The pattern of low pyrene recovery from the LCSs indicates the pyrene results are biased low. The pentachlorophenol recovery from the 9-4-00 and 9-11-00 LCSs does not constitute a pattern because the 9-4-00 LCSD recovery is acceptable. The pentachlorophenol result in the sample associated with the 9-11-00 LCS maybe biased low and has been qualified as estimated detection limit. Several samples have surrogate recovery values below the SAP criteria. However, accuracy is not impacted because only one surrogate per fraction if out-of-criteria. The impact of the bis(2-ethylhexyl)phthalate field blank contamination has been minimized by the proper use of data qualifiers as prescribed by Functional Guidelines. Qualifying contaminates in the associated samples as undetected when their concentration is less than 10 times the blank concentration minimizes the possibility of false positive results.

The accuracy of the metals data meets the SAP DQO, with one exception. The total silver results maybe biased low as shown by the low matrix spike recovery. The impact of the total calcium, cadmium, manganese, lead, and zinc field blank contamination has been minimized by the proper use of data qualifiers as prescribed by Functional Guidelines. Qualifying contaminates in the associated samples as undetected when their concentration is less than 5 times the blank concentration minimizes the possibility of false positive results.

The accuracy of the conventional chemistry data meets the DQO specified by the SAP, with two exceptions. The nitrate and nitrate plus nitrite data maybe biased low due to the low matrix spike recovery values. The impact of the alkalinity, ammonia, nitrate and nitrate plus nitrite field blank contamination has been minimized by the proper use of data qualifiers as prescribed by Functional Guidelines. Qualifying contaminates in the associated samples as undetected when their concentration is less than 5 times the blank concentration minimizes the possibility of false positive results.

8.3 Representativeness

Representativeness is the extent to which the data reflect the actual contaminate levels present in the samples. Representativeness is assessed through method and field blanks, and proper preservation and handling. Method and field blank analyses allow for the detection of artifacts that may be reported as false positive results. Proper sample preservation and handling ensure that sample results reflect the actual sample concentrations.

The data are assumed to be representative, with one exception. The semivolatile organic results of sample WP-3 may not be representative because the sample was extracted past the required holding time. The samples were properly preserved and handled and method blank and trip blank contamination was not present. The target analytes detected in the field blank do not impact the data because the associated sample results were qualified as prescribed in Functional Guidelines to minimize the impact of the contamination.

8.4 Comparability

Comparability is a measure of how easily the data set can be compared and combined with other data sets. The data are assumed to be comparable since standard EPA methods were used to analyze the samples, the method QC criteria were met, and routine detection limits were reported.

8.5 Completeness

Completeness is expressed as the ratio of valid results to the amount of data expected to be obtained under normal conditions. Completeness is determined by assessing the number of samples for which valid results were obtained versus the number of samples that were submitted to the laboratory for analysis. Valid results are results that are determined to be usable during the data validation review process.

The 100% completeness goal was met. The completeness of this data set is 100% because all the samples were analyzed and all the results are valid.

9.0 Definition of Data Qualifiers

9.1 Inorganic Data Qualifiers

The following data validation qualifiers were used in the review of this data set. These qualifiers are taken from Contract Laboratory Program National Functional Guidelines for Inorganic Data Review (USEPA 1994).

U	The material was analyzed for, but was not detected above the level of the associated value. The associated value is either the sample quantitation limit or the sample detection limit.
J	The associated value is an estimated quantity.
UJ	The material was analyzed for, but was not detected. The associated value is an estimate and may be inaccurate or imprecise.
R	The data are unusable. (Note: Analyte may or may not be present.)

9.2 Organic Data Qualifiers

The following data validation qualifiers were used in the review of this data set. These qualifiers are taken from Contract Laboratory Program National Functional Guidelines for Organic Data Review (EPA 1994a).

U	The analyte was analyzed for but not detected above the reported sample quantitation limit.
J	The analyte was positively identified; the associated numerical value is the approximate concentration of the analyte in the sample.
UJ	The analyte was not detected above the reported sample quantitation limit. However, the reported quantitation limit is approximate and may or may not represent the actual limit of quantitation necessary to accurately and precisely measure the analyte in the sample.

N The analysis indicates the presence of an analyte for which there is presumptive evidence to make a "tentative identification".

NJ The analysis indicates the presence of an analyte that has been "tentatively identified" and the associated numerical value represents its approximate concentration.

R The sample results are rejected due to serious deficiencies in the ability to analyze the samples and meet quality control criteria. The presence or absence of the analyte cannot be verified.

10.0 References

Anchor Environmental & AESI. 2000. Work Plan/Sampling and Analysis Plan, Focused Site Characterization Holly Street Landfill Redevelopment Project. Anchor Environmental, L.L.C. and AESI, Inc. March 23, 2000

USEPA. 1994a. Contract Laboratory Program National Functional Guidelines For Inorganic Data Review. Office of Solid Waste and Emergence Response.

USEPA. 1994b. Contract Laboratory Program National Functional Guidelines For Organic Data Review. Office of Solid Waste and Emergence Response.

USEPA. 1995. Test Methods for Evaluating Solid Waste, Physical/Chemical Methods (SW-846) Third Edition, Updates I, II, IIA and IIB.

WDOE. 1997. Analytical Methods for Petroleum Hydrocarbons. Prepared by the Washington State Department of Ecology Toxics Cleanup Program and the Ecology Environmental Laboratory. June 1997

Table 2
Field Duplicate Precision

Sample ID	Duplicate ID	Analyte	Sample Value	Duplicate Value	RPD
A-MW-2	A-MW-4	Di-n-butylphthalate	1.1	1.0 U	NC
		Total Arsenic	1.0	1.1	9.5
		Total Calcium	142,000	139,000	2.1
		Total Iron	49,300	47,900	2.9
		Total Magnesium	29,700	28,900	2.7
		Total Manganese	1,410	1,380	2.2
		Dissolved Arsenic	0.3	0.4	29
		Dissolved Iron	6,980	870	156
		Dissolved Manganese	1,380	1,350	2.2
		Hardness	480	460	4.3
		Alkalinity	560	560	0
		Total Dissolved Solids	600	590	1.7
		Total Suspended Solids	73	74	1.4
		Salinity	0.40	0.40	0
		Conductivity	880	870	1.1
		Chloride	31	30	3.3
		Ammonia	3.8	3.9	2.6
		Nitrite	0.019	0.016	17
		Nitrate + Nitrite	0.019	0.016	17
		Sulfate	13	18	32
		Total Organic Carbon	6.3	6.0	4.9

NC Not calculable
U Analyte not detected above the associated reporting limit
Alkalinity values are in mg/L $CaCO_3$
Total dissolved solids, total suspended solids, chloride, sulfate, and TOC values are in mg/L
Salinity values are in g/kg
Conductivity values are in uS/cm
Ammonia, nitrite, and nitrate + nitrite values are in mg-N/L
Metals and semivolatile organic values are in ug/L
Hardness values are in mg-$CaCO_3$/L

Table 3
Summary of Qualified Data

Sample ID	Analyte	Qualifier*	Reason for Qualification
A-MW-1 A-MW-2 A-MW-3 A-MW-4 WP-1 WP-2 WP-3 WP-5 RB-1 Trip Blank	1,2,4-trichlorobenzene	UJ	CCV percent difference > 25%
WP-3	All semivolatiles	J positive results UJ detection limits	Extraction hold time exceeded
RB-1	Bis(2-ethylhexyl)phthalate	J	CCV Percent difference > 25 (response increased)
WP-3	Hexachlorobenzene	UJ	CCV Percent difference > 25 (response decreased)
A-MW-1 A-MW-2	Bis(2-ethylhexyl)phthalate	U at reported value	Result is greater than the reporting limit and less than 10 times the field blank level
A-MW-1 A-MW-2 A-MW-3 A-MW-4 WP-1 WP-2 WP-3 WP-5 RB-1	Pyrene	UJ	Pattern of low LCS & LCSD recovery
WP-3	Pentachlorophenol	UJ	LCS recovery < 50%
WP-1 WP-2	Total manganese	U at reported value	Result is greater than the reporting limit and less than 5 times the field blank level
WP-5	Dissolved copper	UJ	Negative ICS concentration & comparable levels of interfering elements present
WP-1	Dissolved copper	J	Negative ICS concentration > 2X IDL & > 10% of sample result & comparable levels of interfering elements present
WP-1	Dissolved manganese	UJ	Negative ICS concentration & comparable levels of interfering elements present
A-MW-2 A-MW-4	Dissolved iron	J	Field duplicate RPD > 20
A-MW-2 A-MW-4	Total lead	U at reported value	Result is greater than the reporting limit and less than 5 times the field blank level
A-MW-1	Total Silver	UJ	Matrix spike recovery < 75%

Table 3 Continued

Sample ID	Analyte	Qualifier*	Reason for Qualification
A-MW-2 A-MW-3 A-MW-4	Nitrate	U at reported value	Result is greater than the reporting limit and less than 5 times the field blank level
WP-1 WP-2 WP-3	Ammonia	U at reported value	Result is greater than the reporting limit and less than 5 times the field blank level
WP-5	Nitrate	UJ	Percent recovery < 75
WP-5	Nitrate + Nitrite	UJ	Percent recovery < 75
WP-2 WP-3 WP-5	Chloride	J	RSD of averaged results > 15
A-MW-2 A-MW-4	Sulfate	J	Field duplicate RPD > 20

* When the same qualifier applies to all associated samples it is listed only once.

Appendix A

Laboratory Communications
(7 pages)

Data Validation and Data Quality Assessment Report

Focused Site Characterization
Holly Street Landfill Redevelopment Project
Bellingham, Washington
Winter 2001 Sampling (January 2001)
Project Number: 990062-04(2)

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1.0 Introduction

This report describes the Functional Guidelines data validation of the samples listed in Table 1. The analyses were performed by Analytical Resources, Incorporated (ARI), located in Seattle Washington.

The validation was performed in accordance with the procedures established in the *Contract Laboratory Program National Functional Guidelines for Inorganic and Organic Data Review* (Functional Guidelines) (USEPA 1994 and 1994a). Project detection limits, quality control (QC) sample frequencies, and data quality objectives (DQOs) are from the *Work Plan/Sampling and Analysis Plan, Focused Site Characterization Holly Street Landfill Redevelopment Project* (SAP) (Anchor & AESI 2000). The criteria used to qualify data are taken from Functional Guidelines, the SAP, the analytical methods, or the professional judgment of the validation chemist.

Sections 2 through 7 present the validation findings and Section 9 defines the data qualifiers. Section 8 evaluates the project data against the data quality objectives set forth in the SAP. Table 2 presents an evaluation of field duplicate precision and Table 3 is a summary of the qualified data. Copies of laboratory communications are provided in Appendix A. The original laboratory resubmissions have been placed in the data packages. Validation qualifier flags have been added to the sample data sheets in the Data Summary section of the data packages.

The Anchor Data Table was modified to reflect the data changes and qualifiers prescribed in this report. The validation qualifiers were added to the laboratory flag column of the Data Table.

Table 1
Sample Data Reviewed

Sample ID	Matrix	Laboratory Sample ID	VOA	SVOA	TPH-HCID	Metals	Conventionals
A-MW-6	Water	CQ23A & CQ39A	X	X	X	X	X
WP-6	Water	CQ23B, CQ39B & CT83A	X	X	X	X	X
A-MW-4	Water	CQ23C & CQ39C	X	X	X	X	X
A-MW-5	Water	CQ23D & CQ39D	X	X	X	X	X
A-MW-10	Water	CQ23E & CQ39E	X	X	X	X	X
A-MW-RB	Water	CQ23F & CQ39F	X	X	X	X	X
Trip Blank	Water	CQ23M	X				

VOA: Volatile organic compounds by Method 8260

SVOA: Semivolatile organic compounds by Method 8270

TPH-HCID: Petroleum hydrocarbon identification by Method NWTPH-HCID (WDOE 1997)

Metals: Total and dissolved arsenic, cadmium, lead, and silver by Method 200.8; total and dissolved calcium, chromium, copper, iron, manganese, magnesium, and zinc by Method 6010; and total and dissolved mercury by Method 7470

Conventionals: Total dissolved solids by Method 160.1, total suspended solids by Method 160.2, alkalinity by Method 2320, ammonia by Method 350.1, chloride by Method 325.2, nitrite by Method 353.2, nitrate and nitrite by Method 353.2, sulfate by Method 375.2, total organic carbon by Method 415.1, and conductivity and salinity by Method 2520B

2.0 Data Validation of Volatile Organics Analyses by Method 8260

2.1 Custody, Preservation, Holding Times, and Completeness – Acceptable with Discussion

All samples were analyzed within the required holding times and except as noted below, all samples were received intact and were properly preserved. The data package is complete and contains all the information necessary to recreate the sample results.

The temperature of 3 coolers (out of 4) were above the recommended temperature range of 2 to 6 °C at the time of laboratory receipt. The temperature range of the coolers was 8.5 to 11.0 °C. Data qualifiers are not recommended.

The trip blank was not listed on the chain-of-custody (COC).

For the samples analyzed on 1-15-01, the instrument raw data indicated an analysis date of 1-14-01. The date had been manually changed to 1-15-01, however, the initials and date of the person making the change was not recorded.

For the samples analyzed on 1-15-01, the result sheets indicated an analysis date of 1-14-01. The laboratory resubmitted the results sheets with the correct analysis date of 1-15-01.

2.2 Instrument Tuning and Mass Calibration – Acceptable

The tuning compound bromofluorobenzene was analyzed at the required frequency and all Functional Guidelines criteria were met.

2.3 Initial Calibration – Acceptable

Initial calibrations were analyzed at the required frequency and are calculated correctly. The Functional Guidelines criteria of relative standard deviation (RSD) values less than or equal to 30% and relative response factors greater than 0.05 were met for all target compounds.

2.4 Continuing Calibration – Acceptable with Discussion

Continuing calibrations were analyzed at the required frequency and are calculated correctly. Except as noted below, the Functional Guidelines criteria of percent difference values less than or equal to 25 and relative response factors greater than 0.05 were met.

The percent difference values of toluene-d_8, 4-bromofluorobenzene, and dibromofluoromethane are above the Functional Guidelines criteria (values range from 25.5% to 26.7%). Data qualifiers are not required for surrogate compounds.

2.5 Blank Analyses – Acceptable

2.5.1 Method Blanks

Method blanks were analyzed at the required frequency and target analytes were not detected above the reporting limits.

2.5.2 Field Blanks

One trip blank and one field blank (A-MW-RB) are associated with the samples. Target analytes were not detected above the reporting limits in either blank.

2.6 Surrogate Analyses – Acceptable

Surrogate compounds were added to all samples, blanks and QC samples as required. The percent recovery values are correctly calculated and all are within the SAP criteria of 60 to 140%.

2.7 Matrix Spike/Matrix Spike Duplicate Analyses – Acceptable

Matrix spike/matrix spike duplicates (MS/MSD) were analyzed at the required frequency and are correctly calculated. All percent recovery and relative percent difference (RPD) values are within the SAP criteria (60 to 140% recovery and RPD values less than 35%).

2.8 Laboratory Control Sample Analyses – Acceptable

Laboratory control samples (LCSs) were analyzed as required and are correctly calculated. All percent recovery values are within the SAP criteria.

2.9 Standard Reference Material Analyses

The SAP does not require standard reference material (SRM) analyses for water samples.

2.10 Internal Standard Evaluation – Acceptable

Internal standards were added to all samples, blanks and QC samples as required. The internal standard recovery and retention time criteria of Functional Guidelines were met.

2.11 Compound Quantitation and Laboratory Reporting Limits – Acceptable

The final results are correctly calculated including the amount analyzed and dilution factors. Positive results meet the Functional Guidelines criteria for retention time and mass spectra.

The SAP target detection limits were met. The laboratory reporting limits are all less than or equal to the SAP target detection limits.

2.12 Field Duplicates – Acceptable

Sample A-MW-10 was identified as a field duplicate of sample A-MW-4. Field duplicate precision is acceptable as shown by the low RPD values listed in Table 2.

2.13 Overall Assessment of Data Useability

The useability of the data is based on the guidance documents listed above. Upon consideration of the information presented here, the data are acceptable.

End edit

3.0 Data Validation of Semivolatile Organics Analyses by Method 8270

3.1 Custody, Preservation, Holding Times, and Completeness – Acceptable with Discussion

All samples were extracted and analyzed within the required holding times. Except as noted below, all samples were received intact and were properly preserved. The data package is complete and contains all the information necessary to recreate the sample results.

The temperature of 3 coolers (out of 4) were above the recommended temperature range of 2 to 6 °C at the time of laboratory receipt. The temperature range of the coolers was 8.5 to 11.0 °C. Data qualifiers are not recommended.

The extraction benchsheet for the extractions preformed on 1-10-01 was missing from the data package. The laboratory resubmitted the form.

The raw data for the LCSD extracted 1-9-01 was missing from the data package. The laboratory resubmitted the missing information.

The laboratory reported hexachloroethane instead of 1,2-dimethylphenol. The laboratory resubmitted corrected results sheets for all samples and method blanks.

3.2 Instrument Tuning and Mass Calibration – Acceptable

The tuning compound decafluorotriphenylphosphine was analyzed at the required frequency and all relative abundance values are within Functional Guidelines criteria.

3.3 Initial Calibration – Acceptable

Initial calibrations were analyzed at the required frequency and are correctly calculated. The Functional Guidelines criteria of RSD values less than 30 and relative response factors greater than 0.05 were met for target analytes.

3.4 Continuing Calibration – Acceptable with Discussion

Continuing calibration verifications (CCVs) were analyzed at the required frequency and are correctly calculated. Except as noted below, all percent difference values and relative response factors met the Functional Guidelines criteria of less than 25% and greater than 0.05, respectively.

The percent difference values of hexachlorobutadiene, indeno(1,2,3-cd)pyrene, and 2-fluorophenol in the CCV analyzed on 1-10-01 are above Functional Guidelines criteria (values range from 25.4 to 33.5%). Data qualifiers are not required for hexachlorobutadiene and indeno(1,2,3-cd)pyrene because the response increased and positive results were not detected in the associated samples. Data qualifiers are not required for 2-fluorophenol because it is a surrogate compound.

The percent difference values of indeno(1,2,3-cd)pyrene and dibenz(a,h)anthracene in the CCV analyzed on 1-15-01 are above the Functional Guidelines criteria at 30.9% and 27.5%, respectively. Data qualifiers are not required because the response increased and positive results were not detected in the associated samples.

3.5 Blank Analyses – Acceptable

3.5.1 Method Blanks

Method blanks were analyzed at the required frequency and target analytes were not detected above the reporting limit.

3.5.2 Field Blanks

Sample A-MW-RB was identified as a field blank. Target analytes were not detected above the reporting limit.

3.6 Surrogate Analyses – Acceptable with Qualifications

Surrogate compounds were added to all samples, blanks and QC samples as required and are correctly calculated. Except as noted below, all surrogate recovery values are within the SAP criteria of 60 to 140%.

The 2-fluorophenol, 2-chlorophenol, and 1,2-dichlorobenzene-d_4 surrogate recovery values from sample A-MW-6 are below the SAP criteria at 56.4%, 58.5%, and 48.8%, respectively. Functional Guidelines requires qualifying data when two or more surrogate recovery values in the same fraction (base/neutral or acid) are outside criteria. Therefore, the acid analytes were qualified as estimated (J) or estimated detection limit (UJ) as shown in the following table.

The nitrobenzene-d_5, 2-fluorophenol, 2-chlorophenol-d_4, and 1,2-dichlorobenzene-d_4 surrogate recovery values from sample A-MW-5 are below the SAP criteria at 59.7%, 56.9%, 59.8%, and 49.4%, respectively. All analytes, acid and base/neural, have been qualified as estimated (J) or estimated detection limit (UJ).

The phenol-d_5, 2-fluorophenol, 2-chlorophenol-d_4, and 1,2-dichlorobenzene-d_4 surrogate recovery values from sample A-MW-RB are below the SAP criteria at 58.7%, 52.3%, 56.3%, and 48.5%, respectively. All acid fraction analytes have been qualified as estimated (J) or estimated detection limit (UJ).

The 2-fluorobiphenyl and 1,2-dichlorobenzene-d_4 surrogate recovery values from sample A-MW-4 are below the SAP criteria at 59.4% and 53.4%, respectively. All base/neutral fraction analytes have been qualified as estimated (J) or estimated detection limit (UJ).

The 1,2-dichlorobenzene-d_4 surrogate recovery values from samples WP-6 and A-MW-10 are below the SAP criteria at 57.2% and 59.5%, respectively. Data were not qualified because Functional Guidelines allows one surrogate per fraction (base/neutral or acid) to exceed criteria without qualification.

The 1,2-dichlorobenzene-d_4 surrogate recovery value from the method blank extracted 1-10-01 is below the SAP criteria at 55.7%. Data qualifiers are not required for QC samples.

Sample ID	Analyte	Qualification	Quality Control Exceed
A-MW-6 A-MW-RB	Acid fraction analytes	J positive results UJ detection limits	Surrogate recovery below SAP criteria
A-MW-4	Base/neutral fraction analytes	J positive results UJ detection limits	Surrogate recovery below SAP criteria
A-MW-5	All analytes	J positive results UJ detection limits	Surrogate recovery below SAP criteria

3.7 Matrix Spike/Matrix Spike Duplicate Analyses – Acceptable with Discussion

Except as noted below, MS/MSD analyses were performed at the required frequency, are correctly calculated, and all percent recovery and RPD values are within the SAP criteria.

The laboratory did not perform MS/MSD analyses as required by the SAP due to insufficient sample volume. Data qualifiers are not required.

3.8 Laboratory Control Sample Analyses – Acceptable

Laboratory control samples or LCS/LSCDs were analyzed with each batch and the results are correctly calculated. All percent recovery and RPD values are within the SAP criteria of 60 to 140% and RPD values less than 35.

3.9 Standard Reference Material Analyses

The SAP does not require SRM analyses for water samples.

3.10 Internal Standard Evaluation – Acceptable

Internal standards were added to all samples, blanks and QC samples as required. The recovery and retention time criteria of Functional Guidelines were met.

3.11 Compound Quantitation and Laboratory Reporting Limits – Acceptable with Discussion

The final results are correctly calculated including the amount extracted and dilution factors. Positive results meet the Functional Guidelines criteria for retention time and mass spectra.

The SAP target detection limits were not met in all cases. The laboratory reporting limits for hexachlorobutadiene, phenol, 2-methylphenol, 2,4-dimethylphenol, benzyl alcohol, pentachlorophenol, and benzoic acid are above the SAP target detection limits.

3.12 Field Duplicates – Acceptable

Sample A-MW-10 was identified as a field duplicate of sample A-MW-4. An RPD value could not be calculated because positive results were not detected in either sample.

3.13 Overall Assessment of Data Useability

The useability of the data is based on the guidance documents listed above. Upon consideration of the information presented here, the data are acceptable except where flagged with data qualifiers that modify the usefulness of the individual values.

4.0 Data Validation of Petroleum Hydrocarbons by Method NWTPH-HCID

4.1 Custody, Preservation, Holding Times, and Completeness – Acceptable with Discussion

All samples were extracted and analyzed within the required holding times. Except as noted below, all samples were received intact and were properly preserved. The data package is complete and contains all the information necessary to recreate the sample results.

The temperature of 3 coolers (out of 4) were above the recommended temperature range of 2 to 6 °C at the time of laboratory receipt. The temperature range of the coolers was 8.5 to 11.0 °C. Data qualifiers are not recommended.

4.2 Initial Calibration – Acceptable

Initial calibrations were analyzed at the required frequency and are correctly calculated. The Functional Guidelines linearity criteria (for GC pesticides) of RSD values less than 20% was met.

4.3 Calibration Verifications – Acceptable with Discussion

Continuing calibration verifications were analyzed at the required frequency and are correctly calculated. The method criteria of percent difference values less than or equal to 15% was met.

In the quantitation of the CCVs the peak area of the surrogate o-terphenyl was not manually subtracted as it was for the initial calibration. The laboratory was contacted and verified that a macro to automatically subtract the surrogate area from the diesel area was installed after the initial calibration was analyzed.

4.4 Blank Analyses – Acceptable

4.4.1 Method Blanks

Method blanks were analyzed at the required frequency and target analytes were not detected above the reporting limit.

4.4.2 Field Blanks

Sample A-MW-RB was identified as a field blank. Petroleum hydrocarbons were not detected above the reporting limits.

4.5 Surrogate Analyses – Acceptable

Surrogate compounds were added to all samples, blanks and QC samples as required and are correctly calculated. All percent recovery values are within SAP criteria of 70 to 130%.

4.6 Matrix Spike/Matrix Spike Duplicate Analyses – Acceptable with Discussion

Except as noted below, MS/MSD analyses were performed as required, are correctly calculated, and all percent recovery and relative percent difference values are within the SAP criteria.

The laboratory did not analyze MS/MSDs with the samples due to insufficient sample volume. MS/MSD analyses are not required by Method NWTPH-HCID (WDOE 1997). However, the SAP requires one MS/MSD pair per 20 samples. Data qualifiers are not required.

4.7 Laboratory Control Sample Analysis – Acceptable

One LCS/LCSD was analyzed as required and is correctly calculated. All percent recovery and RPD values are within the SAP criteria of 70 to 130% and less than 30%, respectively.

4.8 Standard Reference Material Analyses

The SAP does not require SRM analyses for petroleum hydrocarbons.

4.9 Compound Quantitation and Laboratory Reporting Limits – Acceptable with Discussion

The final results are correctly calculated, including the amount extracted and dilution factors.

The SAP target detection limit was met for gasoline. The laboratory reporting limit of 0.50 mg/L for diesel range hydrocarbons and motor oil range hydrocarbons is above the SAP target detection limit of 0.25 mg/L.

4.10 Field Duplicates – Acceptable

Sample A-MW-10 was identified as a field duplicate of sample A-MW-4. An RPD value could not be calculated because positive results were not detected in either sample.

4.11 Overall Assessment of Data Useability

The useability of the data is based on the guidance documents listed above. Upon consideration of the information presented here, the data are acceptable.

5.0 Data Validation of Metals by Methods 200.8 and 6010 and Mercury by Method 7470

5.1 Custody, Preservation, Holding Times, and Completeness – Acceptable with Discussion

All samples were analyzed within the required holding times. Except as noted below, all samples were received intact and were properly preserved. The data packages are complete and contain all the information necessary to recreate the sample results.

The temperature of 3 coolers (out of 4) were above the recommended temperature range of 2 to 6 °C at the time of laboratory receipt. The temperature range of the coolers was 8.5 to 11.0 °C. Data qualifiers are not recommended.

For sample delivery group CT83, the data summary section of the data package was missing. A copy of the sample results sheet was made to use as the data summary results sheet.

5.2 Initial Calibration – Acceptable

Initial calibrations were analyzed as required and all quality control checks met Functional Guidelines requirements.

5.3 Calibration Verifications – Acceptable

Initial calibration verifications and continuing calibration verifications were analyzed at the required frequency and are correctly calculated. All Functional Guidelines criteria were met.

5.4 Blank Analyses – Acceptable

5.4.1 Method Blanks

Instrument and method blanks were analyzed at the required frequency. Target analytes were not detected above the reporting limit.

5.4.2 Field Blanks

Sample A-MW-RB was identified as a field blank. Target analytes were not detected above the reporting limit.

5.5 Internal Standard Evaluation – Acceptable

For the ICP-MS analyses (Method 200.8) internal standards were added to all samples, blanks and QC samples as required and all method criteria were met.

5.6 ICP Interference Check – Acceptable with Discussion

ICP interference check samples (ICS) were analyzed at the required frequency and are correctly calculated. All percent recovery values are within Functional Guidelines criteria and, except as noted below, all non-spiked analytes have absolute values less than the instrument detection limit (IDL).

Manganese has positive results greater than the IDL in the opening and closing ICS analyses of 1-16-01. Data qualifiers are not required because the concentration of interfering elements (aluminum, calcium, iron and magnesium) in the associated sample is less than the level in the ICS.

5.7 Duplicate Sample Analysis – Acceptable with Discussion

Sample duplicate analyses were performed at the required frequency and are correctly calculated. Except as noted below, all RPD values are within the SAP criteria of less than 20%.

The total copper RPD value for the duplicate analysis of sample WP-6 is above the SAP criteria at 40%. Data qualifiers are not required because the sample results are less than 5 times the reporting limit and within 1 reporting limit of each other.

5.8 Spike Sample Analyses – Acceptable with Qualifications

Matrix spike analyses were performed at the required frequency and are correctly calculated. Except as noted below, all percent recovery values are within the SAP criteria of 75 to 125%.

The dissolved iron recovery from the matrix spike analysis of sample A-MW-6 is below the SAP criteria at 25%. Data qualifiers are not required because the native sample concentration is 21 times the amount spiked.

The total silver recovery from the matrix spike analysis of sample A-MW-6 is below the SAP criteria at 70.8%. As specified in Functional Guidelines, the silver results in all samples were qualified as estimated (J) or estimated detection limit (UJ).

Sample ID	Analyte	Qualification	Quality Control Exceedance
All	Total Silver	J positive results UJ detection limits	Matrix spike recovery below SAP criteria

5.8 ICP Serial Dilution Analyses – Acceptable

Serial dilutions were performed as required and are correctly calculated. The Functional Guidelines criteria of percent difference values less than 10% for results greater than 50 times the IDL were met.

5.9 Laboratory Control Sample/Standard Reference Material Analyses – Acceptable

Laboratory control samples or standard reference materials were analyzed as required and are correctly calculated. All percent recovery values are within the Functional Guidelines criteria of 80 to 120%.

5.10 Compound Quantitation and Laboratory Reporting Limits – Acceptable

The final results are correctly calculated including the amount digested and dilution factors.

The SAP specified target detection limits were met for samples that were analyzed undiluted.

5.11 Field Duplicates – Acceptable with Qualifications

Sample A-MW-10 was identified as a field duplicate of sample A-MW-4. The SAP criterion for field duplicate precision is RPD values less than 20. The RPD value of total arsenic and total lead are is above the SAP criterion at 32% and 67%, respecitvely. The total arsenic results in samples A-MW-4 and A-MW-10 were qualified as estimated (J). The total lead results do not require qualification because the results are within 5 times the reporting limit and within 1 reporting limit of each other. The precision of the field duplicate pair is presented in Table 2.

Sample ID	Analyte	Quality Control Exceedance	Qualification
A-MW-4 A-MW-10	Total Arsenic	Field duplicate RPD > 20	J

5.12 Overall Assessment of Data Useability

The useability of the data is based on the guidance documents listed above. Upon consideration of the information presented here, the data are acceptable except where flagged with data qualifiers that modify the usefulness of the individual values.

6.0 Data Validation of Conventional Chemistry Analyses

6.1 Custody, Preservation, Holding Times, and Completeness – Acceptable with Discussion

All samples were analyzed within the required holding times. Except as noted below, all samples were received intact and were properly preserved. The data package is complete and contains all the information necessary to recreate the sample results.

Copies of the results sheets were not present in the data summary section of the data package. Copies of the sample results sheets were added to the data summary section of the data package.

The temperature of 3 coolers (out of 4) were above the recommended temperature range of 2 to 6 °C at the time of laboratory receipt. The temperature range of the coolers was 8.5 to 11.0 °C. Data qualifiers are not recommended.

6.2 Initial Calibration – Acceptable

Initial calibrations were performed as required and are correctly calculated. All quality control criteria were met.

6.3 Calibration Verifications – Acceptable

Initial calibration verifications and CCVs were analyzed as required and are correctly calculated. All quality control criteria were met.

6.4 Blank Analyses – Acceptable with Qualifications

6.4.1 Method Blanks

Method blanks were analyzed at the required frequency and target species were not detected above the reporting limits.

6.4.2 Field Blanks

Sample A-MW-RB was identified as a field blank. Ammonia and conductivity were detected in the field blank at 0.014 mg-N/L and 1.5 uS/cm, respectively. Functional Guidelines prescribes three qualifications schemes for blank contamination, (1) associated sample concentrations greater than the action level (5 times the blank concentration) are not qualified, (2) associated sample concentrations less than the action level and greater than the reporting limit are qualified as undetected (U) at the reported value, and (3) associated sample concentrations less than the action level and less than the reporting limit are qualified as undetected (U) at the reporting limit. Therefore, data qualifiers are not required for conductivity because the associated sample results are greater than 5 times the field blank level. Only sample WP-6 requires qualification for ammonia because its concentration is above the reporting limit and less than 5 times the field blank level.

Sample ID	Analyte	Qualification	Quality Control Exceedance
WP-6	Ammonia	U at reported value	Result is greater than the reporting limit and less than 5 times the field blank level

6.5 Replicate Sample Analyses – Acceptable with Discussion

Except as noted below, sample duplicates or triplicates were analyzed at the required frequency and are correctly calculated. All RPD or relative standard deviation (RSD) values are within the SAP criteria of less than 20%.

Duplicate analyses were not preformed for TSS as required by the SAP. Data qualifiers are not recommended.

6.6 Spike Sample Analyses – Acceptable with Discussion

Matrix spike analyses were performed as required and are correctly calculated. All percent recovery values are within the SAP criteria of 75 to 125%.

The laboratory used the field blank sample A-MW-RB for the chloride, nitrite, nitrate + nitrite, sulfate and TOC matrix spike analyses. The use of field QC samples for spiking does not provide accuracy information about the sample matrix and is not considered good laboratory practice. Data qualifiers are not required.

6.7 Laboratory Control Sample Analyses – Acceptable

Laboratory control sample analyses were performed are required and are correctly calculated. All percent recovery values are within the SAP criteria.

6.8 Standard Reference Material Analyses – Acceptable

Standard reference materials were analyzed as required and are correctly calculated. All percent recovery values are meet the SAP criteria.

6.9 Laboratory Reporting Limits – Acceptable

The reporting limits meet the SAP target detection limits, except when samples were analyzed at a dilution.

6.10 Field Duplicates – Acceptable with Qualifications

Sample A-MW-10 was identified as a field duplicate of sample A-MW-4. The SAP criterion for field duplicate precision is RPD values less than 20. The RPD value of sulfate is above the SAP criterion at 29%. The sulfate results in samples A-MW-4 and A-MW-10 were qualified as estimated (J). The precision of the field duplicate set is presented in Table 2.

Sample ID	Analyte	Quality Control Exceedance	Qualification
A-MW-4 A-MW-10	Sulfate	Field duplicate RPD > 20	J

6.11 Overall Assessment of Data Useability

The useability of the data is based on the guidance documents listed above. Upon consideration of the information presented here, the data are acceptable except where flagged with data qualifiers that modify the usefulness of the individual values.

7.0 Assessment of Data Quality Objectives

7.1 Precision

Precision is a measure of the mutual agreement among individual measurements of the same property, under prescribed similar conditions. Precision is determined through analysis of MS/MSDs, LCS/LCSDs, sample duplicates, sample triplicates, and field duplicate samples. Duplicate samples are evaluated for precision in terms of relative percent difference and triplicate samples are evaluated in term of relative standard deviation. Relative percent difference is defined as the difference between the duplicate results divided by the mean and expressed as a percent. Relative standard deviation is the standard deviation divided by the average result and expressed as a percent.

The precision of the volatile organic, semivolatile organic and petroleum hydrocarbon data is good and meets the DQO of the SAP. Laboratory precision as shown by the MS/MSD and LCS/LCSD RPD values and field precision as shown by the field duplicate RPD values are all within the SAP criteria.

The precision of the metals data meets the DQO, with one exception. The field duplicate RPD value for total arsenic is above the SAP criteria. Since the RPD value of the total arsenic sample duplicate is acceptable, the imprecision may be due to field sampling techniques. The total copper sample duplicate and total lead field duplicate RPD values are above the SAP criteria, however, data precision is not affected because the results are within 5 times the reporting limit and within one reporting limit of each other.

The precision of the conventional chemistry data meets the SAP DQO, with one exception. The sulfate field duplicate RPD value is above the SAP criterion. Since the sulfate sample duplicate is acceptable, field sampling techniques maybe the source of the imprecision. The lack of total suspended solids sample duplicate analyses does not adversely affect the data set because the field duplicate demonstrates that precision of the total suspended solids data is acceptable.

7.2 Accuracy

Accuracy is the degree of agreement between a measurement and the accepted reference or true value. The level of accuracy is determined by examination of surrogates, MSs, MSDs, LCSs, LCSDs, SRMs, method blanks, and field blanks. The surrogate, MS, MSD, LCS, LCSD and SRMs recovery values were compared to the criteria set forth in the SAP. Method and field blanks are analyzed to identify compounds that could be introduced during the sampling, laboratory extraction, or analysis phase (i.e., laboratory contaminates) and lead to inaccurate results.

The accuracy of the volatile organics and petroleum hydrocarbon data set meets the DQO of the SAP. The recovery values of the surrogates, MSs, MSDs, LCSs and LCSDs are within the SAP criteria. The method blanks and field blanks are free of contamination.

The accuracy of the semivolatile organic data meets the DQO, with the following exceptions. Several samples have surrogate recovery values below the SAP criteria. When a pattern of low bias is evident, the sample results have been qualified as estimated detection limit. The recovery values of the LCS and LCSD are within the SAP criteria and the method and field blank are free of contamination.

The accuracy of the metals data meets the SAP DQO, with one exception. The total silver recovery from the matrix spike indicates a low bias. The total silver results of all samples have been qualified as estimated detection limit to denote the low bias. The dissolved iron recovery from the matrix spike is also below the SAP criteria. The accuracy of the data is not affected since the native sample concentration overwhelms the spike concentration making the spike recovery meaningless. The method and field blank are free of contamination.

The accuracy of the conventional chemistry data meets the DQO specified by the SAP. The impact of the ammonia and conductivity field blank contamination has been minimized by the proper use of data qualifiers as prescribed by Functional Guidelines. Qualifying contaminates in the associated samples as undetected when their concentration is less than 5 times the blank concentration minimizes the possibility of false positive results. The method blank is free of contamination.

7.3 Representativeness

Representativeness is the extent to which the data reflect the actual contaminate levels present in the samples. Representativeness is assessed through method and field blanks, and proper preservation and handling. Method and field blank analyses allow for the detection of artifacts that may be reported as false positive results. Proper sample preservation and handling ensure that sample results reflect the actual sample concentrations.

The data are assumed to be representative since all samples were analyzed within the required holding time, the samples were properly preserved and handled (the sample receipt temperature deviation is negligible), and method blank contamination was not present. The ammonia and conductivity detected in the field blank does not impact the representativeness of the data since the procedures in Functional Guidelines were followed to minimize the impact of the blank contamination.

7.4 Comparability

Comparability is a measure of how easily the data set can be compared and combined with other data sets. The data are assumed to be comparable since standard EPA methods were used to analyze the samples, the method QC criteria were met, and routine detection limits were reported.

7.5 Completeness

Completeness is expressed as the ratio of valid results to the amount of data expected to be obtained under normal conditions. Completeness is determined by assessing the number of samples for which valid results were obtained versus the number of samples that were submitted to the laboratory for analysis. Valid results are results that are determined to be usable during the data validation review process.

The 100% completeness goal was met. The completeness of this data set is 100% because all the samples were analyzed and all the results are valid.

8.0 Definition of Data Qualifiers

8.1 Inorganic Data Qualifiers

The following data validation qualifiers were used in the review of this data set. These qualifiers are taken from Contract Laboratory Program National Functional Guidelines for Inorganic Data Review (USEPA 1994).

U	The material was analyzed for, but was not detected above the level of the associated value. The associated value is either the sample quantitation limit or the sample detection limit.
J	The associated value is an estimated quantity.
UJ	The material was analyzed for, but was not detected. The associated value is an estimate and may be inaccurate or imprecise.
R	The data are unusable. (Note: Analyte may or may not be present.)

8.2 Organic Data Qualifiers

The following data validation qualifiers were used in the review of this data set. These qualifiers are taken from Contract Laboratory Program National Functional Guidelines for Organic Data Review (EPA 1994a).

U	The analyte was analyzed for but not detected above the reported sample quantitation limit.

J The analyte was positively identified; the associated numerical value is the approximate concentration of the analyte in the sample.

UJ The analyte was not detected above the reported sample quantitation limit. However, the reported quantitation limit is approximate and may or may not represent the actual limit of quantitation necessary to accurately and precisely measure the analyte in the sample.

N The analysis indicates the presence of an analyte for which there is presumptive evidence to make a "tentative identification".

NJ The analysis indicates the presence of an analyte that has been "tentatively identified" and the associated numerical value represents its approximate concentration.

R The sample results are rejected due to serious deficiencies in the ability to analyze the samples and meet quality control criteria. The presence or absence of the analyte cannot be verified.

9.0 References

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USEPA. 1995. Test Methods for Evaluating Solid Waste, Physical/Chemical Methods (SW-846) Third Edition, Updates I, II, IIA and IIB.

WDOE. 1997. Analytical Methods for Petroleum Hydrocarbons. Prepared by the Washington State Department of Ecology Toxics Cleanup Program and the Ecology Environmental Laboratory. June 1997

Table 2
Field Duplicate Precision

Sample ID	Duplicate ID	Analyte	Sample Value	Duplicate Value	RPD
A-MW-4	A-MW-10	Toluene	0.3	0.3	0
		1,4-dichlorobenzene	0.5	0.5	0
		Total Arsenic	1.1	0.8	32
		Total Lead	2	1	67
		Total Calcium	129,000	135,000	4.6
		Total Copper	5	2 U	NC
		Total Iron	33,600	35,700	6.1
		Total Magnesium	30,900	32,600	5.4
		Total Manganese	479	519	8.0
		Total Zinc	13	6 U	NC
		Dissolved Arsenic	0.7	0.8	13
		Dissolved Iron	37,300	37,900	1.6
		Dissolved Manganese	546	554	1.4
		Hardness	450	470	4.4
		Alkalinity	570	560	1.8
		Total Dissolved Solids	580	570	1.7
		Total Suspended Solids	79	77	2.6
		Salinity	0.50	0.50	0
		Conductivity	1,100	1,100	0
		Chloride	30	31	3.2
		Ammonia	14	13	7.4
		Nitrate	0.013	0.010 U	NC
		Nitrate + Nitrite	0.013	0.010 U	NC
		Sulfate	8.4	6.3	29
		Total Organic Carbon	15	14	6.9

NC Not calculable
U Analyte not detected above the associated reporting limit
Alkalinity values are in mg/L $CaCO_3$
Total dissolved solids, total suspended solids, chloride, sulfate, and TOC values are in mg/L
Salinity values are in g/kg
Conductivity values are in uS/cm
Ammonia, nitrite, and nitrate + nitrite values are in mg-N/L
Volatile organics, semivolatile organic, and metals values are in ug/L
Hardness values are in mg-$CaCO_3$/L

Table 3
Summary of Qualified Data

Sample ID	Analyte	Qualifier*	Reason for Qualification
A-MW-6 A-MW-RB	Acid fraction semivolatile analytes	UJ	Surrogate recovery below SAP criteria
A-MW-4	Base/neutral fraction semivolatile analytes	UJ	Surrogate recovery below SAP criteria
A-MW-5	All semivolatile organic analytes	UJ	Surrogate recovery below SAP criteria
A-MW-6 WP-6 A-MW-4 A-MW-5 A-MW-10 A-MW-RB	Total Silver	UJ	Matrix spike recovery below SAP criteria
A-MW-4 A-MW-10	Total Arsenic	J	Field duplicate RPD > 20
WP-6	Ammonia	U at reported value	Result is greater than the reporting limit and less than 5 times the field blank level
A-MW-4 A-MW-10	Sulfate	J	Field duplicate RPD > 20

* When the same qualifier applies to all associated samples it is listed only once.

Appendix A

Laboratory Communications
(33 pages)