Final
Remedial Investigation/Feasibility Study
Volume I: Remedial Investigation Report

R.G. Haley Site
Bellingham, Washington

for
City of Bellingham

February 1, 2016

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R.G. Haley Site
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File No. 0356-114-06

February 1, 2016

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ABBREVIATIONS AND ACRONYMS

AET	apparent effect threshold
AKART	all known and reasonable technology
AOC	area of contamination
APH	air-phase petroleum hydrocarbons
ARARs	applicable or relevant and appropriate requirements
AST	above-ground storage tank
BBIC	Bellingham Bay Improvement Company
bgs	below ground surface
BEP	bis(2-ethylhexyl)phthalate
BETX	benzene, ethylbenzene, toluene, and xylenes
BNSF	Burlington Northern Santa Fe Railway Company
BSAF	biota-sediment accumulation factors
CAD	confined aquatic disposal
CAO	cleanup action objective
CAP	cleanup action plan
City	City of Bellingham
CLARC	Cleanup Levels and Risk Calculations Volume 3.1
CMP	corrugated metal pipe
COCs	constituents of concern
COPC	constituent of potential concern
cPAH	carcinogenic polycyclic aromatic hydrocarbons
Crossarm	International Crossarm Manufacturing Company
CSL	cleanup screening level
CSM	conceptual site model
CUL	cleanup level
CWA	Clean Water Act
DCA	disproportionate cost analysis
DGPS	differential global positioning system
DMMU	dredged material management unit
DNR	Washington State Department of Natural Resources
Douglas	Douglas Management Company

DQOs	data quality objectives
E & E	Ecology and Environment, Inc.
Ecology	Washington State Department of Ecology
EDD	electronic data deliverables
EF	exceedance factor
EIS	environmental impact statement
ENR	enhanced natural recovery
EPA	U.S. Environmental Protection Agency
EPH	extractable petroleum hydrocarbons
ESA	Endangered Species Act
FML	flexible membrane liner
FPM	free product mobility
FS	feasibility study
GP	Georgia Pacific
GRAs	general response actions
H:V	horizontal to vertical
Haley	R.G. Haley International Corporation
HASP	health and safety plan
HDPE	high density polyethylene
HHWM	higher high water mark
HPA	Hydraulic Project Approval
HRS	hazard ranking system
HVOC	halogenated volatile organic compounds
IC	institutional controls
ICA	interim cleanup action
IDL	instrument detection limit
IHS	indicator hazardous substances
IPA	interim placement area
ISS	*in situ* solidification and stabilization
K_{OC}	soil or sediment organic carbon-water partitioning coefficient
Kd	distribution coefficient (soil or sediment-water partitioning coefficient)
LAET	lowest apparent effect threshold

2LAET	second lowest apparent effect threshold
LCS/LCSD	laboratory control sample/sample duplicate
LDRs	land disposal restrictions
LFG	landfill gas
LNAPL	light non-aqueous phase liquid
MDL	method detection limit
MGP	manufactured gas plant
MHHW	mean higher high water
MLLW	mean lower low water
MNR	monitored natural recovery
MS/MSD	matrix spike/matrix spike duplicate
MTBE	methyl tertiary-butyl ether
MTCA	Model Toxics Control Act
NAD83/98	North American Datum 1983 and 1998
NAPL	non-aqueous phase liquid
NAVD88	North American Vertical Datum 1988
NGVD29	National Geodetic Vertical Datum 1929
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
NPL	Superfund National Priorities List
NTU	nephelometric turbidity unit
O&M	operation and maintenance
OC	organic carbon normalized
OHWM	ordinary high water mark
Order	Agreed Order No. DE 2186
PAHs	polycyclic aromatic hydrocarbons
PCBs	polychlorinated biphenyls
PCDDs	polychlorinated dibenzodioxins
PCDFs	polychlorinated dibenzofurans
PCL	preliminary cleanup level
PCP	pentachlorophenol
PLP(s)	potentially liable person or persons

PMA	Port Management Agreement
Port	Port of Bellingham
PQL	practical quantitation limit
PRB	permeable reactive barrier
PSDDA	Puget Sound Dredge Disposal Analysis
PSEP	Puget Sound Estuary Program
PVC	polyvinyl chloride
QA/QC	quality assurance/quality control
QAPP	quality assurance project plan
RCRA	Resource Conservation and Recovery Act
RI	remedial investigation
RI/FS	remedial investigation/feasibility study
RPD	relative percent difference
SAP	sampling and analysis plan
SCO	sediment cleanup objective
SCUBA	self-contained underwater breathing apparatus
SEPA	State Environmental Policy Act
SHA	site hazard assessment
SL	screening level
SMS	Sediment Management Standards
SOPs	standard operating procedures
State	State of Washington
SVOCs	semivolatile organic compounds
SWAC	surface-area weighted average concentration
TBT	tributyl tin
TEE	terrestrial ecological evaluation
TEF	toxic equivalency factor
TEQ	toxicity equivalent
TOC	total organic carbon
TPH	total petroleum hydrocarbon
TSS	total suspended solids
USACE	U.S. Army Corps of Engineers

USCG	United States Coast Guard
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
UST	underground storage tank
UTLs	upper tolerance limit
UV	ultraviolet
VOCs	volatile organic compounds
WAC	Washington Administrative Code
WARM	Washington Ranking Method
WDFW	Washington State Department of Fish and Wildlife
WHO	World Health Organization

UNITS OF MEASURE

°C	degrees Celsius
°F	degrees Fahrenheit
µg/L	microgram per liter
cm	centimeter
cm/s	centimeter per second
cm/yr	centimeter per year
cy	cubic yard
ft	feet
ft/day	feet per day
ft^2	square feet
ft^3	cubic feet
ft^3/day	cubic feet per day
g/kg	gram per kilogram
gpm	gallon per minute
km^2	square kilometer
m/sec	meter per second
m^3	cubic meter
mg/kg	milligram per kilogram
mg/L	milligrams per liter

mi^2	square mile
mL	milliliter
ng/kg	nanogram per kilogram
pg/L	picograms per liter
ppt	parts per trillion
µg/kg	microgram per kilogram

1.0 INTRODUCTION

The City of Bellingham (City) has prepared this Remedial Investigation (RI) and Feasibility Study (FS) Report for the R.G. Haley Site (Haley Site or Site) in Bellingham, Washington under the terms of Washington State Department of Ecology (Ecology) Agreed Order No. DE 2186 (Order), as amended.

The RI was conducted in accordance with the following documents that were approved by Ecology: "Upland Remedial Investigation Work Plan" (GeoEngineers 2004), "Final Sediment Quality Assessment and Remedial Investigation Work Plan" (GeoEngineers 2005a), "Draft Soil Vapor Investigation Work Plan" (GeoEngineers 2005b), "Supplemental Sediment Remedial Investigation Memorandum" (GeoEngineers 2005d), and "Final Work Plan for Supplemental Investigation" (GeoEngineers 2012a).

This report addresses comments issued by Ecology in 2010 after the "Draft Final Remedial Investigation/Feasibility Study Report" (GeoEngineers 2007) (the 2007 RI/FS) was submitted to Ecology by the prior property owner. On behalf of the City, GeoEngineers conducted a "Data Gaps Assessment" (GeoEngineers 2011) that identified additional data and other information needed to further address Ecology's comments on the 2007 RI/FS. The scope of work to address data gaps was documented in the "Final Work Plan for Supplemental Investigation" (GeoEngineers 2012a). The supplemental investigation was performed between May 2012 and March 2013. This RI/FS Report supersedes the 2007 RI/FS and addresses Ecology's consolidated RI and FS review comment letters (Ecology 2013c).

1.1. Objectives of the RI/FS

The overall objective of the RI was to collect and evaluate sufficient information to characterize the Site for the purpose of developing and evaluating cleanup action alternatives. More specifically, the objectives of the RI were to characterize the nature and extent of contamination in affected media, compare contaminant concentrations to screening levels, and present the results of the investigation in the context of a conceptual site model (CSM).

The objective of the FS was to develop and evaluate a range of cleanup action alternatives for contaminated media at the Site in accordance with the Model Toxics Control Act (MTCA) and Sediment Management Standards (SMS) and to identify a preferred alternative.

1.2. General Site Description

The Haley Site is identified as "Facility/Site 2870, RG Haley Intl Corp" in Ecology's database and Hazardous Sites List (Ecology 2013b). The R. G. Haley International Corporation (Haley) or predecessors operated a wood treatment facility on portions of the Site for nearly 40 years, from approximately 1948 to 1985. Buildings associated with the facility were removed in 2010. The Haley property is currently fenced and vacant. Section 2.1 provides additional description of the property conditions. The former facility was located at 500 Cornwall Avenue in the northern half of Section 36, Township 38 North, Range 2 East, Bellingham South Quadrangle (USGS 1995), at approximately latitude 48° 44'28.63" N and longitude 122° 29'28.43" W.

As identified in the Order, the boundaries of the Haley Site (Figure 1-1) include the former Haley wood treatment facility and adjacent upland property. Investigations completed under the Order, however, indicate that the full extent of the Site as defined in the Model Toxics Control Act (MTCA) is broader than identified in the Order. The Haley Site includes both upland property and adjacent aquatic lands in Bellingham Bay. The upland portion of the Site was developed by historical tideland filling. Fill materials historically placed in the tideland currently extend into the marine environment. The upland portion of the Site consists of approximately six acres of generally flat land. The marine portion of the Site (also referred to in this report as the aquatic, or in-water, portion of the Site) extends into both intertidal and subtidal waters of Bellingham Bay. The boundary between the upland and aquatic portions of the Site is defined by the ordinary high water (OHW) line (McMillan 2013).

The Inner Harbor Line extends across a portion of the upland (Figure 1-2) and defines the boundary between land owned by the City east[1] of the line and land owned by the State of Washington west of the line. The State-owned land is managed by the Washington State Department of Natural Resources (DNR). Certain aquatic lands in this area are managed by the Port of Bellingham (Port) under Port Management Agreement (PMA) Parcel 3 with DNR (Figure 1-2). The former Cornwall Avenue Landfill site south of the former Haley wood treatment facility includes upland property east of the Inner Harbor Line that is owned by the City, as well as upland property west of the Inner Harbor Line that is State-owned land managed by DNR (Figure 1-2).

A privately-owned property (currently owned by Nielsen Brothers, Inc.), the Pine Street right-of-way, and a parcel owned by the Port of Bellingham are located immediately north of the Haley property, from east to west, respectively (Figure 1-2). The Port of Bellingham parcel includes a public access beach commonly known as the Pine Street beach (also known as Cornwall Cove beach). Active Burlington Northern/Santa Fe (BNSF) railroad tracks are located immediately east of the Haley property on railroad right-of-way.

The following terminology is used in this report:

- Haley Site (or Site): Upland and in-water areas impacted by contaminant releases from former wood treating operations. The footprint of wood treatment chemicals includes areas where wood waste was historically placed in tidelands prior to existence of the Haley facility. Where wood treatment chemicals are collocated with the wood waste, the Haley Site includes the wood waste and chemicals potentially associated with degradation of the wood waste. The Haley Site overlaps with the adjacent Cornwall and Whatcom Waterway sites as described in Section 2.1.4. The following terms are used in this RI report to reference areas within the Haley Site:
    - Haley property: The portion of the Haley Site owned by the City. The term "Haley property" is used in this report without regard to the prior ownership before, or after, Haley. The former wood treatment facility buildings were located on the Haley property.
    - Haley facility: The upland areas where former wood treatment operations were conducted (see Section 2.2.5). Wood treatment operations were conducted on the Haley property and on State-owned upland immediately to the west where treated wood was stored. The term "Haley facility" is used in this report without regard to the specific

[1] Cardinal directions identified in this report are referenced to "project north," which differs from true north as shown in the figures. According to this convention, Bellingham Bay is located west of the former Haley wood treatment facility.

entities that conducted wood treatment and treated wood storage activities over the years.

- Haley upland: The entire upland extent of the Haley Site. This includes upland areas beyond the boundaries of the Haley facility, such as the areas where impacts from Haley facility operations extend onto the Cornwall site.

- Cornwall Avenue Landfill site (Cornwall Landfill site, or Cornwall site): The area containing the former municipal landfill, plus adjacent upland and in-water areas impacted by releases from the landfill waste and wood waste. The following terms are used with regard to areas located within the Cornwall site:
  - Cornwall property: The portion of the Cornwall site owned by the City.
  - Cornwall Landfill (or landfill): The area containing municipal refuse, including upland and in-water areas.
  - Cornwall upland: The entire upland extent of the Cornwall site. This includes the Cornwall property, State-owned upland to the west and the area where landfill waste extends onto the Haley upland (Figure 1-3).
- State-owned land: Upland and in-water areas seaward (west) of the Inner Harbor Line.

Unless stated otherwise, the term "Site" is used in this report to refer to the extent of contamination associated with Haley wood treating operations and collocated wood waste, as described above. This is consistent with the definition of "Site" under MTCA. The boundaries of the MTCA Site have not yet been fully defined, but encompass a broader area than identified in the Order. Upland areas potentially associated with the Haley Site but not investigated in this report may be the subject of another RI.

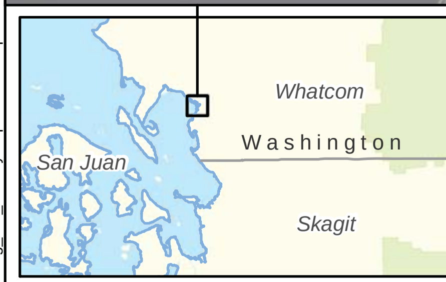
1.3. Relationship to Other Bellingham Bay Projects

The Haley Site is one of twelve cleanup sites that are the subject of the Bellingham Bay Demonstration Pilot Project (Pilot Project). The Pilot Project is a coordinated effort by federal, tribal, state, and local governments to clean up contamination around Bellingham Bay. In 2000, Ecology, in cooperation with the Pilot Project work group, produced the Bellingham Bay Comprehensive Strategy (Ecology 2000), a guidance document that integrates information about bay-wide sediment cleanup, contamination sources, habitat restoration and land use.

Two MTCA cleanup sites are adjacent to the Haley Site and are part of the Pilot Project: the Cornwall site and the Whatcom Waterway site (Figure 1-4). The boundaries of these two sites overlap with the Haley Site. This RI report discusses contamination associated with these other sites in the areas of overlap. Section 2.0 provides more information regarding contaminants associated with these other sites. Several other nearby Pilot Project sites are also shown in Figure 1-4.

Other collaborative planning is underway for portions of the Bellingham waterfront. The City and Port are jointly developing a framework for future redevelopment of 237 acres of waterfront in an area called the "Waterfront District." The Haley Site is located within the Waterfront District (Figure 1-5). The City and Port are currently undertaking extensive planning efforts to facilitate the transformation of the Waterfront District from its historical industrial uses to a mixed-use area that includes residences, shops, offices, marine and light industry, and educational facilities, as well as parks, trails and shoreline amenities. Relevant documents related to the Waterfront District and planning efforts underway include the Waterfront District Final Environmental Impact Statement (EIS) (Blumen 2010), Final EIS Addendum (EA Engineering 2012) and the draft Waterfront District Sub-Area Plan that was published in December 2012 (City/Port 2012).

The Haley Site and the Cornwall site will be part of the future Cornwall Beach Park. The City has recently completed the master planning phase for Cornwall Beach Park (City of Bellingham 2014). The cleanup action alternatives evaluated in the FS for the Haley Site will be compatible with the future land use.



Legend

Haley Site per Agreed Order, Exhibit 1

Project North

2,000 0 2,000

Feet

Reference: Whatcom County GIS, City of Bellingham GIS, Aerial from Esri, 2013.

Notes:

1. The locations of all features shown are approximate.
2. This drawing is for information purposes. It is intended to assist in showing features discussed in an attached document. GeoEngineers, Inc. can not guarantee the accuracy and content of electronic files. The master file is stored by GeoEngineers, Inc. and will serve as the official record of this communication.
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Projection: NAD 1983 UTM Zone 10N

Vicinity Map

R.G. Haley Site
Bellingham, Washington

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Figure 1-1

Path: \\sea\projects\0\0356114\GIS\MXDs\Fig_1-1_VicinityMap.mxd Map Revised: 08 August 2013 cgonzales

True North
Project North

0 100 200
Feet

Reference: Aerial from Esri, 2013.

Notes:
1. The locations of all features shown are approximate.
2. This drawing is for information purposes. It is intended to assist in showing features discussed in an attached document. GeoEngineers, Inc. cannot guarantee the accuracy and content of electronic files. The master file is stored by GeoEngineers, Inc. and will serve as the official record of this communication.

Legend

- City Owned Property, Former R.G. Haley
- Cornwall Property
- Port of Bellingham Property
- Inner Harbor Line
- 1887 Shoreline
- Dedicated Right-of-Way (City)

Current Property Ownership

R.G. Haley Site
Bellingham, Washington

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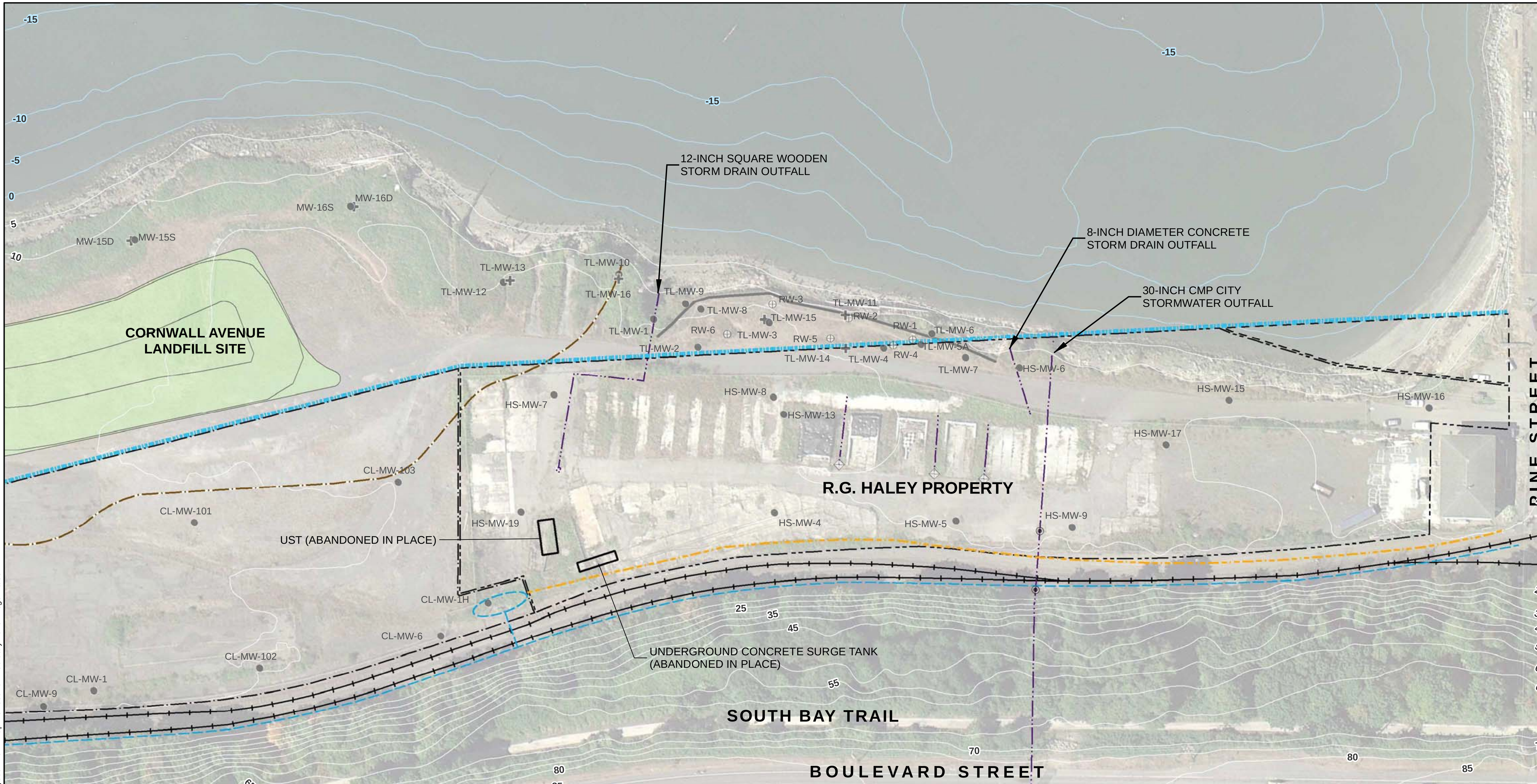
Figure 1-2

Path: \\sea\projects\0\0356114\GIS\MXDs\Fig_1-2_PropertyBoundaries.mxd Map Revised: 30 January 2015 cgonzales



W S N E True North Project North

0 100 200

Feet

Reference: Aerial from Google Earth, August 2011.
Ecology Review Draft Cornwall RI, January 2013, Landau Associates.

Notes:
1. The locations of all features shown are approximate.
2. This drawing is for information purposes. It is intended to assist in showing features discussed in an attached document. GeoEngineers, Inc. cannot guarantee the accuracy and content of electronic files. The master file is stored by GeoEngineers, Inc. and will serve as the official record of this communication.

Legend

- Existing Deep Monitoring Well
- Existing Shallow Monitoring Well
- Existing Recovery Well
- Stormwater Inlet Grate
- Manhole
- City Owned Property, Former R.G. Haley International
- Cornwall Property
- Port of Bellingham Property
- Inner Harbor Line
- Cornwall Approximate Landward Boundary of Landfill Refuse
- Ground Surface and Bathymetric Contour (5ft interval, NAVD88 Datum)
- Cornwall Interim Action Stockpile
- Storm Drain Pipe
- Drainage Ditch or Depression
- 16" Water Main (inactive)
- Sheet Pile Wall

Site Layout

R.G. Haley Site
Bellingham, Washington

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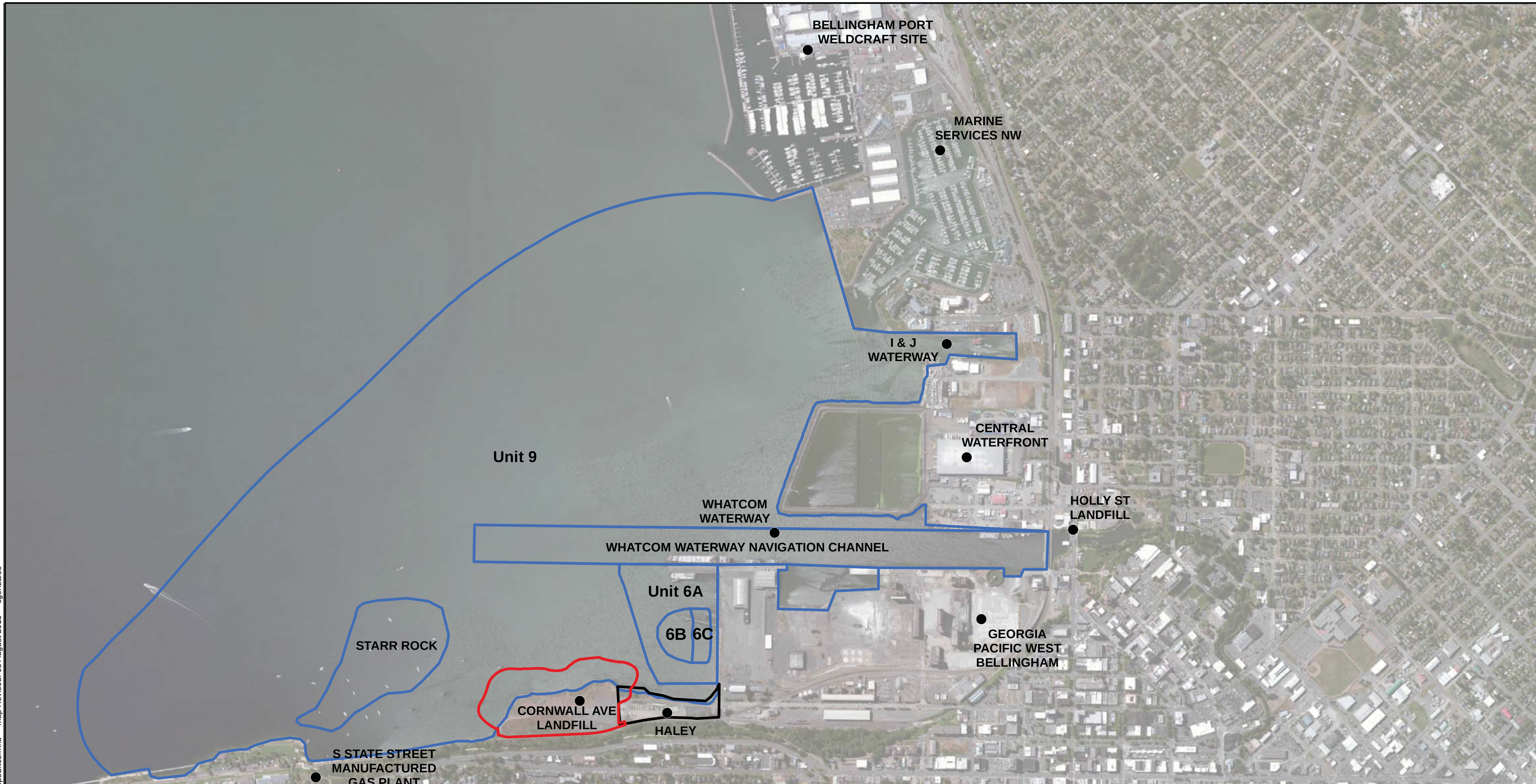
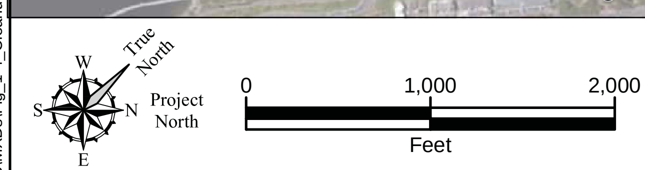
Figure 1-3

Path: \\sea\projects\0\0356114\GIS\MXDs\Fig_1-3_SiteLayout.mxd Map Revised: 02 February 2015 cgonzales





Reference: Aerial from Esri, 2013.
Whatcom Waterway Sediment Site Units digitized from Anchor QEA, 2012.

Notes:
1. The locations of all features shown are approximate.
2. This drawing is for information purposes. It is intended to assist in showing features discussed in an attached document. GeoEngineers, Inc. cannot guarantee the accuracy and content of electronic files. The master file is stored by GeoEngineers, Inc. and will serve as the official record of this communication.

Legend

- ● Bellingham Bay Demonstration Pilot Cleanup Site
- Black outline: Haley Site per Agreed Order, Exhibit 1
- Red outline: Cornwall Landfill Site, per Cornwall Landfill Agreed Order/RI Report
- Blue outline: Whatcom Waterway Areas Shown Include Outer Boundaries of Sediment Site Unit 9, Whatcom Waterway Navigation Channel, Starr Rock, and Sediment Site Sub-Units 6A, 6B, 6C. Areas Identified per Consent Decree (As Updated in Pre-Remedial Design Investigation)

Nearby Bellingham Bay Cleanup Sites

R.G. Haley Site
Bellingham, Washington

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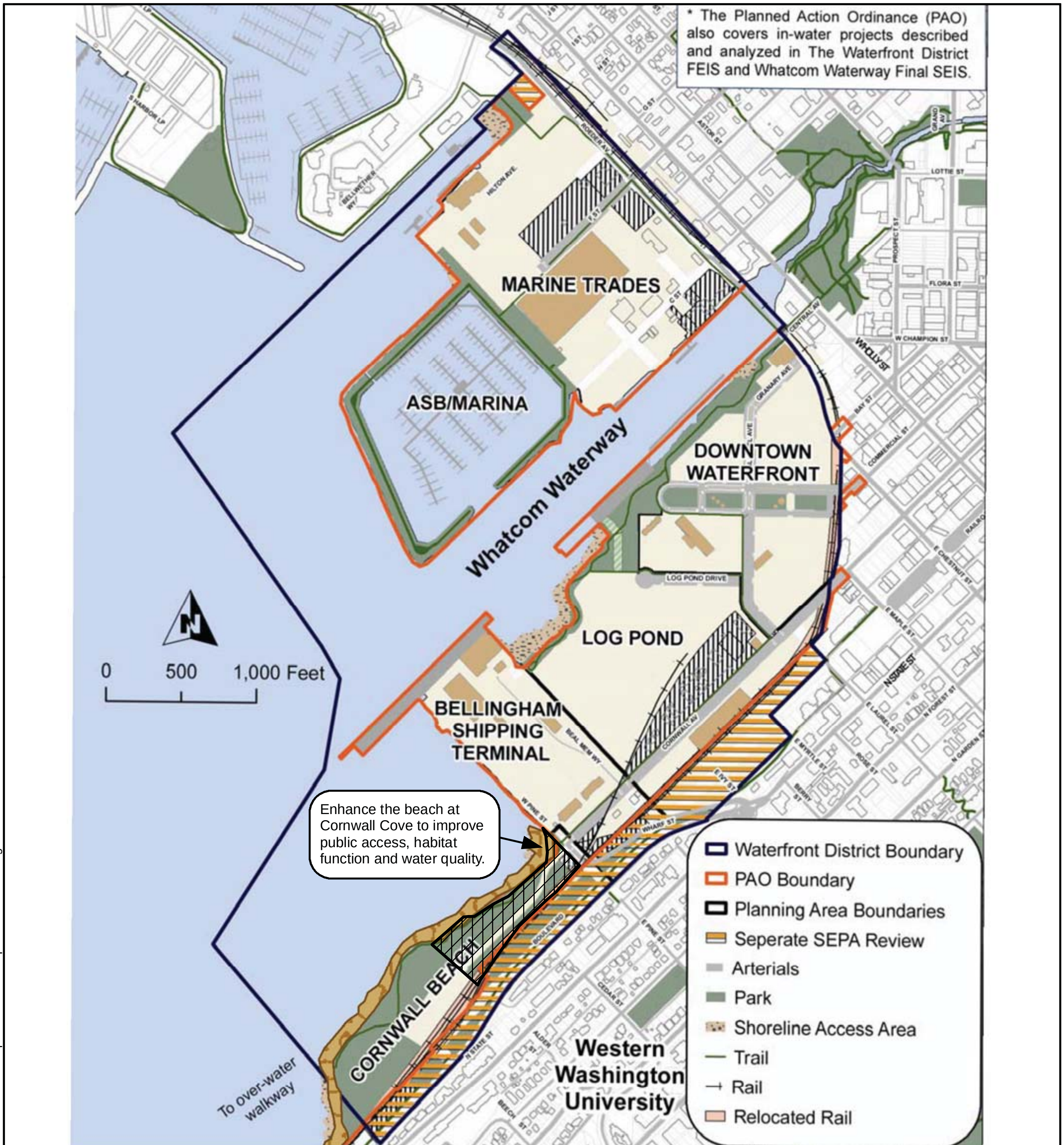
Figure 1-4

Path: \\sea\projects\0\0356114\GIS\MXDs\Fig_1-4_CleanupsSites.mxd Map Revised: 08 August 2013 cgonzales



Legend

Haley Site per Agreed Order, Exhibit 1

Shoreline Restoration Proposed Under District Sub-Area Plan

Project North

Notes:
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Reference: Figures from City of Bellingham Draft Waterfront District Sub-Area Plan 2012

Waterfront District Redevelopment Plan

R.G. Haley Site
Bellingham, Washington

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Figure 1-5

Path: \\sea\projects\0\0356114\GIS\MXDs\Fig_1-5_WaterfrontDistrict.mxd Map Revised: 23 September 2013 cgonzales

2.0 PROJECT BACKGROUND

This section presents a summary of the project background including the Haley Site history, previous investigations and cleanup actions, and relevant background information for the overlapping Cornwall Landfill site and Whatcom Waterway site.

In the discussion of previous investigations, the term "dioxins/furans" is used when generally referring to polychlorinated dibenzodioxins (PCDDs, or dioxins) and polychlorinated dibenzofurans (PCDFs, or furans) as potential contaminants. References in this report to dioxin/furan concentrations represent toxic equivalent concentrations (TEQ) calculated as explained in Section 3.6 for the entire mixture, unless otherwise stated.

2.1. Site Definition and Setting

2.1.1. General Site Location

The Haley upland is located on the eastern shore of Bellingham Bay, at the foot of a steep bluff south of the Central Business District of downtown Bellingham (Figures 2-1 and 2-2). The South Bay Trail and Boulevard Street are east of the Site, near the top of the bluff. A long-established residential neighborhood (Sehome) is located higher on the hill east of Boulevard Street. The residential area extends to the crest of Sehome Hill and the grounds of Western Washington University. Properties immediately adjoining the Haley property include the Nielson Brothers parcel with an associated two-story office building to the north, the Cornwall property to the south, and active BNSF railroad tracks to the east (Figure 1-2). A public access beach, on a parcel owned by the Port of Bellingham (Pine Street beach), is situated north of the northwest boundary of the Haley property.

Other industrial properties are located farther north of the Haley property (Figure 2-1). The most notable of these include the existing Bellingham Shipping Terminal facility, the Encogen cogeneration facility, and the former Georgia Pacific (GP) chlor-alkali plant and pulp and tissue mill.

Notable in-water features in the general Site vicinity include the Whatcom Waterway navigation channel to the west and Starr Rock located to the south (Figure 1-4). Sediment from previous navigational dredging has been disposed of near Starr Rock (RETEC 2006).

2.1.2. Current Site Conditions

Access to the Haley upland is currently restricted by security fencing. The gated, locked entrance to the property is situated at the terminus of Cornwall Avenue at the north end of the property. The southern extension of Cornwall Avenue forms a City-owned paved access road (not a public right-of-way) extending in a north-south orientation across the Haley property toward the Cornwall property. The security fencing extends westward approximately 70 feet onto the beach at the south end of the Haley property, bordering the Cornwall property. The shoreline west of the access road is open to Bellingham Bay; however, shoreline access from the north is limited by large rocks and logs. Shoreline access from the south is limited by security fencing at the northern boundary of the Cornwall site.

A 16-inch-diameter water line, reportedly inactive, extends along the eastern property line, parallel and next to the railroad tracks (Figure 1-3) (Ronald T. Jepson & Associates 1990). This line is not actively maintained by the City (Routhe 2012). The fire hydrant at the northeast corner of the Cornwall property is reportedly inactive (Davis 2013) and may have been connected to this water line in the past. Municipal sanitary sewers are not present on the Haley upland; the closest City sewer main is in Pine Street to the north.

The surface of the Haley upland is essentially flat. The ground surface is comprised of concrete areas corresponding to the locations of former buildings and structures, and asphalt and gravel surfaces in other areas (Figure 2-2). Some sparse vegetation is present. There are no buildings on the property. Ecology blocks surround an area in the central portion of the Haley property where investigation-derived wastes and materials generated during previous cleanup actions are stored (Figure 2-2). The waste materials are stored in drums and covered stockpiles and will be addressed after the conclusion of the RI.

An inactive underground storage tank (UST) that was previously used for P-9 carrier oil and a concrete surge tank used for wood treatment solution remain in the southeast portion of the Haley property (Figure 2-2). Based on measurements collected in June 2004, the 17,000 gallon capacity UST contained three inches of residual liquid (rinsewater) and the 17,000 gallon capacity surge tank contained two inches of rinsewater (GeoEngineers 2007). Other Haley facilities and structures were removed in 2010. Remnant stormwater drainage features (drain inlet grates, pipes, and outfalls) are located on the Site (Figure 2-2) as described in Section 4.1.3.

A vertical sheet pile barrier installed as an independent cleanup action is present along a portion of the shoreline; the seaward face of the wall extends several feet above the beach surface. Product recovery wells and groundwater monitoring wells are also present on the upland (Figure 2-2). The purpose of the sheet pile wall and wells is described in Section 2.4.8.

The marine portion of the Haley Site extends into intertidal and subtidal bedlands of Bellingham Bay. At the shoreline of the Site the near-vertical bank is approximately 4 to 8 feet high and is mostly covered with armoring that includes concrete debris and rip-rap. Logs intermittently accumulate along the shoreline in response to marine (primarily storm) processes. Several portions of the shoreline bank are not armored and have sparse vegetation including small trees.

The beach surface is predominantly composed of gravel and sand with varying amounts of cobbles and silt, and frequent debris. Visible debris includes wood, brick fragments and glass fragments. An area of predominant wood debris is exposed at the sediment surface in the upper intertidal zone on the southwest portion of the Site. This intertidal wood debris consists of sawdust, wood chips and wood fragments. Numerous remnant untreated timber pilings associated with historical overwater structures remain in the intertidal zone.

2.1.3. Site Discovery and Regulatory Status

In 1985, Ecology required that Haley evaluate whether contamination was present on the Haley facility as a condition under the facility's National Pollutant Discharge Elimination System (NPDES) permit. The subsequent investigation identified soil and groundwater contamination in the Haley upland. Ecology requested that the U.S. Environmental Protection Agency (EPA) evaluate and score the Site for possible inclusion on the Superfund National Priorities List (NPL). In 1986, EPA's contractor, Ecology and Environment, Inc. (E & E), completed a site inspection and assigned a hazard ranking system (HRS) score of 11.48. This score was below the minimum score of 28.5 necessary for the Site to be included on the NPL. The principal reason stated by EPA for the score not being higher was “there are no human targets who may be affected by this release at this time.” Due to the low score, EPA took no further action regarding the Site.

Ecology performed a site hazard assessment for the Site in 1992 (Ecology 1992b). The purpose of the site hazard assessment was to rank the Site using the Washington Ranking Method (WARM). According to this method, sites are assigned a rank between 1 and 5, with a rank of 1 indicating the greatest assessed risk to human health and the environment, and a rank of 5 indicating the lowest assessed risk. Ecology assigned the Site a WARM rank of 3 and added the Site to the Hazardous Sites List as required by the MTCA (WAC 173-340-330). Ecology’s facility number for the Site is 2870. The Site status is shown as “Cleanup Started” in recent versions of Ecology’s Hazardous Sites List.

In 2004, Ecology named Douglas Management Company, the previous property owner, a potentially liable person (PLP) for the Site under MTCA. Douglas Management Company performed investigations and a limited cleanup action under MTCA, initially on a voluntary basis with oversight by Ecology, and subsequently under the Order, which was executed on April 5, 2005. The Order required Douglas Management Company to complete an RI/FS for the Site. An RI/FS was conducted, and the results were reported in the 2007 RI/FS.

The City purchased the Haley property from Douglas Management Company in 2009. In 2009, Ecology identified the City as a PLP for the Site along with the Port. The First Amendment to the Order removed previous property owner Douglas Management Company as a signatory to the Order, and added the City as a signatory. The Port, although identified as a PLP, is not a signatory to the Order. The effective date of the First Amendment was October 15, 2010. The City is conducting this RI/FS pursuant to the First Amendment to the Order.

Subsequent to the City and Ecology executing the First Amendment to the Order, an intermittent petroleum release was observed in an area along the shoreline. The City and Ecology executed a Second Amendment to the Order in July 2013. The purpose of the Second Amendment was to accommodate an interim action that was completed by the City to contain the petroleum release (GeoEngineers 2014).

2.1.4. Adjacent MTCA Cleanup Sites

Remedial actions are underway at two adjacent MTCA cleanup sites: the Cornwall site to the south and the Whatcom Waterway site to the west (Figure 1-4). A summary of remedial actions at these sites is included in Sections 2.5 and 2.6, respectively. The boundaries of the Haley, Cornwall and Whatcom Waterway cleanup sites overlap (Figure 1-4). Cleanup action alternatives evaluated in the Haley Site FS (Section 9.0) address all contaminants in the areas of overlap, and cleanup actions for the sites will be designed to be compatible.

The Cornwall site is approximately 25.8 acres in size, which includes about 12.6 acres of aquatic lands (Ecology 2014e). The Cornwall site is ranked 2 on Ecology’s Hazardous Sites List. Constituents of concern associated with the Cornwall site include refuse and wood waste, metals (copper, chromium, nickel, lead, mercury, silver and zinc), semivolatile organic compounds (SVOCs), polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), dioxins/furans in stabilized sediment stockpiled on the Cornwall site, conventional constituents (manganese, fecal coliform and ammonia), and overlapping contaminants associated with the Haley Site and the Whatcom Waterway site (Landau 2013). An interim action and the RI/FS for the Cornwall site were completed under Agreed Order No. 1778, as amended, among the Port, the City and Ecology. Remedial design for the Cornwall site began in 2015 and cleanup construction is scheduled to begin in 2018.

Municipal refuse and wood waste associated with the Cornwall Landfill is present in the southwestern Haley upland (Figure 2-2). Contaminants associated with the Cornwall and Haley sites overlap in the upland and marine areas. The locations where contaminants overlap is referred to as the "overlap area."

The Whatcom Waterway site covers more than 200 acres in Bellingham Bay along the downtown Bellingham waterfront (Figure 1-4). Cleanup of the Whatcom Waterway site is being led by the Port, with involvement by the City, DNR and Meridian-Pacific Hwy, LLC under a 2007 Consent Decree (as amended) with Ecology. The Whatcom Waterway site is ranked 1 on Ecology's Hazardous Sites List. Contamination at the site is the result of operations at the former GP chlor-alkali plant and pulp and tissue mill, and other waterfront industrial facilities. The former GP mill historically discharged pulp wastes to the waterway. Key contaminants associated with the Whatcom Waterway site include mercury and phenolic compounds (primarily 4-methylphenol[2]) (Anchor 2000c). The first phase of cleanup is scheduled to begin in summer 2015. The second phase of cleanup is scheduled to begin in 2018. Principal cleanup actions include dredging and capping contaminated sediment, removing abandoned structures and debris, and enhancing habitat. Mercury contamination in the Whatcom Waterway site sediment units 6A and 9 overlaps with the Haley Site sediments (Figure 1-4). The sediment cleanup action selected for the portions of the Whatcom Waterway site that overlap with the Haley Site is monitored natural recovery (MNR) (Anchor QEA 2013).

The Haley, Cornwall and Whatcom Waterway sites are part of the Pilot Project (Section 1.3). Nine other cleanup sites are also part of the Pilot Project; these include the Central Waterfront, Eldridge Municipal Landfill, GP West (also known as the GP former chlor-alkali plant and pulp and tissue mill), Harris Avenue Shipyard, Holly Street Landfill, I & J Waterway, Little Squalicum Park, South State Street Manufactured Gas Plant (MGP), and Weldcraft Steel and Marine (also known as Bellingham Port Weldcraft) sites. The Pilot Project sites nearest to the Haley site are shown in Figure 1-4. None of these nine other sites is immediately adjacent to the Haley Site; the nearest of the other cleanup sites is GP West (Figure 1-4).

2.2. Historical Waterfront Activities

2.2.1. Overview

The area comprising the Site historically consisted of tidelands. The original shoreline generally corresponded to the base of the bluff east of the Site. Prior to European settlement of this portion of Bellingham Bay in the 1850s, Native American settlement and subsistence shellfish gathering,

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[2] Formed during the anaerobic decomposition of organic material, 4-methylphenol was primarily of concern in subsurface sediment in the Whatcom Waterway where there were historical accumulations of pulp, wood waste and wood. Phenol and 2,4-dimethylphenol were sporadically present in surface sediments; 2,4-dimethylphenol was not thought to be contributing to risk in Whatcom Waterway sediments (RETEC 2006).

fishing and hunting activities took place at times in areas along the Bellingham waterfront (Northwest Archaeological Associates 2007).

Numerous sources of historical information were reviewed to prepare the summary of post-1850s historical activities and potential sources of contamination associated with the Haley Site and surrounding properties discussed in Sections 2.2.2 through 2.2.8. These sources include historical maps, historical aerial photographs and previous reports. Appendix A contains a compilation of pertinent historical records for the Site, including the following two historical summary documents that are relevant to the Site vicinity:

- DNR Site History and Tideland Use, excerpted from letter by Joanne Snarski, DNR Aquatic Land Manager to Ecology (DNR 2002) (Appendix A, Exhibit A-1);
- "Initial Characterization of Contaminants and Uses at the Cornwall Landfill and in Bellingham Bay" (Chapter 5.0 – Cornwall Avenue Landfill and R.G. Haley Sites). Prepared by Tetra Tech Inc. and Historical Research Associates for Attorney General of Washington, dated June 30, 1995 (Appendix A, Exhibit A-2).

In addition to these comprehensive documents, GeoEngineers retained a historical consultant, Dr. Chris Friday, Director of the Center for Pacific Northwest Studies and Professor of History at Western Washington University in Bellingham, Washington to review these two documents, and to locate any additional available historical information that might provide more detailed information regarding historical waterfront activities in the Site vicinity (Appendix A, Exhibit A-3). Dr. Friday concluded that additional information in the historical record beyond the information contained in the referenced 1995 report and 2002 letter did not substantively add to the understanding of historical activities and potential sources of contamination (Friday 2002).

Sections 2.2.2 through 2.2.8 describe historical land uses and potential sources of contamination in the Site vicinity. A chronology of property ownership and leases is summarized below where it pertains to potential sources of contamination.

2.2.2. Railroad

The railroad adjacent to the Haley property, currently the BNSF main line, was constructed in about 1890. No historical references were located that describe or identify the source of fill or ballast used for railroad construction. Treated wood has been and is used for railroad ties along the corridor.

Dr. Friday conducted extensive research to assess the potential for releases of hazardous substances from railroad activities near the Haley property. He searched local files, newspapers and document repositories including Whatcom Museum of History and Art, Washington State Archives (Northwest Region), Port of Bellingham Commission Meeting Minutes, Bellingham Herald Clippings Files, Center for Pacific Northwest Studies at Western Washington University, and Huxley Map Library, also at Western Washington University. Based on his research, Dr. Friday concluded that "local newspaper accounts suggest a rather regular pattern of train derailments 'behind' the R.G Haley Site, but there is nothing to indicate any major spill took place at this spot" (Friday 2002). This information suggests that releases common to train derailments (e.g., petroleum) could have impacted portions of the Haley upland, although more definitive conclusions are not possible.

The present-day South Bay Trail, located near the top of the bluff east of the Haley upland, also was a former railroad line identified on Sanborn Fire Insurance Maps dated 1897 to 1950.

2.2.3. Lumber Mill

Early waterfront activities in Bellingham Bay where the Haley property is now located included a large lumber mill (sawmill) that extended across a significant portion of the shoreline and overwater areas. Various mill operations and mill support activities took place over a span of more than 60 years beginning in the late 1880s. Several wharves and piers were built in the area; these structures were used for mill operations and for coal transport related to historical coal mining activities nearby (Figure 2-3). The mill and related activities covered the entire area shown in Figure 2-3 west of the historical 1887 shoreline and south of the historical ferry slip, including upland and in-water areas of the present-day Cornwall site, Haley Site, Pine Street beach and in-water and shoreline areas south of the GP West site and east of the Whatcom Waterway navigation channel.

The first lumber mill in this area was constructed on pile-supported wharfs in the tidelands in about 1889. Railroad spurs constructed along portions of the waterfront were also on pile-supported structures. The lumber mill was originally owned by the Bellingham Bay Improvement Company (BBIC) from 1889 to 1912, the Bellingham Bay Lumber Company from 1912 to 1913, and the Bloedel Donovan Lumber Company from 1913 to 1947. Bloedel Donovan mill activities ended by 1947 at which time areas comprising the Haley property were purchased by the Port and areas comprising the State-owned land west of the Haley property were leased by the Port.

The following potential sources of contamination were associated with the lumber mill operations referenced above.

- Lumber mill facilities included oil houses, a machine shop, auto repairing, engine room, boilers, electrical shop, electric light works[3] and fuel room in the southern portion of the Haley property and northern portion of the Cornwall property (Figure 2-3).
- Historical mill operations included "hog fuel" burning from the late 1800s until the late 1940s. Therefore, features identified as "waste fires," a refuse burner and a smokestack (Figure 2-3) are potential historical sources of dioxins/furans as a result of burning salt-encrusted wood waste (from logs transported and stored in marine waters) (Ecology 1998).
- Creosote-treated pilings and creosote-treated wooden decking in overwater structures (wharves and piers). Historical treated wood pilings in the Site vicinity were removed by DNR in January and February 2009 (Section 2.4.7).
- Wood waste associated with milling operations and log-rafting in adjacent areas of the Bay (e.g., sawdust, bark, wood pieces, logs).

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[3] The "electric light works" occurred prior to the first manufacturing of PCBs in the United States in 1929 (EPA, http://www.epa.gov/epawaste/hazard/tsd/pcbs/about.htm).

2.2.4. Tideland Filling

Tideland filling in the vicinity of the Haley Site began as early as 1890 with construction of the railroad at the base of the bluff. More extensive filling occurred from about the turn of the century to approximately 1975 based on progressive positions of the shoreline shown in Sanborn Maps and aerial photographs. Investigations completed during this RI suggest that tidelands beneath the Haley Site were filled with wood waste generated by historical lumber mill operations, apparent construction debris, and marine sediment that was likely generated by dredging.

In 1948, the Port filled approximately 2.5 acres of tideland in what is presently the southwest portion of the Haley property (Port 1948b, 1948c and 1949). This was previously an area where lumber mill-related over-water structures were present. Port documents indicate that this area was filled to create additional upland for use by Crossarm, the first company to treat wood within the footprint of the Haley property (Section 2.2.5.1). Evidence of the 1948 filling is visible in the 1950 aerial photograph (Appendix A, Figure A-6) in the southwest portion of the Haley property and adjacent areas to the west and southwest, including west of the Inner Harbor line.

The DNR Site History and Tideland Use (Appendix A) references a map from US Army Corps of Engineers (USACE) files that suggests that in 1953 dredge spoils may have been placed in a portion of the Haley Site. The dredge spoils originated from the “Whatcom Creek waterway” (presumably the present-day Whatcom Waterway). The map noted that dredge spoils were placed in a portion of the harbor area between Alder Street and the ferry slip. Alder Street is the vacated right-of-way corresponding to the boundary between the Cornwall and Haley properties. The ferry slip was north of the Haley facility (Figure 2-3).

Municipal waste associated with the Cornwall Landfill also was placed in the southwest portion of the Haley Site. More detailed information regarding fill conditions beneath the Haley upland is presented in Section 4.2.

2.2.5. Wood Treatment and Storage Operations

2.2.5.1. PROPERTY OWNERSHIP AND LEASES

In 1947, the Port acquired the Haley property. From 1948 through 1951, the Port leased the northern half of the Haley property to Crossarm (Port of Bellingham 1948a), a wood treater. In 1951 the Port extended the area of Crossarm’s lease farther to the south, encompassing approximately the northern two-thirds of the present-day Haley property (Port of Bellingham 1951). The Crossarm lease was assigned to R. G. Haley International Corp. beginning in 1955 (Crossarm 1955). In 1962 the Port entered into a contract to sell the Haley property to Haley (Port of Bellingham 1962); Haley purchased the Haley property in December 1971 (Port of Bellingham 1971). Haley continued wood treating operations at the facility until 1985, when the wood treatment operations were shut down.

Douglas Management Company purchased the Haley property in 1990. Beginning in 1991, the Haley buildings were used by the G.R. Plume Company as a timber millwork shop (City of Bellingham 1991). The G.R. Plume Company manufactured reclaimed wood products such as trusses and structural beams for exposed timber construction and used the buildings for approximately seven years. High-end finishing of wood products occurred at the facility but treatments and coatings, if needed, were usually applied off-site (Plume 2013).

The City acquired the property from Douglas Management Company in 2009.

The State-owned upland west of the Haley property was leased to the Port between 1947 and 1965. Frank Brooks Manufacturing (Brooks) leased this land from 1965 through 1985 (DNR 1965, DNR 1976). The area of Brooks' lease between 1965 and 1976 (DNR 1965) extended from the upland Inner Harbor Line to in-water areas west of the shoreline; however, beginning in 1976 Brooks' lease was limited to only the upland portion of State-owned land (DNR 1976). GP leased the State-owned upland west of the Haley property from 1985 to 2001.

2.2.5.2. WOOD TREATMENT AND WOOD STORAGE FACILITIES

The Haley wood treatment facilities were located on the southern portion of the Haley property (Figure 2-4). Wastewater from wood treatment was released into an unlined seepage pit (Figure 2-4) near the southern boundary of the Haley property. Treated and untreated wood storage areas were located throughout the Haley facility, including the State-owned upland adjacent to the shoreline.

Buildings associated with the former wood treatment facility included a planing and boring building, two drying sheds, a kiln building, a control building, and a shed (Figure 2-4). The control building housed a boiler room, laboratory, pentachlorophenol (PCP) storage, and equipment storage.

A reference on the 1960 Sanborn Map noted "creosote treatment and creosote tanks" at locations corresponding to the Haley wood treatment and above-ground storage tank (AST) areas. However, the use of creosote for wood treatment at the Haley or predecessor businesses was not corroborated by any other historical references (Friday 2002; TetraTech 1995). The 1984 "Best Management Practices Plan" and 1985 "Engineer's Report" for the Haley facility both indicate that treatment was performed using a light oil containing 5 percent PCP, and that "no other wood treating chemical has been used during the history of plant operations" (Edde 1984, 1985a). All other historical references reported only the use of PCP-containing carrier-oil.

The wood treatment equipment included storage tanks and structures that contained P-9 carrier oil. The treatment solution consisted of PCP dissolved in the carrier oil. Tanks and process structures located in the southern portion of the Haley property (Edde 1985a) included:

- A 17,000-gallon UST
- A 17,000-gallon underground surge tank
- A 25,000-gallon retort
- Two 17,000-gallon ASTs
- Wastewater seepage pit
- Underground and aboveground process-related conveyance piping

Drainage features associated with the facility are described in Section 4.0.

Wood was removed from the retort using a tram system and treated wood was placed to dry west of the tram tracks (Edde 1985a). A 1953 aerial photograph shows what appears to be a large area of stained soil in the area west of the tram tracks. Treated wood was stored in many other portions of the property, including the covered drying sheds, uncovered areas east of the drying sheds, and on uncovered, unpaved areas and drip pads on State-owned land near the shoreline (Figure 2-4).

In addition to the facilities described above, a fuel bin or oil house was located on the south side of the planing and boring building, a fuel bin was located on the north side of this building, and a machine shop was located inside the western margin of this building (Figure 2-4) (Sanborn Map 1950).

Wood treatment operations ceased, and the seepage pit was removed, in 1985 (Section 2.4.8). In 2009, buildings on the Haley property were removed due to fire damage that occurred in 2007. The UST and surge tank remain on the property.

Brooks' lease of the State-owned upland west of the Haley property occurred during a period of time (1965 to 1985) that coincided with active Haley wood treatment operations. Treated wood was stored on the land leased by Brooks. Brooks operated a wood treatment facility approximately 2.5 miles away on Pacific Street in Bellingham, from the mid-1940s to at least the early 1990s (Appendix A, Exhibit A-2).

The Oeser Company operates another wood treatment facility west of downtown Bellingham. This facility is not located on the waterfront; however, wood-treating contaminants from the Oeser wood treatment facility impacted sediment in Little Squalicum Creek (E & E 2002 and Ecology 2009a), which flows into Bellingham Bay.

2.2.6. Cornwall Landfill Site Uses

Between approximately 1953 and 1962, the Port subleased the State-owned land of the Cornwall site to the City for disposal of municipal refuse. Another Port tenant performed landfill operations at the Cornwall property through 1965 (Landau 2013). According to the Ecology site hazard assessment for the Cornwall Avenue Landfill, refuse placed in the landfill reportedly included household garbage, pulp waste, and medical waste (Landau 2013). The approximate landward boundary of the Cornwall Landfill refuse is shown in Figure 2-3. The landfill was covered by a soil cap of variable thickness after disposal activities ended in 1965, and the shoreline was protected during various phases of armoring with rock and broken concrete. Environmental controls such as a liner, leachate collection system, or stormwater management system were not constructed. The landfill extends onto the southwest portion of the Haley facility as discussed in Section 4.0. Significant shoreline erosion occurred after the landfill was closed, resulting in exposure of landfill refuse at the surface and redistribution of landfill refuse onto the adjacent beach area (TetraTech 1995).

During the 1950s through approximately the early 1970s, American Fabricators, a division of Brooks Lumber Company, reportedly operated on the Cornwall property (TetraTech 1995). American Fabricators produced laminated beams and arches used in bridge construction and other products (Bellingham Business Journal 2003).

GP leased and/or owned portions of the Cornwall property between 1971 and 2005. Two warehouses previously located on the eastern portion of the Cornwall property were used by American Fabricators (Brooks) and GP.

2.2.7. Reported Oil Dumping

The City Fire Department's file for Brooks Lumber includes a letter dated August 1970 addressed to an individual identified as Quentin Wells, stating that he was dumping "crankcase oil on the open land fill area at the foot of Cornwall Avenue" (City 1970). A DNR file memo dated September 1970 indicated that the harbor area leased by Brooks was being used for unauthorized "dumping of oil" (DNR 1970).

Additional details regarding the parties performing oil dumping and the specific location(s) where the alleged oil dumping occurred were not provided in the documents researched for this RI report. At the time the Bellingham Fire Department and DNR letters were written, Brooks leased the State-owned land west of the Haley property, in-water areas west of current shoreline, portions of the Cornwall landfill (Section 2.2.6), and the southern portion of the Cornwall property (RETEC 1997). The reported oil dumping in the harbor area leased by Brooks therefore may have included portions of the Haley Site or portions of the Cornwall site that overlap the Haley Site (Section 6.3.3).

2.2.8. Pulp and Paper Mill Activities

Historical pulp and paper mill operations have been conducted on the waterfront north of the Haley property since the early 1900s. GP purchased the mills in this area in the 1960s, and constructed a chlor-alkali plant in 1965 (Figure 2-1), which operated until 1999. Mercury-containing discharges from the chlor-alkali plant have impacted sediment in the Whatcom Waterway and adjacent portions of Bellingham Bay. Discharge of pulp and organic sludge to the waterway introduced phenolic compounds as decomposition products, which have also impacted sediment in the waterway. The footprint of this sediment contamination overlaps with the Haley and Cornwall sites. Cleanup actions to address the impacted sediment are underway as discussed in Section 2.1.4.

2.3. Navigational Dredging

Several episodes of navigational dredging have been completed in the Whatcom Waterway, I & J Waterway and associated berth areas (RETEC 2006). Sediment generated by dredging the Whatcom Waterway in 1969 was disposed of at the Starr Rock sediment disposal site (RETEC 2006). As noted in Section 2.2.5, dredged material from the Whatcom Waterway may have been placed as fill within the Haley Site in 1953.

2.4. Previous Studies and Cleanup Actions – Haley Site

Several previous studies and cleanup actions have been completed at the Haley Site since 1985. An overview of the previous studies is presented below (Sections 2.4.1 through 2.4.7). Data for which exploration locations could be verified and chemical analytical data could be verified through data quality reports, where available, were deemed suitable for use in the RI; exceptions are noted below. Exploration and sampling data from previous studies that were deemed suitable for use in the RI were incorporated in the RI database, and are presented in the tables and figures included in this RI report and used to interpret the nature and extent of contamination (Section 6.0). Section 3.6 presents a more detailed summary of the data used in the RI. Previous cleanup actions are described in Section 2.4.8.

Appendix B contains summary tables of previous explorations cross-referenced to the previous studies described below (Tables B-1 and B-2) and maps of previous exploration locations (Figures B-1 through B-3).

2.4.1. Haley Facility Engineering Study

Howard Edde, Inc. (Edde) completed an engineering study to evaluate soil contamination associated with past wood treatment operations (Edde 1985a). This study documented the presence of soil contamination in the wood treatment area and the release of process wastewater to the seepage pit on the east side of the kiln building (Figure 2-4). Several soil samples obtained during this study were analyzed for PCP and are included in the soil sample data evaluated in the RI. One of the soil samples analyzed for PCP was reported to be a “background” sample east of the Haley property and east the railroad tracks; the exact location of this soil sample could not be confirmed based on information in the report. This sample is further discussed in Section 6.3.

The report also indicated that process wastewater was mixing with stormwater in the wood treatment area. Edde recommended that the seepage pit be closed by removing the contaminated free liquid and sludge/soil, and disposing of it at an off-site disposal facility.

Haley submitted Edde’s report to Ecology to fulfill NPDES permit requirements. Ecology subsequently recommended that Haley close the seepage pit and clean certain equipment (Ecology 1985).

The Edde report also indicated that an oil sheen was observed near the shoreline by the US Coast Guard (USCG). The oil sheen was located offshore of the larger (northern) drying shed at the Haley property. The date the sheen was observed and mitigation actions, if any, were not described in the report.

2.4.2. Site Inspection

A site inspection was performed in 1986 by E & E on behalf of EPA (E & E 1986). As discussed in Section 2.1.3, the purpose of the site inspection was to provide information to evaluate and score the Site for possible inclusion on the NPL. Two soil borings and two monitoring wells were completed in the wood treatment area. In addition, groundwater samples were collected from four locations in the intertidal zone. The resulting HRS score was below the threshold necessary for inclusion on the NPL and no further action was planned by EPA.

2.4.3. Phase I Environmental Site Assessment

A Phase I Environmental Site Assessment was completed in 1991 by W. D. Purnell & Associates on behalf of GP for the State-owned upland west of the Haley property (Purnell 1991) and adjacent leased areas to the south on the Cornwall upland. The purpose of the assessment was to review the history, document visual observations of the property, and assess the potential presence of hazardous substances. As part of the assessment, two soil samples were collected from an area of soil staining on the State-owned upland west of the Haley property. The exact location of the samples was not documented in the report, so these samples are not included in the RI database. The soil samples were reportedly collected at a depth between 1 and 2 feet below ground surface (bgs) and analyzed for SVOCs by EPA Method 8270. Concentrations of PCP ranging from 810 to 59,000 mg/kg were detected in the soil samples. PAHs were detected in the samples at concentrations as high as 8,100 mg/kg (fluorene).

2.4.4. Site Hazard Assessment

Ecology visited the Haley facility in the course of conducting a Site Hazard Assessment (Ecology 1992b), and obtained soil samples from several "visibly stained areas" including an unpaved area under a wood storage shed, an unpaved area within the former AST area, and the area of soil staining on the State-owned upland west of the Haley property that was sampled in 1991 by Purnell. The individual soil samples were combined to produce a single composite sample, and the composite sample was analyzed for SVOCs. Analytical results for detected SVOCs were as follows: acenaphthene (36 mg/kg), anthracene (81 mg/kg), fluoranthene (12 mg/kg), 1-methynaphthalene (310 mg/kg), 2-methynaphthalene (130 mg/kg), PCP (8,600 mg/kg), phenanthrene (500 mg/kg) and pyrene (24 mg/kg). The fluoranthene and PCP results were qualified as estimated concentrations ("J" data flag). Due to the composite nature of this sample, the results are not included in the RI database.

2.4.5. Prior Remedial Investigation/Feasibility Study

Several phases of upland and sediment investigation were performed between June 2004 and September 2005 to evaluate the nature and extent of contamination at the Site. In addition, a pilot test was conducted in 2007 to evaluate the feasibility of enhanced soil agitation as a remediation technology for LNAPL removal. Results of these studies were previously presented in the 2007 Draft Final RI/FS Report (GeoEngineers 2007). The enhanced soil agitation pilot test is discussed further in Section 9.3. All data and other relevant information from the 2007 Draft Final RI/FS Report are incorporated in the corresponding sections of this RI Report, and therefore are not discussed further in this section.

2.4.6. Prior Sediment Investigation Near the Haley Site

Ecology commissioned several sediment investigations in the vicinity of the Cornwall and Haley sites, as well as other portions of Bellingham Bay, in support of the Pilot Project for cleanup and restoration of the bay (Hart Crowser 2009b). The sediment investigation sampling was conducted in 2008 by Hart Crowser. Nine sediment cores and three sediment grab samples were collected near creosote-treated pilings and derelict in-water wooden structures near the Haley shoreline. Numerous subsurface and surface sediment samples were analyzed for constituents regulated under the SMS, and for petroleum hydrocarbons and dioxins/furans. Two of the surface sediment samples also were submitted for bioassay testing. Pertinent results from the 2009 sediment investigation report are incorporated in this RI report. The areas sampled near the Haley shoreline were evaluated in anticipation of planned removal of the creosote-treated pilings and structures by DNR; the pilings and structures were subsequently removed in 2009 (EES Consulting 2009) (Section 2.4.7).

2.4.7. Post-Piling Removal Sediment Sampling Near the Haley Site

Subsequent to Hart Crowser's 2008 investigation of sediment conditions near creosote-treated pilings and derelict pier structures, DNR contracted to have the pilings removed and sediment quality documented following removal (EES Consulting 2009). Five surface sediment samples were collected at locations previously sampled by Hart Crowser (one sample was relocated from the original coordinates). Sediment samples were collected by hand or with a Ponar grab sampler; plastic buckets and plastic instruments were used in sample handling. The depth of the samples below the mudline was not documented. The samples were analyzed for copper, lead, mercury, and diesel- and heavy oil-range petroleum hydrocarbons; the three samples with the highest metals concentrations were also analyzed for phenolic compounds. Analytical methods were not entirely consistent with prior investigations, and detection limits for phenolic compounds were elevated. Grain size and total organic carbon were not analyzed in any of the samples collected. These sediment data are not currently included in the RI database due to uncertainties associated with sample collection and analysis methods.

2.4.8. Previous Cleanup Actions

2.4.8.1. WASTEWATER SEEPAGE PIT EXCAVATION

The 1986 report by E & E documents that Haley removed approximately 80 tons of contaminated material from the wastewater seepage pit in 1985 (Appendix B, Figure B-4). The material removed reportedly included a 1-foot thick sludge layer at the bottom of the seepage pit. The excavated material was transported to Chem-Security Systems, Inc., in Arlington, Oregon, for disposal. The completed excavation was reported to be approximately 8 feet deep and extended about 1 foot below the groundwater table. The limits of the excavation extended approximately 2 to 3 feet beyond the boundaries of the seepage pit (Appendix B, Figure B-4).

Confirmation soil samples were collected from one sidewall and the base of the excavation (soil samples 1 and 3, Appendix B, Figure B-4) and at locations 2 feet beyond the excavation limits (soil sample 2 below the base of excavation and sample 4 beyond the excavation sidewall, Appendix B, Figure B-4). These samples are not included in the RI database because chemical analytical data reports were not available and sampling procedures could not be verified. PCP was reportedly detected at concentrations ranging from 21 to 14,000 mg/kg in the confirmation soil samples. The maximum concentration of PCP detected in two soil samples collected 2 feet beyond the final excavation limits (one of which was collected in 1984 by Edde) was 180 mg/kg. The seepage pit excavation was backfilled with “granular fill” and paved with asphalt.

2.4.8.2. FOCUSED CLEANUP ACTIONS

Focused cleanup actions were completed to address oil seeps and/or petroleum sheen observed in the intertidal zone along the Haley shoreline in 2000, 2006 and 2012. The response to each of these releases is described below.

2000 Oil Seep – An oil seep in the intertidal zone was observed near the center of the Haley shoreline (Appendix B, Figure B-2) and reported to the USCG on February 10, 2000. The USCG deployed an oil containment boom around the seep area. The discovery of the oil seep triggered site characterization and cleanup activities to address the seep. Douglas Management Company performed these activities as voluntary actions under MTCA with oversight by Ecology. Results of the site characterization and cleanup activities are presented in several reports (GeoEngineers 2000a; 2000b; 2001a; and 2002).

The site characterization activities in 2000 and 2001 were performed to evaluate the source of the oil seep. Measureable light nonaqueous phase liquid (LNAPL) was identified in upland monitoring wells adjacent to the shoreline (Appendix B, Figure B-5). A cleanup action was performed to address the oil seep as summarized in the “Interim Cleanup Action Report” dated May 20, 2002

(GeoEngineers 2002). The cleanup action included the construction of a 390-foot long vertical sheet pile barrier to contain LNAPL (Appendix B, Figure B-5). An impermeable synthetic liner was installed adjacent to the upland side of the sheet pile barrier to provide additional protection against LNAPL seepage, and an oil recovery system was installed. The sheet pile barrier was designed to allow groundwater to flow beneath the bottom of the sheet piles. In addition, approximately 100 cubic yards (cy) of LNAPL-impacted sediment was removed from the intertidal zone during the cleanup action (Appendix B, Figure B-5). Following sediment removal, shoreline erosion protection measures were installed adjacent to the sheet pile barrier.

Beach sediment next to the oil seep was sampled by GeoEngineers (February 29, 2000), for characterization purposes before sediment removal. The sample collected on February 29, 2000 was analyzed for PCP, PAHs, bis(2-ethylhexyl)phthalate, arsenic, chromium, petroleum hydrocarbons, and total organic carbon. Analytical results for the February 29, 2000 sediment sample were provided in Table 13 of GeoEngineers (2000a); a copy of this table is provided in Appendix B, Figure B-6.

Post-cleanup monitoring indicated that the cleanup action successfully terminated the 2000 oil seep (Ecology 2002).

The 2000 oil seep ultimately led to Douglas Management Company entering Agreed Order No. DE-2186 for preparation of an RI/FS. Douglas Management Company prepared the Draft Final RI/FS Report (GeoEngineers 2007).

2006 Sheen – The Port discovered a petroleum-like sheen on surface water near the southern end of the Haley shoreline in January 2006. Petroleum was observed emerging from sediment in the intertidal zone generally near the former drip pads (Figure 2-4; Appendix B, Figure B-2). The sheen at this location occurred intermittently until June 2006.

The 2006 sheen was contained and collected using a boom and sweeps that were monitored on a regular basis and maintained until they were no longer needed by the end of June 2006. Investigative wastes were bagged and stored on-site. No additional remedial actions were completed in response to this oil seep.

2012/2013 Sheen – A petroleum-like sheen was again observed on surface water in the intertidal zone adjacent to the Haley facility on December 12, 2012 (GeoEngineers 2012b). The sheen was observed emerging from sediment on the beach near the 12-inch stormwater outfall at the shoreline (Figure 2-2; Appendix B, Figure B-2). This outfall was historically used to discharge stormwater captured from the wood treatment area. Notifications were made to appropriate regulatory agencies, and a containment boom and sorbent materials were deployed to contain and collect the sheen.

Based on the evaluation of available data, the source of the 2012 sheen was believed to be petroleum-impacted sediment in the intertidal zone and/or impacted groundwater and residual LNAPL migrating from the adjacent upland (GeoEngineers 2013a). An interim action was completed in Fall 2013 to address the sheen (GeoEngineers 2014).

Oil Recovery, 2000 to Present – Oil recovery through limited pumping from recovery wells and more extensive manual recovery (bailing) from wells has been intermittently conducted from 2002 to the present (Section 6.2.4). Approximately 760 gallons of LNAPL/oily water have been recovered as of February 2013.

2.5. Previous Studies – Cornwall Landfill Site

Several phases of remedial investigation have been performed at the Cornwall site since approximately 1997. The RI/FS report for the Cornwall site was finalized in 2013 (Landau 2013).

Selected data from the Cornwall RI have been incorporated in the Haley RI database. These data include 2012 groundwater data from monitoring wells along the Cornwall shoreline, and soil and groundwater data from the area of overlap between the Cornwall and Haley sites. These data were used to aid the interpretation of the nature and extent of Haley-related contamination (Section 6.0). Similarly, data from several explorations completed for the Haley RI were incorporated in the Cornwall RI report.

Key conclusions from the Cornwall RI report that pertain to the Haley Site are as follows:

- Constituents of concern in soil at the Cornwall site at concentrations exceeding the corresponding Cornwall site screening levels are: refuse and wood waste, metals (copper, chromium, mercury, nickel and zinc), SVOCs (bis[2-ethylhexyl]phthalate, di-n-butyl phthalate, and n-nitrosodiphenylamine), and dioxins/furans in stabilized dredged sediment stockpiles. Additional contaminants of concern in soil include PAHs, diesel- and oil-range petroleum hydrocarbons, PCP and dioxins/furans identified as associated with the Haley Site.
- Constituents of concern in groundwater at the Cornwall site at concentrations exceeding the corresponding Cornwall site screening levels are metals (copper and lead), PCBs, and conventional constituents (manganese, fecal coliform, and ammonia). Additional contaminants of concern in groundwater include PAHs, and diesel- and oil-range petroleum hydrocarbons identified as associated with the Haley Site.
- Constituents of concern in sediment at the Cornwall site are PCBs, metals (copper, silver, lead, mercury and zinc), and SVOCs (bis[2-ethylhexyl]phthalate, dimethylphthalate).
- Buried landfill refuse and wood waste extend onto the Haley upland (Figure 2-2). Approximately 215,000 cy of refuse are estimated to be present in the upland portion of the Cornwall site and approximately 80,000 cy of refuse are estimated to be present in the marine portion of the Cornwall site. The waste horizon is up to 38 feet thick beneath some portions of the Cornwall site.
- Petroleum-contaminated soil and groundwater were identified in the northern and eastern portions of the Cornwall property. The Cornwall RI report indicates that most of the petroleum-impacted area is located east and hydraulically upgradient of the landfill waste boundary. The petroleum in this area was attributed to the southerly migration of groundwater and contaminants from the Haley property to the Cornwall property. It was speculated that the southerly groundwater migration may have resulted from the discharge of liquids (process wastewater) to the seepage pit on the southern portion of the Haley property, or from preferential migration along the historical shoreline.

An interim action was performed at the Cornwall site in 2012. The interim action was designed to beneficially reuse approximately 47,000 cy of dredged sediment from a Port project. The dredged sediment was stabilized and stockpiled on the Cornwall upland (Figure 2-2), and will be used as fill to establish grades as part of the future landfill capping action (Landau 2012). A landfill gas control system was installed beneath the stockpiled sediment during the IA.

The FS report for the Cornwall site presents an evaluation of several remedial alternatives. Key components of the alternatives included landfill gas collection, upland capping and stormwater control, groundwater diversion, shoreline stabilization, sediment capping and MNR. Upland components of the preferred alternative include containment using a low-permeability cap and liner, landfill gas collection and stormwater management. In-water components of the preferred alternative include a shoreline stabilization system with a sand filter to enhance groundwater attenuation, a thin layer sand cap and MNR. The Haley FS addresses compatibility with the preferred remedial alternatives for the Cornwall and Whatcom Waterway sites.

2.6. Previous Studies – Whatcom Waterway Site

The Whatcom Waterway site overlaps with the marine portion of the Haley Site. Sediment quality and physical conditions in Whatcom Waterway have been evaluated during previous studies. Sediment quality data from locations near the Haley Site or in the overlap areas have been incorporated into the Haley RI database and are described in this RI Report. Other information from the Whatcom Waterway RI, such as marine current patterns and sediment transport and deposition information, are referenced in this RI report.

Mercury, 4-methylphenol and phenol were identified as the constituents of concern in Whatcom Waterway sediment (RETEC 2006). The mercury impacts were primarily attributed to releases from the former GP chlor-alkali plant. The 4-methylphenol was believed to originate from the degradation of organic material such as pulp and wood waste from historical log rafting and was primarily found in subsurface sediments. Other phenolic compounds (e.g., phenol, 2,4-dimethylphenol) also were sporadically detected in Whatcom Waterway surface sediment at concentrations above screening levels and may be attributable to several different sources. PAHs and other semivolatile organic compounds were also present at concentrations above screening levels at selected locations.

GP performed an interim action at the log pond from 2000 to 2001 (RETEC 2006). The log pond is an aquatic feature east of, and contiguous with, the Whatcom Waterway. Sediment in the log pond was impacted by the release of mercury-containing wastewater from the former chlor-alkali plant. Contaminated sediment in the log pond was capped using 43,000 cy of dredged materials from the Swinomish navigation channel and Squalicum Waterway.

The Port began another interim action in 2013 to address elevated concentrations of mercury and heavy oil-range petroleum hydrocarbons (Bunker C) in upland areas east of the Whatcom Waterway (Aspect 2011). The areas of interest are located within the GP West site, which encompasses the former GP chlor-alkali plant and pulp and tissue mill.

2.7. Other Bellingham Bay Studies

2.7.1. Georgia Pacific Outfall

As part of its NPDES permit, GP collected and characterized nine sediment samples in the vicinity of GP Outfall 009, their industrial wastewater outfall located about one mile south of the Haley Site

(Ecology 2001). This outfall is approximately 8,000 feet long and discharges at a depth of approximately 50 feet in Bellingham Bay. The sediment samples were analyzed for constituents regulated under SMS; selected samples were also analyzed for resin acids/guaiacols and dioxins/furans. Mercury and 4-methylphenol, two constituents of concern for Whatcom Waterway and the GP site, exceeded SMS criteria; however, bioassay testing results for the samples did not exceed applicable toxicity criteria.

2.7.2. Bellingham Bay Sediment Investigations

Ecology performed three sediment investigations in Bellingham Bay in 2009, 2010 and 2014 (Hart Crowser 2009b, Ecology 2011c, Ecology 2015a). Some sediment samples from the 2009 and 2010 investigations were collected in the immediate vicinity of the Cornwall and Haley sites (Hart Crowser 2009b). Data from the 2009 and 2010 sediment investigations that have been incorporated in this RI Report are explained in Section 3.6.

The study published in 2009 also evaluated sediment quality in the in-water portion of the Cornwall site, along the alignment of the proposed Boulevard Park overwater walkway, and in a broader portion of Bellingham Bay to assess background dioxin/furan concentrations. Based on the 2009 sediment investigation data collected, Hart Crowser concluded that background dioxin/furan concentrations in Bellingham Bay were greater than in unimpacted portions of Puget Sound. Furthermore, the data suggested that dioxins/furans in Bellingham Bay had decreased by a factor of 10 or more since 2000 due to natural recovery resulting from the influx of cleaner sediment from the Nooksack River (Hart Crowser 2009b).

The purpose of Ecology's 2014 sediment investigation was to characterize regional background concentrations of dioxins/furans, polychlorinated biphenyls (PCBs), carcinogenic polycyclic aromatic hydrocarbons (cPAHs) and lead. The regional background values published in the 2015 data report are used in the FS. These data and their use are further discussed in the FS.

2.7.3. Marine and Nearshore Survey and Data Reports

Information from several recent studies regarding marine and nearshore physical and biological data and conditions in the vicinity of the Haley Site or nearby Bellingham Bay, were also incorporated into this RI:

- "WRIA 1 Nearshore & Estuarine Assessment and Restoration Prioritization" (Coastal Geologic Services [CGS} 2013)
- "Whatcom County Nearshore Habitat Restoration Prioritization" (CGS 2007)
- "Marine Resources of Whatcom County" (Anchor 2001)
- "Final Technical Memorandum: Whatcom County Feeder Bluff Mapping and Drift Cell Ranking Analysis" (CGS 2006).

Legend

- Haley Site per Agreed Order, Exhibit 1
- Ground Surface Contour (10 ft interval, NAVD88 Datum)
- Bathymetry Contours (5 ft Interval, NAVD88 Datum)

Reference: Aerial from Esri, 2013
Whatcom Waterway Sediment Site Units digitized from Anchor QEA, 2012.

Notes:
1. The locations of all features shown are approximate.
2. This drawing is for information purposes. It is intended to assist in showing features discussed in an attached document. GeoEngineers, Inc. cannot guarantee the accuracy and content of electronic files. The master file is stored by GeoEngineers, Inc. and will serve as the official record of this communication.

Site Vicinity

R.G. Haley Site
Bellingham, Washington

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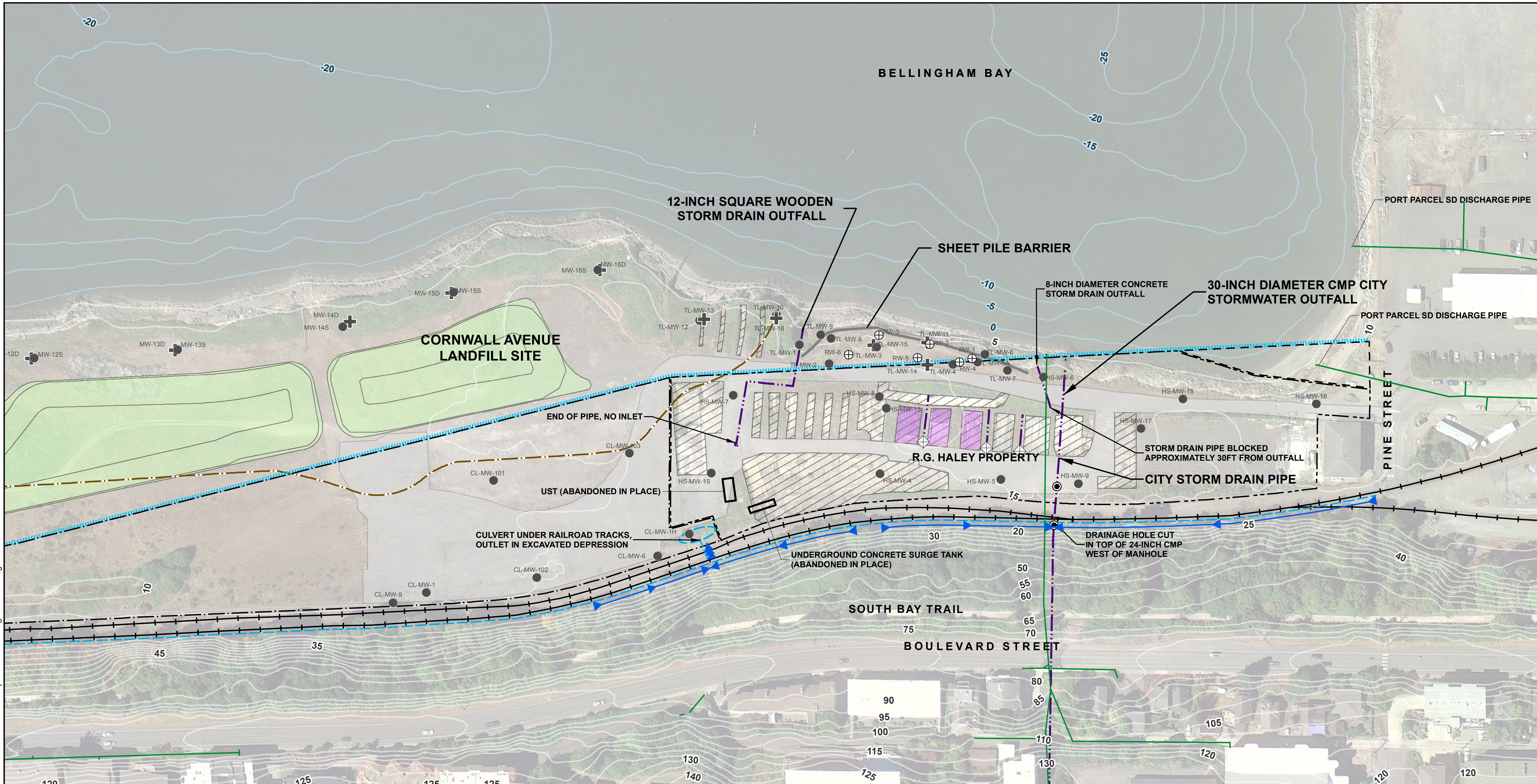
Figure 2-1

Path: \\sea\projects\0\0356114\GIS\MXDs\Fig_2-1_Site_Vicinity.mxd Map Revised: 12 August 2013 cgonzales



Map Revised: 17 August 2015 cgonzales

Path: \\sea\projects\0\0356114\GIS\MXD\Fig_2-2_CurrentSiteConditions.mxd

True North
Project North

0 75 150
Feet

Reference: Aerial from Google Earth, August 2011.
Ecology Review Draft Cornwall RI, January 2013, Landau Associates.

Notes:
1. The locations of all features shown are approximate.
2. This drawing is for information purposes. It is intended to assist in showing features discussed in an attached document. GeoEngineers, Inc. cannot guarantee the accuracy and content of electronic files. The master file is stored by GeoEngineers, Inc. and will serve as the official record of this communication.

Legend

- Existing Deep Monitoring Well
- Existing Shallow Monitoring Well
- Existing Recovery Well
- Stormwater Inlet Grate
- Manhole
- Asphalt
- Concrete
- Cornwall Interim Action Stockpile
- Investigative and Oil Recovery Waste Storage Areas
- City Owned Property, Former R.G. Haley International
- Cornwall Property
- Port of Bellingham Property
- Inner Harbor Line
- Cornwall Approximate Landward Boundary of Landfill Refuse
- Port Parcel Storm Drain Discharge Pipe
- Storm Drain Pipe
- Drainage Ditch or Depression
- Apparent Stormwater Flow Direction
- UST
- Sheet Pile Wall

Current Site Conditions and Drainage

R.G. Haley Site
Bellingham, Washington

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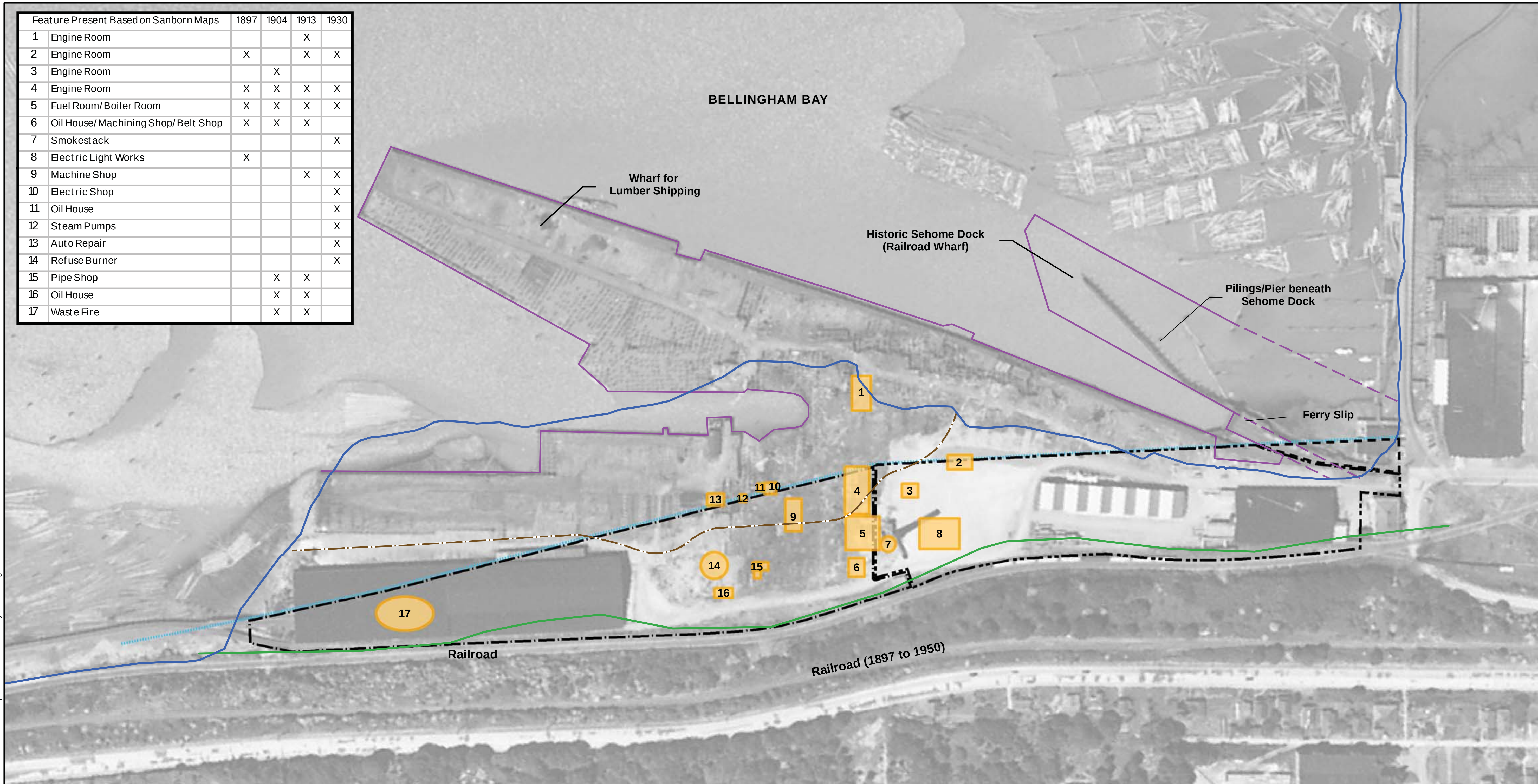
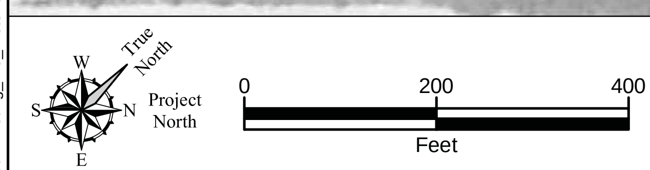
Figure 2-2

Feature Present Based on Sanborn Maps		1897	1904	1913	1930
1	Engine Room			X	
2	Engine Room	X		X	X
3	Engine Room		X		
4	Engine Room	X	X	X	X
5	Fuel Room/Boiler Room	X	X	X	X
6	Oil House/Machining Shop/Belt Shop	X	X	X	
7	Smokestack				X
8	Electric Light Works	X			
9	Machine Shop			X	X
10	Electric Shop				X
11	Oil House				X
12	Steam Pumps				X
13	Auto Repair				X
14	Refuse Burner				X
15	Pipe Shop		X	X	
16	Oil House		X	X	
17	Waste Fire		X	X	





Reference: Walker and Associates photograph, 1950. Sanborn Maps, 1897-1930.

Notes:
1. Extent of Cornwall Landfill refuse approximated from Figure 2-1 of Ecology Review Draft, Cornwall Avenue Landfill Remedial Investigation/Feasibility Study, Bellingham WA, Landau Associates Inc, 2013.
2. The locations of all features shown are approximate.
3. This drawing is for information purposes. It is intended to assist in showing features discussed in an attached document. GeoEngineers, Inc. cannot guarantee the accuracy and content of electronic files. The master file is stored by GeoEngineers, Inc. and will serve as the official record of this communication.

Legend

- City Owned Property, Former R.G. Haley International
- Cornwall Property
- Port of Bellingham Property
- Inner Harbor Line
- Historical Lumber Mill Features, Map Legend in Upper Left (Buildings Not Shown)
- Footprint of Historic Over Water Wharf or Pier
- Current Shoreline
- 1887 Shoreline
- Cornwall Approximate Landward Boundary of Landfill Refuse (Post Lumber Mill)

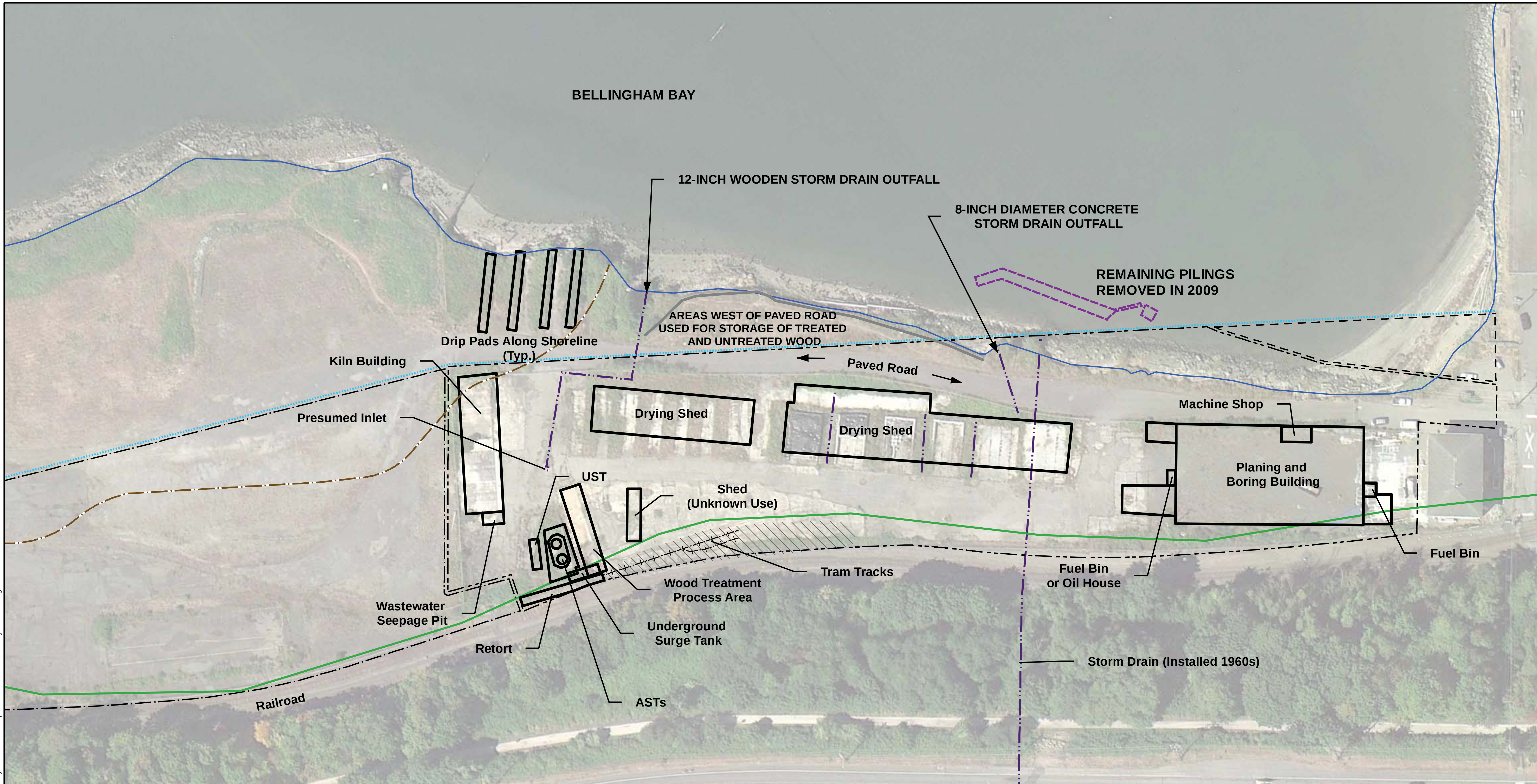
Pre-1950 Lumber Mill Features and Wharves

R.G. Haley Site
Bellingham, Washington

GEOENGINEERS

Figure 2-3

Path: \\seal\projects\0\0356114\GIS\MXD\Fig_2-3_HistoricalFeatures.mxd Map Revised: 19 February 2015 cgonzales



W
True North
S
N
Project North
E

0 100 200
Feet

Reference: Aerial from Google Earth, August 2011

Notes:
1. Extent of Cornwall Landfill refuse approximated from Figure 2-1 of Ecology Review Draft, Cornwall Avenue Landfill Remedial Investigation/Feasibility Study, Bellingham WA, Landau Associates Inc, 2013.
2. The locations of all features shown are approximate.
3. This drawing is for information purposes. It is intended to assist in showing features discussed in an attached document. GeoEngineers, Inc. cannot guarantee the accuracy and content of electronic files. The master file is stored by GeoEngineers, Inc. and will serve as the official record of this communication.

Legend

- City Owned Property, Former R.G. Haley International
- Cornwall Property
- Port of Bellingham Property
- Inner Harbor Line
- Sheet Pile Wall (Installed 2000)
- Storm Drain
- Current Shoreline
- 1887 Shoreline
- Cornwall Approximate Landward Boundary of Landfill Refuse
- Historical features associated with former wood treatment operations based on 1950 aerial photograph or other references
- Apparent Stained Soil Visible in Historical Photographs
- Remaining Pilings Removed in 2009

Haley Facility Layout

R.G. Haley Site
Bellingham, Washington

GEOENGINEERS

Figure 2-4

Path: \\sea\projects\0\0356114\GIS\MXDs\Fig_2-4_FacilityLayout.mxd Map Revised: 19 February 2015 cgonzales

3.0 SUPPLEMENTAL INVESTIGATION METHODS

This section summarizes the work performed for the 2012 supplemental RI field investigation and describes the data set used in preparing this RI Report. The analytical schedules for RI samples are provided in Appendix C, and RI exploration logs are presented in Appendix D. Field procedures and other supporting information are included in Appendices E through M (see Table of Contents). The findings from the 2012 supplemental field investigation are combined with previous RI data and presented in the following sections of this report:

- Section 4.1 – Physical Conditions
- Section 4.2 – Geology and Hydrogeology
- Section 4.3 – Natural Resources
- Section 6.0 – Nature and Extent of Contamination
- Section 7.0 – LNAPL Mobility

3.1. Overview

The 2012 supplemental investigation included both upland and sediment explorations, and was completed in general accordance with the scope and methodologies presented in the February 2012 Work Plan (Work Plan; GeoEngineers 2012a). Field procedures for the supplemental investigation, including deviations from the Work Plan, are described in Appendix E. The supplemental explorations completed in 2012 are shown in Figure 3-1 and summarized in Table 3-1; explorations completed during previous investigations are shown in Figures 3-2A through 3-2C.

The upland supplemental investigation was conducted between May 3 and August 9, 2012. The sediment supplemental investigation was conducted between July 30 and August 28, 2012. The storm drain assessment was performed in March 2013.

The upland explorations were completed using direct-push and hollow-stem auger drilling equipment, or a hand-auger for shallow surface soil sampling. Surface sediment samples were collected using a Van Veen grab sampler deployed from a boat. Subsurface sediment cores were collected in the intertidal zone using track-mounted sonic drilling equipment. Sediment cores at subtidal sampling locations were collected from a barge using truck-mounted drilling equipment.

Upland exploration locations and elevations were surveyed relative to North American Datum 1983 and 1998 (NAD83/98) and North American Vertical Datum 1988 (NAVD88), respectively. Sediment sampling locations were recorded using digital Global Positioning System (GPS) equipment. Mudline elevations at sediment sampling locations were estimated by subtracting measured water depths from tidal elevations at the time of drilling. Tidal elevations were obtained from National Oceanographic and Atmospheric Administration (NOAA) tide charts (NOAA 2012). The sediment sampling locations and mudline elevations also are referenced to NAD83/98 and NAVD88. There is 8.51 feet of elevation difference between Mean Lower Low Water (MLLW) and Mean Higher High Water (MHHW) in the vicinity of the Haley Site.

3.2. Upland Investigation

3.2.1. Soil Borings and Monitoring Wells

The upland field investigation included the installation/completion of nine soil borings, one hand-augered exploration, and ten groundwater monitoring wells (Figure 3-1). Six of the groundwater monitoring wells were completed at shallow depths and screened across the groundwater table; the other four monitoring wells were deeper and constructed with shorter, discrete screens below the groundwater table. The deep monitoring wells are positioned near the shoreline. The purpose of drilling four deep boreholes for monitoring wells near the shoreline was to evaluate the vertical profile of fill and native soil units, focusing on lithology, contaminant concentrations and aquifer characteristics. The screen intervals for the deep monitoring wells were selected based on lithology (Appendix D, 2012 Exploration Logs).

In accordance with the Work Plan, an inventory of previously existing groundwater monitoring wells on the Haley Site and adjacent Cornwall property was completed prior to installing new monitoring wells in 2012. To account for findings from the updated well inventory, modifications were made to the locations and number of monitoring wells proposed in the Work Plan. Monitoring wells were installed at two additional locations to provide groundwater data where existing monitoring wells could not be found. One of the additional monitoring wells was installed in the southern portion of the Haley property near the former wood treatment facilities (HS-MW-19); the other monitoring well was installed in the northern portion of the Cornwall property (CL-MW-103). One deep monitoring well originally proposed to be installed south of the southern drying shed on the Haley property (identified as HS-MW-18 in the Work Plan and shown as soil boring HS-SB-18 in Figure 3-1) was not installed because an existing monitoring well nearby (HS-MW-7) was considered sufficient to monitor groundwater conditions at this location. Deviations from the Work Plan are described in more detail in Appendix E.

3.2.2. Soil and Groundwater Sampling

Soil and groundwater sampling and chemical analyses were performed in general accordance with the Work Plan. The chemical analytical schedules are included in Appendix C. Tabulated chemical analytical results are presented in Section 6.0. Data validation reports are included in Appendix L. Groundwater general chemistry parameters (e.g., pH, conductivity, dissolved oxygen, temperature, redox potential, ferrous iron, soluble manganese, nitrate-nitrogen, sulfate, total dissolved solids, dissolved inorganic carbon and total organic carbon) measured during 2004 and 2012 sampling activities are included in Appendix K (Table K-1).

Supplemental groundwater monitoring was performed in 2012 to assess current groundwater conditions and the distribution and thickness of LNAPL in monitoring wells on the Haley upland (Section 4.2). In addition, vertical profiles of electrical conductivity in groundwater were measured in selected monitoring wells to evaluate whether a seawater-freshwater boundary can be distinguished beneath the Haley upland. Electrical conductivity measurements were obtained in four monitoring wells with at least 10 feet of well screen below the groundwater table (HS-MW-6, HS-MW-7, TL-MW-1, and TL-MW-9). The measurements were obtained on July 18, 2012 during a 2-hour period after low tide. Three of the wells selected for electrical conductivity measurements were located within the anticipated zone of tidal influence; the fourth well was located more than 160 feet from the shoreline, outside the anticipated zone of tidal influence. Electrical conductivity of the seawater also was measured at three locations along the shoreline for comparison. The conductivity measurements in the wells were obtained at 2-foot depth increments using a downhole water quality meter.

3.2.3. Aquifer Testing

The upland investigation included completion of slug tests and a tidal study in selected monitoring wells to evaluate the hydraulic conductivity of wood waste fill beneath the upland, groundwater gradients, and the influence of tidal fluctuations on groundwater levels. Brief descriptions of these field investigations are presented below; field procedures and supporting information are included in Appendices F and G. In addition to slug testing and the tidal study, groundwater modeling was performed to evaluate and refine the CSM, which is discussed in Section 8.0. The groundwater modeling is described in Appendix H.

Slug testing was performed on four shallow monitoring wells (Figure 3-1) screened in wood waste to evaluate the variability of hydraulic conductivity in wood waste fill. The wood waste was targeted for aquifer testing because it is a prevalent unit that extends from the upland into the marine environment, is often heavily impacted by Site contaminants, and may be a key unit controlling contaminant fate and transport.

Prior to conducting the slug test in each well, an electronic pressure transducer was installed and the depth to groundwater was measured manually using an electronic water level meter to establish static groundwater levels. A solid polyvinyl chloride (PVC) slug was then lowered into the well and the displaced groundwater head was allowed to equilibrate in the well. The falling head data collected during this portion of the test was not analyzed because the wells are screened across the groundwater table and the falling head response was affected by partial groundwater drainage into the vadose zone. A rising head test was then conducted by rapidly removing the slug from the well and measuring the hydraulic response (rate of groundwater level rise) manually and with the pressure transducer. The groundwater level in the well was monitored until it returned to static, pre-test conditions. The rising head data were analyzed using the Bouwer and Rice (1989) analytical method for slug tests.

A tidal study was conducted between July 30 and August 8, 2012 to evaluate the influence of tidal fluctuations on groundwater levels beneath the Haley upland. Monitoring wells that are screened across different stratigraphic intervals and located at varying distances from the shoreline were chosen for the tidal study (Figure 3-1). The monitoring wells for the tidal study were selected after an initial groundwater monitoring event was completed in May 2012 and additional monitoring wells were installed and sampled. Pressure transducers were installed in 13 monitoring wells (Figure 3-1) and programmed to record hydraulic heads in the monitoring wells at regular intervals. A tidal gauge was installed on the Port dock north of the Site to directly monitor and record tidal fluctuations in Bellingham Bay for comparison to groundwater levels in monitoring wells on the Haley upland. The findings of the tidal study are integrated into the discussion of hydrogeologic conditions presented in Section 4.0.

3.2.4. LNAPL Occurrence and Properties

Testing was conducted to evaluate LNAPL mobility and recoverability beneath the Haley upland. Additionally, several tests were completed to evaluate whether LNAPL preferentially occurs in certain stratigraphic units. Information from this testing was used to refine the CSM and to evaluate remediation technologies in the FS (Section 9.0).

LNAPL bail-down tests were performed in selected monitoring wells to evaluate LNAPL mobility and recoverability. Four monitoring wells (Figure 3-1) with at least 0.5 feet of LNAPL at the time of monitoring were selected for the LNAPL bail-down tests.

Each LNAPL bail-down test was completed using a peristaltic pump with dedicated polyethylene tubing to remove the approximate volume of LNAPL accumulated in the well. After LNAPL was removed from the monitoring well to the maximum extent practicable, an electronic oil-water interface probe was used to measure the depth to water and product thickness at regular intervals until at least 80 percent of the original LNAPL thickness recovered. Supporting information and analysis of the bail-down tests is included in Appendix I. LNAPL mobility based on the LNAPL bail-down and other evaluations is discussed in Section 7.0 and utilized in the FS (Section 9.0).

The possible preferential occurrence of LNAPL in certain stratigraphic units was evaluated using visible and ultra-violet (UV) light photography (digital imaging). LNAPL occurrence is indicated under UV light by the fluorescence of PAHs present in the LNAPL. Soil cores from two monitoring well boreholes behind the sheet pile wall (TL-MW-14 and TL-MW-15; Figure 3-1) were obtained for digital imaging in general accordance with ASTM D 5079-08 and API RP 40. These locations were selected for digital imaging because they were within the area where LNAPL had been previously measured in monitoring wells. Due to poor soil core recovery at TL-MW-16 situated outside the sheet pile wall, a core could not be obtained from this borehole for digital imaging (or petrophysical testing) as originally planned. UV-light core photographs are included in Appendix J.

Free product mobility (FPM) testing was performed using a centrifugal method based on modified ASTM Method D425. Soil samples were selected for FPM testing based on the results of the UV photography; the samples were chosen to represent different lithologies and saturation conditions as observed at the time of sample collection. The samples were centrifuged, removed from the centrifuge, and submitted for chemical analyses of petroleum hydrocarbons. FPM data are included in Appendix J.

An LNAPL sample obtained from one well was submitted for testing of density, specific gravity, and kinematic viscosity using ASTM Methods D1217, D1481, and D445, respectively (Appendix J).

3.3. Stormwater System Investigation

Outfalls for two stormwater drains previously associated with the Haley facility are located on the shoreline of the Haley upland (Figure 2-2). Site reconnaissance and underground utility locating techniques were used during the supplemental investigation to evaluate the alignment, depth and condition of these utilities to the extent feasible. In addition, an active City storm drain pipe exists beneath the Haley property and discharges at an outfall north of the sheet pile barrier (Figure 2-2). The orientation of this pipe is described in Section 4.1.3.1. A stormwater sample was obtained from the City storm drain outfall and submitted for chemical analysis. These activities were completed in March 2013. The information from these activities was used to evaluate whether the stormwater utilities may be acting as preferential migration pathways for contaminants from the upland to sediment.

Holes in the walls or joints of the City's storm drain pipe, if they exist, may provide a preferential pathway for contaminant migration. To evaluate this possibility, the City completed a video survey of the inside of its active storm drain pipe in December 2010 (Section 4.1.3.1). The video survey extended in both directions (east and west) from the storm drain access manhole on the Haley property. The video was used to assess the condition of the pipe and pipe joints for the segments extending from the manhole west to the outfall at the shoreline, and from the manhole east to the City's next manhole on the bluff that is east of the Haley property. The pipe segments surveyed comprise the entire length of interest with respect to evaluating the City's storm drain pipe as a potential preferential pathway.

To further evaluate the possibility that the City's storm drain may be acting as a preferential pathway for the migration of contaminated groundwater, historical groundwater elevations measured in wells in the vicinity of the City storm drain during monitoring events conducted between 2001 and 2012 were reviewed. This review indicated that there were three instances in which the groundwater elevation in one shoreline well rose above the storm drain elevation. The dates of the highest measured groundwater elevations in this well all corresponded to winter high tides (December/January). In accordance with the Work Plan, the water discharging from the City's storm drain outfall at the Haley shoreline was sampled in March 2013. The outfall sampling procedures are included in Appendix E; the results of the sampling are provided in Section 6.0. The outfall sample was obtained at least 24-hours after a storm or rainfall event, and several hours after a high tide, so that any tidal inundation of surface water had drained out of the pipe.

3.4. Sediment Investigation

The sediment supplemental investigation was performed in the summer of 2012. Surface and subsurface sediment sampling are summarized below. Detailed sampling protocols are provided in Appendix E.

3.4.1. Surface Sediment Sampling

Surface sediment samples were collected at eight locations (COB-SS-01 through -08 [Figure 3-1]) using a boat provided by the EPA on August 3 and 4, 2012. Two reference sediment samples were also collected in Samish Bay (off-site) on August 3. Surface sediments were collected using a Van Veen grab sampler. At each location, sediment was collected from the upper 12 centimeters (cm) below the mudline. The compliance interval in Bellingham Bay (the "biologically active zone") is considered to be 12 cm. Multiple grab sampler deployments at each location were typically required to collect sufficient sample volume from the individual deployments that met sample acceptance criteria described in the Work Plan (GeoEngineers 2012). Sediment descriptions and field screening observations were logged on a sample collection form, and the sediment was homogenized and placed in laboratory-prepared containers for chemical analyses.

In addition to chemical analysis, bioassay testing was performed on samples collected at COB-SS-02 through COB-SS-05, COB-SS-09 and COB-SS10. The bioassay testing included the following analyses:

- Larval sediment toxicity test using the mussel *Mytilus galloprovincialis*
- Juvenile polychaete (*Neanthes sp.)* 20-day sediment toxicity test
- Amphipod (*Eohaustorius estuarius*) 10-day toxicity test

3.4.2. Subsurface Sediment Sampling

Subsurface sediment coring was performed from July 30 through August 4, and on August 27 and 28, 2012. Coring was performed using sonic drilling technology at four locations on land and five overwater locations from a barge (COB-SC-01 through -09; Figure 3-1). In general, at each location, sediment was collected in 2- to 5-foot intervals in disposable, 3-inch diameter, acetate-lined cores. Cores that met acceptance criteria as defined in the Work Plan were capped at both ends and temporarily stored on ice until processing, which occurred within 24 hours of collection. Core processing included opening the core, recording observations of sediment condition, collecting samples for volatile organic compound (VOC) analyses, logging the sediment on boring logs (Appendix D), homogenizing 2-foot sample intervals, and placing samples in laboratory-prepared containers for chemical analyses.

3.5. Habitat Surveys

Intertidal and subtidal benthic habitat surveys were conducted at the Site in June and September 2012, respectively. The scope of these surveys is summarized below. The findings of the habitat surveys are discussed in Section 4.3.

3.5.1. Intertidal Habitat Survey

An intertidal habitat survey was performed on June 4 and June 5, 2012, when tides were below MLLW. The survey was conducted on foot, along ten transects extending from approximately +10 feet to -2 feet (NAVD88). Substrate materials and plant and animal species were documented along the transects, and major species zones were delineated.

3.5.2. Benthic Habitat Survey

A subtidal benthic habitat survey was performed between September 25 and September 27, 2012. The benthic habitat survey was performed along transects, and used side-scan sonar and scuba diving observations to assess the occurrence and density of eelgrass. The benthic habitat survey methodology is described further in Appendix M.

3.6. Data Used in this RI Report

Data sources for this RI Report include the 2012 supplemental investigation described above, previous RI sampling and other prior studies completed for the Haley Site, and other studies completed for the adjacent Cornwall Landfill and Whatcom Waterway sites in the areas of overlap. The data sources are referenced throughout this report. Tables B-1 and B-2 in Appendix B present cross references of exploration names, completion dates, and media sampled, and the respective studies used as data sources. All of these data sources were utilized to develop an understanding of the environmental and physical conditions at the Site, including the interpretation of geologic and hydrogeologic conditions described in Section 4.0.

The horizontal datum for the Haley RI is the NAD83/98. The vertical datum for the Haley RI is the NAVD88. Where elevation data from other studies were used in the RI report, the following elevation translations were used (Nelson 2013):

- 0.47 feet was subtracted from elevations originally reported in MLLW (1983-2001 National Tidal Datum Epoch)

- 1.72 feet was subtracted from elevations originally reported in City vertical datum
- 3.93 feet was added to elevations originally reported in NGVD29

The chemical analytical data used as the RI data set for evaluation of indicator hazardous substances (IHSs) (Section 5.0) and the nature and extent of contamination (Section 6.0) are described below in Sections 3.6.1 through 3.6.5.

References in this report to dioxin/furan concentrations represent the TEQ for the total mixture of dioxins/furans unless stated otherwise. A dioxin TEQ is the toxicity-weighted sum of dioxin and furan congener concentrations expressed as an equivalent 2,3,7,8-TCDD concentration using the World Health Organization (WHO) 2005 congener-specific toxic equivalency factors (TEFs) for mammals and humans. For undetected congeners, a value of one-half the detection limit is assumed in the TEQ calculation. Where defined and calculated the same way in other studies and reports, "total dioxins" and "total dioxins/furans" concentrations reported in other studies are comparable to the dioxin TEQ values presented in this RI Report. Similarly, analytical results for total cPAHs are expressed as cPAH TEQ concentrations calculated in accordance with MTCA, using toxic equivalency factors relative to benzo(a)pyrene. References in this report to dioxin/furan or cPAH concentrations represent TEQs for the entire mixture unless otherwise stated.

The RI data set constitutes the Haley RI database (EQuIS) entered into Ecology's Environmental Information Management System (EIM).

3.6.1. Soil

The RI soil analytical data set includes all soil samples obtained from the Haley upland (except as noted below), and from the Cornwall upland in the overlap or potential overlap areas, regardless of sample date. There were numerous Cornwall RI explorations from which soil samples were not submitted for chemical analyses because of the presence of landfill refuse; however, exploration logs for these locations were reviewed and field observations were noted. In additional to soil samples obtained on the Cornwall site for the Haley RI, soil sample chemical analytical data were available for only five other explorations on the Cornwall site (AF-MW-01, AF-MW-02, AF-SB01, AF-SB02, and AF-SB04); these data were used in this RI to help delineate the Haley Site boundaries. Soil field screening information from boring and test pit logs prepared by Landau or other consultants for the Cornwall site were used to interpret the extent of the petroleum smear zone in soil.

Soil samples "S-1" and "S-2" presented in Purnell (1991) are discussed in Section 2.0 for the purpose of background discussion but were excluded from the RI data set because the sample locations could not be confirmed. Similarly, soil samples "1, 2, 3 and 4" obtained by Haley in 1984 in connection with removal of soil from the seepage pit (E & E 1986) are discussed in Section 2.0 but were excluded from the RI data set because analytical data or sampling procedures either were not available or could not be verified.

A composite soil sample obtained in 1992 by Ecology during their Site Hazard Assessment was excluded from the RI data set because the subsample locations could not be confirmed. Each of these samples is discussed in Section 2.0 for the purpose of providing background.

One soil stockpile sample (HS-SSPS-01) obtained in 2000 was not included in the RI data set, but was during the FS for evaluation of waste disposal options and costs.

3.6.2. Groundwater

The network of wells used to evaluate hydrogeologic conditions for the supplemental investigation comprises 34 monitoring wells screened in the shallow unconfined aquifer (Table 3-2) and six large-diameter oil recovery wells. Five of the 34 monitoring wells (TL-MW-11, TL-MW-13, TL-MW-14, TL-MW-15 and TL-MW-16) are constructed with discrete depth, deep well screens and are used to evaluate vertical variability in hydrogeologic conditions (these wells are typically referred to as deep wells in this report). The remaining wells are shallow wells, the majority of which are screened across the zone of groundwater table fluctuation. Well screen depths and positions vary (Table 3-2). Of the 29 shallow monitoring wells, seven have well screens positioned a few inches to a few feet below the water table (HS-MW-13, HS-MW-15, HS-MW-16, TL-MW-10, CL-MW-1H, CL-MW-6 and CL-MW-9). The current well network consists of three side-by-side pairs of shallow/deep wells: RW-2/TL-MW-11; TLMW-10/TLMW-16; and TLMW-12/TLMW-13. There are six large-diameter wells installed specifically for oil recovery, although oil recovery is conducted at several of the smaller diameter monitoring wells in addition to the large-diameter oil recovery wells. Well logs are included in Appendix D.

The groundwater chemical analytical data set for the RI consists of groundwater samples obtained by GeoEngineers between May and August 2012 from existing monitoring wells associated with the Haley upland, and groundwater samples obtained by Landau in July and in September 2012 from six shallow/deep shoreline monitoring well pairs on the Cornwall site. Well construction details for the six shoreline monitoring well pairs on the Cornwall site provided in the Cornwall RI report (Landau 2013) are included in Appendix D.

Groundwater monitoring wells for which historical groundwater monitoring data are available are listed in Appendix B, Table B-1; the corresponding historical groundwater analytical data are included in Appendix B, Tables B-3 and B-4. Historical groundwater analytical data were reviewed relative to 2012 groundwater analytical data for the purpose of evaluating the geographic footprint of contaminants and evaluating data trends through time as discussed in Section 6.4.6. At locations where recent (2012) groundwater data were not available, historical groundwater data were considered when evaluating the extent of contaminants. Historical groundwater sample chemical analytical data from monitoring wells sampled during previous Haley studies and at the Cornwall site, however, were excluded from the RI data set used for the statistical evaluation and determination of IHSs because pre-2012 groundwater monitoring data are not representative of current groundwater conditions.

3.6.3. Sediment

The sediment analytical data set evaluated for the RI includes all sediment samples obtained from the Haley Site, and from the Cornwall and Whatcom Waterway sites in the overlap areas, regardless of sample date (Appendix B, Table B-1), except as noted below.

Two samples were obtained from the sediment in the beach oil seep area identified in February 2000 ("Beach," obtained February 10, 2000 by Douglas Management Company, and "BWT-BS-01," obtained February 29, 2000 by GeoEngineers). These samples are not included in the RI data set because they were subsequently overexcavated during the focused cleanup action (Section 2.0), and therefore are not representative of current conditions. Analytical results for these samples are discussed in Section 2.0.

As discussed in Section 2.0, a DNR contractor obtained five surface sediment samples northeast of the Haley Site in 2009 after DNR's removal of treated wood pilings in this area. The surface sediment samples were at the same locations previously sampled by Hart Crowser in 2008 (one sample was relocated from the original coordinates). These data are not included in the RI database due to uncertainties associated with sample handling and analytical procedures.

Bellingham Bay sediment samples obtained from locations beyond the overlap areas for Bay-wide studies (Hart Crowser 2009b, Ecology 2011c, Ecology 2015a), or as part of Whatcom Waterway investigations, were not included in the RI sediment data set. Results from the Ecology studies to establish regional background values for selected contaminants (Ecology 2015a) have been incorporated into the FS.

3.6.4. Soil Vapor

Section 5.0 presents a discussion of pathways and receptors considered in developing screening levels for the Haley RI, including the soil vapor pathway. During the RI, soil vapor samples were obtained in 2005 from eight locations in the Haley upland. These data were included in the RI and are presented in Section 6.0.

3.6.5. Stormwater

One water sample was obtained from the outfall of the City's 30-inch-diameter storm drain in March 2013. This water sample was included in the RI database to evaluate the potential for the storm drain to act as a preferential pathway for contaminant migration.

Table 3-1

2012 Supplemental Investigations

R.G. Haley Site

Bellingham, Washington

Exploration Name (on RI Figures)	Type of Exploration	Date Completed	Soil Sampled	Groundwater Sampled	Sediment Sampled
HS-SS-104	Hand Auger Boring	05/15/12	Yes, 0 to 1 foot interval	--	--
TL-MW-12	Monitoring Well - Hollow Stem Auger	07/11/12	--	Yes	--
TL-MW-13	Monitoring Well - Hollow Stem Auger	07/03/12	Yes	Yes	--
TL-MW-14	Monitoring Well - Hollow Stem Auger	07/02/12	Yes	Yes	--
TL-MW-15	Monitoring Well - Hollow Stem Auger	06/27/12	Yes	Yes	--
TL-MW-16	Monitoring Well - Hollow Stem Auger	06/28/12	Yes	Yes	--
TL-SB-101	Direct Push Soil Boring	06/26/12	Yes	--	--
HS-SB-101	Direct Push Soil Boring	06/26/12	Yes	--	--
HS-SB-102	Direct Push Soil Boring	06/25/12	Yes, including 0.5-1 foot interval	--	--
HS-SB-103	Direct Push Soil Boring	06/25/12	Yes	--	--
HS-SB-104	Direct Push Soil Boring	06/25/12	Yes, including 0.5-1 foot interval	--	--
HS-MW-17	Monitoring Well - Hollow Stem Auger	06/27/12	Yes	Yes	--
HS-SB-18	Hollow Stem Auger Boring	07/11/12	Yes	--	--
HS-MW-19	Monitoring Well - Hollow Stem Auger	07/10/12	Yes, including 1.5-2.5 foot interval	Yes	--
CL-SB-101	Direct Push Soil Boring	06/25/12	Yes	--	--
CL-SB-102	Direct Push Soil Boring	06/25/12	Yes	--	--
CL-SB-103	Direct Push Soil Boring	06/25/12	Yes	--	--
CL-MW-101	Monitoring Well - Hollow Stem Auger	06/29/12	Yes	Yes	--
CL-MW-102	Monitoring Well - Hollow Stem Auger	06/29/12	Yes	Yes	--
CL-MW-103	Monitoring Well - Hollow Stem Auger	07/10/12	Yes	Yes	--
COB-SC-01	Sediment Core/Subsurface Sediment	08/27/12	--	--	Yes
COB-SC-02	Sediment Core/Subsurface Sediment	08/27/12	--	--	Yes
COB-SC-03	Sediment Core/Subsurface Sediment	08/01/12	--	--	Yes
COB-SC-04	Sediment Core/Subsurface Sediment	08/02/12	--	--	Yes
COB-SC-05	Sediment Core/Subsurface Sediment	08/01/12	--	--	Yes
COB-SC-06	Sediment Core/Subsurface Sediment	08/02/12	--	--	Yes
COB-SC-07	Sediment Core/Subsurface Sediment	08/27/12	--	--	Yes
COB-SC-08	Sediment Core/Subsurface Sediment	08/03/12	--	--	Yes
COB-SC-09	Sediment Core/Subsurface Sediment	08/01/12	--	--	Yes
COB-SS-01	Surface Sediment	08/03/12	--	--	Yes
COB-SS-02	Surface Sediment	08/03/12	--	--	Yes
COB-SS-03	Surface Sediment	08/03/12	--	--	Yes
COB-SS-04	Surface Sediment	08/03/12	--	--	Yes
COB-SS-05	Surface Sediment	08/03/12	--	--	Yes
COB-SS-06	Surface Sediment	08/04/12	--	--	Yes
COB-SS-07	Surface Sediment	08/04/12	--	--	Yes
COB-SS-08	Surface Sediment	08/14/12	--	--	Yes

Table 3-2

Summary of Well Elevation and Construction Details

Existing Monitoring Well Network

R.G. Haley Site

Bellingham, Washington

		Survey Coordinates[4]		NAVD88[4]			Screened Interval							
Well Identification[1]	Well Type[2, 3]	Easting	Northing	Elevation Rim (Top of Monument)	Elevation Top of Casing (TOC)	Total Depth (feet bgs)	Depth to Top of Screen (feet bgs)	Approx. Top of Screen Elevation (NAVD88)	Depth to Bottom of Screen (feet bgs)	Bottom of Screen Elevation (NAVD88)	Screen Elevation (Midpoint) (ft bgs)	Screen Elevation (Midpoint) (NAVD88)	Dominant Screen Lithology (Soil Type)	2012 Aquifer and LNAPL Tests
TL-MW-1	Shallow	639405.8668	1240069.287	14.24	13.7	19	4	10	19	-4.8	11.5	2.7	Sand/wood	Tidal Study
TL-MW-2	Shallow	639385.5507	1240057.43	16.59	14.93	19	4	13	19	-2.4	11.5	5.1	Sand/wood	LNAPL Baildown
TL-MW-3	Shallow	639485.5827	1240153.316	15.83	12.43	19	4	12	19	-3.2	11.5	4.3	Sand/wood/coal	
TL-MW-4	Shallow	639548.4113	1240252.122	14.97	11.62	19	4	11	19	-4.0	11.5	3.5	Sand/wood	LNAPL Baildown
TL-MW-5A	Shallow	639576.8316	1240276.413	12.85	12.49	19	3	10	19	-6.2	11	1.9	Silt	LNAPL Baildown
TL-MW-6	Shallow	639592.5841	1240276.361	12.04	11.72	14	3	9	14	-2.0	8.5	3.5	Silty sand	LNAPL Baildown
TL-MW-7	Shallow	639599.4702	1240317.233	12.57	12.21	19	3	10	19	-6.4	11	1.6	Silt/sand	
TL-MW-8	Shallow	639446.2861	1240095.529	14.86	14.56	18	3	12	18	-3.1	10.5	4.4	Sand	
TL-MW-9	Shallow	639439.0758	1240081.042	14.09	13.73	14	3	11	14	0.1	8.5	5.6	Sand	Tidal Study
TL-MW-10	Shallow	639413.1813	1240012.546	13.34	13.01	13	10	3	13	0.3	11.5	1.8	Wood	
TL-MW-11	Deep	639544.7644	1240202.282	15.7	14.93	20	17	-1	20	-4.3	18.5	-2.8	Wood	Tidal Study
TL-MW-12	Shallow	639325.6165	1239936.672	15.1	14.66	12.7	2.7	12	12.7	2.4	7.7	7.4	Interlayered silt/sand	Tidal Study
TL-MW-13	Deep	639331.7831	1239940.605	15.06	14.6	46.1	43.1	-28	46.1	-31.0	44.6	-29.5	Sand on siltstone	Tidal Study
TL-MW-14	Deep	639520.9004	1240226.215	14.41	13.9	30.3	27.3	-13	30.3	-15.9	28.8	-14.4	Sand	Tidal Study
TL-MW-15	Deep	639484.186	1240148.132	15.4	14.85	30.3	27.3	-12	30.3	-14.9	28.8	-13.4	Sand/silt	Tidal Study
TL-MW-16	Deep	639409.5904	1240016.054	13.53	12.99	32.7	29.7	-16	32.7	-19.2	31.2	-17.7	Sand	Tidal Study
HS-MW-4	Shallow	639354.2365	1240291.683	15.81	15.64	13	3	13	13	2.8	8	7.8	Silt (screen on bedrock)	Tidal Study
HS-MW-5	Shallow	639476.8624	1240426.049	14.75	14.39	13	3	12	13	1.8	8	6.8	Silt/wood/gravel (screen on bedrock)	Slug Test
HS-MW-6	Shallow	639630.6757	1240362.488	12.37	11.81	19	4	8	19	-6.6	11.5	0.9	Sand/wood	Slug Test, Tidal Study
HS-MW-7	Shallow	639281.7584	1240052.403	15.49	15.22	19	4	11	19	-3.5	11.5	4.0	Silt/wood/gravel	Slug Test
HS-MW-8	Shallow	639435.3611	1240209.044	14.49	14.33	19	4	10	19	-4.5	11.5	3.0	Silt/wood/sand	Tidal Study
HS-MW-9	Shallow	639554.4627	1240513.118	14.38	14.05	13	3	11	13	1.4	8	6.4	Sand/wood and bedrock	Slug Test
HS-MW-13	Shallow	639430.2987	1240228.651	14.21	13.44	11	8	6	11	3.2	9.5	4.7	Silt and wood	
HS-MW-15	Shallow	639755.7784	1240533.666	12.11	11.88	11	8	4	11	1.1	9.5	2.6	Unknown (no recovery during drilling; presumed silty sand fill)	Tidal Study
HS-MW-16	Shallow	639891.9545	1240680.797	12.08	11.76	11	8	4	11	1.1	9.5	2.6	Sand	
HS-MW-17	Shallow	639679.5503	1240520.649	13.38	13.11	13.2	3.2	10	13.2	0.2	8.2	5.2	Sand/wood	
HS-MW-19	Shallow	639175.3418	1240111.779	16.42	16.06	12.7	2.7	14	12.7	3.7	7.7	8.7	Sand/silt	
RW-1	Recovery Well constructed in backfill of sheet pile wall	NA	NA	NA	15.14	13	3	12	13	2.1	8	7.1	Sandy gravel (drainage slot behind sheet pile wall and liner)	
RW-2	Recovery Well constructed in backfill of sheet pile wall	NA	NA	NA	15.39	13	3	12	13	2.4	8	7.2	Sandy gravel (drainage slot behind sheet pile wall and liner)	
RW-3	Recovery Well constructed in backfill of sheet pile wall	NA	NA	NA	16.14	13	3	13	13	3.1	8	8.1	Sandy gravel (drainage slot behind sheet pile wall and liner)	
RW-4	Recovery Well	NA	NA	NA	14.24	15	5	9	15	-0.8	10	4.1	Sand	
RW-5	Recovery Well	NA	NA	NA	14.88	15	5	10	15	-0.1	10	4.9	Sand	
RW-6	Recovery Well	NA	NA	NA	13.45	15	5	8	15	-1.6	10	3.2	Sand	
CL-MW-1H	Shallow	639087.4943	1240153.017	18.01	17.89	11.7	8.7	9	11.7	6.3	10.2	7.7	Gravel, sand, bedrock	

Well Identification[1]	Well Type[2, 3]	Survey Coordinates[4]		NAVD88[4]		Total Depth (feet bgs)	Screened Interval				Screen Elevation (Midpoint) (ft bgs)	Screen Elevation (Midpoint) (NAVD88)	Dominant Screen Lithology (Soil Type)	2012 Aquifer and LNAPL Tests
		Easting	Northing	Elevation Rim (Top of Monument)	Elevation Top of Casing (TOC)		Depth to Top of Screen (feet bgs)	Approx. Top of Screen Elevation (NAVD88)	Depth to Bottom of Screen (feet bgs)	Bottom of Screen Elevation (NAVD88)				
CL-MW-1	Shallow	638746.4291	1239936.043	14.22	13.68	11	3	11	11	3.2	7	7.1	Wood, weathered bedrock, screen into bedrock	
CL-MW-6	Shallow	639030.6418	1240142.714	16.12	15.89	15	11	5	15	1.1	13	3.1	Sand, coal, silt	
CL-MW-9	Shallow	638699.766	1239911.607	14.03	13.62	15	11	3	15	-1.0	13	1.0	Sand	
CL-MW-101	Shallow	638936.6771	1239888.195	13.65	13.06	9.4	4.4	9	9.4	4.3	6.9	6.6	Silt/wood	
CL-MW-102	Shallow	638879.5327	1240037.413	14.58	14.27	8.2	4.2	10	8.2	6.4	6.2	8.2	Silt/wood on wet siltstone	
CL-MW-103	Shallow	639109.6148	1240003.495	14.8	14.41	15	3	12	15	-0.2	9	5.9	Wood/silty sand on bedrock	Tidal Study

Notes:

[1] Refer to Appendix B, Table B-1 for dates installed.

Appendix B includes well construction details for the following monitoring wells decommissioned or not located as of 2012: HS-MW-2, HS-MW-3, HS-MW-10, HS-MW-11, IZ-MW-1, IZ-MW-2, IZ-MW-3, IZ-MW-4, CL-MW-1S, CL-MW-1D, CLMW-2, CL-MW-3, CL-MW-4, CL-MW-5, CL-MW-7, CL-MW-8, CL-MW-10.

[2] Shallow well completions are screened across the zone of water table fluctuation or with the top of well screen a few inches to a few feet below the water table elevation.

[3] Deep well completions are screened significantly lower than the water table.

[4] Horizontal and vertical survey coordinates based on 2012 survey by Pacific Survey and Engineering, Inc. (PSE)

Horizontal Datum: NAD 83/98 Washington State Plane North Zone

Vertical Datum: NAVD 88

Datum Conversions, from PSE (2012):

NAVD88 + 0.47 feet = MLLW Tidal Datum (1983-2001 epoch) values

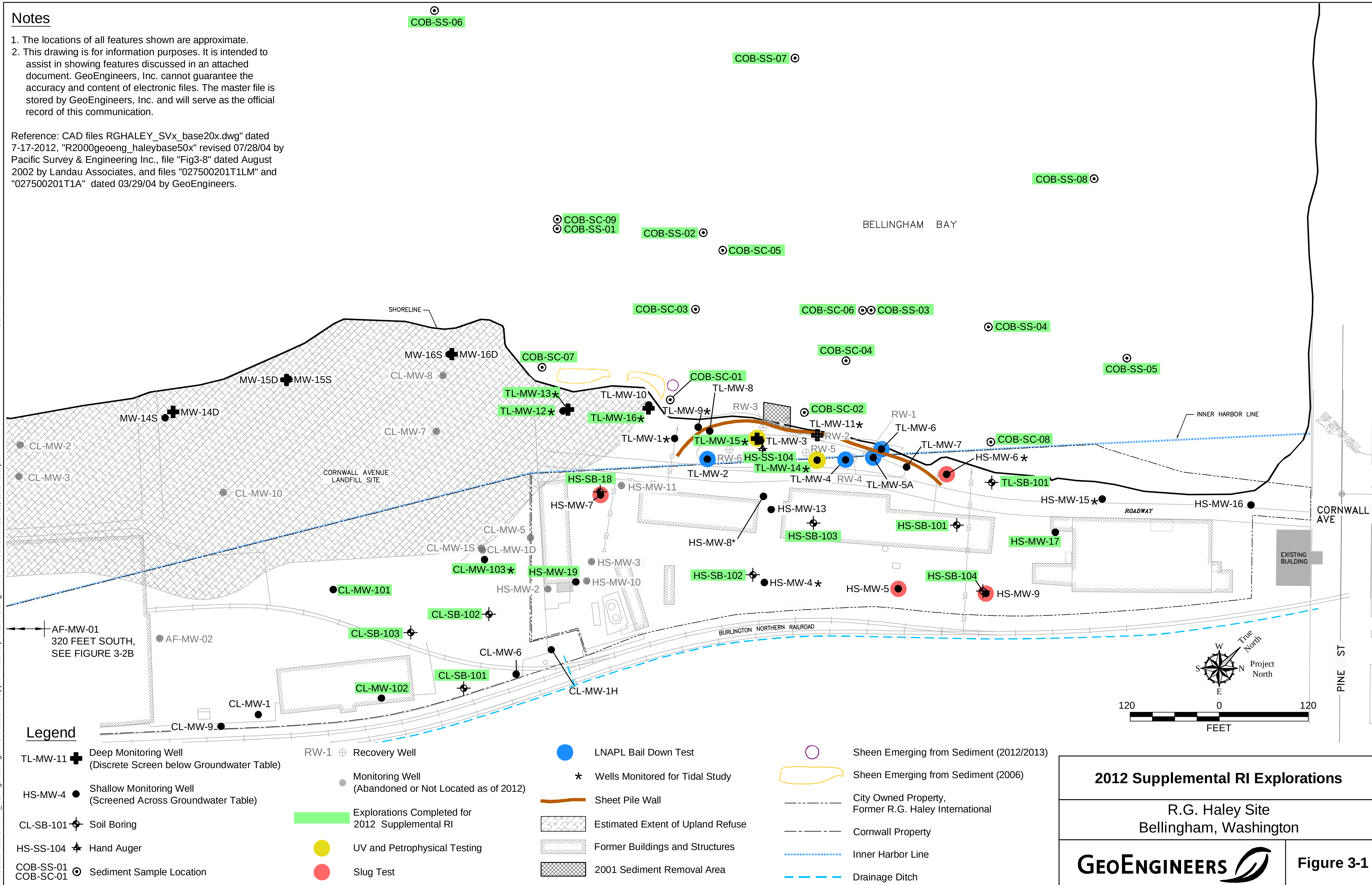
NAVD88 +1.72 = City of Bellingham (COB) Datum

NAVD88 -3.93 = NGVD29 Datum

bgs = below ground surface

NA = Not Available

Refer to Appendix D for exploration logs.



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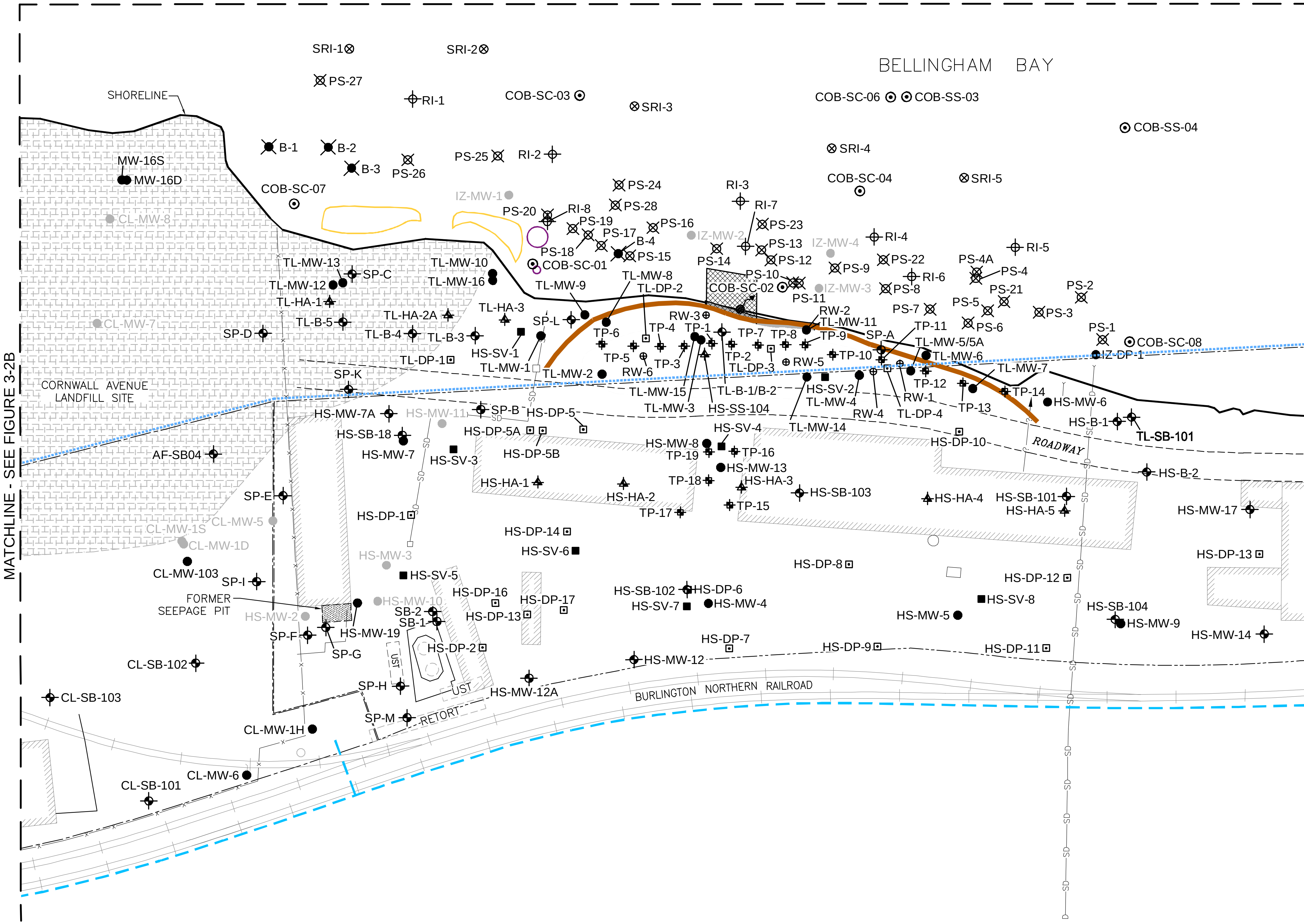
NOTE: REFER TO FIGURE 3-1 FOR SEDIMENT SAMPLES TO THE WEST



Legend

- SRI-1 ⊗ Supplemental Remedial Sediment Investigation Sampling Location
- PS-1 Preliminary Sediment Quality Assessment Sampling Location
- RI-1 September 2004 Sediment Sample Location
- HS-MW-1 Monitoring Well
- HS/SB/SP Boring
- HS-DP-4 Direct Push Boring
- HS-SV-1 Soil Vapor Sample Location
- HS-HA-1 Hand Auger/Surface Soil Sample
- RW-1 Oil Recovery Well
- COB-SS-05 Sediment Sample Location
- HS-MW-13 Grayed Monitoring Wells are Abandoned as of 2012
- B-1 Temporary Groundwater Sampling Point
- TP-15 Test Pit
- Existing Sheet Pile Barrier
- Estimated Extent of Upland Refuse
- Former Buildings and Structures
- 2000 Petroleum Seep
- 2001 Sediment Removal Area
- Sheen Emerging from Sediment (2012/2013)
- Sheen Emerging from Sediment (2006)
- City Owned Property, Former R.G. Haley International
- Cornwall Property
- Inner Harbor Line
- Drainage Ditch

W S N E True North Project North

80 0 80
Feet

Notes

1. The locations of all features shown are approximate.
2. This drawing is for information purposes. It is intended to assist in showing features discussed in an attached document. GeoEngineers, Inc. cannot guarantee the accuracy and content of electronic files. The master file is stored by GeoEngineers, Inc. and will serve as the official record of this communication.

Reference: CAD files RGHALEY_SVx_base20x.dwg" dated 7-17-2012, "R2000geoeng_haleybase50x" revised 07/28/04 by Pacific Survey & Engineering Inc., file "Fig3-8" dated August 2002 by Landau Associates, and files "027500201T1LM" and "027500201T1A" dated 03/29/04 by GeoEngineers.

All Previous and Supplemental RI Exploration Locations

R.G. Haley Site
Bellingham, Washington

GEOENGINEERS

Figure 3-2A

P:\0\0356114\06\CAD\RI_FS Figures\Figure 3-2A to 2C All Exploration Locations.dwg\TAB:3-2A Upland Central modified on Jan 28, 2015 - 3:11pm

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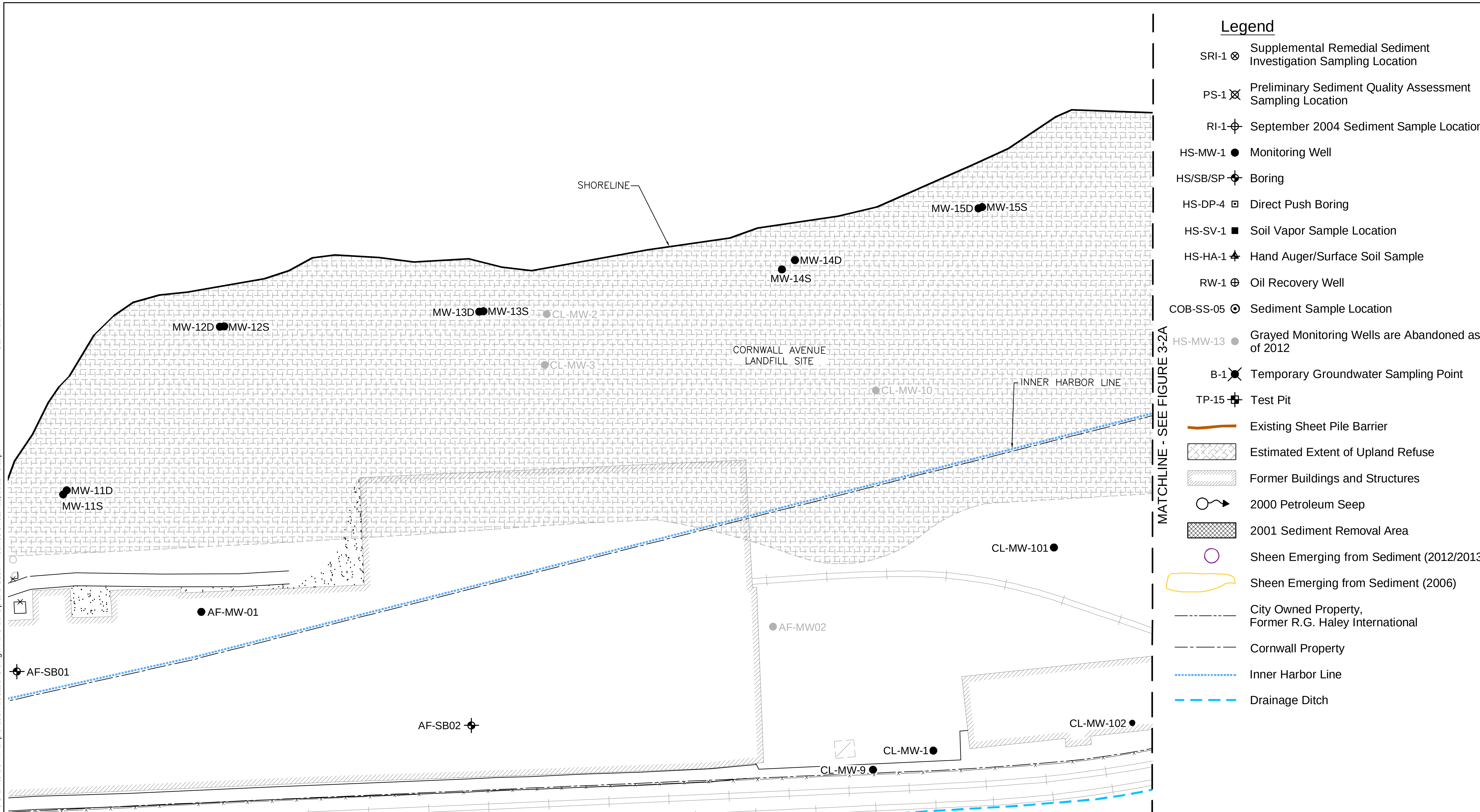
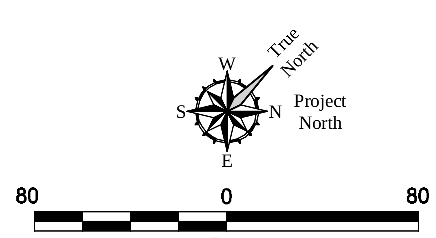


Notes

1. The locations of all features shown are approximate.
2. This drawing is for information purposes. It is intended to assist in showing features discussed in an attached document. GeoEngineers, Inc. cannot guarantee the accuracy and content of electronic files. The master file is stored by GeoEngineers, Inc. and will serve as the official record of this communication.

Reference: CAD files RGHALEY_SVx_base20x.dwg" dated 7-17-2012, "R2000geoeng_haleybase50x" revised 07/28/04 by Pacific Survey & Engineering Inc., file "Fig3-8" dated August 2002 by Landau Associates, and files "027500201T1LM" and "027500201T1A" dated 03/29/04 by GeoEngineers.



All Previous and Supplemental RI Exploration Locations

R.G. Haley Site
Bellingham, Washington

GEOENGINEERS

Figure 3-2B

P:\0\0356114\06\CAD\RI_FS Figures\Figure 3-2A to 2C All Exploration Locations.dwg\TAB:3-2B Upland South modified on Jan 28, 2015 - 3:11pm

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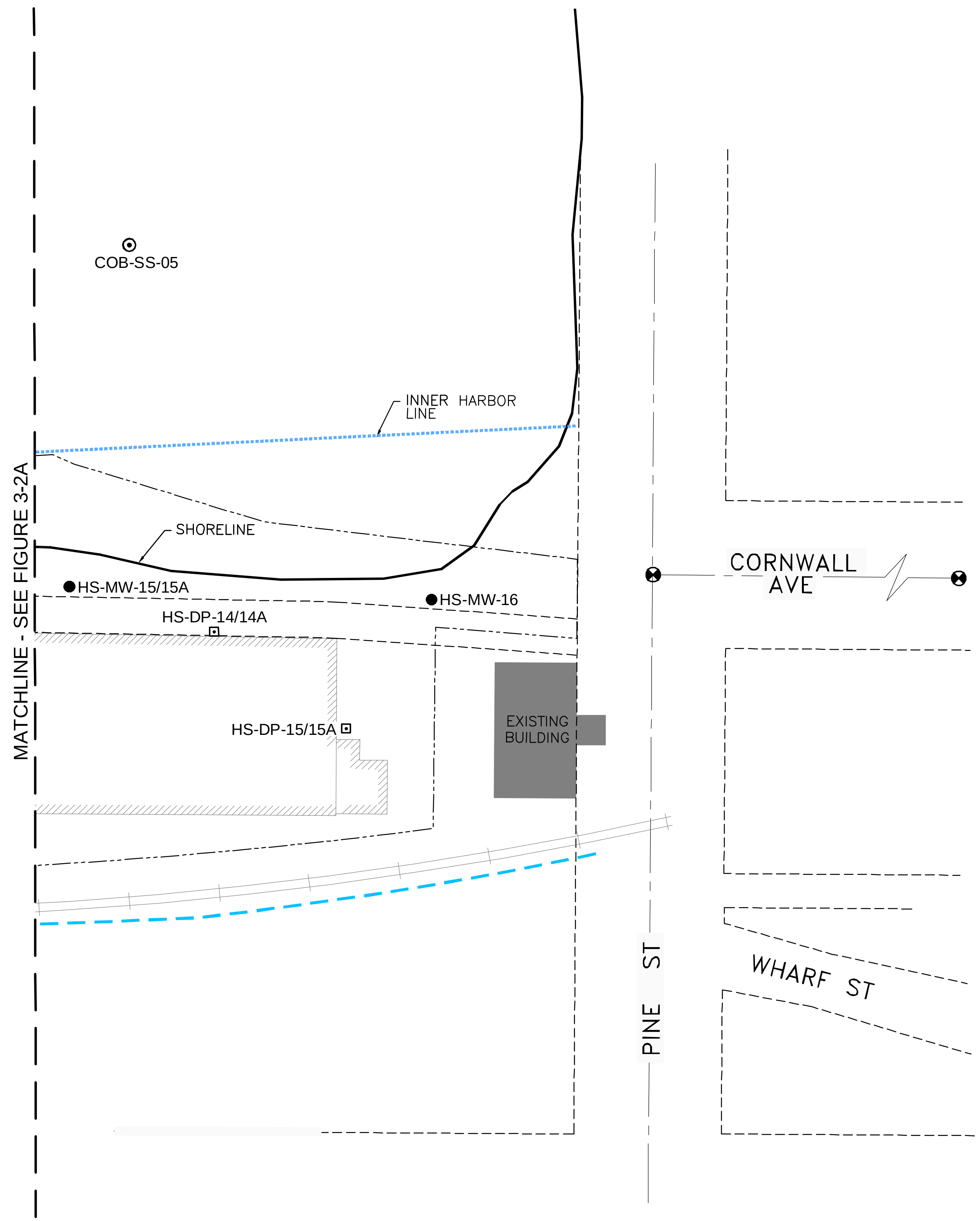


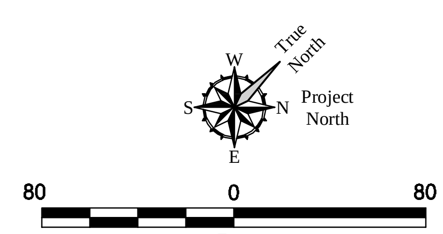
Legend

- SRI-1 — Supplemental Remedial Sediment Investigation Sampling Location
- PS-1 — Preliminary Sediment Quality Assessment Sampling Location
- RI-1 — September 2004 Sediment Sample Location
- HS-MW-1 — Monitoring Well
- HS/SB/SP — Boring
- HS-DP-4 — Direct Push Boring
- HS-SV-1 — Soil Vapor Sample Location
- HS-HA-1 — Hand Auger/Surface Soil Sample
- RW-1 — Oil Recovery Well
- COB-SS-05 — Sediment Sample Location
- HS-MW-13 — Grayed Monitoring Wells are Abandoned as of 2012
- B-1 — Temporary Groundwater Sampling Point
- TP-15 — Test Pit
- Existing Sheet Pile Barrier
- Estimated Extent of Upland Refuse
- Former Buildings and Structures
- 2000 Petroleum Seep
- 2001 Sediment Removal Area
- Sheen Emerging from Sediment (2012/2013)
- Sheen Emerging from Sediment (2006)
- City Owned Property, Former R.G. Haley International
- Cornwall Property
- Inner Harbor Line
- Drainage Ditch

Notes

1. The locations of all features shown are approximate.
2. This drawing is for information purposes. It is intended to assist in showing features discussed in an attached document. GeoEngineers, Inc. cannot guarantee the accuracy and content of electronic files. The master file is stored by GeoEngineers, Inc. and will serve as the official record of this communication.

Reference: CAD files RGHALEY_SVx_base20x.dwg" dated 7-17-2012, "R2000geoeng_haleybase50x" revised 07/28/04 by Pacific Survey & Engineering Inc., file "Fig3-8" dated August 2002 by Landau Associates, and files "027500201T1LM" and "027500201T1A" dated 03/29/04 by GeoEngineers.



All Previous and Supplemental RI Exploration Locations

R.G. Haley Site
Bellingham, Washington

GEOENGINEERS

Figure 3-2C

P:\0\0356114\06\CAD\RI_FS Figures\Figure 3-2A to 2C All Exploration Locations.dwg\TAB:3-2C Upland North modified on Jan 28, 2015 - 3:12pm

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4.0 ENVIRONMENTAL SETTING

This section describes key elements of the environmental setting of the Haley Site, including physical conditions, geology and hydrogeology, natural resources, historical and cultural resources, and land and navigational uses.

4.1. Physical Conditions

The following subsections describe the physical conditions at the Site, including climate and the nature of the upland and marine environments that compose the Site.

4.1.1. Climate

Bellingham has a maritime climate with a mean annual precipitation of about 35 inches and monthly average temperatures that range from approximately 32°F in January to 71°F in August (WRCC 2012). On average, the period of greatest precipitation extends from November through January; the period of least precipitation occurs during the summer months. The evapo-transpiration rate for the Site is estimated to be 10 inches/year based on site-specific calculations (GeoEngineers 2000a).

Water temperatures in Bellingham Bay vary with depth and over time primarily as the result of seasonal air temperature changes. Water temperatures range from approximately 46º to 55º F and are warmest in the summer and early fall and coldest during winter and spring.

4.1.2. Topography and Bathymetry

The Haley upland is located on the eastern shore of Bellingham Bay, and is situated at the foot of a steep bluff south of the Central Business District of downtown Bellingham (Figure 2-1). The Haley upland between the shoreline and the fence at the eastern property line is generally flat (Figure 2-2). The top of the present-day shoreline bank at the Haley Site has an approximate elevation of +12 to +15 feet (NAVD88); the toe of the shoreline bank ranges from approximately +7 to +10 feet (NAVD88) in the intertidal zone. The bank slope varies from near vertical in some areas to about 1.5H:1V in other areas. The shoreline bank is generally covered with armoring consisting of riprap and concrete debris. Surface topography is shown in Figure 2-2. Surface topography data used in this RI Report for the Haley upland and surrounding areas are based on City geographic information system data and site-specific survey data collected in portions of the upland in 2005, 2012, and 2013.

The marine portion of the Site extends from the shoreline into adjacent intertidal and subtidal portions of Bellingham Bay. The bathymetry at and near the Site is illustrated in Figure 2-2. The bathymetry data were obtained from a 2008 survey of the Whatcom Waterway (Anchor QEA 2010); elevation data from this survey were converted to NAVD88 elevations. The intertidal zone extends from approximately +10 feet to -4 feet NAVD88; the average tidal range (MHHW to MLLW) is +8.04 to -0.47 feet NAVD88. The subtidal zone extends from -4 feet NAVD88 into deeper water.

The intertidal zone extends 80 to 100 feet from the shoreline into Bellingham Bay. Below the shoreline bank, the intertidal zone generally slopes at 10 feet horizontal to 1 foot vertical (i.e., 10H:1V) on the southern portion of the Site and 5H:1V on the northern portion of the Site. The bathymetry of the shallow subtidal zone, from approximately -4 feet to -15 feet NAVD88, is relatively steep and generally slopes from about 5H:1V to 6H:1V until reaching deeper water more than 300 feet west of the shoreline bank, where the slope becomes less steep (Figure 2-1).

4.1.3. Site Drainage and Stormwater

Stormwater runoff from Boulevard Street at the top of the bluff and the Sehome neighborhood east of the Haley property is managed through the municipal storm drain system. This system connects catch basins in the public rights-of-way to the City storm drain that runs under the Haley property and discharges at the shoreline (Figure 2-2 and Section 4.1.3.1). There is no inlet for stormwater from the Haley property to enter the City storm drain.

Stormwater also discharges from a pipe on the Port of Bellingham Pine Street beach parcel directly northwest of the Haley Site (Figure 2-2). The source of this stormwater includes runoff from areas north of the Haley property along Cornwall Avenue.

Stormwater runoff that flows off the bluff east of the Haley property collects in a drainage ditch along the base of the bluff. This ditch is oriented parallel to the railroad tracks (Figure 2-2). Flow has been observed in this ditch during wet and dry weather conditions. Flow in the northern half of the ditch enters the City storm drain that runs beneath the Haley property. Flow in the southern portion of the ditch appears to flow to the south into a culvert that crosses beneath the railroad tracks and discharges to a man-made depression at the northeastern corner of the Cornwall property (Figure 2-2). Stormwater apparently infiltrates at the depression, but is present as standing water during periods of wet weather.

Based on observations during site visits, precipitation that falls on the Haley upland infiltrates in the upland; however, during heavy precipitation, stormwater has been observed to pond in local depressions. The Haley property is not served by an active stormwater drainage system, although remnants of a former stormwater system are present. Two inactive storm drain pipes daylight on the shoreline bank: a 12-inch square wooden outfall and an 8-inch diameter concrete outfall. There are three stormwater inlet grates in the central portion of the Haley property (Figure 2-2) that connect to piping that daylights nearby.

The layout and condition of the active City-owned storm drain and the remnant Haley stormwater drainage system were evaluated as part of the 2012 supplemental investigation. Details are discussed below.

4.1.3.1. CITY STORM DRAIN

The City storm drain conveys stormwater to Bellingham Bay through a 30-inch diameter, corrugated metal pipe (CMP) outfall. According to information provided by the City, this storm drain, known as the Cedar Street extension, was constructed in 1961 and is part of the Western Washington University North Campus stormwater conveyance system that serves neighborhoods east of the Site. One manhole provides access to this utility on the eastern portion of the Haley property; another manhole (referred to as the eastern manhole) is located near the base of the bluff east of the railroad tracks (Figure 2-2). These manholes have solid lids to prevent stormwater runoff from entering. Between the two manholes the pipe is 24 inches in diameter (concrete), and between the eastern manhole and Boulevard Street the pipe is 18-inch-diameter CMP (City of Bellingham Online Map Viewer http://www.cob.org/services/maps/online-mapping/index.aspx).

According to information received from the City, the design 10-year storm discharge flow rate from the outfall is approximately 9,400 gallons per minute. Elevation data and information from the City confirm that the pipe outfall is inundated with marine surface water during high tide events. The outfall invert elevation is +7.8 feet (NAVD88), which is below the MHHW elevation of +8.04 feet (NAVD88).

As discussed in Section 3.3, the supplemental investigation included an assessment of whether the City storm drain may be acting as a preferential pathway for contaminant migration from the Haley property to Bellingham Bay. A video survey of the inside of the entire length of the pipe between the outfall and the eastern manhole was performed in December 2010. The video survey did not identify any physical abnormalities in the pipe that might allow the entry of soil or groundwater from the Haley property. The pipe joints appeared to be intact, and visible solids were not observed in the bottom of the pipe. The video indicates that stormwaterenters the pipe east of the Haley property at the eastern edge of the railroad right-of-way. The source of this water is stormwater runoff in the conveyance ditch on the east side of the railroad tracks. Runoff in this ditch enters the storm drain through a hole cut in the top of the 24-inch concrete pipe.

Additionally, as discussed in Section 3.3, historical groundwater elevations beneath the Haley facility were evaluated relative to the invert elevation of the City storm drain. Based on existing data from the monitoring wells closest to the City storm drain (HS-MW-5, HS-MW-6, HS-MW-9, and HS-MW-15; Figure 3-1), it is estimated that historical groundwater elevations at the west end of the pipe, near the shoreline (HS-MW-6), rose above the pipe invert elevation on at least three occasions between 2001 and 2012. These periods of high groundwater elevations corresponded to the typical wet season (December and January) and seasonal high tides. This finding triggered the sampling of stormwater from the City outfall in accordance with the Work Plan. The stormwater sample results are presented in Section 6.7.

4.1.3.2. REMNANT HALEY FACILITY STORMWATER SYSTEM

The 8-inch diameter concrete pipe that daylights on the shoreline bank south of the City storm drain (Figure 2-2) has an invert elevation of +9.2 feet (NAVD88), which is above MHHW. The results of the supplemental investigation indicate that this pipe transitions from concrete to plastic east of the outfall. The pipe is blocked (broken or bent) approximately 30 feet east of the outfall and therefore is non-functioning. The original function of this pipe could not be verified, but it is assumed that it was part of a stormwater drainage system that served the Haley facility. No water has been observed discharging from this pipe during periodic inspections.

The 12-inch square wooden conveyance pipe that daylights on the shoreline bank south of the existing sheet pile barrier (Figure 2-2) was part of the former Haley facility stormwater system (Edde 1985a). A storm drain catch basin inlet (not currently present) west of the wood treatment area in the southern portion of the Haley facility was connected to this pipe (Edde 1985a). Historical facility plans show a shut-off valve for this storm drain located approximately 40 feet east of the outfall. This shut-off valve, if present, is no longer accessible. The facility report (Edde 1985a) suggests that due to surface grades in the wood treatment area of the Haley facility, runoff from the wood treatment area may have entered the storm drain catch basin.

The 12-inch wooden outfall has an invert elevation of +10.70 feet (NAVD88), which is above MHHW. Limited water seepage has been observed at the shoreline near the edges of the wooden outfall during periods of wet weather, but the rate of the seepage is too small to be indicative of a functioning storm drain.

4.1.4. Shoreline Features

4.1.4.1. GENERAL

The shoreline of this portion of Bellingham Bay has been extensively modified by filling for commercial and industrial uses since the early 1900s; navigational dredging has also occurred in areas to the north and northwest (Section 2.3). The original shoreline circa 1887 was located near the foot of the bluff east of the Haley property (Figure 4-1). The current shoreline is approximately 130 to 300 feet west of the circa 1887 shoreline. Numerous timber pilings associated with historical wharf structures are present in the intertidal zone.

4.1.4.2. SHEET PILE BARRIER

The 390-foot long sheet pile barrier extends along a portion of the Haley shoreline, just inboard of the top of the shoreline bank. In 2001 after the construction of the wall was complete, shoreline and bank erosion protection materials (riprap) were placed in a portion of the intertidal zone in front of the barrier (Appendix B, Figure B-5).

Potential erosion seaward of the sheet pile barrier was evaluated by Hart Crowser in 2009 to assess stability of the barrier (Hart Crowser 2009a). Hart Crowser noted that as of January 2009, the exposed wall height above the beach surface was approximately 4 to 5 feet in some areas where there were no erosion protection materials. Hart Crowser concluded that the sheet pile wall was not in immediate danger of failing and there was no evidence of slope instability in front of the wall. Hart Crowser concluded that there was no deep-seated slope instability affecting the barrier, and that approximately 5 feet of additional beach erosion could occur before stability of the barrier may be at risk (i.e. resultant exposed wall height of 9 to 10 feet). The current exposed wall height above the beach surface is 3 to 7 feet. Exposed wall height is checked during routine quarterly monitoring. Hart Crowser also noted that a short term loss of 5 feet of erosion would not be expected to occur during typical seasonal conditions in this area.

4.1.4.3. SHORELINE EROSION

Shoreline erosion at the Site was evaluated based on an estimate of the top-of-bank location in aerial photographs dated 1969, 1997, and 2011, and a topographic survey of the Haley upland dated 2005 (Figure 4-1). The Haley shoreline appears to have migrated as much as 34 feet in an easterly direction as a result of erosion between 1969 and 2011 (Figure 4-1). The central portion of the Haley shoreline experienced more erosion than the southern or northern ends. The average rate of erosion over the length of the Haley shoreline was estimated[4] to be about 12 feet over a period of approximately 42 years (approximately 3 inches per year), although the erosion rate has decreased with time (approximately 6 inches per year from 1969 to 1997, followed by 4 inches per year from 1997 to 2005). The most significant shoreline erosion since 1969 (up to 34 feet) occurred in the vicinity of the

[4] Estimates for rates of shoreline erosion were calculated by measuring the distances between the estimated shoreline positions (Figure 4-1) at regularly spaced intervals along the Haley shoreline and calculating the average. Accuracy is limited by interpretation of shoreline from aerial photographs.

current sheet pile barrier and the area where an oil seep was identified in 2000. As part of the sheet pile barrier construction in 2000/2001, shoreline erosion protection measures were placed in this area (GeoEngineers 2002). No substantial erosion has occurred since then, and the shoreline profiles from 2005 and 2011 are very similar.

A shoreline erosion evaluation performed on the adjacent Cornwall site (Landau 2013) indicated that about 10 to 30 feet of inland erosion occurred on the northern portion of the Cornwall site (nearest the Haley Site), and approximately 60 feet of inland erosion occurred at the southwestern corner of the Cornwall upland, between 1969 and 1994. The corresponding average rates of erosion at the Cornwall site (4 inches per year to over 2 feet per year) are greater than the estimated erosion rates at the Haley Site, and may reflect greater exposure of portions of the Cornwall site to storms and currents.

4.1.5. Sediment Characteristics

Ecology considers the ordinary high water line (OHW; +9.73 feet NAVD88) to be the boundary between the marine area and upland area (McMillan 2013). OHW is the approximate upper extent of the intertidal zone (approximately +10 feet NAVD88). Within the marine portion of the Site, a variety of natural substrate types and anthropogenic materials are present as discussed in detail in Sections 4.2 and 4.3. Beach surface materials exposed at low tides generally consist of sand and cobbles. Debris including ceramic and glass fragments, bricks, wood waste, lumber and riprap is also present on the beach surface. In the southern portion of the Site, there is an abundance of sawdust, wood chips and dimensional lumber exposed at the beach surface.

Numerous remnant untreated timber pilings are present in the upper intertidal portion of the Site (at or above +2.5 feet NAVD88). The timber pilings in this area are the remnants of a former wharf structure that supported historical lumber mill operations. Creosote-treated pilings associated with several remnant structures also previously existed in the northern portion of the Haley Site (Section 2.4).

Surface sediment in the shallow subtidal zone (from about -4 feet to -15 feet NAVD88) is finer-grained than surface sediment in the intertidal zone as discussed in more detail in Section 4.3.2. Debris observed in the shallow subtidal zone primarily consists of wood fragments (e.g., wood chips, sticks and sawdust), glass fragments, plastic, and wire. Organisms including small worms, snails and clams were observed in approximately half of the sediment samples collected in 2012. All sediment samples collected in 2012 had a slight to moderate sulfide odor.

The physical characteristics of sediment in the intertidal and shallow subtidal zones generally reflect the amount of energy input from wind, waves, and currents in each zone, as well as the dominant sediment transport process (i.e., erosion or deposition that are further discussed in Section 7.0). The coarser grain size of surface sediment in the intertidal zone, and observations of bank erosion, suggest this zone is subject to relatively higher energy input and erosion from wind, waves, and currents. Conversely, the finer grain size of surface sediment in the shallow subtidal zone suggests this zone experiences relatively lower energy input, and is an area of potential sediment deposition.

4.1.6. Marine Processes

Marine processes in Bellingham Bay have been extensively documented as part of the Whatcom Waterway site investigations (RETEC 2006). Relevant information applicable to the Haley Site for the purposes of this RI is discussed below.

4.1.6.1. LOCAL WATERSHEDS

The inner Bellingham Bay area is primarily influenced by drainage from three watersheds: the Nooksack River, Whatcom Creek and Squalicum Creek watersheds (Figure 4-2). The Nooksack River watershed, which discharges to both Lummi and Bellingham Bays, drains approximately 1,500 square kilometers (km^2) and is the largest watershed in the Bellingham area. The Nooksack River is the primary source of sediment to Bellingham Bay, with an annual sediment discharge of 650,000 cubic meters (m^3).

The Whatcom Creek watershed drains an area of approximately 26 km^2. Whatcom Creek flows from Lake Whatcom through Bellingham to Bellingham Bay. The Squalicum Creek watershed drains an area of 65 km^2. Squalicum Creek originates at Squalicum Lake and also flows through Bellingham. Five other smaller watersheds also drain to Bellingham Bay.

4.1.6.2. REGIONAL BOTTOM CURRENTS

Bellingham Bay exchanges water with Rosario Strait, the Strait of Georgia, and ultimately the Pacific Ocean through a network of channels and passages as described in Collias et al. (1966), Shea et al. (1981), Broad et al. (1984) and Colyer (1998).

Most oceanic waters enter Bellingham Bay at depth through the southern end of the Strait of Georgia between Lummi and Vendovi Islands. Some water from Puget Sound enters from the south through Bellingham Channel. The residence time for water in Bellingham Bay varies between one and eleven days, but is typically four to five days.

The lateral and vertical spreading of water discharging from the Nooksack River results in net southward flow (i.e., flow to the southeast relative to Haley Site Project North) throughout Bellingham Bay at depth. The currents in the inner bay, both shallow and deep, are variable; some authors have reported dominant oscillating north-south longshore flow (USACE 1997) while others have reported dominant flows from west to east (Colyer 1998). Eddies may form near the shore, particularly in the inner harbor region, depending on wind speed and direction, freshwater input, and strength of the tidal exchange (Colyer 1998). Shallow, nearshore bottom current velocities typically range from 0.2 to 0.3 meters per second (m/sec). Deep current velocities are lower, typically ranging from 0.04 to 0.18 m/sec in the inner bay, although they can be as high as 0.4 m/sec (Colyer 1998). Bottom current velocities greater than approximately 0.3 to 0.4 m/sec may be capable of resuspending fine-grained sediments[5] (i.e., silt and fine sand particles [Downing 1983]). Inner Bellingham Bay is likely a net depositional environment based on the high percentage of silts present

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[5] Erosion velocity thresholds for silts can range from 0.02 to 0.5 m/sec or greater depending on the cohesiveness of the sediment bed. Cohesiveness is a function of chemical and biological processes in the sediment; the more cohesive sediment particles are, the more energy it takes to re-suspend them.

in surface sediments. However, periodic re-suspension and transport of fine-grained sediment likely occurs in shallow water areas where wind and wave action influence currents.

4.1.6.3. REGIONAL SURFACE CURRENTS

Wind stress is the dominant factor influencing surface currents in Bellingham Bay (Shea et al. 1981). Inclement weather in the region originates from the south or southwest during much of the year, which results in wind-driven flow of shallow surface water toward the northern part of the Bay, with return flow along the shorelines of Lummi Peninsula, Portage Island, and Lummi Island. Seasonal fair-weather winds from the west or northwest cause shallow surface water to flow toward the east and south along the northern and eastern shorelines. However, on a local scale, surface currents driven by the tidal cycle can vary from seasonal patterns. Typical surface currents range from 0.02 to 0.06 m/sec in the inner bay, reaching maximum velocities of 0.36 m/sec (Colyer 1998). These seasonal wind variations and surface currents result in complex patterns of sediment deposition and shoreline erosion within the Bay.

4.1.6.4. FLOODING, STORM SURGE, TSUNAMIS AND SEA LEVEL RISE

Flooding, storm surge and tsunamis can increase tidal elevations in Bellingham Bay locally and Bay-wide. In addition, there is a potential for sea level rise in the future due to global climate changes. These factors are discussed below in relation to the Haley Site and are considered in the FS evaluation of remedies.

The upland portion of the Haley Site is rated as a moderate to low risk area for flooding above elevation 11.93 feet (NAVD88) (FEMA 2004 FIRM Panels 1651D and 1213D). This elevation is slightly below the lowest surveyed top of bank at approximately 12 feet (NAVD88).

The effects of storm surge on water elevations vary with wind speed, wind direction, and tidal cycle. For example, storm surges only produce extraordinarily high water elevations if they occur during a near-maximum high tide event. RETEC estimates that storm surge in inner Bellingham Bay is capable of increasing the elevation of high tide by an incremental 0.8 feet (RETEC 2006). A recent winter storm on December 17, 2012 produced a water elevation approximately 1.41 feet higher than the predicted high tide at the nearest NOAA measurement station at Cherry Point, located north of Bellingham Bay.

In the Site area, a tsunami from a design seismic event could increase the water height as much as 1.6 feet above the tidal elevation at the time (Walsh, et al. 2004) assuming the tsunami occurs independently from flooding and/or storm surge.

The Waterfront District Redevelopment Final Draft Environmental Impact Statement (Port of Bellingham 2010) states that sea level in the Bellingham area could increase by 2.4 feet by the year 2100. This estimate was based on an evaluation of sea level by the University of Washington and Ecology (University of Washington/Ecology 2008). A potential sea level rise of 2.4 feet corresponds to a potential future MHHW elevation at the Site of approximately +10.44 feet (NAVD88).

4.1.6.5. SEDIMENT DEPOSITION

The results of the 2008 Ecology sediment investigation at the Cornwall site indicate that significant sediment accumulation has occurred throughout much of the aquatic portion of the Cornwall site (Hart Crowser 2009b). Sediment accumulation above the in-water landfill waste was observed at 41 of the 44 sediment core locations. The observed thickness of accumulated sediments in the core samples ranged from 0.5 to 3.5 feet, with an average thickness of 1.6 feet. Based on these observations and the elapsed time since landfill closure (approximately 43 years), the sediment deposition rate at the Cornwall site was estimated to range from 0.35 to 1.35 centimeters per year (cm/year); the average deposition rate was estimated as 1.1 cm/year (Hart Crowser 2009b).

A study of sediment deposition for the Whatcom Waterway project identified sediment deposition rates of 1.52 to 1.77 cm/year for inner Bellingham Bay, based on different methodology than the Hart Crowser study[6] (RETEC 2006).

4.2. Geology and Hydrogeology

4.2.1. Geology

Almost the entire upland portion of the Site was created by the placement of fill at the margin of Bellingham Bay. The fill is composed of imported soil, dredged sediment, lumber mill wastes (wood debris), landfill refuse associated with the Cornwall site, and construction debris from unknown sources. Native marine sediment of variable composition is present beneath the fill materials. Locally, glacial sediment, which is referred to as glacial marine drift (GMD), is present beneath the native marine sediment. The Chuckanut Formation (bedrock) is present beneath all of these units. Bedrock is exposed at the ground surface near the eastern boundary of the Site on the slope adjacent to the railroad tracks. The depth to bedrock below ground surface increases from the eastern boundary of the Site west toward Bellingham Bay (Figure 4-3). Three geologic cross sections (Figure 4-4) were prepared to illustrate geologic units and the CSM. Cross section A-A' (Figure 4-5) shows the vertical relationship of the geologic and fill units beneath the Site. Subsurface conditions and materials are described in more detail below.

Geologic and fill units beneath the upland and marine portions of the Haley Site are variable and complex. Exploration logs prepared for subsurface explorations document rapid changes in material type over relatively short horizontal and vertical distances. The geologic cross sections shown in Figures 4-5, 4-6 and 4-7 are based on interpretation of exploration logs; considerable stratigraphic/lithologic variation exists within the units shown in the cross sections. These variations affect contaminant distribution and potential migration beneath the Site. Generalized descriptions of the various geologic and fill units beneath the Site are presented below. Detailed descriptions of the subsurface materials can be found in the exploration logs (Appendix D).

- Upland Fill: The upland fill material is the uppermost unit encountered in the upland portion of the Site. It was imported to the Site from various sources (DNR 2002), and consists predominantly of poorly-graded silty sand, sand, and gravel, with some silt and variable amounts of coal fragments, brick fragments, wood debris, construction debris and sawdust. The upland fill material ranges from approximately 8 to 15 feet thick. The upland fill is covered with concrete or asphalt pavement in several locations.

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[6] Depositional characteristics in the Whatcom Waterway were evaluated using sediment dating (Cesium[137] and Lead[210]) methods, along with sediment traps.

- Landfill Debris: Municipal solid waste from the former Cornwall Landfill extends onto the southwestern corner of the upland portion of the Haley Site (Figures 4-4 and 4-7). The landfill debris includes typical solid waste materials (plastic, wood, wire, glass, paper and other refuse) mixed with soil.
- Wood Fill: Wood fill beneath the Site originated primarily from past lumber mill activities. The wood fill is present beneath much of the upland area and extends into the adjacent aquatic lands, most notably in the upper intertidal areas. The wood fill appears to have accumulated at different times and in different places, as it is locally discontinuous, and various wood fill horizons are separated by soil/sediment fill material. For the purposes of this RI, fill material that contained roughly 50 percent or more woody material mixed with silt, sand and gravel was characterized as wood fill. The woody material includes sawdust, wood chips, dimensional lumber and log ends.
- Marine Fill: Marine fill was placed prior to, coincident with, and/or after placement of the wood fill. Portions of the marine fill likely were produced by dredging operations in Bellingham Bay. The marine fill is highly variable and includes silt, silty sand, and poorly-graded fine- to medium-grained sand with shell fragments and occasional wood fragments. Where the marine fill consists mainly of sand, it is difficult to distinguish from native marine sediment. At the majority of exploration locations, the marine fill consisted of silt and silty sand, present from the mudline to approximately 2 to 10 feet below the mudline. The fill occasionally contained or consisted of wood waste, and occasionally contained trace shell fragments. Distinct wood waste layers consisting of 50 to 100 percent sawdust, and ranging in thickness from 1 to 11 feet, were observed intermixed with the marine fill. The fill also occasionally contained other debris including glass, brick and plastic.
- Native Marine Sediment: Native marine sediments also are variable and include gray silt, silty sand, and poorly-graded fine to coarse-grained sand with occasional gravel, shell fragments, and wood fragments. The native marine sediment deposits were encountered west of the historical 1887 shoreline and appear to thicken to the west beneath the marine portion of the Site. Where present, native marine sediment deposits are the shallowest native deposits encountered at the Site. The native sediment generally did not contain wood waste or other debris.
- Glacial Marine Drift: The GMD is composed of gray silt, and clay with occasional gravel and shells, and typically does not contain organic matter. GMD appears to be limited to the south-central area of the Haley upland and is shown on cross section A-A’ (Figure 4-5). Although GMD appears to have a limited distribution beneath the Haley upland, it is estimated to be greater than 20 feet thick near the shoreline of the Cornwall site (Landau 2013).
- Chuckanut Formation (Bedrock): The Eocene-age Chuckanut Formation (Padden Member) forms the bluff adjacent to the railroad tracks, east of the Site. Regionally, the Padden Member of the Chuckanut Formation consists of moderately to poorly-graded sandstone and conglomerate alternating with mudstone and minor coal (Lapen 2000). The Chuckanut Formation crops out at the surface in places east of the Haley Site and in other places has a thin overlying soil mantle supporting vegetation. The upper surface of the bedrock slopes downward toward the west (Figure 4-3). The top of the bedrock unit is over 30 feet deep near the shoreline of the Haley Site. The surface of the Chuckanut Formation was observed to be weathered in some borings. The base of the Chuckanut Formation was not reached in any of the explorations at the Site.

4.2.2. Hydrogeology

4.2.2.1. GROUNDWATER OCCURRENCE

Shallowest groundwater beneath the Site occurs in fill under unconfined conditions. This wedge-shaped saturated horizon is a manmade aquifer that exists only because fill was historically placed in the tidelands. Characteristics of the hydrostratigraphic units beneath the Haley upland are discussed in Sections 4.2.2.2 and 4.2.2.3.

Quarterly groundwater monitoring has been performed for more than a decade at the Haley Site. The monitoring data, including groundwater elevations and LNAPL thickness (if present) measured in wells since 2004, when the well network was significantly expanded, are compiled in Appendix B, Table B-6. This section discusses groundwater occurrence based on the most recent and comprehensive set of groundwater data, which was collected between December 2010 and February 2013 (Table 4-1).

The depth to groundwater beneath the Haley upland generally ranges from approximately 3 to 11 feet bgs. Groundwater elevations are highest during the wet season. Away from the shoreline, groundwater elevations are highest at the south end of the Haley upland and the northeast corner of the Cornwall property.

Groundwater elevation contour maps for monitoring events corresponding to one low tide (July 2012) and one high tide (August 2012) event are shown in Figures 4-8 and 4-9. Groundwater elevation contour maps for five quarterly monitoring events in 2004 and 2005 are included in Appendix B, Exhibit B-2.

The groundwater table elevation is generally higher to the east near the bluff, and lower near the shoreline. The highest groundwater elevations have typically been observed in the monitoring wells at the southeast corner of the Haley property and northeast corner of the Cornwall property, near the outfall of the drainage ditch culvert on the Cornwall property (Figures 4-8 and 4-9).

Hydrographs for selected shoreline wells (Figure 4-10) indicate that groundwater elevations typically fluctuate seasonally on the order of 1 up to 5 feet at the shoreline wells that are influenced by seasonal precipitation patterns and tides. The elevation of the groundwater table in the shoreline wells typically ranges between 2 and 9 feet (NAVD88). At the shoreline wells the highest groundwater elevations usually occur in December, and the lowest groundwater elevations usually occur in June (Figure 4-10).

Groundwater elevations for selected inland wells (Figures 4-11a and 4-11b) fluctuate 1 to 2 feet seasonally. The elevation of the groundwater table at the inland wells typically ranges between 6 and 12 feet (NAVD88) depending on season and location. Groundwater elevations inland from the shoreline are typically highest in winter and early spring and lowest in summer (Figures 4-11a and 4-11b). The greatest seasonal fluctuation for the selected inland monitoring wells was at CL-MW-6, located near the culvert outfall in the northeast corner of the Cornwall property.

In addition to seasonal groundwater level fluctuations, short-period (diurnal) groundwater fluctuations occur in shoreline wells due to tidal influence. During a tidal study conducted on the Haley facility in April 2000 (GeoEngineers 2000a), the maximum observed groundwater response to a 7.5-foot tidal fluctuation was 1.45 feet in well HS-MW-6, which is about 20 feet from the shoreline bank (Figure 3-1). There was less than 0.1 foot of groundwater response in monitoring wells HS-MW-4, HS-MW-5 and HS-MW-9, which are located approximately 170 to 220 feet from the shoreline bank.

A subsequent tidal study was conducted over a nine-day period from July 30, 2012 through August 8, 2012. During this study, most shoreline wells exhibited a groundwater response of up to 2 feet, compared to a tidal fluctuation of up to 10 feet.

4.2.2.2. HYDROSTRATIGRAPHIC UNITS

Three hydrostratigraphic units have been defined for the Site. The hydrostratigraphic units are composed of the geologic units described in Section 4.1. Geologic units that are in direct contact with each other and have similar characteristics were grouped together to define the hydrostratigraphic units. The hydrostratigraphic units and their corresponding geologic units are as follows:

HYDROSTRATIGRAPHIC UNITS

Hydrostratigraphic Unit	Corresponding Geologic Units
Fill Unit	Upland Fill
	Landfill Debris
	Wood Fill
	Marine Fill
Native Marine Unit	Native Marine Sediment
	Glacial Marine Drift
Chuckanut Formation	Chuckanut Formation

The three hydrostratigraphic units defined for the Haley Site are the same as those defined for the Cornwall site (Landau 2013). The Fill and Native Marine Units are the most significant groundwater-bearing units beneath the Site; the bedrock of the Chuckanut Formation is not expected to store or transmit significant quantities of groundwater. The inland extent of the geologic units that constitute the Fill and Native Marine Units approximately coincides with the eastern boundary of the Haley property (Figures 4-5 and 4-6). The thickness of the Fill and Native Marine Units increases toward Bellingham Bay. The hydrostratigraphic units are further described below.

Fill Unit: The Fill Unit is the primary groundwater-bearing unit, and is present beneath the entire upland portion of the Site. The Fill Unit comprises four different geologic units: upland fill, landfill debris (where present), wood fill and marine fill. Each of these geologic units, and thus the Fill Unit, is highly variable and heterogeneous. The Fill Unit generally consists of mixtures of silt, silty sand, sand, gravel, wood debris ranging from sawdust to log ends, and coal, brick and shell fragments. Additionally, the Fill Unit includes landfill debris in the upland overlap area between the Haley Site and Cornwall site. Despite its highly variable/heterogeneous nature, the Fill Unit appears to behave as a single hydrostratigraphic unit. However, the high degree of variability within the Fill Unit makes it difficult to apply standard hydrogeologic methods to interpret the results of aquifer testing and tidal studies.

Native Marine Unit: The Native Marine Unit consists almost entirely of Native Marine Sediment, and GMD where present locally. The GMD was identified only to a very limited extent beneath the Haley upland, and does not appear to be an important component of hydrogeology for the Haley Site; it is grouped into the Native Marine Unit for convenience. The Native Marine Unit consists mostly of silt, silty sand, and sand. The thickness of the Native Marine Unit decreases from west to east beneath the Site (Figures 4-5 and 4-6); this unit is absent beneath the eastern portion of the upland.

Chuckanut Formation: The Chuckanut Formation is a bedrock unit that forms the lower hydraulic boundary of the upper groundwater flow system. It consists of sandstone and conglomerate alternating with mudstone and minor coal. The Chuckanut Formation underlies the entire upland and slopes steeply downward to the west. The upper portion of the Chuckanut Formation is locally weathered and may contain groundwater. Based on references and research cited in the Cornwall RI report (Landau 2013), the Chuckanut Formation has a low overall bulk permeability, although it may produce small amounts of water for domestic uses in some locations (USGS 1999). In the Cornwall RI report, the Chuckanut Formation is interpreted to be a semi-confining unit in the Cornwall site vicinity (Landau 2013). This interpretation was based on observations of localized groundwater seepage that appear to occur intermittently at bedrock outcroppings along the base of the bluff east of the Cornwall site (Section 4.1.3 of Cornwall RI report). Based on the water balance described in Section 4.2.2.5, the Chuckanut Formation beneath the Haley Site is considered to be only a minor localized source of shallow groundwater recharge to the Fill Unit as compared to direct surface water infiltration. However, the Chuckanut Formation could contribute more recharge than anticipated if there are areas of significant weathering or fractures in this bedrock unit.

The characteristics of some of the hydrostratigraphic units differ between the Haley Site and the Cornwall site. The primary difference between the Fill Unit at the two sites is the greater proportion of lithic soil and sediment particles at the Haley Site compared to the Cornwall site, which is dominated by solid waste landfill materials. The Native Marine Unit appears to differ considerably between the two sites. The primary difference is the thickness and extent of the GMD; the GMD is thicker and more extensive beneath the Cornwall site. The native marine sediment underlying the Cornwall site appears to be Nooksack deposits, which are described as fine-grained silts and clays. In contrast, native marine sediments underlying the Haley Site are coarser, consisting mostly of silt and sand. Based on the greater extent of the GMD and the finer-grained texture of the native marine sediments at the Cornwall site, the Native Marine Unit is designated as an aquitard in the Cornwall RI report (Landau 2013). However, although it is finer-grained than the overlying Fill Unit, the Native Marine Unit is not considered to be an aquitard beneath the Haley Site.

The remainder of the hydrogeology discussion focuses on the groundwater-bearing hydrostratigraphic units of the upper groundwater flow system.

4.2.2.3. HYDRAULIC CHARACTERISTICS OF GROUNDWATER BEARING UNITS

The combined saturated thickness of the two groundwater-bearing hydrostratigraphic units beneath the Haley upland ranges from zero east of the railroad tracks (where there is only a thin soil layer over the bedrock), to approximately 30 feet near the shoreline (Figures 4-5 and 4-6). The greatest saturated thickness occurs in the southwest corner of the Haley upland (TL-MW-13, Figure 3-1), where the combined saturated thickness of the Fill and Native Marine Units is about 40 feet.

The hydraulic characteristics of the groundwater-bearing units were evaluated through tidal studies, and slug tests, and groundwater flow modeling. The July-August 2012 tidal study measured groundwater response to tidal fluctuations in 13 monitoring wells. Standard published methods for estimating aquifer properties (e.g., hydraulic conductivity) based on tidal studies were difficult to apply at the Haley Site because the Fill Unit is highly variable (see Appendix G for further discussion). However, analysis of tidal study data did provide insight into the hydraulic characteristics of the groundwater-bearing units.

The ratio of groundwater response to tidal fluctuation is called the "stage ratio." The results of the 2012 tidal study indicate that the tidal response ("stage ratio") decreases exponentially with increasing distance inland from the shoreline and the phase shift ("time lag" between the tidal fluctuation and the associated groundwater response) increases linearly with distance inland. The largest groundwater responses/stage ratios were observed in wells within approximately 20 to 50 feet of the shoreline bank. However, stage ratios for these wells were relatively small—generally between 10 and 20 percent—suggesting that the groundwater response is dissipated by unconfined aquifer conditions. Beyond a distance of 20 to 50 feet inland, groundwater response to tides attenuates rapidly. The stage ratio drops to less than 1 percent 100 feet from the shoreline bank. Similar results were obtained at the Cornwall site (Landau 2013), where tidal influence was observed not to extend beyond about 100 feet inland from the shoreline. Appendix G includes more detailed discussion of groundwater response to tidal fluctuations.

For the ten wells that exhibited a measurable tidal response, analysis of the response data using the Ferris method (Ferris 1952) suggested two types of responses: (1) slower-responding wells that generally exhibit groundwater responses typical of unconfined aquifers; and (2) faster-responding wells that generally exhibit groundwater responses typical of confined or leaky-confined aquifers.

The wells included in each of these groups are listed below:

WELL GROUPINGS BASED ON TIDAL RESPONSE

Well Group	Type of Aquifer Response	Monitoring Wells	Screen Elevation (feet NAVD88)	Relative Depth
Slower Responding	Unconfined	HS-MW-15 TL-MW-1 TL-MW-9 TL-MW-11 (see Note 1) HS-MW-6 (see Note 2)	4 to 1.1 10 to -4.8 11 to 0.1 -1 to -4.3 8 to -6.6	Shallow Shallow Shallow Deep Shallow
Faster Responding	Confined/ leaky-confined	TL-MW-12 TL-MW-13 TL-MW-14 TL-MW-15 TL-MW-16	12 to 2.4 -28 to -31 -13 to -15.9 -12 to -14.9 -16 to -19.2	Shallow Deep Deep Deep Deep

Notes:

1. Well TL-MW-11 exhibited both unconfined and confined/leaky-confined aquifer behavior. This well is included in the "Slower" (unconfined) group because the confined aquifer behavior observed during the tidal study may reflect this well's location immediately upgradient of the sheet pile barrier and screened below the tip of the sheet pile barrier.

2. The extended time lag response at well HS-MW-6 given is proximity to the shoreline may be explained by the presence of a silt and fine silty sand layer at the water table elevation that may create confined/leaky-confined conditions local to this well.

In general, shallow groundwater in most locations in the Fill Unit exhibits unconfined aquifer behavior in response to tidal fluctuations, whereas deeper groundwater in the Fill Unit and the underlying Native Marine Unit generally exhibits confined or leaky-confined aquifer behavior.

The hydraulic conductivity of the Fill Unit was estimated from slug tests performed at shallow monitoring wells HS-MW-5, HS-MW-6, HS-MW-7 and HS-MW-9 (Figure 3-1) during the 2012 supplemental investigation (Appendix F). Estimated values of hydraulic conductivity based on these slug tests ranged from 1.2 feet/day at well HS-MW-9 (near the eastern property boundary) to 17.9 feet/day at well HS-MW-6 (near the shoreline) (Table 4-2).

Hydraulic conductivity estimates for the Fill and Native Marine Units were also derived using data from the tidal studies conducted in 2000 and 2012 (Table 4-2). Previous analysis of data from the 2000 study indicated the hydraulic conductivity of the Fill Unit near the shoreline ranges from approximately 22 to 50 feet/day (GeoEngineers 2000a), which is typical for a fine to medium sand (Domenico and Schwartz 1990). Hydraulic conductivities based on data from the 2000 tidal study were recalculated for this RI Report using different values for storativity (drainable porosity) based on the expanded 2012 tidal study results. Hydraulic conductivity estimates based on this updated analysis range from 3 to 44 feet/day (Table 4-2).

The limited inland extent of tidal influence observed during the 2012 tidal study indicates the groundwater-bearing units beneath the Haley upland have moderate to low transmissivity. Estimates of transmissivity and hydraulic conductivity derived from the 2012 study vary widely depending on the method of analysis used (Appendix G). This variability likely reflects the highly heterogeneous nature of the groundwater-bearing units and the complex boundary between groundwater and tidal surface water in Bellingham Bay. An approach based on best professional judgment was selected to estimate aquifer properties from the 2012 tidal study. The selected approach evaluated the ten wells that exhibited a response using the Stage Ratio method (Appendix G) and used well-specific aquifer saturated thickness and storativity values. The hydraulic conductivity estimates derived from the 2012 tidal study are presented in Table 4-2 and ranged from 2 to 13 feet per day for the Fill Unit and 6 to 9 feet per day for the Native Marine Unit.

Hydraulic conductivity was further evaluated through groundwater flow modeling. Groundwater modeling was used in 2000 with the limited hydrogeologic data available at the time to derive hydraulic conductivity estimates for the Fill Unit of 10 to 40 feet/day (GeoEngineers 2000a). As with the 2000 tidal study, updated groundwater modeling was completed for this RI. The three-dimensional flow modeling utilized the U.S. Geological Survey modular finite-difference groundwater flow model (MODFLOW) and the commercial software program Groundwater Modeling System (GMS) with Parameter Estimation and Uncertainty Analysis (PEST). Appendix H presents a selection of tables and figures that represent the model assumptions and results.

The model-calculated, vertically-averaged hydraulic conductivity field for the Fill and Native Marine Units is presented in Figure 4-12. The model-calculated hydraulic conductivities ranged from 0.1 to 120 feet/day, with an arithmetic mean of 6.9 feet/day and a geometric mean of 4.9 feet/day. These mean hydraulic conductivity values are comparable to the average and median values derived from slug test and tidal study data (Table 4-2). Because the model utilized hydraulic conductivity estimates for specific wells derived from field studies (i.e., slug tests and tidal studies) and incorporated hydraulic heads from the site-wide network of monitoring wells, the modeling results provide the best estimate of site-wide hydraulic conductivities. Use of the groundwater flow model is discussed further in the FS.

4.2.2.4. GROUNDWATER GRADIENTS AND FLOW DIRECTIONS

Typical groundwater elevation contour maps for the Haley upland are presented in Figures 4-8 and 4-9. Groundwater beneath the upland is inferred to flow to the west and discharge to Bellingham Bay. Downward vertical groundwater gradients occur in the inland areas that are farthest from the shoreline, where most of the groundwater recharge likely occurs. Upward vertical gradients occur nearer to the shoreline. As described in Section 4.2.2.5, water appears to enter the groundwater flow system primarily through infiltration of precipitation/stormwater in unpaved areas on the Haley property and in the drainage ditch east of the property boundary.

The horizontal groundwater gradients that existed before the sheet pile barrier was installed were previously estimated for low-tide, mid-tide, and high-tide conditions based on groundwater level measurements collected on April 10, 2000 (GeoEngineers 2000a). This evaluation indicated that the inferred groundwater flow direction was toward Bellingham Bay, under a horizontal gradient of approximately 0.01 feet/foot during low- and mid-tide, and 0.004 feet/foot during high tide.

Horizontal groundwater gradients with the sheet pile barrier in place were estimated from the July 17, 2012 (low tide) and August 9, 2012 (high tide) groundwater elevation contour maps (Figures 4-8 and 4-9). The estimated horizontal groundwater gradient immediately east (upgradient) of the sheet pile barrier was approximately 0.02 feet/foot at low tide and 0.014 feet/foot at high tide. Farther east of the sheet pile barrier (east of the former drying sheds), the horizontal gradient remained relatively constant (0.014 to 0.018 feet/foot) between low and high tide. Steeper gradients occurred in the southeastern portion of the Haley upland near the former seepage pit, where gradients of 0.027 feet/foot and 0.021 feet/foot were measured at low and high tide, respectively. The average horizontal gradient calculated by the groundwater flow model developed for the Haley Site is 0.016 feet/foot. This average gradient is approximately three to five times steeper than the horizontal gradients calculated for the Cornwall site (0.003 to 0.006 feet/foot, Cornwall 2013a); the difference is consistent with the difference in the mean hydraulic conductivity estimates for the two sites (25 feet/day at the Cornwall site [Cornwall 2013a], 4.9 feet/day at the Haley Site based on the geometric mean derived from the groundwater model).

Horizontal groundwater flowpaths predicted by the groundwater flow model are shown in Figure 4-13. The model-predicted flowpaths are consistent with the overall westerly groundwater flow direction inferred from groundwater elevation contour maps (Figures 4-8 and 4-9). Groundwater flow in the northeast corner of the Cornwall property and southeast corner of the Haley property is influenced by groundwater mounding in this portion of the upland. The mounding at this location appears to be caused by infiltration of stormwater that discharges from the drainage culvert (Figure 2-2) described in Section 4.1.3. As a result of the mounding, groundwater beneath the southeast corner of the Haley property flows to the northwest discharging at the Haley shoreline. Groundwater beneath the northeast corner of the Cornwall property flows to the southwest, away from the Haley property. The inferred flow directions near this groundwater mound based on Haley RI data are consistent with the groundwater flow directions shown in the Cornwall RI (Landau 2013).

Seasonal variations in groundwater flow direction and gradient in the mounding area are best interpreted using data from five monitoring events in 2004 and 2005 (Appendix B, Exhibit B-2). The location of the mound and general groundwater flow directions in this area were generally the same during these monitoring events. The groundwater gradient varied between monitoring events based on groundwater elevation differences along two transects: CL-MW-6 to CL-MW-1S, and CL-MW-6 to HS-MW-10. During the five 2004/2005 monitoring events, groundwater elevations along the first transect differed by a minimum of 0.47 feet and a maximum of 1.32 feet. Groundwater elevations along the second transect differed by a minimum of 0.33 feet and a maximum of 2.14 feet. Gradients along the first transect were generally higher during the wet season, as would be expected because the groundwater mound is produced by the focused infiltration of stormwater. Groundwater gradients along the second transect, however, do not appear to be seasonally influenced. The lowest (0.33 feet) and highest (2.14 feet) groundwater elevation differences along this transect both occurred during September (September 2004 versus September 2005). Comparisons of the 2004/2005 versus 2012 gradients are not meaningful because groundwater elevations are not available for the same monitoring wells.

Groundwater flow modeling suggests that groundwater east (upgradient) of the sheet pile barrier converges as it flows toward the barrier. This model-predicted convergence is supported by the hydraulic conductivity field generated by the model (Figure 4-12). The model-calculated hydraulic conductivities are lower at the northern and southern ends of the sheet pile barrier and higher in the areas directly east and west of the barrier. The hydraulic conductivity field shown in Figure 4-12 is supported by field data (i.e., slug test results).

Vertical groundwater gradients in an area not affected by tides or the sheet pile barrier were evaluated in June and September 2004 by comparing groundwater elevations in well pair CL-MW-1S/CL-MW-1D, located just north of the landfill waste body on the Cornwall site (Figure 3-1; these wells have since been abandoned). Wells CL-MW-1S (shallow) and CL-MW-1D (deep) had short screens installed at different depths below the groundwater table. The groundwater elevations measured in these wells in June and September 2004 indicated a slight upward gradient of approximately 0.02 feet/foot. Vertical gradients were also evaluated at three well pairs on the Haley upland as summarized in the table below.

ESTIMATED VERTICAL GRADIENTS AT SHALLOW/DEEP WELL PAIRS ON HALEY UPLAND

Shallow Well	Deep Well	Well Pair Location	Estimated Vertical Gradient
RW-2	TL-MW-11	East of sheet pile barrier	Downward (0.005 to 0.47 feet/foot), based on 2004-2011 data in Appendix B, Table B-6.
TL-MW-10	TL-MW-16	Near shoreline, south of sheet pile barrier	Upward (0.001 to 0.08 feet/foot), based on August 2012 and January-February 2013 data in Table 4-1.
TL-MW-12	TL-MW-13	Near shoreline, south of sheet pile barrier	Primarily upward (0.006 to 0.04 feet/foot), based on July-August 2012 and January-February 2013 data in Table 4-1 (slight downward gradients of 0.003 and 0.006 feet/foot were measured during two low tide events).

The differences in groundwater/potentiometric surface elevations measured in shallow/deep well pairs in August 2012 are depicted in the cross sections shown in Figures 4-5, 4-6 and 4-7.

Shallow/deep well pairs were not installed in the eastern portion of the Haley upland due to the small saturated thickness in this area. However, groundwater flow in the eastern portion of the upland is expected to have a slight downward component, reflecting the groundwater recharge (infiltration of precipitation/stormwater) assumed to occur in this area. The upward vertical gradients measured at well pairs TL-MW-10/TL-MW-16 and TL-MW-12/TL-MW-13 (near the shoreline south of the sheet pile barrier) suggest that groundwater flows slightly upward near the shoreline, consistent with findings for the Cornwall landfill shoreline wells (Landau 2013).

Groundwater flow is altered by the sheet pile barrier. The sheet piles extend to a maximum depth of approximately 19 feet bgs. The barrier was designed to restrict the migration of LNAPL in the shallow portion of the saturated zone, while allowing deeper groundwater to flow under the barrier. Groundwater mounding behind the sheet pile barrier increases downward vertical gradients locally and thus the potential for groundwater flow under the barrier. Groundwater elevations measured between 2006 and 2011 at well pair RW-2/TL-MW-11 confirm a downward gradient behind the barrier, ranging from 0.005 to 0.47 feet/foot. The magnitude of the vertical gradients near the upper end of this range, and the coarse texture of the fill materials behind the sheet pile barrier, suggest the potential for significant groundwater flow downward and under the barrier.

The groundwater flow model was used to generate three-dimensional views of groundwater flow in the vicinity of the sheet pile barrier (Figures 4-14, 4-15 and 4-16). The model-predicted groundwater flow pattern is represented by the groundwater particle tracking lines shown in Figures 4-14, 4-15 and 4-16. The particle tracking lines illustrate the expected flowpaths of discrete groundwater “particles” that flow toward the sheet pile barrier from the area east (upgradient) of the barrier. The model predicts that groundwater initially converges toward the barrier due to the lower hydraulic conductivities near the northern and southern ends of the barrier and the higher hydraulic conductivity east of the wall. As groundwater approaches the sheet pile barrier, some groundwater flows around the northern and southern ends of the barrier, but most of the groundwater flows downward and under the barrier. Figure 4-14 shows near-vertical upward groundwater flow west of the barrier, and Figure 4-16 shows steep downward groundwater flow east of the barrier.

4.2.2.5. GROUNDWATER RECHARGE AND DISCHARGE

Groundwater beneath the Haley upland is recharged primarily by precipitation that falls directly on the Site. Some recharge also may occur by the downslope movement of water in shallow soil that overlies the bedrock bluff east of the Site. Bedrock beneath the Haley upland is considered to be only a minor localized source of shallow groundwater recharge to the Site. As noted previously, groundwater beneath the upland discharges to Bellingham Bay. To estimate the volumetric rate of groundwater discharge to the Bay, the seasonally-variable groundwater recharge from precipitation was first estimated and used to calibrate the groundwater flow model. The model was then used to estimate groundwater discharge rates for each month of the year.

A water balance was previously conducted for the Haley upland using a numerical model (GeoEngineers 2000a) to assist in the design of the sheet pile barrier. The groundwater recharge rates used in the model were based on an assumed annual precipitation rate of 8 inches/year and an assumed recharge rate from the Chuckanut Formation of 1 gallon/minute (gpm) per 100 horizontal feet along the eastern property boundary. The estimated rate of groundwater discharge to Bellingham Bay calculated by the model under steady-state conditions was approximately 44 gpm, or 8,470 cubic feet per day (ft^3/day).

A more robust water balance was conducted using the updated groundwater flow model. The water balance was conducted for the month of July 2012; this period was selected because it included the most comprehensive site-wide groundwater level data that could be used to calibrate the model. Groundwater was assumed to be recharged by precipitation, stormwater discharging from the drainage culvert at the northeast corner of the Cornwall property, and precipitation retained in, or groundwater flowing beneath, the drainage ditch east of the railroad tracks and migrating into the Fill Unit (Appendix H, Figure H-4).

A conservative, default annual infiltration value based on MTCA Equation 747-5 was used for the water balance. The rate of groundwater recharge from infiltration of precipitation and stormwater was estimated to be approximately 3,000 ft^3/day, based on MTCA Equation 747-5 and the following assumptions:

- Average precipitation: 2.2 inches for the month of May, reflecting a two-month lag time to correspond to July groundwater level measurements (Western Regional Climate Center for Bellingham Station 450574)
- Percentage of precipitation that infiltrates: 70 percent
- Surface area of the model domain: 678,902 square feet (ft^2)
- Surface area of upland drainage basin that contributes stormwater to drainage culvert near northeast corner of Cornwall property: 27,547 ft^2
- Surface area of upland drainage basin that contributes stormwater to drainage ditch along railroad tracks east of Haley property: 210,912 ft^2
- Percentage of stormwater entering drainage culvert and drainage ditch that infiltrates: 50 percent

The estimated rate of groundwater recharge from infiltration (3,000 ft^3/day) was distributed among six separate recharge areas within the model domain to account for assumed differences in infiltration based on surface conditions (Appendix H, Figure H-4, and generally depicted in Figure 2-2):

- Area 1 — Unpaved areas along the shoreline.
- Area 2 — Paved areas. Precipitation falling on paved areas was assumed to be partially redistributed to adjoining unpaved areas to simulate runoff. Twenty percent of the total recharge from precipitation was assumed to infiltrate in paved areas; the remaining 80 percent was redistributed to adjoining unpaved areas.
- Area 3 — Vegetated area and drainage ditches east of the sheet pile barrier (Figure 2-2).
- Area 4 — Depression at the northeast corner of the Cornwall property at the outfall of the drainage culvert under the railroad tracks (Figure 2-2). Groundwater mounding appears to occur in this area as previously discussed.

- Area 5 — Vegetated area north of wells HS-MW-9 and HS-MW-17.
- Area 6 — Drainage ditch (Figure 2-2) along the railroad tracks. Infiltration in this ditch is from stormwater runoff from the bluff and groundwater seepage from the Chuckanut Formation.

The distribution of infiltration rates among these six areas was adjusted during the model calibration process. The calibrated model was used to estimate average daily groundwater discharge rates to Bellingham Bay for each month of the year, based on published monthly precipitation data for 2012. Total groundwater discharge rates estimated by the model vary from approximately 1,700 ft^3/day in September to approximately 7,100 ft^3/day in January (Table 4-3).

4.2.2.6. GROUNDWATER AND SURFACE WATER INTERACTION

Groundwater flow into Bellingham Bay is influenced by tides and interactions of fresh groundwater with intruding seawater in the subsurface groundwater-surface water mixing zone. Conceptually, submarine discharge of shallow, unconfined groundwater is assumed to occur relatively close to the shoreline. Groundwater flow modeling and observed vertical gradients suggest that more than 90 percent of the discharge of shallow groundwater beneath the Haley upland to Bellingham Bay is within 125 feet of the shoreline.

The vertical conductivity profile in groundwater was measured in selected monitoring wells to evaluate whether a salt water-freshwater boundary can be distinguished beneath the Haley upland. Conductivity measurements in monitoring wells near the shoreline with at least 10 feet of well screen extending below the groundwater table (wells HS-MW-6, HS-MW-7, TL-MW-1 and TL-MW-9) did not indicate evidence of a salt water-freshwater boundary (Table 4-4). However, the measured conductivity values in well TL-MW-9 were similar to seawater based on seawater conductivity measurements at three locations along the shoreline.

4.2.2.7. NON-POTABLE GROUNDWATER

Drinking water in the Site vicinity is currently supplied by the City. Water supply wells are not known to exist at or near the Site, and groundwater beneath the Site is not used as drinking water. Ecology has developed a non-potable classification for shallow groundwater at the Bellingham Bay waterfront cleanup sites (Ecology 2012). Ecology has decided that for most of these sites, including the Haley Site, shallow groundwater in fill is non-potable based on the criteria under WAC 173-340-720(2) (Section 5.0).

4.3. Natural Resources

This section discusses the upland and marine natural resources at the Site. The information presented is based on field surveys performed as part of the 2012 supplemental investigation, including an upland survey conducted in November 2012 to assess groundcover, vegetation, and use of the Site by wildlife; an intertidal habitat survey conducted on June 4 and 5, 2012, when tides were below MLLW; a subtidal habitat survey conducted between September 25 and 27, 2012; and a forage fish spawning survey conducted July 23, 2012.

4.3.1. Upland Environment

The ground surface in areas not covered by asphalt or concrete consists of a mixture of fill materials, including granular fill and gravel that in most upland areas is compacted from historical Site activities (Figure 2-2).

Vegetation along the perimeter of the investigative waste storage areas (Figure 2-2) consists of shrubs and small trees such as young red alder, young black cottonwood, butterfly bush, common tansy and Himalayan blackberry. Butterfly bush is listed as a Class B weed, and Himalayan blackberry is listed as a Class C weed, by the Washington State and Whatcom County Noxious Weed Control Boards. Other observed plant species include white sweet clover, thistle and burdock. Moss, tansy, and young butterfly bush were observed to be growing up through graveled areas and cracks and joints in paved areas.

Vegetation on the forested slope of the bluff east of the Haley property includes bigleaf maple and red alder; the understory consists of Himalayan blackberry and old man's beard/traveler's joy.

Wildlife observed at the Site during the November 2012 upland survey included dark-eyed juncos, glaucous-winged gulls, bufflehead, and double-crested cormorants. Deer scat and hoof prints were observed throughout the upland. The remains of a bird (scattered feathers and limb parts) were observed in one area. No evidence of vole runways or shallow burrows was observed. Similarly, no evidence of habitat use by shrews was observed (signs of habitat use by shrews can be difficult to find; however, shrews often co-exist with voles and make use of voles' runways). On previous visits to the Site, Canada geese and harbor seals were observed in Bellingham Bay adjacent to the upland.

Deer scat

Deer hoof prints

Ponded water observed in within a concrete depression did not appear to support aquatic life. A small patch of reed canary grass was observed in the southern corner of the concrete depression.

A marine riparian area approximately 90 to 100 feet wide exists along the upland shoreline bank. Vegetation within this marine riparian area consists of red alder, black cottonwood, Douglas-fir, Scotch broom, Himalayan blackberry, common tansy, and common mullein. The majority of the marine riparian area is dominated by grasses and weedy herbaceous species (e.g., tansy), with patches of native trees and non-native shrubs. Immediately southwest of the sheet pile barrier, ten Douglas-fir and four red alder trees

Marine Riparian Area: blackberry and small trees.

(15 to 30 feet tall) were observed along the shoreline bank.

4.3.1.1. LISTED SPECIES AND CRITICAL HABITAT

The table below provides a summary of species that are listed as endangered or threatened under the Federal Endangered Species Act (ESA), as well as critical habitats, that may occur at or near the Site (GeoEngineers 2013).

LISTED SPECIES AND CRITICAL HABITAT THAT MAY OCCUR AT OR NEAR THE SITE

Common Name	Scientific Name	Jurisdiction	Status	Critical Habitat
Bull Trout	*Salvelinus confluentus*	USFWS	Threatened	Designated[1]
Puget Sound Chinook Salmon	*Oncorhynchus tshawyscha*	NMFS	Threatened	Designated[1]
Puget Sound Steelhead	*Oncorhynchus mykiss*	NMFS	Threatened	N/A[2]
Southern Resident Killer Whale	*Orcinus orca*	NMFS	Endangered	Designated
Marbled Murrelet	*Brachyramphus marmoratus*	USFWS	Threatened	N/A[2]
Bocaccio Rockfish	*Sebastes paucispinis*	NMFS	Endangered	N/A[3]
Yelloweye Rockfish	*Sebastes ruberrimus*	NMFS	Threatened	N/A[3]
Canary Rockfish	*Sebastes pinniger*	NMFS	Threatened	N/A[3]

Notes:

USFWS – U.S. Fish and Wildlife Service

NMFS – National Marine Fisheries Service

N/A – Not Applicable

[1.] Includes nearshore marine areas in Puget Sound.

[2.] Although critical habitat has been designated (proposed for Steelhead) for this species, it does not occur at the Site.

[3.] Critical habitat has not been designated at this time for these species.

Refer to the recent Biological Evaluation (GeoEngineers 2013) for additional information specific to ESA-listed species and critical habitats that may occur in Whatcom County and/or Puget Sound but are not expected to occur at the Haley Site.

The species and critical habitats listed in the table above are discussed further below. In addition to these species and habitats, priority habitats and species data (WDFW 2013) indicate that two priority seabird colonies (glaucus-winged gull and pigeon guillemot) exist approximately 1 mile northwest of the Site, and two priority harbor seal haul-outs are present just south of the Site.

Bull Trout (*Salvelinus confluentis*)

Bull trout are known to occur in the Nooksack River (WDFW 2013), and may occur in Whatcom Creek (Whatcom County 2005). Because these waterways empty into Bellingham Bay, bull trout may occasionally be present in marine areas near the Site. Eelgrass beds in the vicinity of the Site may provide suitable habitat for bull trout.

Puget Sound Chinook Salmon (*Oncorhynchus tshawytscha*)

Puget Sound Chinook salmon occur in Whatcom Creek, Squalicum Creek and the Nooksack River (WDFW 2013), all of which empty into Bellingham Bay. Accordingly, Chinook salmon may occasionally be present in marine areas near the Site. Eelgrass beds in the vicinity of the Site may provide suitable habitat for Chinook salmon.

Puget Sound Steelhead (*Oncorhynchus mykiss*)

Puget Sound steelhead occur in Whatcom Creek, Squalicum Creek and the Nooksack River (WDFW 2013). Critical habitat criteria and areas for Puget Sound steelhead have not yet been developed, although NOAA proposed critical habitat areas for Puget Sound steelhead on January 14, 2013 (78 FR 2726). Bellingham Bay is not included in the proposed critical habitat areas. Eelgrass beds in the vicinity of the Site may provide suitable foraging habitat for steelhead.

Southern Resident Killer Whale (*Orcinus orca*)

Although not often observed in Bellingham Bay (NOAA 2013), killer whales may occasionally occur in deeper-water areas of the Bay. However, because killer whales do not frequent nearshore areas with shallow water depths, the marine portion of the Haley Site likely does not constitute favorable habitat for southern resident killer whales.

Marbled Murrelet (*Brachyramphus marmoratus*)

Marbled murrelets are small seabirds that forage in the nearshore marine environment and nest in large trees in coniferous forests, as far as 50 miles inland. Even when not foraging, they spend most of their time on the water (USFWS 1997). Although marbled murrelets may occasionally be present in the marine portion of the Site, the high level of human activity in the Site vicinity, including marine vessel traffic, likely discourages their utilization of the Site. Murrelets are more likely to be found in nearshore environments farther from urban development, such as near the northern or western shores of Bellingham Bay, and/or in Chuckanut Bay to the south, which has been identified as an area of winter concentration for murrelets (USFWS 1997).

Designated critical habitat for marbled murrelets includes large continuous blocks of nesting habitat (i.e., old growth forest) located proximal to marine foraging habitat, but does not include marine areas (61 FR 26255). The terrestrial habitats in the Site vicinity are urban, and do not include critical habitat for marbled murrelets.

Rockfishes

Rockfish habitat information presented in this section is summarized from the information presented in the proposed listing (74 FR 18516) and final rule (75 FR 22275) published in the Federal Register. Adult rockfish are generally benthic organisms that prefer rocky bottoms and outcrops, and feed on bottom and mid-water dwelling invertebrates and small fishes. Juveniles feed primarily on zooplankton.

Adult bocaccio rockfish are most commonly found at water depths ranging from 160 to 820 feet, but sometimes inhabit waters as shallow as 40 feet. Bocaccio rockfish are rare in the North Puget Sound, where the Haley Site is located. Adult yelloweye rockfish are most commonly found at water depths ranging from 300 to 590 feet and are not known to inhabit waters less than 80 feet deep. Yelloweye rockfish are relatively common in the North Puget Sound. Adult canary rockfish are most commonly found at water depths ranging from 160 to 820 feet. This species is highly associated with rocky or coarse sediment habitats. Canary rockfish are relatively common in the North Puget Sound.

Because of the Site location in the North Puget Sound, it is unlikely that bocaccio rockfish would be found at the Site. Additionally, marine habitat conditions at the Site generally are unfavorable for the rockfish species discussed above. These species generally occur in rocky areas or areas with hard substrates, and adults are typically found at water depths much greater than those at the Site.

4.3.2. Aquatic Environment

4.3.2.1. INTERTIDAL ENVIRONMENT

An intertidal habitat survey was performed at the Site on June 4 and 5, 2012 when tides were below MLLW. The survey was conducted along ten transects extending from approximately +10 feet to -2 feet (NAVD88) (Figure 4-18).

There is a general pattern of decreasing grain size with decreasing bottom elevation across the intertidal zone (Figure 4-17). In the upper tidal zone (extending from approximately +10 feet to +8 feet), particle sizes are large (e.g., 1- to 3-foot median diameter) and substrates are composed of sandstone boulders, riprap, and/or concrete. Along some transects, the upper tidal zone has patches of mixed sand, gravel, glass, and shell fragments. At or above +10 feet, terrestrial vegetation in the form of small trees, shrubs and weedy herbs dominate, while below +10 feet sparse patches of lichen and filamentous algae dominate.

Below the upper tidal zone is the Fucus Zone (*Fucus* spp.), extending from approximately +8 feet to +3 feet (NAVD88). *Fucus* are a type of brown macroalgae commonly known as wrack or rockweed. *Enteromorpha* spp., a type of green macroalgae, were also observed within the Fucus Zone. Substrates in this zone generally consist of sandstone boulders, riprap, and/or concrete in the upper half and sand, gravel and cobble/brick/concrete in the lower half. Animal life observed in the Fucus Zone included barnacles, mussels, limpets, littorinid snails and shore crabs.

Below the Fucus Zone is the Ulva Zone (*Ulva* spp.), extending from approximately +3 feet to 0 feet (NAVD88). *Ulva* are a type of green macroalgae commonly known as sea lettuce. Although *Ulva* are present from +8 to -2 feet, they are most dominant in the Ulva Zone. Gravel, sand, shells and glass are the dominant substrates in the Ulva Zone. *Ulva* has colonized scattered pieces of cobble, brick, concrete, and/or wood. Barnacles and shore crabs were the most common animals observed in the Ulva Zone.

Below the Ulva Zone is the Eelgrass Zone, extending from approximately 0 feet to -12 feet (NAVD88). The lower portion of the Eelgrass Zone is within the subtidal zone, and eelgrass observed in the intertidal zone extended into the subtidal zone. Eelgrass is a marine grass that grows submerged or partially floating in sandy or muddy substrates of the lower intertidal/subtidal zone (approximately 0 feet to -10 feet). In the vicinity of Transect 9 (Figure 4-18) eelgrass was observed growing above -2 feet; however, throughout the rest of the survey area, the landward edge of the eelgrass is below -2 feet. The observed eelgrass area boundaries are shown in Figure 4-19.

Relatively large derelict wood piles (extending 3 to 8 feet above the mudline) were observed in the upper half of the survey area (+10 feet to +2.5 feet) in the vicinity of all transects except Transect 1, while smaller derelict piles (extending 0 to 1 foot above the mudline) were observed in the lower half of the survey area (+5 feet to -2 feet). Wood debris (large logs approximately 5 to 10 feet long and 12 to 24 inches in diameter) was observed in the upper portion of the survey area; the wood debris is mixed in with large rock.

Half-buried logs filled with burrowed holes, likely from shipworms (Teredinidae), were observed along some transects in the lower portion of the survey area (+3 to -2 feet). In some locations, grayish-black water with a hydrogen sulfide odor was surfacing from beneath these logs. Other types of wood debris observed at the Site include old planks and driftwood.

4.3.2.2. SUBTIDAL ENVIRONMENT

GeoEngineers conducted a benthic habitat survey in the subtidal zone between September 25 and 27, 2012 (Appendix M). The survey was conducted using side-scan sonar and scuba diving techniques. Multiple patches of eelgrass with moderate to high densities were observed totaling approximately 11,665 square feet (Figure 4-19). Eelgrass generally is distributed between -2.5 feet and -12.5 feet (NAVD88), with the greatest densities occurring at an elevation of approximately -6.5 feet. The eelgrass distribution generally runs parallel to the shoreline as shown in Figure 4-19.

Besides characterizing the distribution of eelgrass, the benthic survey of the subtidal zone also identified numerous juvenile Dungeness crabs and significant amounts of submerged debris.

4.3.2.3. FORAGE FISH

Three species of forage fish (Pacific herring, surf smelt, and Pacific sand lance) are commonly present in North Puget Sound and Bellingham Bay. Other species that may be present in these water bodies include northern anchovy, eulachon and longfin smelt. Forage fish are a major food source for many other species, including threatened and endangered species (e.g., salmonids and murrelets).

Two common forage fish species (surf smelt and Pacific sand lance) are known to spawn within several hundred feet north of the Haley property at the Port beach parcel (WDFW 2013; Figure 1-2). Surf smelt may spawn year round in the uppermost (above +6.5 feet [NAVD88]) portion of a beach in coarse sand and gravel substrates, whereas sand lance spawn from November to February in fine to medium sands slightly lower on a beach (+4.5 feet to +8 feet [NAVD88]). Although Pacific herring often use eel grass as a spawning substrate, they have not been documented as spawning in the eelgrass on or adjacent to the Haley Site.

GeoEngineers conducted a forage fish spawning survey on July 23, 2012 along the Haley shoreline. As part of this survey, the presence of spawning substrate and fish eggs in the upper intertidal zone (between +5.5 feet and +7.5 feet [NAVD88]) was evaluated according to WDFW protocols at four locations. The only portion of the Site with appropriate surf smelt spawning substrate was near the northwestern margin of the Haley property, adjacent to the public access beach. All other substrates in the upper intertidal zone were coarser-grained than the substrate required by forage fish. No fish eggs were observed at the time of the survey.

4.4. Historical and Cultural Resources

Historical and cultural resources in the vicinity of the Site were evaluated by the Port and City through the Waterfront District EIS (Northwest Archaeological Associates 2007) and recently for the intertidal portion of the Site for the Interim Action (Cultural Resources Consultants, Inc. 2013).

Prior to the 19th century, ancestors of the present-day Lummi Nation and Nooksack Indian Tribe traditionally occupied the Bellingham waterfront (Northwest Archaeological Associates 2007).

Historical settlement or subsistence activities in the Site vicinity by Native Americans may have included shellfish gathering, fishing and hunting (Northwest Archaeological Associates 2007).

The upland portion of the Haley Site is mapped in the Port EIS as "high probability" of finding "intact Native American archaeological materials." However, with the exception of a narrow area at the base of the bluff along the railroad tracks east of the Haley property, the Haley upland was utilized for wharf, lumber and other industrial activities during and after filling began in about 1890, and therefore it is unlikely that cultural resources would be encountered in the filled areas. Buried cultural artifacts were not encountered during the 2012 supplemental investigation or previous investigations at the Site.

Archaeologically sensitive areas (i.e., former Native American fishing encampments) are located near the Haley Site (Northwest Archaeological Associates 2007). Typical buried cultural artifacts found in these areas are characterized as chipped or ground stone, historical refuse, building foundations, or human bone. Based on the Site's proximity to mapped archaeologically sensitive areas, it is possible that buried cultural artifacts may be present on the former tidal flat surface at the base of the bluff or beneath the deepest (oldest) fill on the Haley Site.

The marine portions of the Site are mapped in the Port EIS as "low probability" of finding archaeological materials. Consistent with the Port EIS, a cultural resources assessment conducted in 2013 (Cultural Resources Consultants, Inc. 2013) to support permitting for the interim action at the Haley Site indicated a low potential for buried cultural resources in the intertidal portion of the Site. Additionally, there are no designated historic structures at the Haley Site (Washington State Department of Archaeology and Historic Preservation on-line database; http://www.dahp.wa.gov/learn-and-research/find-a-historic-place).

4.5. Land and Navigational Uses

Current owners of the parcels comprising the Site and adjoining areas include the City, Washington State, Port and Neilsen Brothers Inc. (Figure 1-2). The Site is currently fenced and unused except for environmental investigation.

Land use planning activities for the Site led by the Port and City are currently underway as part of the Waterfront District master planning as discussed in Section 1.0.

The City Parks and Recreation Department recently completed the Master Plan for Cornwall Beach Park (City 2014), a proposed 17-acre park comprising the upland (City- and State-owned) and intertidal portions (State-owned) of the Cornwall site and the Haley Site. Consistent with the proposed Waterfront District Sub-Area Plan, the Cornwall Beach Master Plan includes such features as enhanced shoreline access, shoreline and beach restoration, paved and lighted parking with associated underground utilities and other park amenities such as restrooms, picnic shelters, a playground, a pavilion and concessions. Remedial alternatives for the Site, presented in the FS (Sections 9.0 and 10.0), are consistent with known redevelopment plans for the Site.

Marine vessel traffic through the marine areas on or near the Site includes vessels entering and leaving the Whatcom Waterway, Bellingham Shipping Terminal, and nearby barge dock. Marine vessels are not typically anchored at or offshore of the Site. Former pier and wharf structures historically associated with the Site have been removed, and future installation of such structures at the Site is not anticipated.

Table 4-1

Monitoring Well Groundwater Elevations and LNAPL Thickness December 2010 through February 2013

R.G. Haley Site

Bellingham, Washington

Location	Elevation Top of Casing (TOC) (feet NAVD88)	Approximate Elevation Top of Screen (NAVD88)	Date Measured	Time Measured	Depth to LNAPL (feet below TOC)	Depth to Water (feet below TOC)	LNAPL Thickness (feet)	Groundwater Elevation (Corrected for LNAPL Thickness If Present)[1] (feet NAVD88)
Groundwater Monitoring Wells on Haley Upland								
HS-MW-4	15.64	13	10/10/2011	847	--	8.88	0	6.76
			5/3/2012	NA	--	6.91	0	8.73
			5/8/2012	1308	--	7.10	trace[2]	8.54
			7/17/2012	1020	--	7.82	0	7.82
			7/30/2012	1723	--	7.97	0	7.67
			8/9/2012	1230	--	8.18	0	7.46
HS-MW-5	14.39	12	10/10/2011	841	--	8.18	0	7.46
			5/3/2012	NA	--	6.07	0	9.57
			5/8/2012	1303	--	6.26	0	9.38
			7/17/2012	1140	--	7.01	0	8.63
			8/9/2012	1225	--	7.52	0	8.12
HS-MW-6	11.81	8	12/14/2010	1150	--	3.13	0	12.51
			10/10/2011	930	--	6.43	0	9.21
			12/13/2011	1110	--	4.76	0	10.88
			5/3/2012	NA	--	5.01	0	10.63
			5/8/2012	1235	--	5.37	0	10.27
			7/17/2012	1050	--	6.05	0	9.59
			7/30/2012	1713	--	5.31	0	10.33
			8/9/2012	1305	--	5.71	0	9.93
			9/24/2012	1311	--	6.23	0	9.41
			12/12/2012	1405	--	3.52	0	12.12
			1/22/2013	1433	--	4.28	0	11.36
HS-MW-7	15.22	11	5/3/2012	NA	--	6.82	0	8.82
			5/8/2012	1307	--	7.01	trace[2]	8.63
			7/17/2012	1038	--	7.93	0	7.71
			8/9/2012	1235	--	8.57	0	7.07
HS-MW-8	14.33	10	5/3/2012	NA	Not gauged - inaccessible during monitoring event			
			7/17/2012	1030	7.13	7.29	0.16	7.19
			7/30/2012	1721	--	7.52	trace[2]	6.81
			8/9/2012	1245	7.75	7.94	0.19	6.39
HS-MW-9	14.05	11	10/10/2011	836	--	7.89	0	6.44
			5/3/2012	NA	--	5.79	0	8.54
			5/8/2012	1300	--	5.89	0	8.44
			7/17/2012	1135	--	6.43	0	7.90
			8/9/2012	1218	--	7.11	0	7.22
HS-MW-13	13.44	6	5/3/2012	NA	--	5.02	0	9.31
			5/8/2012	1255	--	5.32	0	9.01
			7/17/2012	1025	--	6.26	0	8.07
			8/9/2012	1245	--	6.85	0	7.48

Location	Elevation Top of Casing (TOC) (feet NAVD88)	Approximate Elevation Top of Screen (NAVD88)	Date Measured	Time Measured	Depth to LNAPL (feet below TOC)	Depth to Water (feet below TOC)	LNAPL Thickness (feet)	Groundwater Elevation (Corrected for LNAPL Thickness If Present)[1] (feet NAVD88)
HS-MW-15	11.88	4	5/3/2012	NA	--	4.82	0	9.51
			5/8/2012	1225	--	4.87	0	9.46
			7/17/2012	1045	--	5.12	0	9.21
			7/30/2012	1716	--	5.40	0	8.93
			8/9/2012	1258	--	5.99	0	8.34
HS-MW-16	11.76	4	5/3/2012	NA	--	4.28	0	10.05
			5/8/2012	1220	--	4.35	0	9.98
			7/17/2012	1040	--	4.46	0	9.87
			8/9/2012	1250	--	5.15	0	9.18
HS-MW-17	13.11	10	7/11/2012	1100	--	5.32	0	9.01
			7/17/2012	1130	--	5.52	0	8.81
			7/30/2012	1725	--	8.33	0	6.00
			8/9/2012	1210	--	6.19	0	8.14
HS-MW-19	16.06	14	7/12/2012	1446	--	7.16	0	7.17
			7/17/2012	1035	--	7.40	0	6.93
			8/9/2012	1238	--	8.06	0	6.27
TL-MW-1	13.7	10	12/14/2010	1105	--	5.57	0	8.76
			3/21/2011	1220	--	6.35	0	7.98
			6/15/2011	1410	--	7.33	0	7.00
			9/22/2011	850	--	8.49	0	5.84
			10/10/2011	1150	--	7.95	0	6.38
			12/13/2011	943	--	6.89	0	7.44
			3/26/2012	1025	--	6.04	0	8.29
			5/3/2012	NA	--	6.49	0	7.84
			5/8/2012	1250	--	6.64	0	7.69
			7/17/2012	1120	--	7.33	0	7.00
			7/30/2012	1658	--	7.78	0	6.55
			8/9/2012	1344	--	7.82	0	6.51
			9/24/2012	1105	--	8.54	0	5.79
			12/12/2012	1230	--	6.15	0	8.18
			1/10/2013	900	--	5.97	0	8.36
			1/15/2013	1208	--	6.40	0	7.93
			1/22/2013	1410	--	6.50	0	7.83
			1/29/2013	1005	--	6.62	0	7.71
			2/6/2013	1245	--	6.45	0	7.88
			2/14/2013	1019	--	7.02	0	7.31
			2/20/2013	1255	--	7.05	0	7.28

Location	Elevation Top of Casing (TOC) (feet NAVD88)	Approximate Elevation Top of Screen (NAVD88)	Date Measured	Time Measured	Depth to LNAPL (feet below TOC)	Depth to Water (feet below TOC)	LNAPL Thickness (feet)	Groundwater Elevation (Corrected for LNAPL Thickness If Present)[1] (feet NAVD88)
TL-MW-2	14.93	13	12/14/2010	1325	5.64	7.86	2.22	6.47
			3/21/2011	1405	6.75	12.95	6.20	1.38
			6/18/2011	1405	8.14	11.83	3.69	2.50
			9/22/2011	1040	9.26	10.23	0.97	4.10
			10/10/2011	1110	8.80	9.75	0.95	4.58
			12/13/2011	1150	7.75	8.79	1.04	5.54
			5/3/2012	NA	6.74	11.73	4.99	2.60
			6/29/2012	1345	8.17	8.41	0.24	5.92
			8/9/2012	1408	8.29	11.22	2.93	3.11
			9/24/2012	1356	9.02	11.40	2.38	2.93
			12/12/2012	1245	6.23	11.09	4.86	3.24
			1/10/2013	849	5.87	11.42	5.55	2.91
			1/15/2013	1217	6.30	12.22	5.92	2.11
			1/22/2013	1425	6.80	10.61	3.81	3.72
			1/29/2013	1000	6.68	11.72	5.04	2.61
			2/6/2013	1230	6.73	10.63	3.90	3.70
			2/14/2013	1030	7.23	11.70	4.47	2.63
			2/20/2013	1250	7.33	11.62	4.29	2.71
TL-MW-3	12.43	12	12/14/2010	1310	3.33	3.90	0.57	10.43
			3/21/2011	1350	4.49	5.35	0.86	8.98
			6/15/2011	1350	5.88	6.50	0.62	7.83
			9/22/2011	1030	7.11	8.16	1.05	6.17
			10/10/2011	1055	6.80	7.95	1.15	6.38
			12/13/2011	1135	5.55	6.21	0.66	8.12
			5/3/2012	NA	4.51	5.20	0.69	9.13
			8/9/2012	1415	6.16	7.18	1.02	7.15
			9/24/2012	1340	6.89	7.40	0.51	6.93
			12/12/2012	1305	4.08	4.32	0.24	10.01
TL-MW-4	11.62	11	12/14/2010	1235	2.49	4.98	2.49	9.35
			3/21/2011	1335	4.61	9.20	4.59	5.13
			6/15/2011	1328	6.44	9.96	3.52	4.37
			9/22/2011	955	7.17	8.65	1.48	5.68
			10/10/2011	1017	6.11	6.72	0.61	7.61
			12/13/2011	1115	4.89	5.90	1.01	8.43
			5/3/2012	NA	4.40	5.21	0.81	9.12
			6/29/2012	1338	5.18	5.72	0.54	8.61
			8/9/2012	1425	5.60	6.21	0.61	8.12
			9/24/2012	1326	--	8.25	0	6.08
			12/12/2012	1340	3.28	4.15	0.87	10.18

Location	Elevation Top of Casing (TOC) (feet NAVD88)	Approximate Elevation Top of Screen (NAVD88)	Date Measured	Time Measured	Depth to LNAPL (feet below TOC)	Depth to Water (feet below TOC)	LNAPL Thickness (feet)	Groundwater Elevation (Corrected for LNAPL Thickness If Present)[1] (feet NAVD88)
TL-MW-5A	12.49	10	12/14/2010	1215	3.33	4.30	0.97	10.03
			3/21/2011	1302	4.89	6.09	1.20	8.24
			6/15/2011	1320	6.38	8.51	2.13	5.82
			9/22/2011	930	7.35	8.52	1.17	5.81
			10/10/2011	958	--	8.23	0	6.10
			12/13/2011	1045	5.76	5.9	0.14	8.43
			5/3/2012	NA	5.01	5.74	0.73	8.59
			6/29/2012	1333	5.95	6.41	0.46	7.92
			8/9/2012	1430	6.34	7.12	0.78	7.21
			9/24/2012	1321	7.10	7.65	0.55	6.68
			12/12/2012	1355	4.04	4.29	0.25	10.04
TL-MW-6	11.72	9	12/14/2010	1210	3.36	3.37	0.01	10.96
			3/21/2011	1310	8.02	9.25	1.23	5.08
			6/15/2011	1315	10.12	12.04	1.92	2.29
			9/22/2011	935	9.14	9.36	0.22	4.97
			10/10/2011	1010	--	6.80	0	7.53
			12/13/2011	1055	--	5.22	0	9.11
			5/3/2012	NA	7.92	8.78	0.86	5.55
			8/9/2012	1435	6.68	6.71	0.03	7.62
			9/24/2012	1319	--	7.00	0	7.33
			12/12/2012	1358	--	3.82	0	10.51
			1/22/2013	1354	5.23	5.28	0.05	9.05
			1/29/2013	950	5.46	5.50	0.04	8.83
			2/6/2013	1220	--	4.56	0	9.77
			2/14/2013	1006	5.74	5.83	0.09	8.50
			2/20/2013	1240	5.73	5.88	0.15	8.45
TL-MW-7	12.21	10	12/14/2010	1200	3.84	3.84	trace[2]	10.49
			3/21/2011	1315	4.75	4.77	0.02	9.56
			6/15/2011	1300	--	6.04	trace[2]	8.29
			9/22/2011	940	--	7.03	0	7.30
			10/10/2011	940	--	6.71	0	7.62
			12/13/2011	1105	--	5.42	0	8.91
			5/3/2012	NA	--	4.75	0	9.58
			5/8/2012	1240	--	4.99	trace[2]	9.34
			8/9/2012	1440	6.19	6.21	0.02	8.12
			9/24/2012	1314	--	7.02	0	7.31
			12/12/2012	1400	--	4.68	0	9.65

Location	Elevation Top of Casing (TOC) (feet NAVD88)	Approximate Elevation Top of Screen (NAVD88)	Date Measured	Time Measured	Depth to LNAPL (feet below TOC)	Depth to Water (feet below TOC)	LNAPL Thickness (feet)	Groundwater Elevation (Corrected for LNAPL Thickness If Present)[1] (feet NAVD88)
TL-MW-8	14.56	12	12/14/2010	1115	--	5.61	0	8.72
			3/21/2011	1230	6.65	6.93	0.28	7.40
			6/15/2011	1225	8.11	8.52	0.41	5.81
			9/22/2011	900	9.94	10.05	0.11	4.28
			10/10/2011	1120	8.90	9.3	0.40	5.03
			12/13/2011	955	7.83	7.97	0.14	6.36
			5/3/2012	NA	6.85	7.91	1.06	6.42
			8/9/2012	1400	8.39	8.84	0.45	5.49
			9/24/2012	1111	9.12	9.71	0.59	4.62
			12/12/2012	1240	6.23	6.26	0.03	8.07
			1/10/2013	910	5.50	5.59	0.09	8.74
			1/15/2013	1215	--	6.51	0	7.82
			1/22/2013	1417	--	6.99	0	7.34
			1/29/2013	1025	6.62	6.64	0.02	7.69
			2/6/2013	1235	--	6.91	0	7.42
			2/14/2013	1012	--	7.50	0	6.83
			2/20/2013	1303	--	7.57	0	6.76
TL-MW-9	13.73	11	12/14/2010	1110	--	4.83	0	9.50
			3/21/2011	1225	--	5.50	0	8.83
			6/15/2011	1205	--	8.10	0	6.23
			9/22/2011	855	--	5.96	0	8.37
			10/10/2011	1130	--	8.20	0	6.13
			12/13/2011	948	--	5.90	0	8.43
			3/26/2012	1030	--	5.78	0	8.55
			5/3/2012	NA	--	7.13	0	7.20
			5/8/2012	1248	--	7.22	0	7.11
			7/17/2012	1115	--	7.73	0	6.60
			7/30/2012	1700	--	7.16	0	7.17
			8/9/2012	1346	--	7.81	0	6.52
			9/24/2012	1108	--	8.56	0	5.77
			12/12/2012	1235	--	6.02	0	8.31
			1/10/2013	905	--	6.13	0	8.20
			1/15/2013	1211	--	6.71	0	7.62
			1/22/2013	1415	--	6.83	0	7.50
			1/29/2013	1010	--	6.63	0	7.70
			2/6/2013	1250	--	6.33	0	8.00
			2/14/2013	1024	--	7.12	0	7.21
			2/20/2013	1300	--	7.32	0	7.01

Location	Elevation Top of Casing (TOC) (feet NAVD88)	Approximate Elevation Top of Screen (NAVD88)	Date Measured	Time Measured	Depth to LNAPL (feet below TOC)	Depth to Water (feet below TOC)	LNAPL Thickness (feet)	Groundwater Elevation (Corrected for LNAPL Thickness If Present)[1] (feet NAVD88)
TL-MW-10	13.01	3	12/14/2010	1335	--	5.08	0	9.25
			3/21/2011	1155	9.13	9.21	0.08	5.12
			10/10/2011	1135	--	9.81	0	4.52
			12/13/2011	930	6.85	6.98	0.13	7.35
			5/3/2012	NA	9.38	9.44	0.06	4.89
			8/9/2012	1338	7.93	8.12	0.19	6.21
			9/24/2012	1100	10.20	10.55	0.35	3.78
			12/12/2012	1215	6.73	7.12	0.39	7.21
			1/10/2013	935	6.64	6.96	0.32	7.37
			1/15/2013	1120	7.20	7.80	0.60	6.53
			1/22/2013	1402	6.66	7.10	0.44	7.23
			1/29/2013	1030	7.05	7.10	0.05	7.23
			2/6/2013	1250	--	6.45	0	7.88
			2/14/2013	951	7.10	7.15	0.05	7.18
			2/20/2013	1315	7.19	7.21	0.02	7.12
TL-MW-11	14.93	-1	12/14/2010	1127	--	6.42	0	7.91
			3/21/2011	1250	--	10.52	0	3.81
			6/15/2011	1243	--	12.71	0	1.62
			9/22/2011	1010	--	11.38	0	2.95
			12/13/2011	1035	--	8.44	0	5.89
			5/3/2012	NA	--	10.69	0	3.64
			5/8/2012	1243	--	11.74	0	2.59
			7/17/2012	1100	--	12.23	Note 2	2.10
			8/9/2012	1355		9.82	0	4.51
			9/24/2012	1303	--	10.42	0	3.91
			12/12/2012	1315	--	7.12	0	7.21
TL-MW-12	14.66	12	7/11/2012	1750	--	8.70	0	5.63
			7/17/2012	1119	--	9.34	0	4.99
			7/30/2012	1650	--	9.02	0	5.31
			8/9/2012	1329	9.14	9.17	0.03	5.16
			1/10/2013	915	7.09	7.45	0	6.88
			1/15/2013	1150	7.64	8.12	0.48	6.21
			1/22/2013	1338	7.70	8.00	0.30	6.33
			1/29/2013	1055	7.78	8.36	0.58	5.97
			2/6/2013	1310	7.48	7.64	0.16	6.69
			2/14/2013	933	8.17	8.90	0.73	5.43
			2/20/2013	1325	8.26	8.62	0.36	5.71

Location	Elevation Top of Casing (TOC) (feet NAVD88)	Approximate Elevation Top of Screen (NAVD88)	Date Measured	Time Measured	Depth to LNAPL (feet below TOC)	Depth to Water (feet below TOC)	LNAPL Thickness (feet)	Groundwater Elevation (Corrected for LNAPL Thickness If Present)[1] (feet NAVD88)
TL-MW-13	14.6	-28	7/12/2012	1045	--	9.98	0	4.35
			7/17/2012	1121	--	9.51	0	4.82
			7/30/2012	1652	--	8.31	0	6.02
			8/9/2012	1333		8.64	0	5.69
			1/10/2013	920	--	6.79	0	7.54
			1/15/2013	1153	--	7.75	0	6.58
			1/22/2013	1348	--	7.19	0	7.14
			1/29/2013	1055	--	7.20	0	7.13
			2/6/2013	1305	--	7.19	0	7.14
			2/14/2013	940	--	6.71	0	7.62
			2/20/2013	1330	--	7.37	0	6.96
TL-MW-14	13.9	-13	7/12/2012	1730	--	7.86	0	6.47
			7/17/2012	1054	--	8.24	0	6.09
			7/30/2012	1710	--	8.38	0	5.95
			8/9/2012	1353	--	8.36	0	5.97
TL-MW-15	14.85	-12	7/12/2012	1615	--	8.36	0	5.97
			7/17/2012	1108	--	9.27	0	5.58
			7/30/2012	1702	--	8.49	0	6.36
			8/9/2012	1350		8.91	0	5.94
TL-MW-16	12.99	-16	7/12/2012	1230	--	6.35	0	8.50
			7/17/2012	1134	--	7.29	0	7.56
			7/30/2012	1654	--	6.23	0	8.62
			8/9/2012	1335	--	6.81	0	8.04
			1/10/2013	931	Note 1	5.41	0	9.44
			1/15/2013	1200	--	5.75	0	9.10
			1/22/2013	1354	--	5.60	0	9.25
			1/29/2013	1035	--	5.83	0	9.02
			2/6/2013	1300	--	6.41	0	8.44
			2/14/2013	947	--	6.05	0	8.80
			2/20/2013	1318	--	6.12	0	8.73
Groundwater Monitoring Wells on Cornwall Property								
CL-MW-1	13.68	11	5/3/2012	NA	--	4.49	0	9.19
			5/8/2012	1247	--	4.73	0	8.95
			7/17/2012	1048	--	5.74	0	7.94
			8/9/2012	1316	--	6.33	0	7.35
CL-MW-1H	17.89	9	5/3/2012	NA	--	6.25	0	7.43
			5/8/2012	1304	--	6.55	0	7.13
			7/17/2012	1030	--	8.67	0	5.01
			8/9/2012	1240	--	9.45	0	4.23
CL-MW-6	15.89	5	5/3/2012	NA	--	4.51	0	9.17
			5/8/2012	1256	--	4.78	trace[2]	8.90
			7/17/2012	1059	--	6.78	0	6.90
			8/9/2012	1310	--	7.50	0	6.18

Location	Elevation Top of Casing (TOC) (feet NAVD88)	Approximate Elevation Top of Screen (NAVD88)	Date Measured	Time Measured	Depth to LNAPL (feet below TOC)	Depth to Water (feet below TOC)	LNAPL Thickness (feet)	Groundwater Elevation (Corrected for LNAPL Thickness If Present)[1] (feet NAVD88)
CL-MW-9	13.62	3	5/3/2012	NA	--	4.39	0	9.29
			5/8/2012	1245	--	4.62	0	9.06
			7/17/2012	1044	--	5.41	0	8.27
			8/9/2012	1320	--	6.40		7.28
CL-MW-101	13.06	9	7/11/2012	1316	--	4.52	0	9.16
			7/17/2012	1106	--	4.76	0	8.92
			8/9/2012	1323	--	5.39	0	8.29
CL-MW-102	14.27	10	7/11/2012	1422	--	5.31	0	8.37
			7/17/2012	1103	--	5.51	0	8.17
			8/9/2012	1313	--	5.83		7.85
CL-MW-103	14.41	12	7/11/2012	1600	--	5.03	0	8.65
			7/17/2012	1110	--	5.31	trace[2]	8.37
			7/30/2012	1643	--	5.77	trace[2]	7.91
			8/9/2012	1308	--	6.09	0	8.32

Notes:

[1] Corrected groundwater elevation based on the formula Corrected Groundwater Elevation = ((Reference Elevation at Top of Casing - Depth to Groundwater in Feet) + (LNAPL Thickness in Feet)*(LNAPL Specific Gravity))

[2] Trace refers to indication of LNAPL on probe but thickness not measureable (less than 0.01 feet). References to "sheen" indicate that visible sheen was noted on the surface of groundwater removed from the well.

Note 1: 01/10/13 reading at TL-MW-16: oil/water interface probe signal indicated possible LNAPL, however there was no visible evidence of LNAPL in the well on this date or other indications of possible LNAPL on other dates, therefore the reading was considered anomalous (not verifiable).

Note 2: 07/17/12 reading at TL-MW-11: Depth to water indicator probe had trace brown product during this reading however there was no visible evidence of LNAPL on groundwater from the well on this date, the observation may have been affected by nearby wells.

Table 4-2

Summary of Hydraulic Conductivity Values

R.G. Haley Site
Bellingham, Washington

Monitoring Well	Well Screen Position and Hydrostatigraphic Unit	Methodology[1]	Date	(ft/day)	(cm/sec)
Fill Unit					
TLMW-1	Shallow; Fill Unit	Tidal Monitoring Study	April 8 to 11, 2000	3.2	1.1E-03
		Tidal Monitoring Study	July 30 to August 8, 2012	2.0	7.1E-04
TL-MW-2	Shallow; Fill Unit	Exploration Soil Sample Grain Size Data (average of values calculated from soil samples at 14 and 19 feet bgs)	July 1, 2000	19	6.5E-03
TL-MW-3	Shallow; Fill Unit	Tidal Monitoring Study	April 8 to 11, 2000	3.1	1.1E-03
TL-MW-4	Shallow; Fill Unit	Tidal Monitoring Study	April 8 to 11, 2000	13.3	4.7E-03
TL-MW-9	Shallow; Fill Unit	Tidal Monitoring Study	July 30 to August 8, 2012	3.0	1.1E-03
TL-MW-11	Discrete screen below water table; Fill Unit	Tidal Monitoring Study	July 30 to August 8, 2012	2.7	9.5E-04
TL-MW-12	Shallow; Fill Unit	Tidal Monitoring Study	July 30 to August 8, 2012	7.7	2.7E-03
HS-MW-5	Shallow; Fill Unit	Rising Head Slug Test	June 8, 2012	3.2	1.1E-03
HS-MW-6	Shallow; Fill Unit	Rising Head Slug Test	June 8, 2012	17.9	6.3E-03
		Tidal Monitoring Study	April 8 to 11, 2000	3.1	1.1E-03
		Exploration Soil Sample Grain Size Data (average of values calculated from Fill Unit soil samples at 21.5, 24 and 24.5 feet bgs)	July 1, 2000	17	5.9E-03
		Tidal Monitoring Study	July 30 to August 8, 2012	11.6	4.1E-03
HS-MW-7	Shallow; Fill Unit	Rising Head Slug Test	June 8, 2012	3.5	1.2E-03
HS-MW-8	Shallow; Fill Unit	Tidal Monitoring Study	April 8 to 11, 2000	44.3	1.6E-02
HS-MW-9	Shallow; Fill Unit	Rising Head Slug Test	June 8, 2012	1.2	4.3E-04
HS-MW-15	Shallow; Fill Unit	Tidal Monitoring Study	July 30 to August 8, 2012	14	4.9E-03
High				44	1.6E-02
Low				1.2	4.3E-04
Average				10	3.5E-03
Median				3	1.2E-03
Native Marine Unit					
TL-MW-13	Deep; Native Marine Unit	Tidal Monitoring Study	July 30 to August 8, 2012	5.8	2.0E-03
TL-MW-14	Deep; Native Marine Unit	Tidal Monitoring Study	July 30 to August 8, 2012	9.3	3.3E-03
TL-MW-15	Deep; Native Marine Unit	Tidal Monitoring Study	July 30 to August 8, 2012	8.8	3.1E-03
TL-MW-16	Deep; Native Marine Unit	Tidal Monitoring Study	July 30 to August 8, 2012	6.7	2.4E-03
High				9.3	1.6E-02
Low				5.8	4.3E-04
Average				7.7	3.6E-03
Median				7.8	3.9E-03

Notes:

[1] Values based on 2012 slug test and tidal studies are described in the respective appendices. Values shown for the 2012 Tidal Monitoring Study are based on the Stage Ratio Method (Appendix G) which was determined to be the better of the available methods used for analysis. Data for the 2000 Tidal Monitoring Study and 2000 Slug Test Study were re-analyzed in 2012 using values for storativity which were determined to be more applicable to the site based on interpretations from the 2012 supplemental investigation. Exploration Soil Sample Grain Size Data based on Fair-Hatch Method, Freeze & Cherry 1979

Table 4-3

Summary of Predicted Monthly Discharge Volumes Data Based on Groundwater Model

R.G. Haley Site

Bellingham, Washington

Month	Flow (ft^3/d)
January	7,100
February	6,500
March	6,400
April	5,300
May	4,200
June	3,800
July	3,000
August	2,600
September	1,700
October	1,900
November	2,600
December	4,726
Average (ft^3/day)	**4,152**

Table 4-4

Summary of Groundwater Conductivity Measurements
July 2012

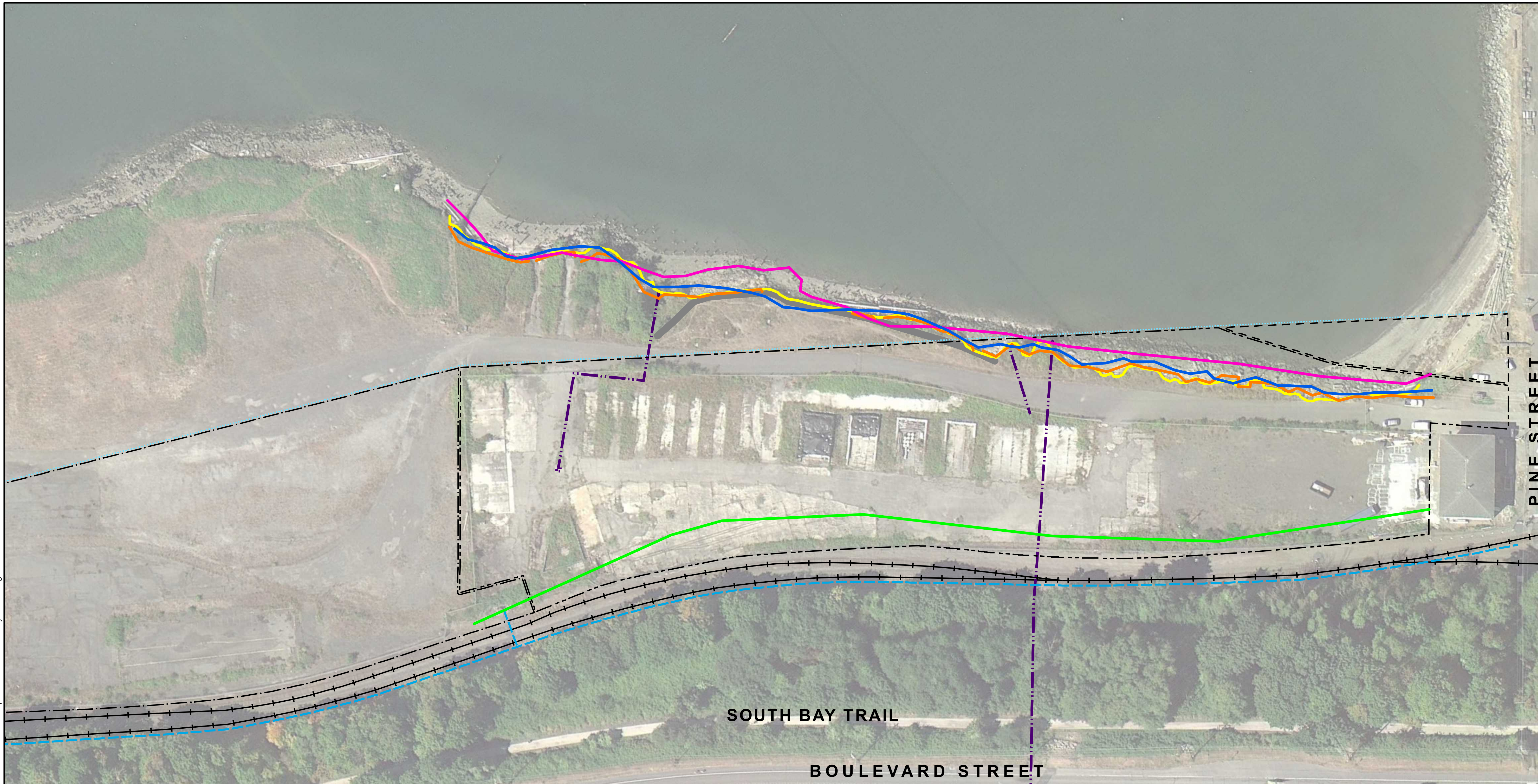
R.G. Haley Site
Bellingham, Washington

HS-MW-6 (36 Feet from Shoreline, Top of Screen at 8.3 Feet, Bottom of Screen at -6.6 Feet)		TL-MW-9 (36 Feet from Shoreline, Top of Screen at 11.1 Feet, Bottom of Screen at 0.1 Feet)		TL-MW-1 (56 Feet from Shoreline, Top of Screen at 10.2 Feet, Bottom of Screen at -4.8 Feet)		HS-MW-7 (164 Feet from Shoreline, Top of Screen at 11.5 Feet, Bottom of Screen at -3.5 Feet)		Seawater
Groundwater Elevation (Feet) (NAVD88)	Conductivity (uS/cm)	Groundwater Elevation (Feet) (NAVD88)	Conductivity (uS/cm)	Groundwater Elevation (Feet) (NAVD88)	Conductivity (uS/cm)	Groundwater Elevation (Feet) (NAVD88)	Conductivity (uS/cm)	Conductivity (uS/cm)
4.81	703	4.73	13,917	5.2	3,312	6.22	609	16,920
3.81	698	3.73	14,075	4.2	3,308	5.22	618	15,836
2.81	697	2.73	14,080	3.2	3,301	4.22	635	16,169
1.81	695	1.73	14,082	2.2	3,298	3.22	644	**16,308**
0.81	696	--	--	1.2	3,297	2.22	655	--
-0.19	696	--	--	0.2	3,295	1.22	656	--
-1.19	696	--	--	-0.8	3,284	0.22	657	--
-2.19	697	--	--	-1.8	3,293	-0.78	657	--
-3.19	697	--	--	-2.8	3,293	--	--	--
-4.19	697	--	--	-3.8	3,292	--	--	--
-5.19	697	--	--	-4.8	3,292	--	--	--

Notes:

Bold is average of Seawater

Measurements were obtained on July 18, 2012 during a 2-hour period after low tide.



True North
W
S
N
E
Project North

0 100 200
Feet

References: Aerial from Google Earth, August 2011.
1887 shoreline from Northwest Archeological Associates December 2007. 1969, 1997 and 2011 shoreline based on aerial photographs. 2005 shoreline based on survey (Pacific Survey and Engineering 2005)

Notes:
1. The locations of all features shown are approximate.
2. Shoreline position in 1950 cannot be discerned in aerial photographs due to presence of over-water wharves.
3. This drawing is for information purposes. It is intended to assist in showing features discussed in an attached document. GeoEngineers, Inc. cannot guarantee the accuracy and content of electronic files. The master file is stored by GeoEngineers, Inc. and will serve as the official record of this communication.

Legend

- City Owned Property, Former R.G. Haley International
- Cornwall Property
- Port of Bellingham Property
- Inner Harbor Line
- Storm Drain
- Drainage Features
- Sheet Pile Wall (installed 2000)
- BNSF Railroad

Estimated Location of Top of Shoreline Bank Based on Aerial Photographs

- 2011
- 2005
- 1997 (Surveyed Location)
- 1969
- 1887

Estimated Effects of Shoreline Erosion

R.G. Haley Site
Bellingham, Washington

GeoEngineers

Figure 4-1

Path: \\sea\projects\0\0356114\GIS\MXDs\Fig_4-1_ShorelineErosion.mxd Map Revised: 19 February 2015 cgonzales

Data Source: Esri imagery, 2013. Adapted from Landau 2013.

Projection: NAD 1983 StatePlane Washington North FIPS 4601 Feet

Notes:
1. The locations of all features shown are approximate.
2. This drawing is for information purposes. It is intended to assist in showing features discussed in an attached document. GeoEngineers, Inc. cannot guarantee the accuracy and content of electronic files. The master file is stored by GeoEngineers, Inc. and will serve as the official record of this communication.
3. Net current drift directions adapted from Retec 2006 and Colyen 1998

Watershed Discharges and Current Directions in Greater Bellingham Bay Area

R.G. Haley Site
Bellingham, Washington

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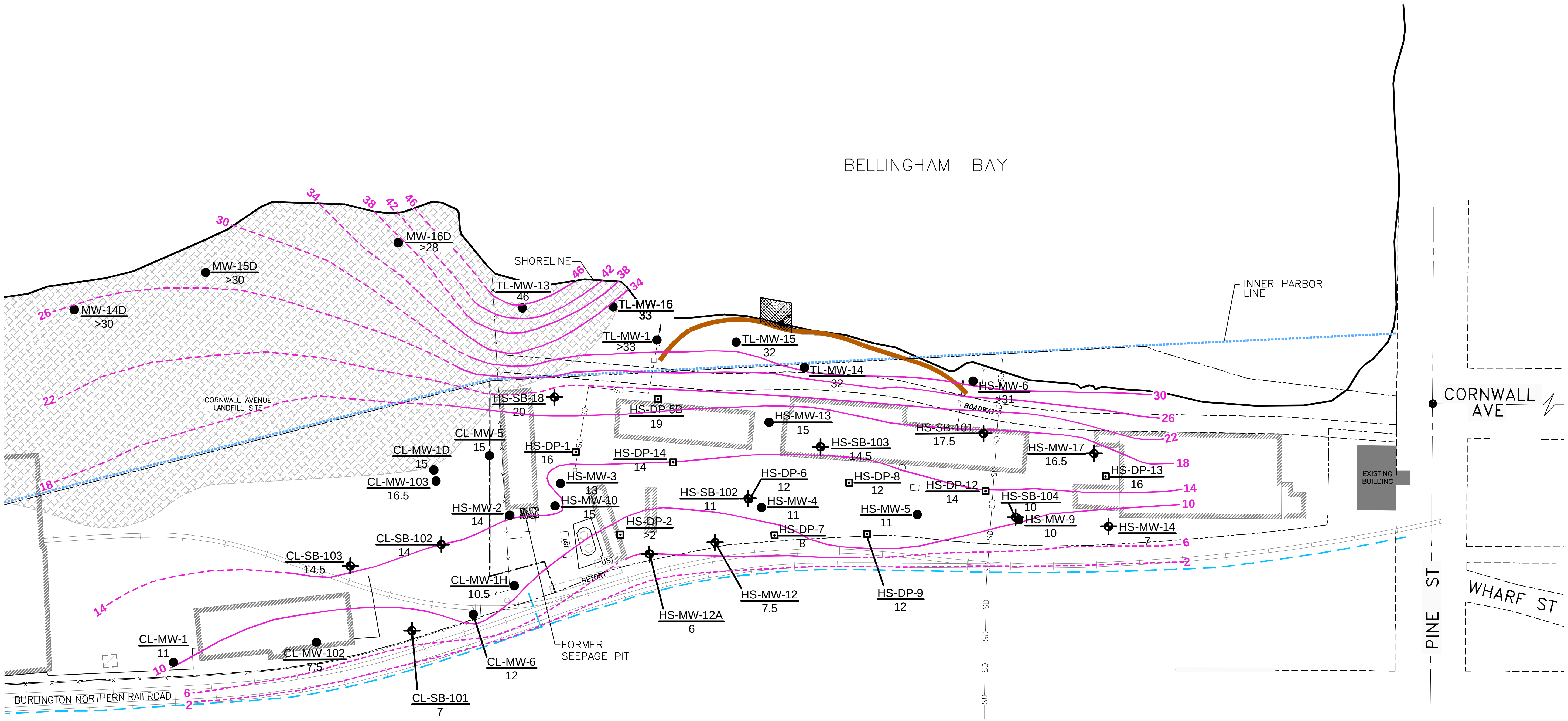
Figure 4-2

Path: \\seal\projects\0\0356114\GIS\MXDs\Fig_4-2_Watershed_Discharge.mxd Map Revised: 19 February 2015 cgonzales



Legend

6 —— 6	Depth to Bedrock Contour (Contour Interval is 4 feet)
TL-MW-16 33 ●	Exploratory Borehole for Monitoring Well Depth of Bedrock Below Ground Surface (feet)
HS-MW-1 ●	Monitoring Well
HS/SB/SP ⊕	Boring
HS-DP-4 ▣	Direct Push Boring
UST	Underground Storage Tank
	Existing Sheet Pile Barrier
	Estimated Extent of Upland Refuse
	Former Buildings
	2001 Sediment Removal Area
	2000 Petroleum Seep
	Inner Harbor Line
	Drainage Ditch

Notes

1. The locations of all features shown are approximate.
2. This drawing is for information purposes. It is intended to assist in showing features discussed in an attached document. GeoEngineers, Inc. cannot guarantee the accuracy and content of electronic files. The master file is stored by GeoEngineers, Inc. and will serve as the official record of this communication.

Reference: CAD files RGHALEY_SVx_base20x.dwg" dated 7-17-2012, "R2000geoeng_haleybase50x" revised 07/28/04 by Pacific Survey & Engineering Inc., file "Fig3-8" dated August 2002 by Landau Associates, and files "027500201T1LM" and "027500201T1A" dated 03/29/04 by GeoEngineers.

Depth to Bedrock

R.G. Haley Site
Bellingham, Washington

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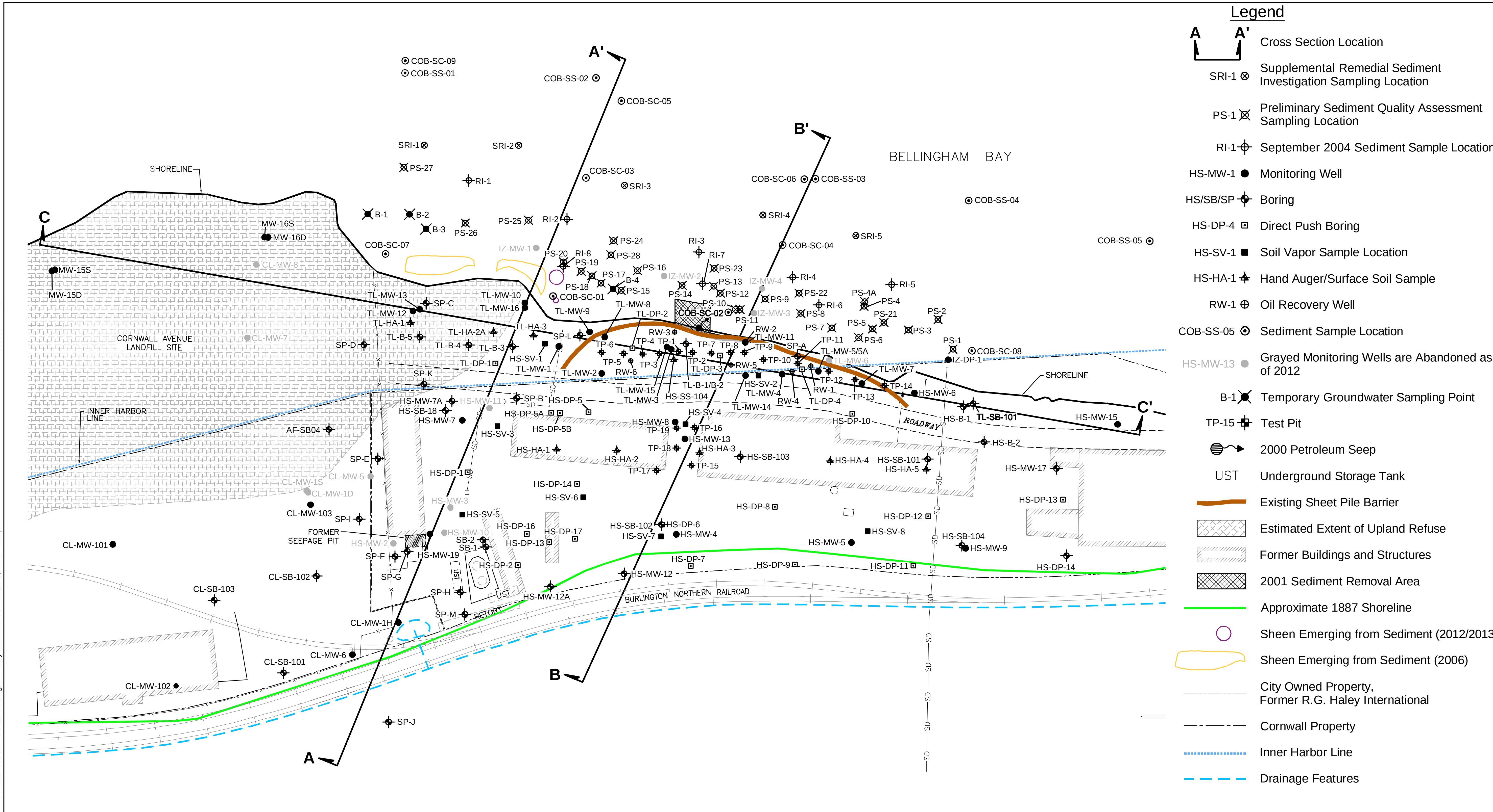
Figure 4-3

P:\0\0356114\06\CAD\RI_FS Figures\Figure 4-3 Depth to Bedrock.dwg\TAB:4-13 Depth to Bedrock modified on Jan 28, 2015 - 3:14pm

SEAT:JL : TJM



Legend

Notes

1. The locations of all features shown are approximate.
2. This drawing is for information purposes. It is intended to assist in showing features discussed in an attached document. GeoEngineers, Inc. cannot guarantee the accuracy and content of electronic files. The master file is stored by GeoEngineers, Inc. and will serve as the official record of this communication.

Reference: CAD files RGHALEY_SVx_base20x.dwg" dated 7-17-2012, "R2000geoeng_haleybase50x" revised 07/28/04 by Pacific Survey & Engineering Inc., file "Fig3-8" dated August 2002 by Landau Associates, and files "027500201T1LM" and "027500201T1A" dated 03/29/04 by GeoEngineers.

Cross Section Locations

R.G. Haley Site
Bellingham, Washington

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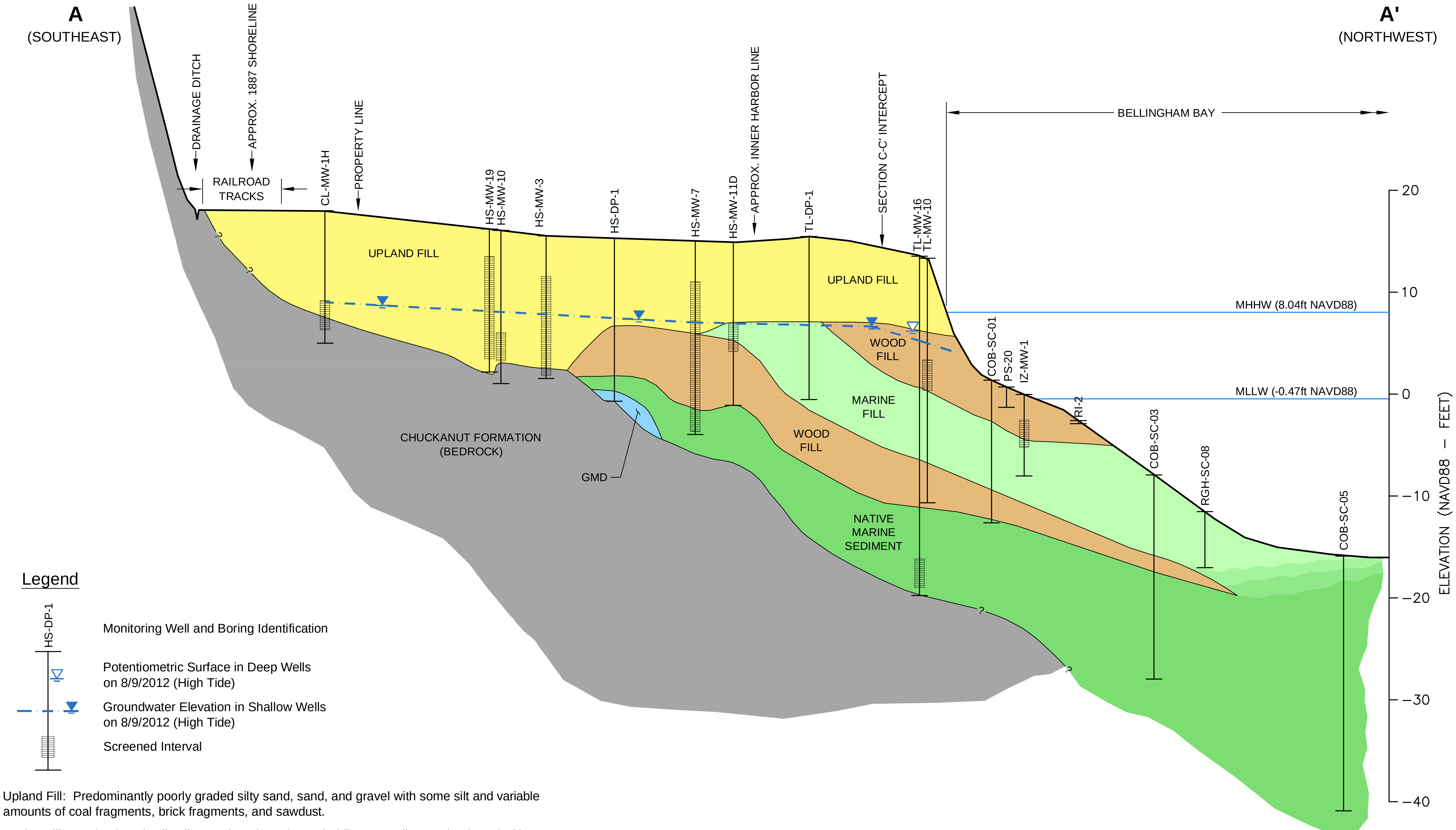
Figure 4-4



Upland Fill: Predominantly poorly graded silty sand, sand, and gravel with some silt and variable amounts of coal fragments, brick fragments, and sawdust.

Marine Fill: Predominantly silt, silty sand, and poorly graded fine to medium grained sand with shell fragments and occasional wood fragments.

Wood Fill: At least 50 percent wood based on visual estimate with some silt and occasional sand. Wood present as sawdust, chips, or fragments.

Native Marine Sediment: Predominantly silt, silty sand, and poorly graded fine to coarse grained sand with occasional gravel, shell fragments, and wood fragments.

GMD (Glacial Marine Drift): Stiff silt and clay with occasional gravel and shells.

Chuckanut Formation: The Eocene-age Padden Member of the Chuckanut Formation is predominantly siltstone where encountered in borings.

HORIZONTAL SCALE: 1"= 60'
VERTICAL SCALE: 1"= 10'
VERTICAL EXAGGERATION: 6X

60 0 60
FEET

Notes

1. Directions given on cross section line refer to Project North.
2. The subsurface conditions shown are based on interpolation between widely spaced explorations and should be considered approximate; actual subsurface conditions may vary from those shown.
3. Please refer to Figure 4-4 for cross section location.
4. This figure is for informational purposes only. It is intended to assist in the identification of features discussed in a related document.

Cross Section A-A'

R.G. Haley Site
Bellingham, Washington

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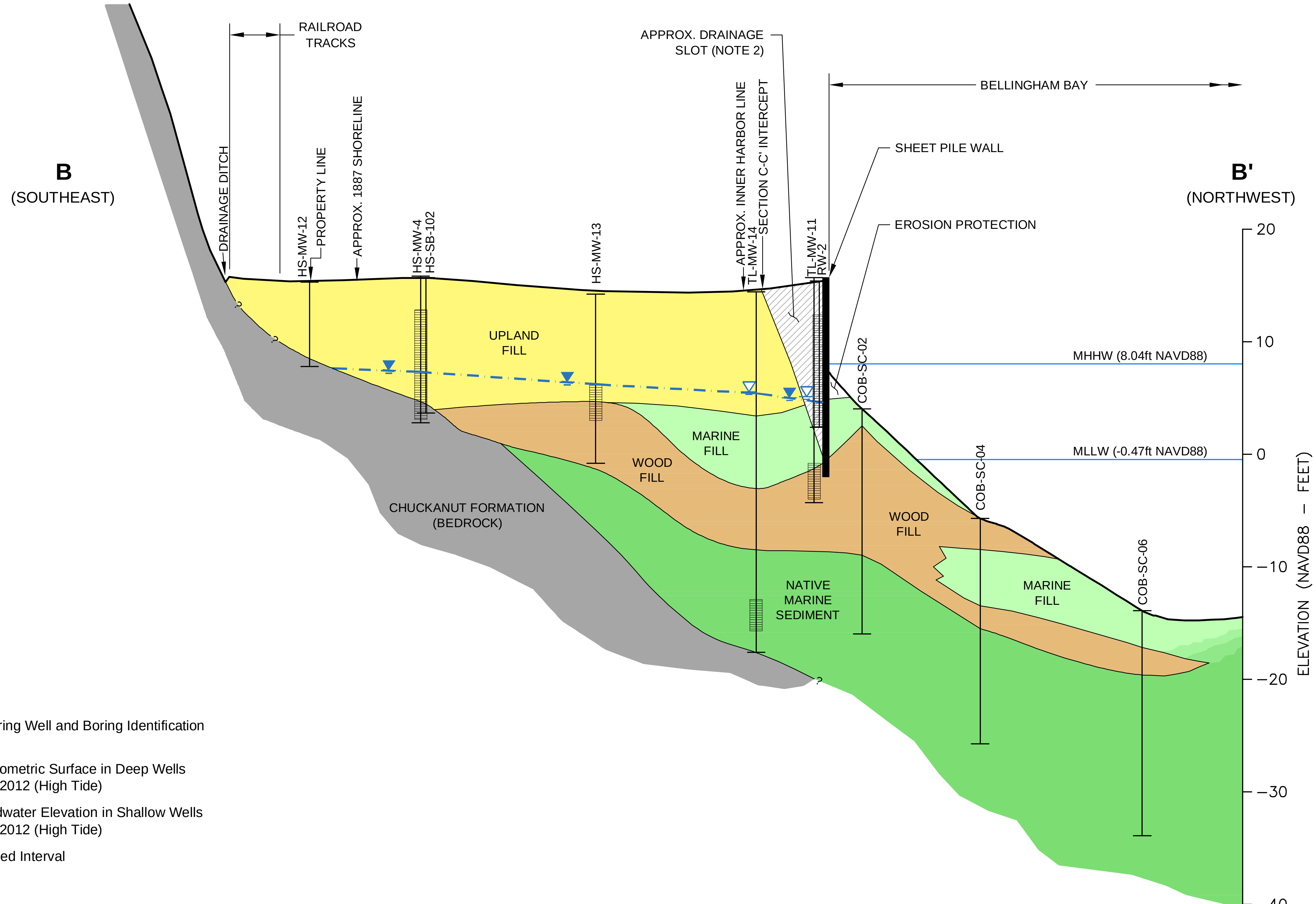
Figure 4-5



HS-MW-4 Monitoring Well and Boring Identification

Potentiometric Surface in Deep Wells on 8/9/2012 (High Tide)

Groundwater Elevation in Shallow Wells on 8/9/2012 (High Tide)

Screened Interval

Upland Fill: Predominantly poorly graded silty sand, sand, and gravel with some silt and variable amounts of coal fragments, brick fragments, and sawdust.

Marine Fill: Predominantly silt, silty sand, and poorly graded fine to medium grained sand with shell fragments and occasional wood fragments.

Wood Fill: At least 50 percent wood based on visual estimate with some silt and occasional sand. Wood present as sawdust, chips, or fragments.

Native Marine Sediment: Predominantly silt, silty sand, and poorly graded fine to coarse grained sand with occasional gravel, shell fragments, and wood fragments.

Chuckanut Formation: The Eocene-age Padden Member of the Chuckanut Formation is predominantly siltstone where encountered in borings.

HORIZONTAL SCALE: 1"= 60'
VERTICAL SCALE: 1"= 10'
VERTICAL EXAGGERATION: 6X

60 0 60
FEET

Notes

1. Directions given on cross section line refer to Project North.
2. Drainage slot consists of coarse sand gravel backfill.
3. The subsurface conditions shown are based on interpolation between widely spaced explorations and should be considered approximate; actual subsurface conditions may vary from those shown.
4. Please refer to Figure 4-4 for cross section location.
5. This figure is for informational purposes only. It is intended to assist in the identification of features discussed in a related document.

Cross Section B-B'

R.G. Haley Site
Bellingham, Washington

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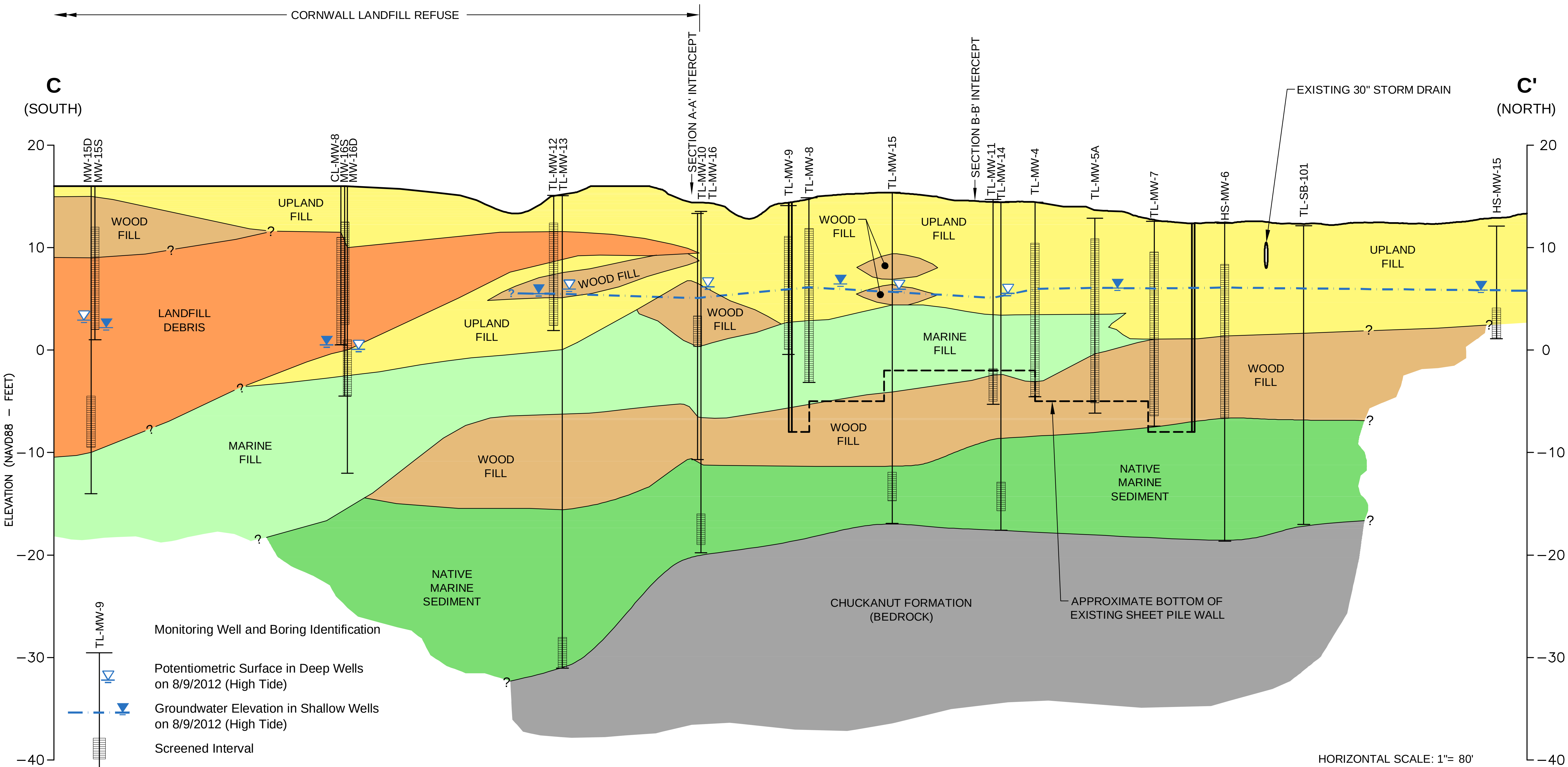
Figure 4-6



HORIZONTAL SCALE: 1"= 80'
VERTICAL SCALE: 1"= 10'
VERTICAL EXAGGERATION: 8X

80 0 80
FEET

Landfill Debris: Miscellaneous municipal solid waste with variable amounts of silt, sand, gravel and wood debris.

Upland Fill: Predominantly poorly graded silty sand, sand, and gravel with some silt and variable amounts of coal fragments, brick fragments, and sawdust.

Marine Fill: Predominantly silt, silty sand, and poorly graded fine to medium grained sand with shell fragments and occasional wood fragments.

Wood Fill: At least 50 percent wood based on visual estimate with some silt and occasional sand. Wood present as sawdust, chips, or fragments.

Native Marine Sediment: Predominantly silt, silty sand, and poorly graded fine to coarse grained sand with occasional gravel, shell fragments, and wood fragments.

Chuckanut Formation: The Eocene-age Padden Member of the Chuckanut Formation is predominantly siltstone where encountered in borings.

Notes

1. Directions given on cross section line refer to Project North.
2. The subsurface conditions shown are based on interpolation between widely spaced explorations and should be considered approximate; actual subsurface conditions may vary from those shown.
3. Please refer to Figure 4-4 for cross section location.
4. Depth to groundwater in Cornwall wells MW-15D/15S and MW-16D/16S based on Cornwall RI (Landau 2013a) for September 2012 (high tide).
5. This figure is for informational purposes only. It is intended to assist in the identification of features discussed in a related document.

Cross Section C-C'

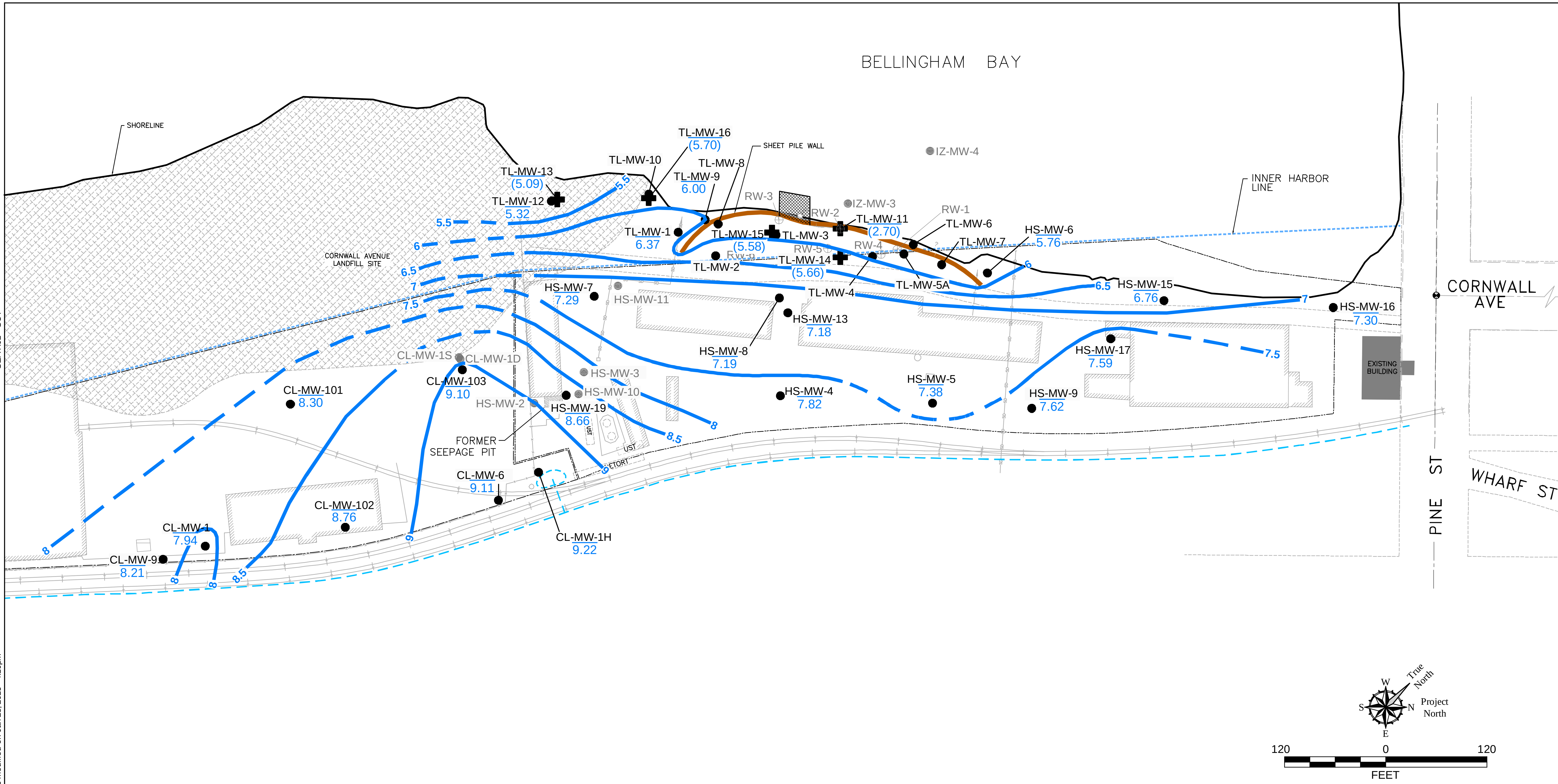
R.G. Haley Site
Bellingham, Washington

GEOENGINEERS

Figure 4-7

P:\0\0356114\06\CAD\RI_FS Figures\Figure 4-7 Geologic Cross-Section CC.dwg\TAB:CC modified on Dec 26, 2013 - 10:19am

SEAT:JL : TJM



Notes

1. The locations of all features shown are approximate.
2. This drawing is for information purposes. It is intended to assist in showing features discussed in an attached document. GeoEngineers, Inc. can not guarantee the accuracy and content of electronic files. The master file is stored by GeoEngineers, Inc. and will serve as the official record of this communication.

Reference: CAD files "R2000geoeng_haleybase50x" revised 07/28/04 by Pacific Survey & Engineering Inc., file "Fig3-8" dated August 2002 by Landau Associates, and files "027500201T1LM" and "027500201T1A" dated 03/29/04 by GeoEngineers.

Legend

TL-MW-11 ✚	Existing Deep Monitoring Well
HS-MW-4 ●	Existing Shallow Monitoring Well
RW-1 ⊕	Recovery Well (will not be sampled)
●	Historical Monitoring Well (Abandoned)
6 6.00	Groundwater Contour (dashed where inferred) - Groundwater elevation in feet (NAVD88)
(5.96)	Deep Well Groundwater Elevations in Parentheses (not used for contouring)
UST	Underground Storage Tank
	Sheet Pile Barrier
	Estimated Extent of Upland Refuse
	Inner Harbor Line
	Drainage Ditch and Culvert

Groundwater Elevation Contours During Low Tide - July 17, 2012

R.G. Haley Site
Bellingham, Washington

GEOENGINEERS

Figure 4-8

SEAT:JL : SCY

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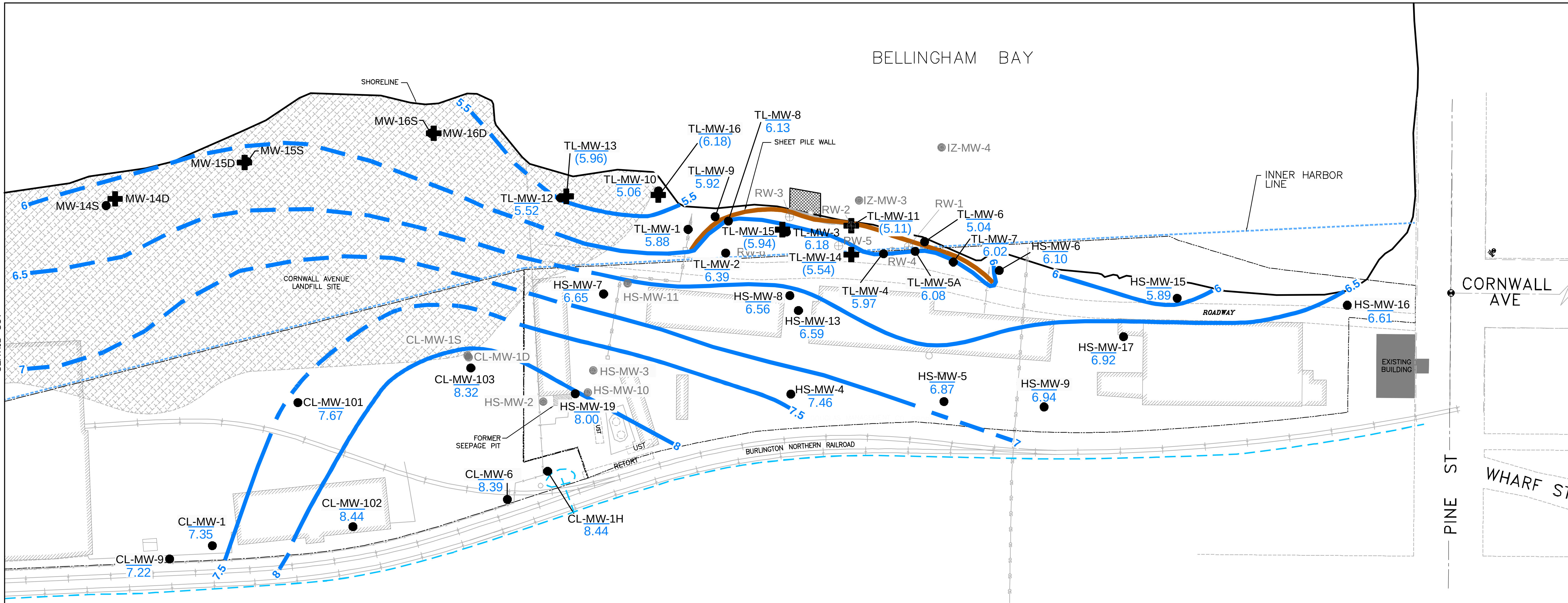

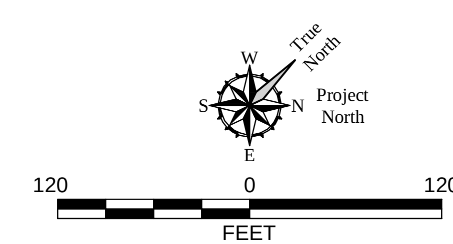

Notes

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3. Approximate groundwater elevation contours to the south based on Cornwall RI (Landau 2013) Figure 4-11 for September 2012.

Reference: CAD files "R2000geoeng_haleybase50x" revised 07/28/04 by Pacific Survey & Engineering Inc., file "Fig3-8" dated August 2002 by Landau Associates, and files "027500201T1LM" and "027500201T1A" dated 03/29/04 by GeoEngineers.

Legend

TL-MW-11 ✚	Existing Deep Monitoring Well
HS-MW-4 ●	Existing Shallow Monitoring Well
RW-1 ⊕	Recovery Well (will not be sampled)
●	Historical Monitoring Well (Abandoned)
6 — — ———	Groundwater Contour (dashed where inferred)
6.00	- Groundwater elevation in feet (NAVD88)
(5.96)	Deep Well Groundwater Elevations in Parentheses (not used for contouring)
UST	Underground Storage Tank
	Sheet Pile Barrier
	Estimated Extent of Upland Refuse
	Inner Harbor Line
	Drainage Ditch and Culvert

Groundwater Elevation Contours During High Tide - August 9, 2012

R.G. Haley Site
Bellingham, Washington

GEOENGINEERS

Figure 4-9

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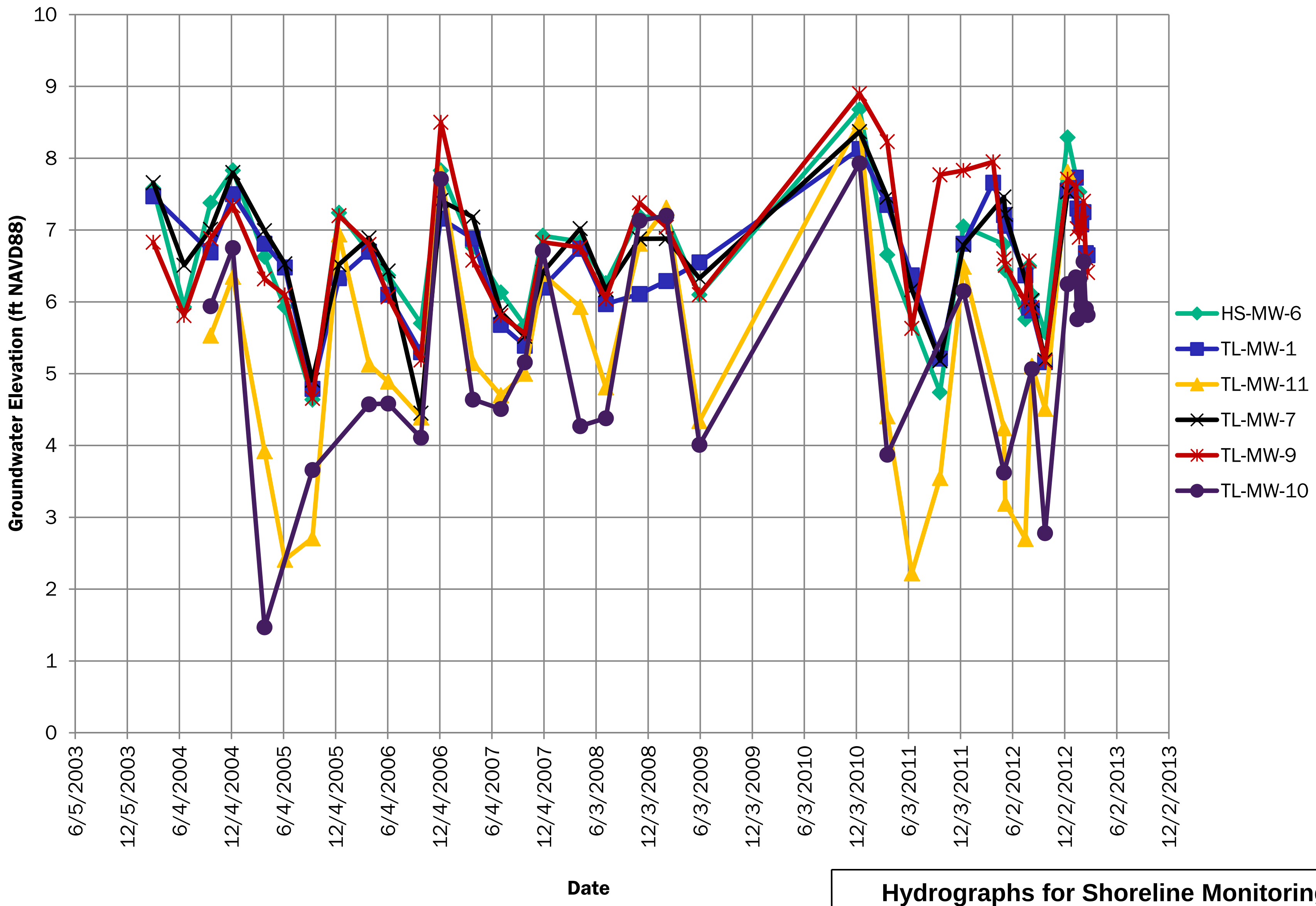
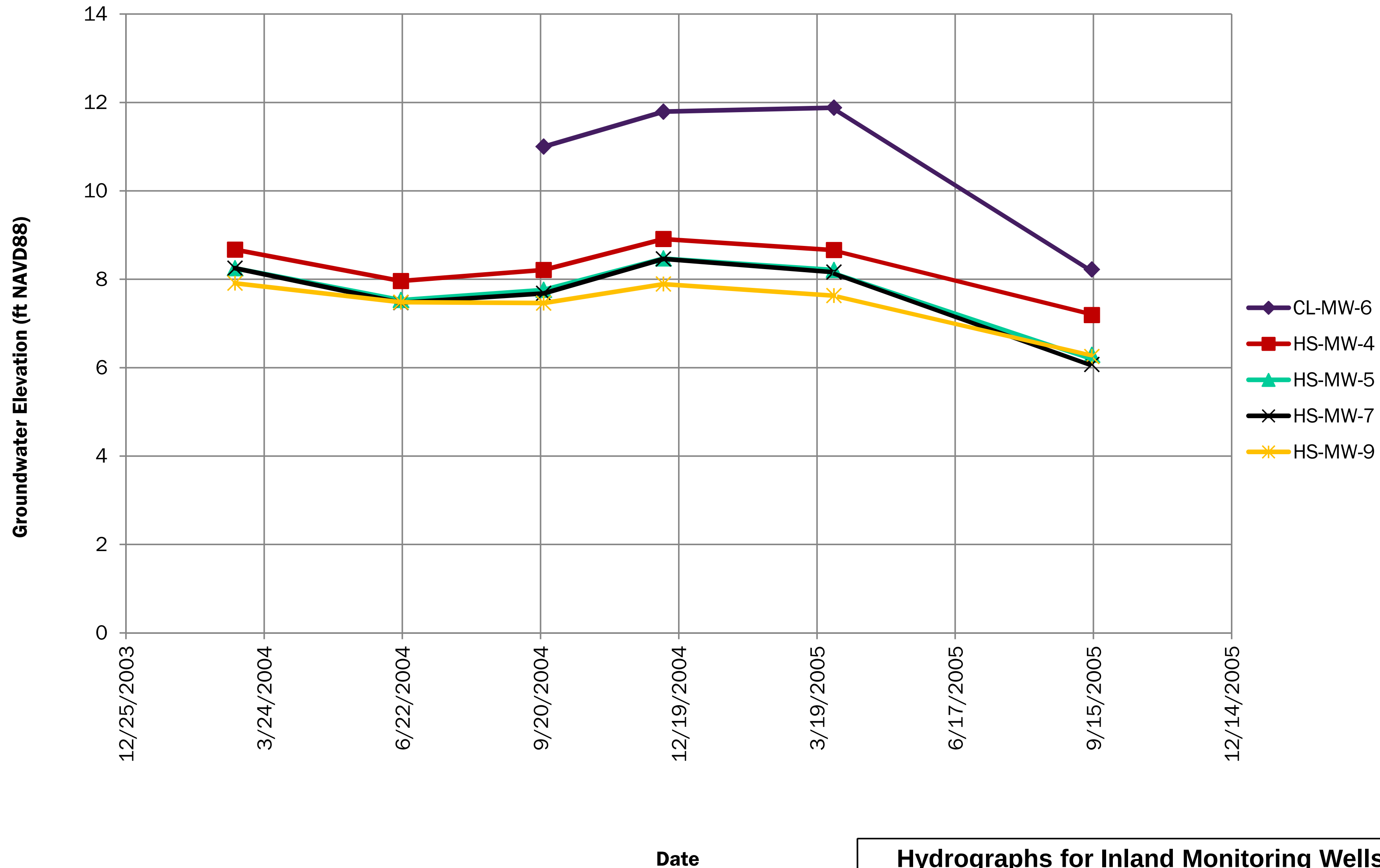


Hydrographs for Shoreline Monitoring Wells, 2004-2013

R.G. Haley Site
Bellingham, Washington

GEOENGINEERS

Figure 4-10

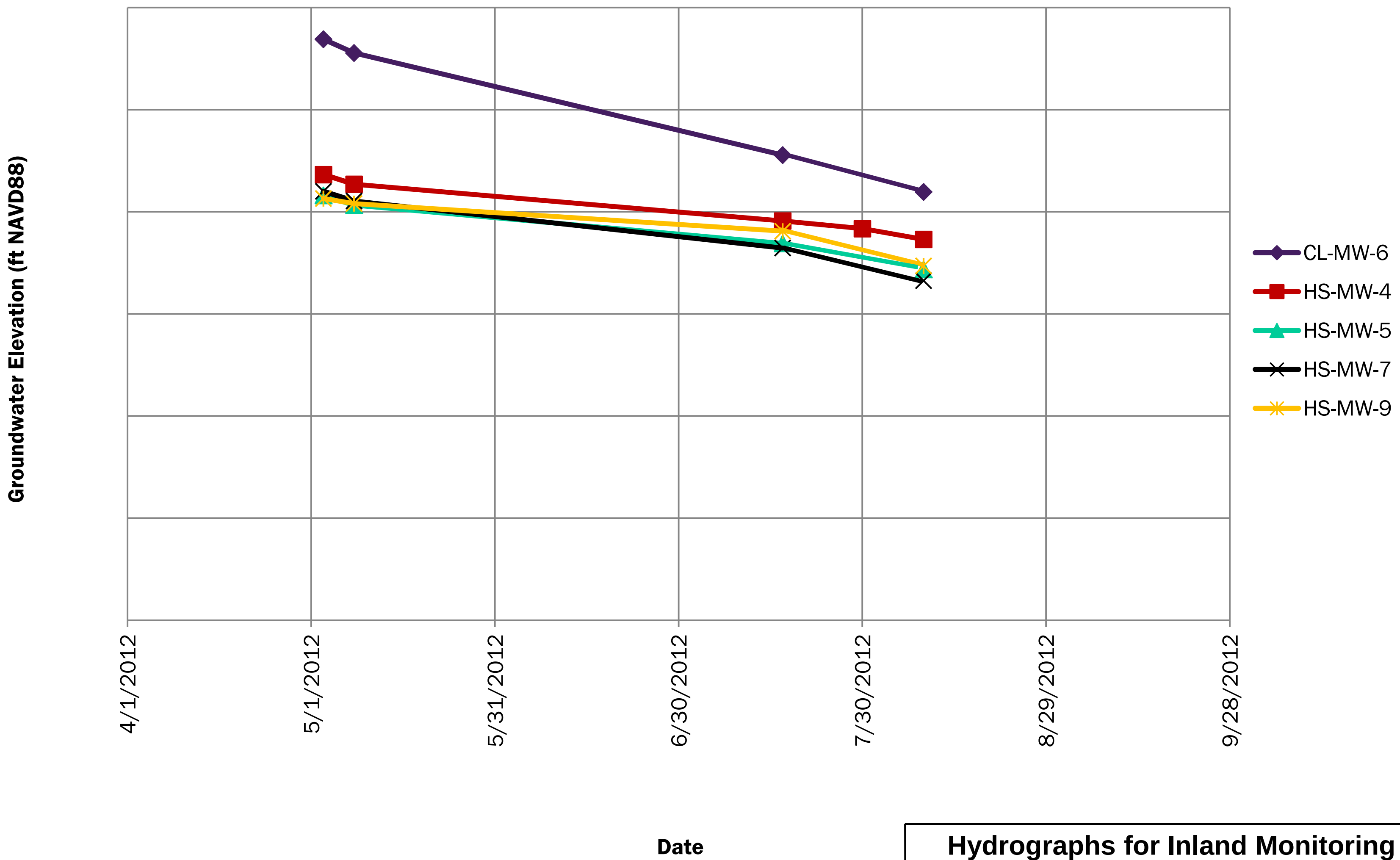


Hydrographs for Inland Monitoring Wells 2004 and 2005

R.G. Haley Site
Bellingham, Washington

GEOENGINEERS

Figure 4-11a

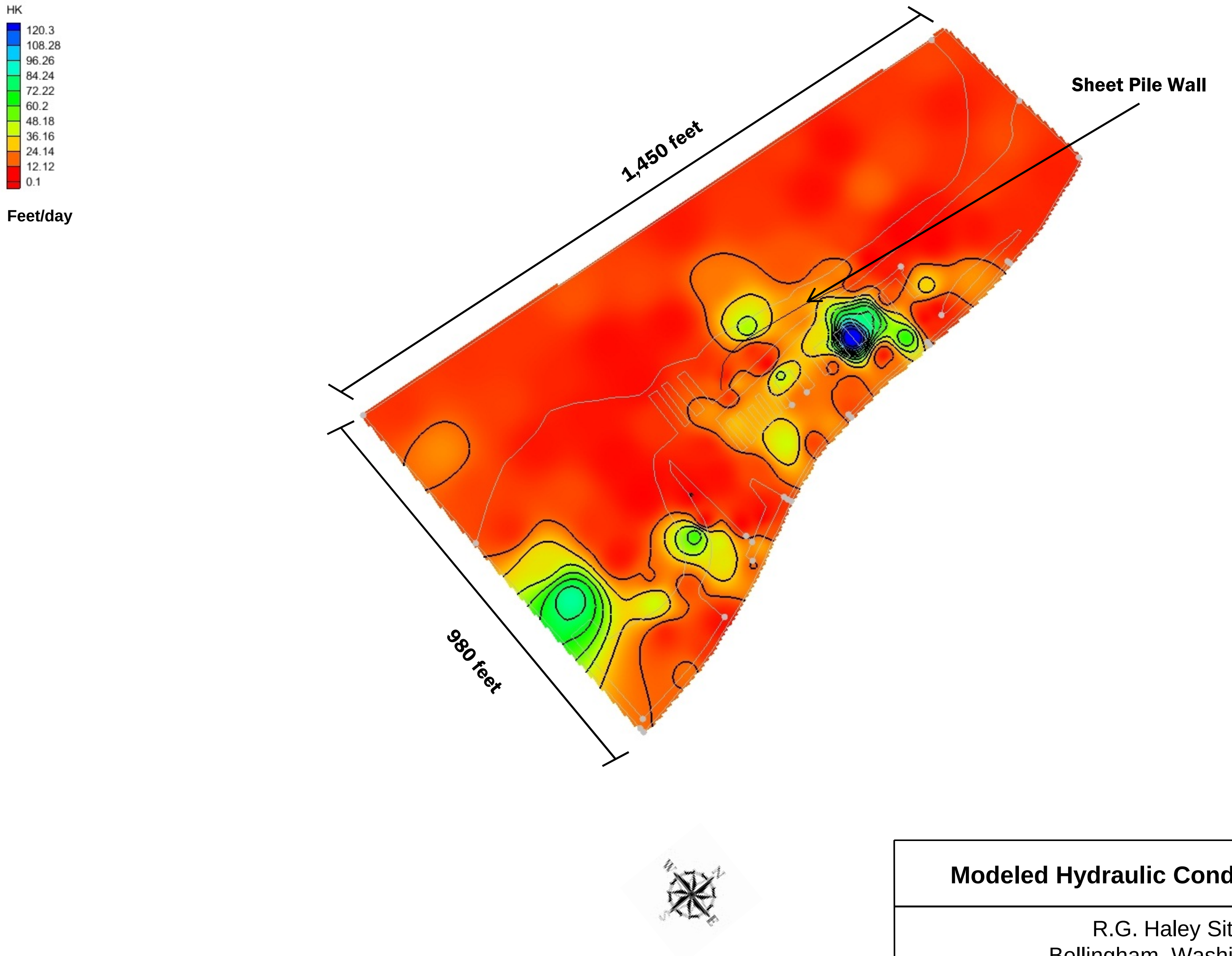


Hydrographs for Inland Monitoring Wells May-August 2012

R.G. Haley Site
Bellingham, Washington

GEOENGINEERS

Figure 4-11b

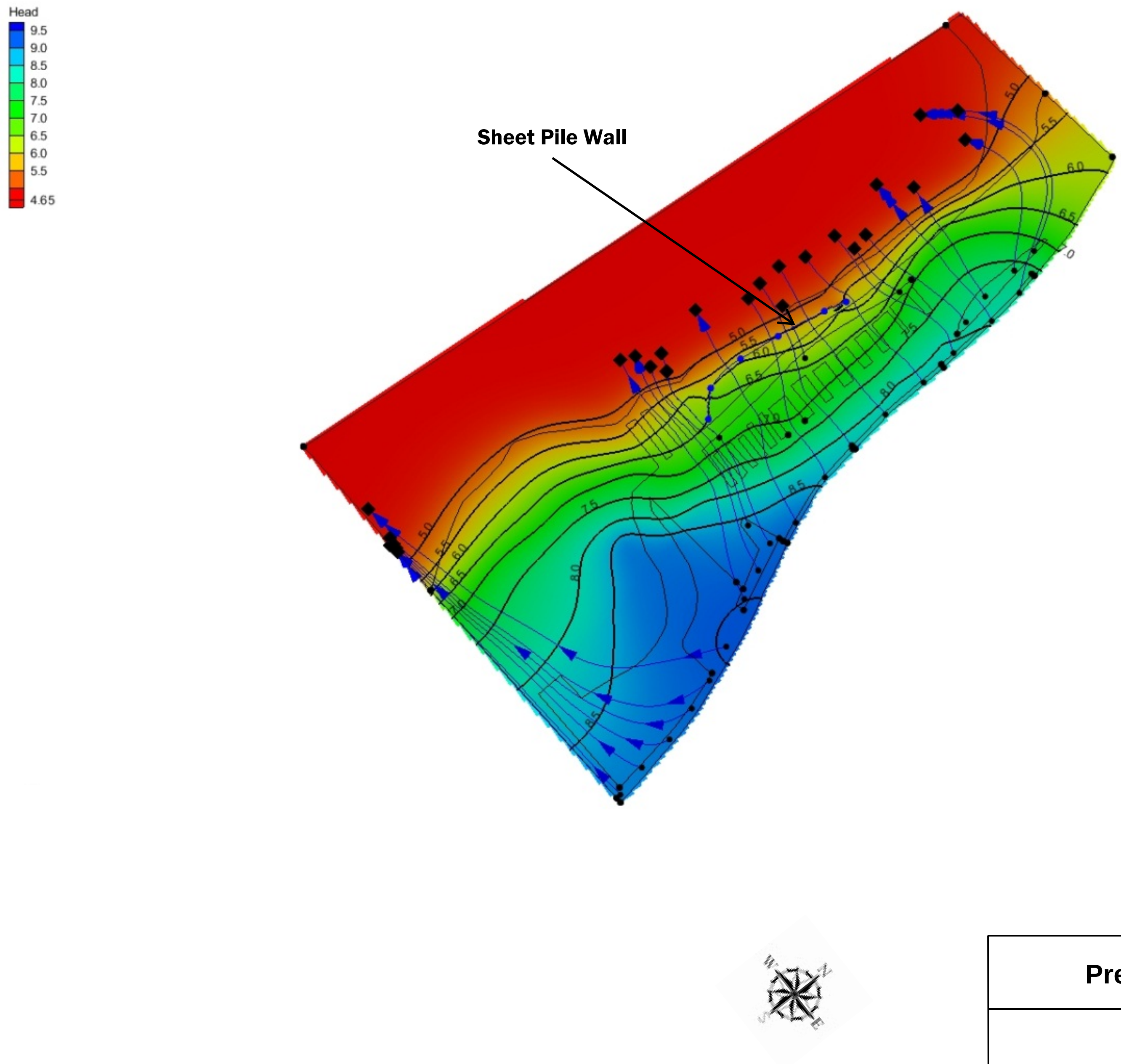


Modeled Hydraulic Conductivity Field

R.G. Haley Site
Bellingham, Washington

GeoEngineers

Figure 4-12

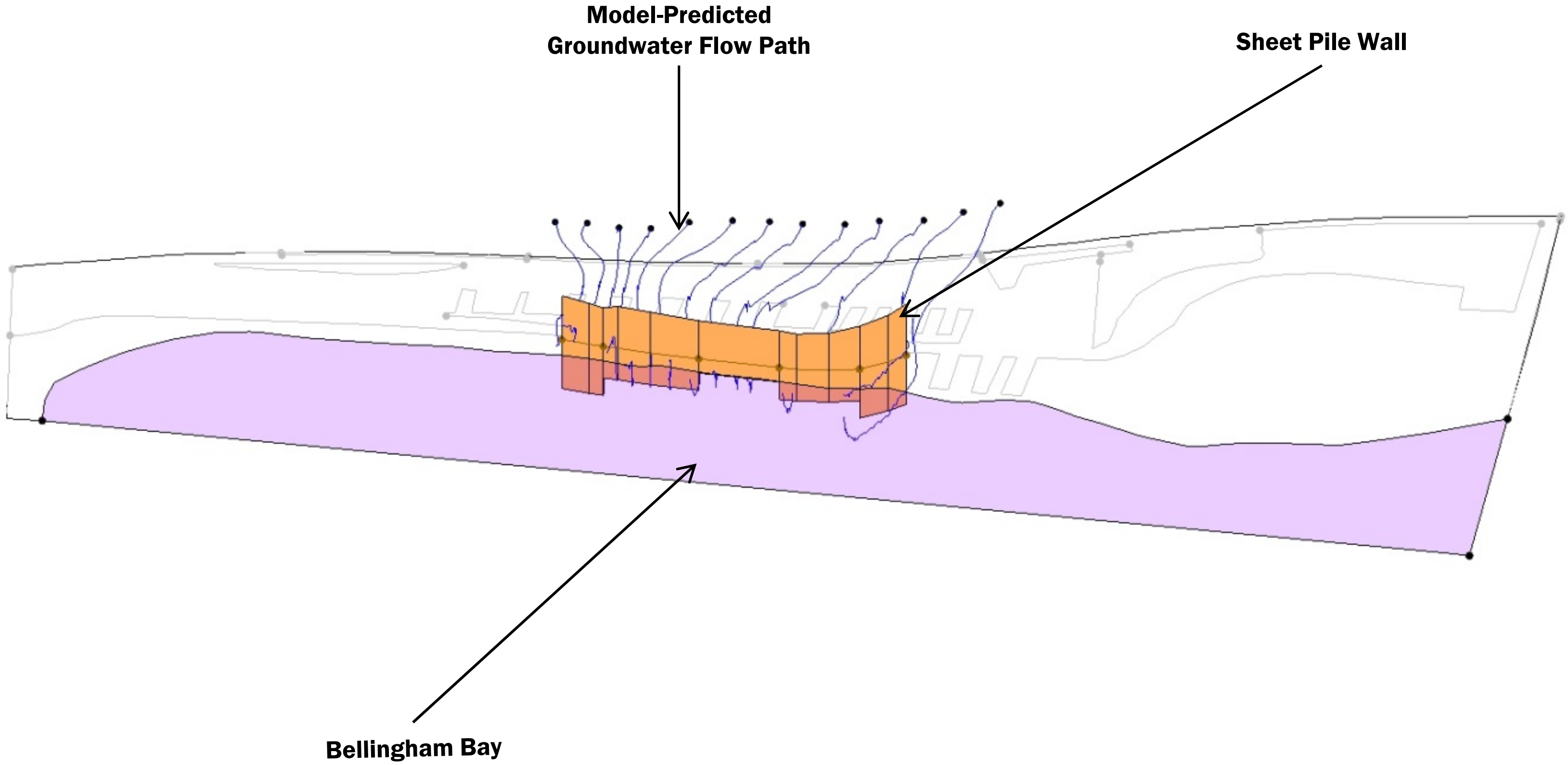


Predicted Horizontal Flowpaths

R.G. Haley Site
Bellingham, Washington

GEOENGINEERS

Figure 4-13

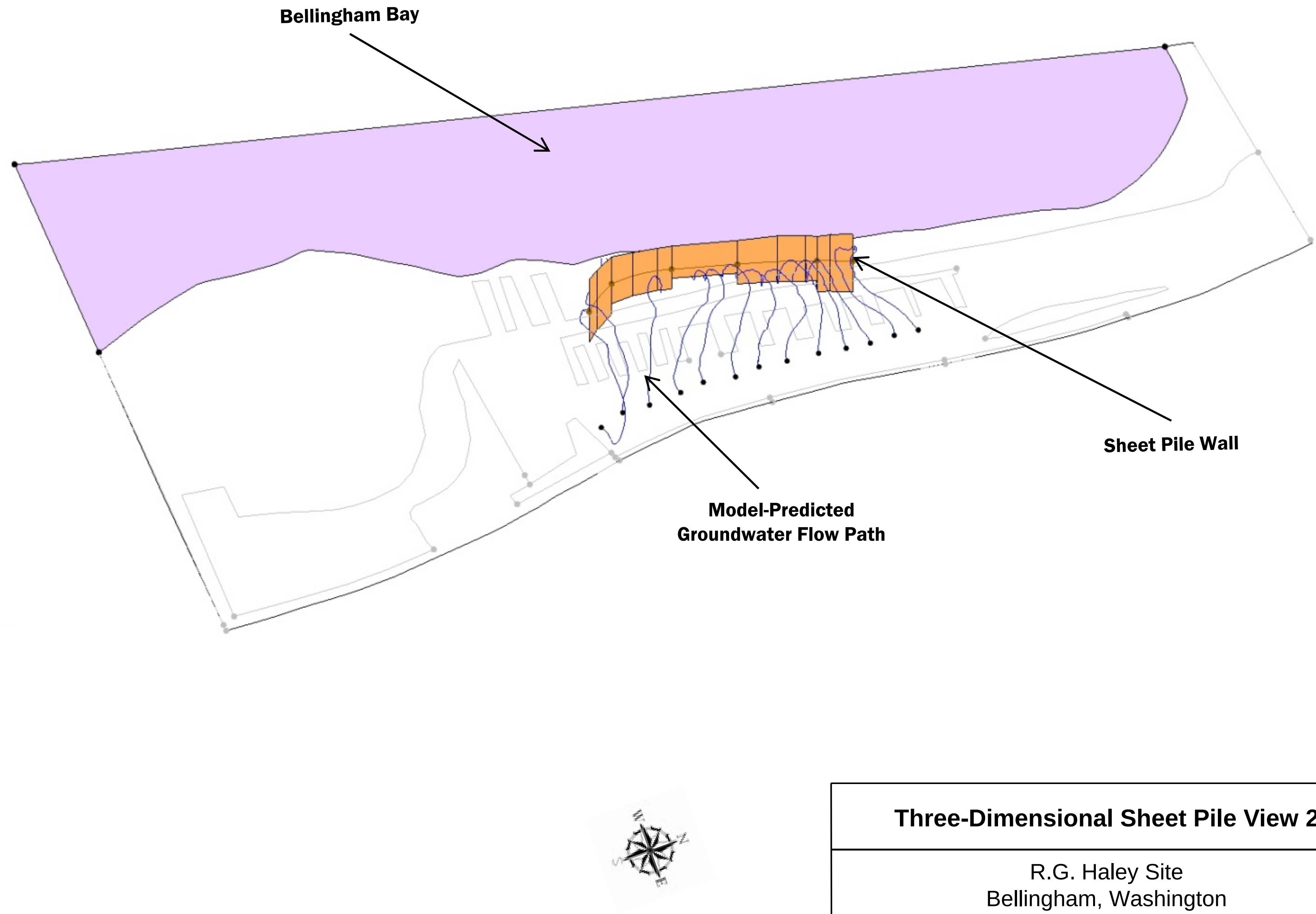


Three-Dimensional Sheet Pile View 1

R.G. Haley Site
Bellingham, Washington

GEOENGINEERS

Figure 4-14

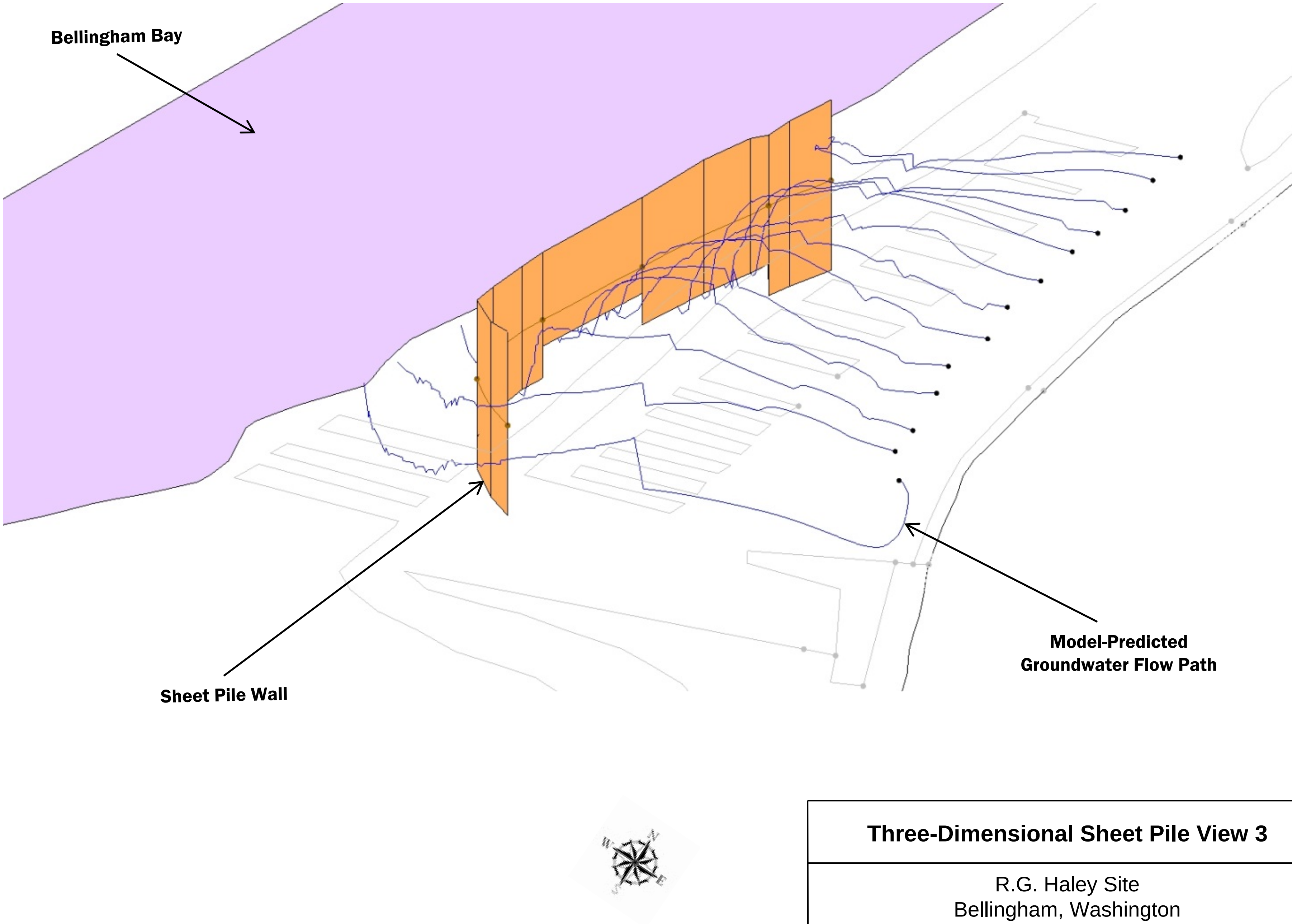


Three-Dimensional Sheet Pile View 2

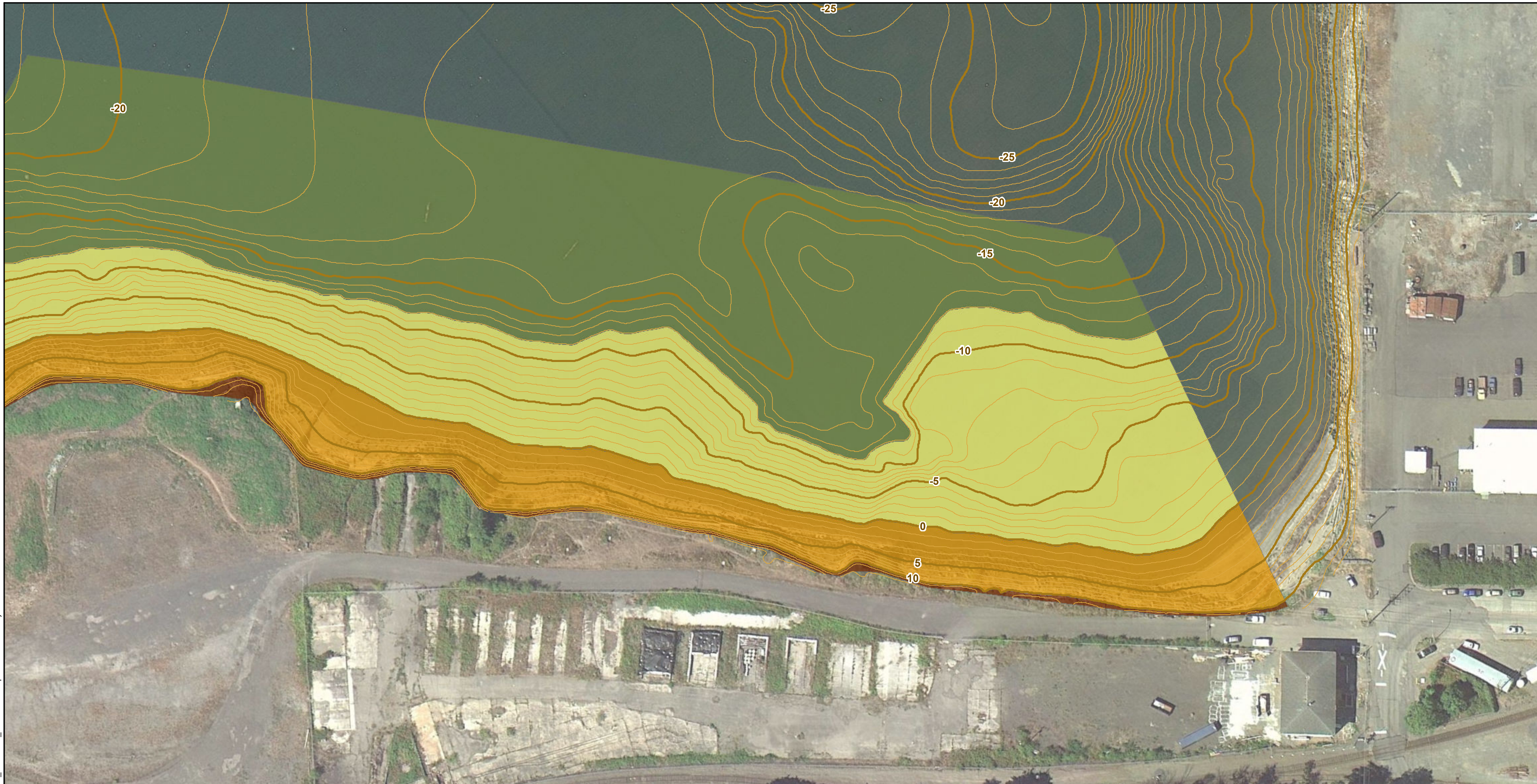
R.G. Haley Site
Bellingham, Washington

GeoEngineers

Figure 4-15



Three-Dimensional Sheet Pile View 3	
R.G. Haley Site Bellingham, Washington	
GeoEngineers	Figure 4-16



Legend

Contour (5 ft interval) NAVD88

Contour (1 ft interval) NAVD88

Cobble Zone (>10 ft)
Large cobbles and boulders with fine to coarse gravel and occasional fine to coarse sand. Debris consists primarily of concrete rubble and large woody debris.

Gravel Zone (10 to approximately 0 ft)
Fine to coarse gravel with fine to coarse sand and trace silt. Debris consists primarily of concrete, bricks, old piles, glass, and woody debris.

Sand Zone (0 to -12 ft)
Silty fine to coarse sand with fine to coarse gravel. Debris consists of bricks, concrete, glass, plastic, metal debris, and wood debris.

Silt Zone (>-12 ft)
Silt with occasional fine sand. Debris consists primarily of large lumber, old piles, and some rail track metal.

True North / Project North

0 50 100 Feet

Reference: Aerial from Google Earth, August 2011.

Notes:
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2. This drawing is for information purposes. It is intended to assist in showing features discussed in an attached document. GeoEngineers, Inc. cannot guarantee the accuracy and content of electronic files. The master file is stored by GeoEngineers, Inc. and will serve as the official record of this communication.

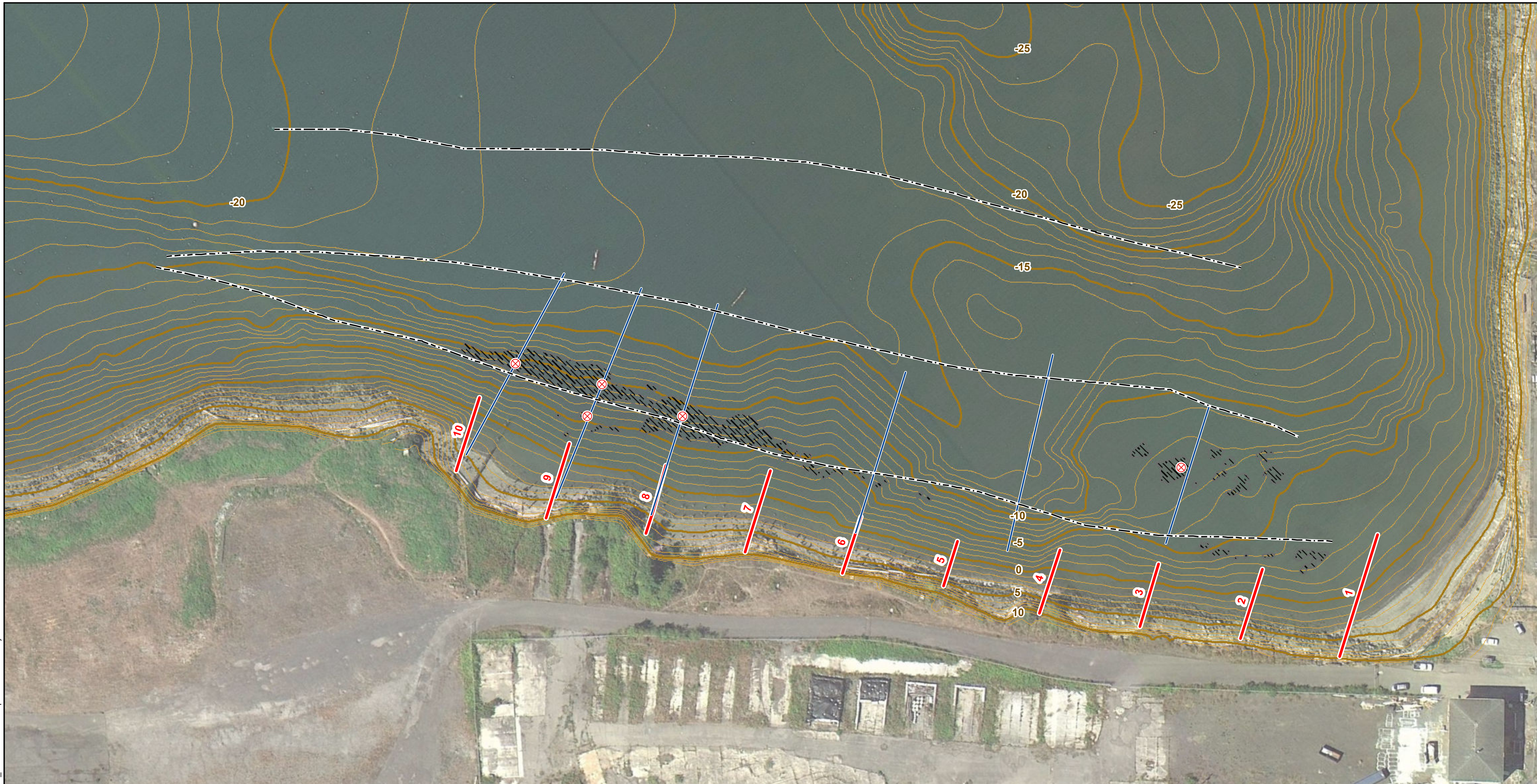
Substrate Zones

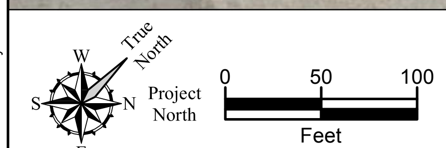
R.G. Haley Site
Bellingham, Washington

GeoEngineers

Figure 4-17

Path: \\SEA\projects\0\0356114\GIS\HabitatSurvey\0356114_Substrate_F1.mxd Map Revised: 29 July 2013 tward





Reference: Aerial from Google Earth, August 2011.

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Legend

- Low Tide Transects
- Side Scan Sonar Vessel Track
- Dive Transects
- Substrate/debris verification points
- Eelgrass
- Contour (5 ft interval; NAVD88)
- Contour (1 ft interval; NAVD88)

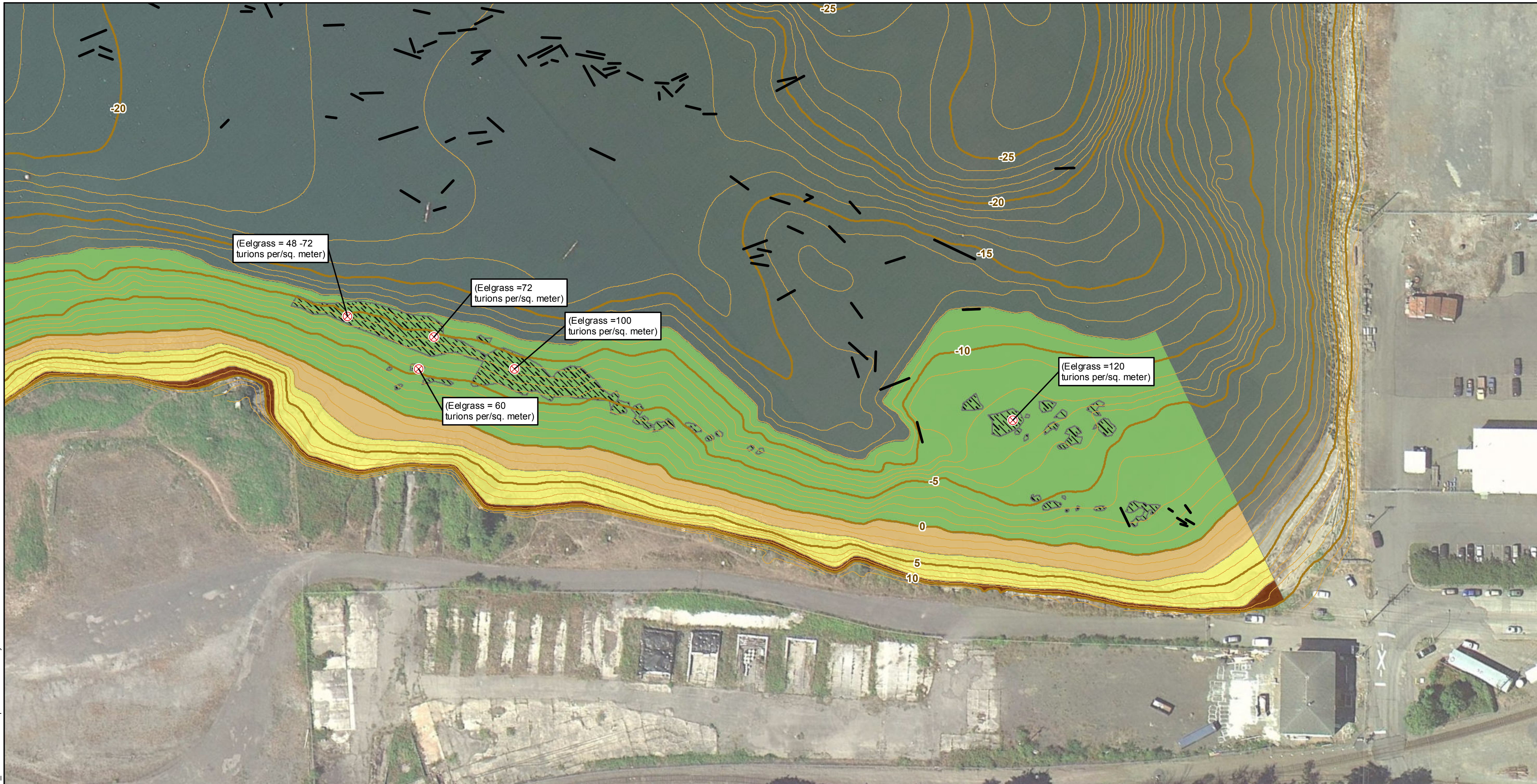
Habitat Survey Investigation Activities

R.G. Haley Site
Bellingham, Washington

GeoEngineers

Figure 4-18

Path: \\SEA\projects\0\0356114\GIS\HabitatSurvey\0356114_Habitat.mxd Map Revised: 29 July 2013 tward



Project North

True North

0 50 100

Feet

Reference: Aerial from Google Earth, August 2011.

Notes:
1. The locations of all features shown are approximate.
2. This drawing is for information purposes. It is intended to assist in showing features discussed in an attached document. GeoEngineers, Inc. cannot guarantee the accuracy and content of electronic files. The master file is stored by GeoEngineers, Inc. and will serve as the official record of this communication.

Legend

Upper Tidal Zone (10 to 8 ft)
Primarily consists of filamentous algae and sparse patches of lichen with occasional barnacles on hard substrates.

Fucus Zone (8 to 3 ft)
Primarily consists of Rockweed (*Fucus* spp.) with some Sea Lettuce (*Ulva* spp.). Also present is a green macro algae (*Enteromorpha* spp.) with barnacles on hard substrates, mussels, limpets, snails and some rock crabs.

Ulva Zone (3 to 0 ft)
Primarily consists of Sea Lettuce (*Ulva* spp.). Also present is some Rockweed (*Fucus* spp.) with limpets, snails, and rock crabs.

Eelgrass Zone (0 to -12 ft)
Primary Eelgrass (*Zostera marina* spp.) area. Also present is some Sea Lettuce (*Ulva* spp.) with sea stars, clams, crabs, sea cucumber, and snails.

Eelgrass (one clump = 1 turion)

Debris (Logs, etc.)

Contour (5 ft interval; NAVD88)

Contour (1 ft interval; NAVD88)

Biotic Zones and Eelgrass Locations

R.G. Haley Site
Bellingham, Washington

GeoEngineers

Figure 4-19

Path: \\sea\projects\0\0356114\GIS\HabitatSurvey\0356114_Biotic.mxd Map Revised: 31 July 2013 tward

5.0 SCREENING LEVELS AND INDICATOR HAZARDOUS SUBSTANCES

5.1. Screening Levels

This section summarizes the screening levels developed during the RI for use in evaluating the extent of contamination and potential risks to human health and the environment at the Site. These screening levels have been developed in accordance with MTCA (WAC 173-340-720 through 740) and the Sediment Management Standards (SMS; Chapter 173-204 WAC). Soil, groundwater and sediment cleanup levels, including sediment cleanup levels protective of bioaccumulative risks for human and ecological health, are developed and explained in the FS (Section 9.2).

Screening levels were developed for those constituents detected in sediment, groundwater and soil at the Haley Site that have numerical regulatory criteria listed in Ecology's online Cleanup Levels and Risk Calculations (CLARC) database (Ecology 2013a) or toxicity data that can be used to calculate protective criteria. The screening levels for these media are presented in Tables 5-1 through 5-3. Screening levels were also developed for constituents in soil vapor. The soil vapor screening levels were obtained from Ecology's draft soil vapor intrusion guidance (Ecology 2009b) and are presented in Table 6-9.

5.1.1. Sediment Screening Levels

Sediment screening levels were identified for constituents present in sediment at the Haley Site and are discussed in the following sections and presented in Table 5-1. SMS standards (Chapter 173-204 WAC) include numeric Sediment Cleanup Objectives (SCO) and Cleanup Screening Levels (CSL) for both chemical and biological endpoints that are protective of benthic invertebrate communities. The SCO criteria correspond to sediment concentrations or biological criteria below which adverse effects (acute or chronic) to benthic invertebrates are unlikely. The CSL criteria correspond to concentrations or effects thresholds above which adverse effects to benthic invertebrate communities from toxic compounds are anticipated, and represent the maximum allowed chemical concentrations and biological effects for use in evaluating cleanup alternatives. Chemical concentrations or biological effects falling between the SCO and CSL represent potential minor adverse effects or minimal risks. SMS numerical criteria are based on either dry weight- or organic carbon-normalized concentrations, depending on chemical properties and sample-specific organic carbon content. The analytical results for non-ionizable SVOCs are carbon-normalized when the total organic carbon (TOC) concentration in a sediment sample ranges from 0.5 to 3.5 percent (inclusive). The carbon-normalized analytical results are then compared to the published SMS criteria (SCO and CSL). Analytical results for samples with TOC concentrations outside of the 0.5 to 3.5 percent range are screened against the apparent effects threshold (AET) values, which are expressed on a dry weight basis (EPA 1988). The lowest AET (LAET) is considered equivalent to the SCO, and the second lowest AET (2LAET) is considered equivalent to the CSL.

The SMS and AET criteria were used as sediment screening levels for evaluating contaminant extent and risks and are included in Table 5-1. Biological tests, which measure effects on survival and growth for several different marine invertebrate species, were also used to help determine whether sediment may pose an unacceptable risk to benthic organisms (see Section 6.0). Biological test results are considered definitive with respect to compliance with SMS, and override conclusions that are based on data comparisons to chemical criteria.

SMS numerical criteria were not available for several chemicals associated with the Site including total petroleum hydrcarbons (TPH), dioxins/furans and total cPAHs. In addition, the criteria do not address some of the pathways that could potentially expose Site receptors to contaminants in sediment (i.e., direct contact, net-fishing) or fish and shellfish (i.e., seafood consumption). Conservative screening levels were identified for characterizing the extent of these contaminants, for the RI as discussed below.

TPH screening levels are generally developed on a case-by-case basis. Bioassay testing can be used to develop site-specific numerical criteria or to directly evaluate potential adverse effects from petroleum hydrocarbons. Six sediment samples from the Haley RI data set were available to evaluate site-specific toxicity of diesel- and heavy oil-range petroleum hydrocarbons to larval mussels, amphipods and juvenile polychaete worms. Four of the six samples passed the bioassay testing criterion; TPH concentrations (sum of diesel- and heavy oil-range hydrocarbons) detected in the samples that passed ranged from 70 to 260 mg/kg. These data suggest that petroleum hydrocarbons at the Site do not pose a risk to benthic organisms at concentrations at least as high as 260 mg/kg. Therefore, the proposed sediment screening level for TPH in marine sediments at the Haley Site is 260 mg/kg.

SMS does not provide cleanup levels for constituents that pose a risk to human and ecological receptors as a result of bioaccumulation. Bioaccumulative compounds detected in sediment at the Haley Site that are potentially site-related include PAHs, PCP, and dioxins/furans. Guidance for development of screening levels for bioaccumulative compounds is provided in the SMS and takes into account potential site-specific exposures, as well as background concentrations and practical quantitation limits (PQLs). Available guidance and risk assessments from other studies indicate that risk-based bioaccumulation screening levels are typically lower than background concentrations in Bellingham Bay or PQLs; the SMS allows the use of background concentrations or PQLs as screening levels in such cases. Therefore, for cPAHs and dioxins/furans, natural background concentrations for these chemical groups have been incorporated as the screening levels in this RI report (see Table 5-1). The natural background values, calculated as the 90/90 upper tolerance limit (UTL), were obtained from Ecology's SCUM II guidance (Table 11-1; Ecology 2013f). No natural background concentration is available for PCP; therefore the screening level for PCP that is used in the RI is the PQL.

No screening level was developed for wood waste, as there are no quantitative regulatory guidelines for cleanup of wood; however, several chemicals potentially associated with the decomposition of wood waste (e.g., methylphenols, benzoic acid) were evaluated relative to regulatory criteria. Potential effects of wood are incorporated in biological testing and are discussed as part of the benthic community toxicity assessment.

Screening levels to address people contacting contaminated sediment during beach play or fishing were not developed. Any remedial action completed near the Haley shoreline will require armoring to prevent erosion that has historically occurred. The armoring required to stabilize the shoreline environment will limit exposure of people or other receptors (e.g., crab, fish). Screening levels that address benthic toxicity and bioaccumulation would also be protective for people directly exposed to contaminated sediment during net fishing activities; therefore, additional screening levels for the net fisher pathway were not developed.

5.1.2. Groundwater Screening Levels

Ecology has determined that groundwater beneath the Haley Site and other waterfront cleanup sites in Bellingham Bay is non-potable. Groundwater beneath the Haley Site is classified as non-potable based on the criteria specified in WAC 173-340-720(2), as follows:

> *(2)(a) The ground water does not serve as a current source of drinking water.*

Applicability: Drinking water in Bellingham is currently supplied by the City. Water supply wells are not known to exist at or near the Site.

> *(2)(c) The department determines it is unlikely that hazardous substances will be transported from the contaminated ground water to ground water that is a current or potential future source of drinking water, as defined in (a) and (b) of this subsection [i.e., -720(2)], at concentrations which exceed ground water quality criteria published in Chapter 173-200 WAC.*

Applicability: Contaminated groundwater beneath the Haley Site occurs in the uppermost groundwater-bearing zone comprised of fill and underlying native sediment ("shallow aquifer"). The shallow aquifer discharges directly into Bellingham Bay and will not flow toward other aquifers that may be a current or potential future source of drinking water, because the inland aquifers are hydraulically upgradient of the shallow aquifer.

> *(2)(d) Even if ground water is classified as a potential future source of drinking water..., the department recognizes that there may be sites where there is an extremely low probability that the ground water will be used for that purpose because of the site's proximity to surface water that is not suitable as a domestic water supply. An example of this situation would be shallow ground waters in close proximity to marine waters such as on Harbor Island in Seattle. At such sites, the department may allow ground water to be classified as non-potable if each of the following conditions can be demonstrated. These determinations must be for reasons other than that the ground water or surface water has been contaminated by a release of a hazardous substance at the site.*

> *(2)(d)(i) There are known or projected points of entry of the ground water into the surface water.*

Applicability: Groundwater at the Site discharges directly into Bellingham Bay.

> *(2)(d)(ii) The surface water is not classified as a suitable domestic water supply source under Chapter 173-201A WAC.*

Applicability: Bellingham Bay is a marine surface water body, and is not suitable as a domestic water supply under Chapter 173-201A WAC.

(2)(d)(iii) The ground water is sufficiently hydraulically connected to the surface water that the ground water is not practicable to use as a drinking water source.

Applicability: The shallow aquifer beneath the Site is directly connected with and discharges into Bellingham Bay. It is not practicable to utilize the shallow aquifer for water supply due to the potential for drawing saline water into the aquifer (salt water intrusion).

Screening levels for groundwater are presented in Table 5-2. The groundwater screening levels are based on protection of the following media/exposure scenarios:

- **Marine Surface Water.** Groundwater numerical criteria protective of marine surface water are based on MTCA standard Method B surface water cleanup levels prescribed in WAC 173-340-730(3)(b). The Method B surface water cleanup levels are protective of aquatic organisms and human health. Many of the SVOCs and petroleum-related compounds in Table 5-2 do not have established surface water criteria protective of aquatic organisms. For these compounds, the groundwater criteria protective of marine sediment (i.e., protective of benthic organisms) will serve as a surrogate for protection of the surface water exposure pathway. The rationale for this approach is that the sediment criteria (e.g., SCO values) were developed to be protective of benthic organisms that live in water-saturated sediment, where potential exposures to contaminated groundwater in sediment pore spaces would be much greater than in the overlying water column.
- **Sediment.** Groundwater numerical criteria protective of marine sediment were calculated from SCO criteria published in SMS (Chapter 173-204 WAC). Methods used to calculate groundwater concentrations protective of sediment are described below.
- **Indoor Air (Vapor Intrusion).** Groundwater numerical criteria protective of indoor air (via the vapor intrusion pathway) were obtained from Table B-1 of Ecology's draft "Guidance for Evaluating Soil Vapor Intrusion in Washington State: Investigation and Remedial Action" (draft VI guidance; Ecology 2009b). The groundwater criteria protective of indoor air were calculated by Ecology from MTCA Method B indoor air cleanup levels.

Groundwater concentrations protective of sediment were calculated assuming equilibrium partitioning between sediment and groundwater in sediment pore spaces. The following equations were used to calculate groundwater concentrations protective of organic carbon-normalized and dry weight SCO criteria:

Organic Carbon-Normalized Criteria:

$Cw = (SCO/K_{oc}) \times CF$

Where:

Cw = groundwater concentration protective of sediment (µg/L)
SCO = sediment cleanup objective (WAC 173-204-320) (mg/kg organic carbon)
K_{oc} = organic carbon partitioning coefficient (L/kg)
CF = conversion factor (1,000 µg/mg)

Dry Weight Criteria:

$Cw = (SCO/(K_{oc} \times f_{oc})) \times CF$

Where:

Cw = groundwater concentration protective of sediment (µg/L)
SCO = sediment cleanup objective (WAC 173-204-320) (mg/kg dry weight)
K_{oc} = organic carbon partitioning coefficient (L/kg)
f_{oc} = decimal fraction organic carbon (assumed to be 0.025 or 2.5%; Table 9-1, Draft Sediment Cleanup User's Manual II) (Ecology Publication No. 12-09-057)
CF = conversion factor (1,000 µg/mg)

K_{oc} values were taken directly from Ecology's CLARC database. Where K_{oc} values were not available in CLARC, they were obtained from EPA's Estimation Program Interface (EPI) Suite, Version 4.10.

MTCA (WAC 173-340-705[6]) specifies that the cleanup level for a given constituent shall not be set at a level below the natural background concentration or analytical practical quantitation limit (PQL), whichever is higher. Preliminary groundwater screening levels were selected based on the lowest of the applicable numerical criteria described above. The preliminary groundwater screening levels were then adjusted as necessary based on background concentrations (arsenic only) and PQLs. The background value for arsenic in groundwater is based on the MTCA Method A groundwater cleanup level, which is identified as the regulatory background concentration of arsenic in Washington state. The PQLs listed in Table 5-2 were obtained from Analytical Resources Incorporated of Tukwila, Washington (ARI) and Frontier Analytical Laboratory (Frontier) of El Dorado Hills, California, both of which are Washington-certified laboratories. Discussions with these laboratories regarding the analytical requirements for this project indicate that the listed groundwater PQLs in Table 5-2 are the lowest practicably attainable values using conventional/accepted analytical methods. For those analytes listed in Table 5-2 with PQLs greater than the lowest applicable protective criteria, the laboratories have determined that PQLs below the protective criteria cannot be practicably achieved.

Groundwater screening levels listed in the column titled "Screening Level (before adjustment for PQL)" in Table 5-2 have been adjusted for background, where necessary (arsenic only). The groundwater screening levels after adjustment for PQL are presented in the last column of Table 5-2.

5.1.3. Soil Screening Levels

Screening levels for soil are presented in Table 5-3. The soil screening levels were selected from the following criteria:

- **Human Direct Contact:** MTCA standard Method B soil cleanup levels protective of human health for unrestricted land use (WAC 173-340-740[3][b]), obtained from Ecology's CLARC database or calculated using equations in WAC 173-340-740(3)(b)(iii)(B).
- **Groundwater Protection:** Soil criteria protective of groundwater quality (based on the lowest groundwater criteria that are presented in Table 5-2 and discussed in Section 5.1.2). These soil criteria address the soil to groundwater pathway, and were calculated using the MTCA fixed parameter three-phase partitioning model (WAC 173-340-747[4]). Default assumptions provided in WAC 173-340-747(4)(b) (Equation 747-1) for vadose and saturated zone soils were

used in the calculations, and model input parameter values (K_{oc} and Henry's Law constants) were taken directly from Ecology's CLARC database. Where input parameter values were not available in CLARC, they were obtained from EPA's EPI Suite, Version 4.10.

Additional potentially complete exposure and transport pathways were considered when developing soil screening levels for the Site. These pathways are described below, along with the rationale for not developing soil screening levels for these pathways.

- **Terrestrial Ecological Evaluation (TEE):** Existing contaminant concentrations are greater than the screening levels in MTCA (Tables 749-2 and 749-3) that are considered protective of terrestrial species. However, the upland remedy for the Site is anticipated to include an engineered cap in addition to removal and/or treatment actions. The design of any future cap will be integrated with Site redevelopment plans. Collectively, any future paved parking areas, buildings and capped areas will prevent plant and wildlife exposures to underlying contaminated soil. Institutional controls would be established to maintain an engineered cap. Therefore, the Site qualifies for an exclusion under WAC 173-340-7491(1)(b), which states that a TEE is not required if "all soil contaminated with hazardous substances is, or will be, covered by buildings, paved roads, pavement, or other physical barriers that will prevent plants or wildlife from being exposed to the soil contamination." Construction of the upland remedy is anticipated to begin in 2016 or 2017.
- **Soil Erosion to Sediment:** Direct soil erosion and transport to sediment is another potential transport pathway at the Site. However, soil screening levels for this pathway are not included in Table 5-3 because any upland remedy will prevent soil erosion and provide for stormwater management.
- **Vapor Intrusion:** Ecology's draft VI guidance (Ecology 2009b) does not allow for the calculation of soil cleanup levels protective of the vapor intrusion pathway. The vapor intrusion pathway will be addressed, if needed, by institutional controls that would prevent the future construction of residential structures at the Site, and/or require evaluation of any mitigation measures potentially needed if infrequently occupied park structures were constructed. Additionally, the potential for methane generation is being addressed as part of the Cornwall FS (Landau 2013).

MTCA (WAC 173-340-705[6]) specifies that the cleanup level for a given constituent shall not be set at a level lower than the natural background concentration or the PQL, whichever is higher. Preliminary soil screening levels were selected based on the lowest of the applicable numerical criteria. The preliminary soil screening levels were then adjusted as necessary based on background concentrations (metals and dioxins/furans) and PQLs. The background metals concentrations used are the Puget Sound Region 90th percentile values reported by Ecology (1994), except for arsenic, which is based on MTCA Table 740-1. The background value for dioxins/furans is the natural background concentration for upland soils reported by Ecology (2010b). The PQLs listed in Table 5-3 were obtained from ARI and Frontier, both of which are Washington-certified laboratories.

Soil screening levels listed in the column titled "Screening Level (before adjustment for PQL)" in Table 5-3 have been adjusted for background, where necessary (metals and dioxins/furans). The soil screening levels after adjustment for PQL are presented in the last column of Table 5-3. Values shown in the column labeled saturated soil were identified as the screening levels for the RI based on the relatively shallow depth to groundwater as discussed in Section 4.0.

5.1.3.1. PETROLEUM HYDROCARBON SOIL SCREENING LEVEL

A site-specific soil screening level for petroleum hydrocarbons protective of human direct contact was calculated using the MTCA-defined approach for calculating Method B cleanup levels for petroleum mixtures (WAC 173-340-740[3][b][iii][B][III]) and Ecology's "Guidance for Remediation of Petroleum-Contaminated Sites" (Ecology 2011d). This site-specific screening level is applicable to the diesel- and heavy oil-range petroleum hydrocarbon fractions. The terms "TPH" and "petroleum hydrocarbons" are used interchangeably in this report; both of these terms refer to the sum of diesel- and heavy oil-range petroleum hydrocarbons unless specified otherwise. Gasoline-range petroleum hydrocarbons were evaluated separately.

Six soil samples collected in 2004 were analyzed for extractable petroleum hydrocarbons (EPH); diesel- and lube/heavy oil-range petroleum hydrocarbons; benzene, ethylbenzene, toluene, and xylenes (BETX); and PAHs (GeoEngineers 2007). Based on the interpretation of chromatograms from the chemical analyses, the following types of petroleum were present in the samples:

- Diesel-range hydrocarbons (one product type): samples TL-DP-2-8-10, HS-DP-4-8-11, HS-DP-8-8-11, and HS-MW-13D-8-10
- Diesel- and heavy oil-range hydrocarbons (two product types): sample TL-MW-10-12-13
- Other heavy oil-range hydrocarbons (different than the heavy oil-range product in sample TL-MW-10-12-13): sample HS-MW-10-12-13

Based on a review of other soil sample chromatograms from the broader Haley Site (Section 6.3.2), these six samples appear to be generally representative of the types of petroleum present in upland soil. The most prevalent petroleum hydrocarbon (diesel-range) appears to be characteristic of the wood treatment carrier oil used at the Haley facility. Other petroleum products were present to a lesser extent. These include lube or motor oil, other heavy oil-range hydrocarbons, and a combination of these products.

The site-specific soil screening level for petroleum hydrocarbons was calculated using analytical results for EPH, carcinogenic PAHs (cPAHs), naphthalene, 2-methylnaphthalene and BETX for the six soil samples identified above. The four samples that contained only diesel-range hydrocarbons (interpreted to be carrier oil) yielded the lowest calculated protective values. The calculated values for these samples ranged from 1,276 to 1,828 mg/kg. In accordance with Section 10.2 of the guidance (Ecology 2011d), the median value for these samples (1,534 mg/kg) was selected as the site-specific screening level for petroleum hydrocarbons in upland soil (Table 5-3). This value is considered protective of human health based on the direct contact pathway.

Ecology's guidance (Ecology 2011d) provides three methods for comparing site investigation data derived from NWTPH-Dx analytical methods to MTCA Method B cleanup levels derived from EPH (and other) analytical methods. Based on the Haley RI data set, the most appropriate method was identified to be Alternative 1 in the guidance. This method consisted of summing diesel- and heavy oil-range hydrocarbon concentrations (derived from NWTPH-Dx analyses) in individual samples, and then comparing the sums[7] to the screening level (1,534 mg/kg). This approach enabled the use of a substantial amount of NWTPH-Dx analytical data collected during previous studies. The soil screening level presented in the table for gasoline-range hydrocarbons is the MTCA Method A cleanup level for unrestricted land use.

5.1.4. Soil Vapor Screening Levels

Soil vapor screening levels are presented in Table 6-9 and are used in Section 6.0 to evaluate soil vapor data collected in 2005 relative to the vapor intrusion pathway. The soil vapor screening levels were obtained from Table B-1 of Ecology's 2009 draft VI guidance (Ecology 2009b). Ecology derived the soil vapor screening levels for sub-slab or "shallow" soil vapor by dividing the MTCA Method B indoor air cleanup levels (WAC 173-340-750[3]) by a vapor attenuation factor of 0.1. The MTCA Method B indoor air cleanup levels that were used as the basis for the soil vapor screening levels were verified using Ecology's CLARC online database.

5.1.5. Surrogates

For a number of constituents, regulatory criteria were not available for developing screening levels. For these constituents, the screening levels developed for other constituents were considered to be appropriate surrogates. The surrogate constituents were selected based on similar chemical structures and similar toxicological and chemical properties. Surrogate screening levels were used for the following constituents:

- **1-Methylnaphthalene:** The groundwater screening level for 2-methylnaphthalene was used as the screening level for 1-methylnaphthalene, because these compounds have similar toxicological and chemical properties (e.g., solubility, partitioning, etc.; EPA 2003a).
- **2,3,4,5- and 2,3,5,6-Tetrachlorophenol:** The groundwater screening level for 2,3,4,6-tetrachlorophenol was used as the screening level for these two chlorinated phenolic compounds, because all three compounds have similar chemical structures.
- **Carbazole:** The groundwater screening level for dibenzofuran was used as the screening level for carbazole because these compounds have similar chemical structures.
- **m,p-Cresol (3,4-methylphenol):** m,p-Cresol is often reported by the analytical laboratory when 3-methylphenol and 4-methylphenol cannot be distinguished. The soil and groundwater screening levels for p-cresol (4-methylphenol) were used as the screening levels for m,p-cresol, as p-cresol is the major component of m,p-cresol.
- Wood waste: Anaerobic biodegradation of wood waste in sediment can produce methylphenols and benzoic acid; therefore, these chemicals were used to support an evaluation of the distribution and potential effects of wood waste in the marine portion of the Site.

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[7] "Non-detect" results were assumed to be equal to ½ the analytical reporting limit for the purpose of calculating the TPH sum.

5.2. Indicator Hazardous Substances

Indicator hazardous substances (IHSs) for the Site were selected according to WAC 173-340-703 and will be used to focus the evaluation of Site cleanup requirements (Tables 5-4 through 5-6). This process was used to eliminate individual hazardous substances that contribute a small percentage of the overall threat to human health and the environment.

The first step in selecting IHSs in each matrix (sediment, groundwater, and soil) was to identify the frequency and magnitude at which constituents exceeded their respective screening levels. The frequency at which a constituent exceeds its screening level is termed the “exceedance frequency;” the magnitude by which a constituent exceeds its screening level is termed the “exceedance factor” (EF), and is derived by dividing the detected concentration by the screening level concentration. EFs discussed in the remainder of this report are rounded to whole numbers except for values between 1 and 2 which are rounded to the nearest tenth. Constituents were first considered as potential IHSs if they met either of the following criteria:

1. the constituent had an exceedance frequency of at least 10 percent, or
2. the constituent had an EF of 2 or more.

Constituents were then further screened to select IHSs based on consideration of the following additional characteristics:

1. whether or not a constituent that exceeded screening levels was identified as an IHS in other media;
2. geographic (spatial) footprint of exceedances;
3. detection frequency;
4. contaminant mobility;
5. density/distribution of investigation data; and
6. occurrence and magnitude of analytical reporting limits elevated above screening levels.

The selection of sediment, groundwater, and soil IHSs is summarized in Tables 5-4 through 5-6. These tables present selected summary statistics and information for the constituents detected in each matrix, as well as comments and rationale for IHS selection. The data sets used to calculate data statistics presented in Tables 5-4 through 5-6 are explained in Section 3.6. Due to the smaller number of analytes in the soil vapor evaluation presented in Section 6.6, it was not necessary to reduce the analyte list to a subset of IHSs for soil vapor.

5.2.1. Sediment IHSs

Preliminary sediment IHSs meeting the exceedance frequency criterion included petroleum hydrocarbons, select individual PAHs, cPAHs, PCP and mercury. The EF is a measure of potential risk; there were 27 constituents that exceeded their respective screening levels by a factor of 2 or more in at least one sample. Preliminary IHSs with EFs of 2 or more included petroleum hydrocarbons, cPAHs, select individual PAHs, dioxins/furans, two phthalates (butylbenzylphthalate and dimethylphthalate), two phenolic compounds (2,4-dimethylphenol and PCP), dibenzofuran and mercury.

Of the constituents meeting either the exceedance frequency or EF criteria, TPH, dioxins/furans, cPAHs and PCP are associated with historical wood-treating processes and are relatively widely distributed in the marine portion of the Site. The other chlorinated phenol meeting preliminary IHS criteria (2,4-dimethylphenol) occurs within the footprint of the PCP exceedances and had a lower EF. No other methylphenols met IHS criteria[8]. The PAHs (including cPAHs) detected in sediment are likely associated with the historical use of petroleum as a carrier for PCP. The distribution of PAHs in sediment can be characterized using cPAHs and the six individual PAHs listed below; the other detected PAHs occur within the footprint of these six PAHs and have lower EFs. Phthalates and mercury are not selected as IHSs because there are no known sources of these constituents at the Haley Site; these constituents are associated with the Cornwall Landfill and Whatcom Waterway sites, respectively. The geographic footprints of the preliminary sediment IHSs were evaluated, along with their relationships to groundwater and soil IHSs, resulting in the selection of 10 sediment IHSs:

- **TPH:** TPH is a key Site contaminant, is an IHS in soil and is present in groundwater.
- **2-Methylnaphthalene:** This PAH is a key IHS in groundwater and soil based on detection and exceedance frequency, EF and geographic footprint. It is also one of the more mobile PAHs.
- **Acenaphthene:** This PAH was selected as an IHS in groundwater and soil based on detection and exceedance frequency, EF and geographic footprint. It is also one of the more mobile PAHs.
- **Naphthalene:** This PAH was frequently detected and has a broad footprint in sediment. Naphthalene exceeded its screening level at the three locations where low molecular-weight PAHs (LPAHs) were detected above the LPAH screening level and phenanthrene was not detected.
- **Phenanthrene:** This PAH was selected as an IHS in sediment based on detection and exceedance frequency, EF and geographic footprint. Phenanthrene exceeded its screening level at all but three locations where LPAHs were detected above the LPAH screening level.
- **Benzo(a)anthracene:** This PAH was selected as an IHS in sediment based on detection frequency and geographic footprint. Benzo(a)anthracene exceeded its screening level at all but three locations where high molecular-weight PAHs (HPAHs) were detected above the HPAH screening level. It is also an IHS in groundwater and soil based on detection and exceedance frequency, EF and geographic footprint. Benzo(a)anthracene is among the most mobile HPAHs.
- **cPAHs:** Total cPAHs, calculated as the cPAH TEQ, were selected as an IHS in sediment based on detection and exceedance frequency, maximum EF, and geographic footprint. Additionally, cPAHs were selected as an IHS in groundwater and soil.

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[8] Other phenolic compounds (2-methylphenol, 4-methylphenol, and phenol) were detected above screening levels at selected locations but had low frequency of exceedance (≤5 percent) and low exceedance factors (EF≤1.1). All were collocated with PCP or PAHs in sediment. In addition, none of these phenolic compounds met IHS criteria for other media.

- **Fluoranthene:** This PAH is an IHS in sediment based on detection and exceedance frequency, EF and geographic footprint. Fluoranthene exceeded its screening level at the locations where HPAHs were detected above the HPAH screening level.
- **PCP:** PCP was the active ingredient in the petroleum-based solution used to treat wood at the Haley facility; it is a key Site contaminant and an IHS in sediment, groundwater and soil.
- **Dioxins/Furans:** Dioxins/furans were selected as an IHS in sediment based on detection and exceedance frequency, maximum EF, and geographic footprint. Dioxins/furans are a key Site contaminant associated with the PCP historically used in wood treatment at the Haley facility and were selected as an IHS in groundwater and soil.

Constituents that were detected in sediment but did not meet the initial IHS selection criteria were carefully evaluated. None of these constituents was selected as an IHS in sediment based on consideration of other selection factors. The effect of elevated analytical reporting limits on the IHS selection process also was evaluated. Nine sediment analytes had elevated reporting limits in at least 10 percent of the sediment samples in the RI database. However, these analytes either: (1) have no known source associated with Haley activities; (2) were not detected in soil, groundwater and sediment; or (3) where detected in sediment, fell within the geographic footprint of one or more of the IHSs listed above. Therefore, the elevated reporting limits for the referenced analytes do not adversely affect the sediment characterization or the selection of sediment IHSs at the Haley Site.

As previously described, wood and wood waste are present in nearshore sediment adjacent to the former Haley facility; however, wood waste was not identified as an IHS for the Haley Site. The potential effects of wood waste on the benthic community were evaluated through biological testing (bioassays) and by comparing the concentrations of chemicals potentially associated with wood waste degradation to regulatory criteria. Wood waste is co-located with wood treatment chemicals, and will be addressed as part of the Site remedy.

5.2.2. Groundwater IHSs

As shown in Table 5-5, seven constituents were selected as groundwater IHSs:

- **1- and 2-Methylnaphthalene:** These PAHs are key IHSs in groundwater based on detection and exceedance frequency, EF, geographic footprint and mobility. The EFs for 1- and 2-methylnaphthalene at individual monitoring wells are generally greater than the EFs for other noncarcinogenic PAHs. One or both of these constituents are also IHSs in soil and sediment.
- **Acenaphthene:** The geographic footprint and EFs for acenaphthene are generally smaller than those for 1- and 2-methylnaphthalene. This PAH is an IHS in groundwater primarily because of its vertical distribution near the shoreline.
- **Benzo(a)anthracene and cPAHs:** Benzo(a)anthracene is the key individual cPAH IHS in groundwater based on detection and exceedance frequency, EF, geographic footprint and mobility. Total cPAHs calculated as the cPAH TEQ represents all cPAHs, and is an IHS in groundwater because EFs for cPAH concentrations at individual monitoring wells are generally greater than the EFs for individual cPAHs. Benzo(a)anthracene and cPAHs are also IHSs in soil and sediment.

- **PCP:** The geographic footprint of PCP in groundwater is very limited. PCP is nonetheless an IHS in groundwater for several reasons: (1) PCP was the active ingredient in the petroleum-based solution used to treat wood at the Haley facility; (2) PCP wood treatment solutions are known to historically contain dioxins/furans as impurities; and (3) PCP is an IHS in soil and sediment.
- **Dioxins/Furans:** Dioxins/furans are key Site contaminants associated with the PCP historically used in wood treatment at the Haley facility. Additionally, dioxins/furans are an IHS in soil and sediment.

Constituents that were detected in groundwater but did not meet the initial IHS selection criteria were carefully evaluated. None of these constituents were selected as an IHS in groundwater based on consideration of other selection factors. The effect of elevated analytical reporting limits on the IHS selection process also was evaluated. Mercury and bis(2-ethylhexyl)phthalate had elevated reporting limits in at least 24 percent of the groundwater samples obtained in 2012. However, most of these elevated reporting limits were in samples obtained on the Cornwall site in the shoreline monitoring wells for the Cornwall RI. In addition, mercury and bis(2-ethylhexyl)phthalate are not constituents associated with the Haley Site. PAH reporting limits were elevated in 40 to 50 percent of the groundwater samples obtained in 2012. Most of these elevated reporting limits were in samples that had elevated concentrations of 1- and/or 2-methylnaphthalene, which are groundwater IHSs. Therefore, the elevated PAH reporting limits do not adversely affect the groundwater characterization or the selection of groundwater IHSs at the Haley Site.

5.2.3. Soil IHSs

As shown in Table 5-6, seven constituents were selected as soil IHSs:

- **TPH:** TPH (sum of diesel- and heavy oil-range hydrocarbons) is an IHS in soil based on detection and exceedance frequency, EF and geographic footprint. TPH occurrence is closely related to the occurrence of other soil IHSs because of the historical use of carrier oil in the wood treatment process. TPH is also an IHS in sediment.
- **1- and 2-Methylnaphthalene:** These PAHs are IHSs in soil based on detection and exceedance frequency, EF, geographic footprint and mobility. The EFs for 1- and 2-methylnaphthalene are generally greater than the EFs for other noncarcinogenic PAHs. One or both of these constituents are also IHSs in groundwater and sediment.
- **Benzo(a)anthracene and cPAHs:** Benzo(a)anthracene is the key individual cPAH in soil based on detection and exceedance frequency, EF, geographic footprint and mobility. Total cPAHs calculated as the cPAH TEQ represents all cPAHs, and is an IHS in soil based on exceedance frequency and EF. Benzo(a)anthracene and cPAHs are also IHSs in groundwater and sediment.
- **PCP:** PCP was the active ingredient in the petroleum-based solution used to treat wood at the Haley facility; it is a key Site contaminant and an IHS in soil, groundwater and sediment.
- **Dioxins/Furans:** Dioxins/furans are key Site contaminants associated with the PCP historically used in wood treatment at the Haley facility. Additionally, dioxins/furans are an IHS in groundwater and sediment.

Constituents that were detected in soil but did not meet the initial IHS selection criteria were carefully evaluated. None of these constituents was selected as an IHS in soil based on consideration of other selection factors.

There was no documented Haley wood treatment use of chromated copper arsenate or other wood treatment solutions that contained metals as the active ingredient operations. Six soil samples from two borings on the Haley property (Figure 3-2A, HS-DP-1 and HS-DP-5B, Table 6-4) and three groundwater samples from the Haley property (Figure 3-1, HS-MW-10, HS-MW-11 and HS-MW-13) were, nonetheless, analyzed for arsenic, chromium and copper (Appendix B, Table B-3) in 2004. Copper was the only metal detected at concentrations exceeding screening levels in two of the soil samples and three of the groundwater samples. Based on these results, one soil sample (HS-MW-19) and four groundwater samples (HS-MW-7, HS-MW-17, TL-MW-1 and TL-MW-15) were analyzed for copper during the 2012 supplemental investigation (Table 6-4 and Table 6-8). Copper concentrations did not exceed the screening level in the 2012 groundwater samples, and only marginally exceeded the screening level in the soil sample tested. Copper and other metals were not selected as IHSs because of the limited detections at the Site.

The effect of elevated analytical reporting limits on the IHS selection process also was evaluated. Total xylenes, 12 PAHs and 12 SVOCs had elevated reporting limits in at least 10 percent of the soil samples in the RI database. However, most of these elevated reporting limits were in samples that had elevated concentrations of TPH, 1-methylnaphthalene, 2-methylnaphthalene and/or PCP, which are soil IHSs. Therefore, the elevated reporting limits for xylenes, PAHs and SVOCs do not adversely affect the soil characterization or the selection of soil IHSs at the Haley Site.

Table 5-1

Sediment Screening Levels

R.G. Haley Site

Bellingham, Washington

Constituent	Direct Contact - Benthic Organisms				Sediment Screening Level	
	SMS Criteria[1]		AET Criteria[2]		Organic Carbon	
	SCO[3]	CSL[4]	LAET[5]	2LAET[6]	0.5% to 3.5%	<0.5% and >3.5%
Metals	mg/kg		mg/kg		mg/kg	mg/kg
Mercury[8]	0.41	0.59	0.41	0.59	0.41	0.41
Total LPAHs	mg/kg OC		µg/kg		mg/kg OC	µg/kg
Total LPAH	370	780	5,200	5,200	370	5200
Naphthalene	99	170	2,100	2,100	99	2100
Acenaphthylene	66	66	1,300	1,300	66	1300
Acenaphthene	16	57	500	500	16	500
Fluorene	23	79	540	540	23	540
Phenanthrene	100	480	1,500	1,500	100	1500
Anthracene	220	1,200	960	960	220	960
2-Methylnaphthalene	38	64	670	670	38	670
Total HPAHs	mg/kg OC		µg/kg		mg/kg OC	µg/kg
Total HPAH	960	5,300	12,000	17,000	960	12000
Fluoranthene	160	1,200	1,700	2,500	160	1700
Pyrene	1,000	1,400	2,600	3,300	1000	2600
Benzo(a)anthracene	110	270	1,300	1,600	110	1300
Chrysene	110	460	1,400	2,800	110	1400
Total benzofluoranthenes	230	450	3,200	3,600	230	3200
Benzo(a)pyrene	99	210	1,600	1,600	99	1600
Indeno(1,2,3-cd)pyrene	34	88	600	690	34	600
Dibenzo(a,h)anthracene	12	33	230	230	12	230
Benzo(ghi)perylene	31	78	670	720	31	670
cPAHs TEQ[11]	--	--	--	--	21 µg/kg	21
Chlorinated Hydrocarbons	mg/kg OC		µg/kg		mg/kg OC	µg/kg
1,2-Dichlorobenzene	2.3	2.3	35	50	2.3	35
1,3-Dichlorobenzene	--	--	--	--	--	--
1,4-Dichlorobenzene	3.1	9	110	110	3.1	110
1,2,4-Trichlorobenzene	0.81	1.8	31	51	0.81	31
Hexachlorobenzene	0.38	2.3	22	70	0.38	22
Phthalates	mg/kg OC		µg/kg		mg/kg OC	µg/kg
Dimethylphthalate[7]	53	53	71	160	53	71
Diethylphthalate	61	110	200	>200	61	200
Dibutylphthalate	220	1,700	1,400		220	1400
Butylbenzylphthalate	4.9	64	63	900	4.9	63
Bis(2-ethylhexyl)phthalate[7]	47	78	1,300	1,900	47	1300
Di-n-octylphthalate	58	4,500	6,200	6,200	58	6200
Miscellaneous Extractables	mg/kg OC		µg/kg		mg/kg OC	µg/kg
Dibenzofuran	15	58	540	540	15	540
Hexachlorobutadiene	3.9	6.2	11	120	3.9	11
n-Nitrosodiphenylamine	11	11	28	40	11	28

Constituent	Direct Contact - Benthic Organisms				Sediment Screening Level	
	SMS Criteria[1]		AET Criteria[2]		Organic Carbon	
	SCO[3]	CSL[4]	LAET[5]	2LAET[6]	0.5% to 3.5%	<0.5% and >3.5%
Miscellaneous Extractables	µg/kg		µg/kg		µg/kg	µg/kg
Benzyl alcohol	57	73	57	73	57	57
Benzoic acid	650	650	650	650	650	650
Phenols	µg/kg		µg/kg		µg/kg	µg/kg
Phenol[8]	420	1,200	420	1,200	420	420
2-Methylphenol[8]	63	63	63	63	63	63
4-Methylphenol[8]	670	670	670	670	670	670
2,4-Dimethylphenol	29	29	29	29	29	29
Pentachlorophenol[9]	100	690	100	690	100	100
Petroleum Hydrocarbons	mg/kg		mg/kg		mg/kg	mg/kg
Diesel-range hydrocarbons	--	--	--	--	see TPH	see TPH
Heavy oil-range hydrocarbons	--	--	--	--	see TPH	see TPH
Total petroleum hydrocarbons[10]	260	--	--	--	260	260
Dioxins/Furans	ng/kg		ng/kg		ng/kg	ng/kg
Dioxins TEQ [11]		--	--	--	4	4

Notes:

[1] Sediment Management Standards (Chapter 173-204 WAC)

[2] Apparent Effects Threshold Criteria

[3] Sediment Cleanup Objective (Chapter 173-204-320)

[4] Cleanup Screening Level (Chapter 173-204-520)

[5] Lowest Apparent Effects Threshold Criteria from SCUM II (2015).

[6] Second-Lowest Apparent Effects Threshold Criteria (SCUM II 2015).

[7] This analyte was identified as a constituent of concern for the Cornwall Avenue Landfill site Cornwall Avenue Landfill RIFS Report, Landau 2013)

[8] This analyte was identified as a constituent of concern for the Whatcom Waterway site (RETEC, 2006, Whatcom Waterway Supplemental RI/FS) and/or the Cornwall Avenue Landfill site (Landau 2013)

[9] Screening level for pentachlorophenol (PCP) based on practical quantitation limit (PQL) to provide a conservative assessment of the potential for bioaccumulative effects.

[10] Screening level for total petroleum hydrocarbons (TPH) are based on Haley site-specific bioassay results. Total petroleum hydrocarbons represent the sum of diesel- and lube oil-range hydrocarbons.

[11] Screening levels based on natural background concentrations established by Ecology (Ecology 2015b) to provide a conservative assessment of the potential for bioaccumulative effects; expressed as toxicity equivalent (TEQ) concentrations. See Section 5 for further discussion.

Shading indicates basis for proposed screening level

-- = No criterion is currently available for this analyte

µg/kg = micrograms per kilogram

2LAET = Second Lowest Apparent Effects Threshold

CSL = Cleanup Screening Levels

LAET = Lowest Apparent Effects Threshold

mg/kg OC = milligrams per kilogram organic carbon

ng/kg = nanogram per kilogram

SCO = Sediment Cleanup Objective

SMS = Sediment Management Standards

Total HPAHs are the sum of detected concentrations of fluoranthene, pyrene, benzo(a)anthracene, chrysene, benzofluoranthenes, benzo(a)pyrene, indeno(1,2,3-c-d)pyrene, dibenzo(a,h)anthracene and benzo(g,h,i)perylene.

Total LPAHs are the sum of detected concentrations of naphthalene, acenapthylene, acenapthene, fluorene, phenanthrene and anthracene; 2-methylnaphthalene is not included in the sum of LPAHs.

Table 5-2

Groundwater Screening Levels

R.G. Haley Site

Bellingham, Washington

Analyte Group	CASRN	Constituent		Protection of Surface Water: 40 CFR Part 131.36[1] Protection of Aquatic Organisms Marine Water Acute (µg/L)	40 CFR Part 131.36[1] Protection of Aquatic Organisms Marine Water Chronic (µg/L)	40 CFR Part 131.36[1] Protection of Human Health For Consumption of: Organism Only (µg/L)	Section 304 of the Clean Water Act[2] Protection of Aquatic Organisms Marine Water Acute (µg/L)	Section 304 of the Clean Water Act[2] Protection of Aquatic Organisms Marine Water Chronic (µg/L)	Section 304 of the Clean Water Act[2] Protection of Human Health For Consumption of: Organism Only (µg/L)	WAC 173-201A[3] Protection of Aquatic Organisms Marine water Acute (µg/L)	WAC 173-201A[3] Protection of Aquatic Organisms Marine water Chronic (µg/L)	WAC 173-340-730[4] Protection of Human Health (fish consumption) MTCA Method B Carcino-gen (µg/L)	WAC 173-340-730[4] Protection of Human Health (fish consumption) MTCA Method B Non-Carcinogen (µg/L)	Protection of Sediment (SMS and AET values in Table 5-3)[5] (µg/L)	Protection of Vapor Intrusion MTCA Method B[6] Carcino-gen (µg/L)	Protection of Vapor Intrusion MTCA Method B[6] Non-Carcinogen (µg/L)	Screening Level (before adjustment for PQL) (µg/L)	PQL[7] (µg/L)	Screening Level (after adjustment for PQL) (µg/L)
Petroleum Hydrocarbons	n/a	Gasoline-range hydrocarbons		--	--	--	--	--	--	--	--	--	--	No Sed COPC	NTV	NTV	--	250	--
	n/a	Diesel-range hydrocarbons		--	--	--	--	--	--	--	--	--	--	No Sed COPC	NTV	NTV	--	250	--
	n/a	Lube oil-range hydrocarbons		--	--	--	--	--	--	--	--	--	--	No Sed COPC	NTV	NTV	--	500	--
BETX	71-43-2	Benzene		--	--	71	--	--	51	--	--	--	--	No Sed COPC	2.4	100	2.4	0.45	2.4
	100-41-4	Ethylbenzene		--	--	29000	--	--	2100	--	--	--	--	No Sed COPC	--	2800	2100	0.42	2,100
	108-88-3	Toluene		--	--	200000	--	--	15000	--	--	--	--	No Sed COPC	--	15000	15000	0.48	15,000
	1330-20-7	Xylenes (total)		--	--	--	--	--	--	--	--	--	--	No Sed COPC	--	310	310	0.78	310
SVOCs	90-12-0	1-Methylnaphthalene		--	--	--	--	--	--	--	--	--	--	15	NTV	NTV	15	1	15
	58-90-2	2,3,4,6-Tetrachlorophenol		--	--	--	--	--	--	--	--	--	320	No Sed COPC	NTV	NTV	320	1	320
	935-95-5	2,3,5,6-Tetrachlorophenol		--	--	--	--	--	--	--	--	--	320	ND Haley Sed	NTV	NTV	320	1	320
	88-06-2	2,4,6-Trichlorophenol		--	--	6.5	--	--	2.4	--	--	--	--	No Sed COPC	NTV	NTV	2.4	5	5
	91-57-6	2-Methylnaphthalene		--	--	--	--	--	--	--	--	--	--	15	NTV	NTV	15	1	15
	83-32-9	Acenaphthene		--	--	--	--	--	990	--	--	--	640	3.3	NTV	NTV	3.3	0.01	3.3
	208-96-8	Acenaphthylene		--	--	--	--	--	--	--	--	--	--	13	NTV	NTV	13	0.01	13
	120-12-7	Anthracene		--	--	110000	--	--	40000	--	--	--	26000	9.6	NTV	NTV	9.6	0.01	9.6
	191-24-2	Benzo(g,h,i)perylene		--	--	--	--	--	--	--	--	--	--	0.016	NTV	NTV	0.016	0.01	0.016
	117-81-7	Bis(2-ethylhexyl)phthalate		--	--	6	--	--	2	--	--	--	--	0.43	NTV	NTV	0.4	1	1
	86-74-8	Carbazole		--	--	--	--	--	--	--	--	--	--	1.6	NTV	NTV	1.6	1	1.6
	n/a	m,p-Cresol (3 & 4-methylphenol)		--	--	--	--	--	--	--	--	--	--	79	NTV	NTV	79	1	79
	132-64-9	Dibenzofuran		--	--	--	--	--	--	--	--	--	--	1.6	NTV	NTV	1.6	1	1.6
	206-44-0	Fluoranthene		--	--	370	--	--	140	--	--	--	90	3.3	NTV	NTV	3.3	0.01	3.3
	86-73-7	Fluorene		--	--	14000	--	--	5300	--	--	--	3500	3	NTV	NTV	3	0.01	3
	91-20-3	Naphthalene		--	--	--	--	--	--	--	--	--	4900	83	--	170.0	83	0.01	83
	86-30-6	n-Nitrosodiphenylamine		--	--	16	--	--	6	--	--	--	--	8.5	NTV	NTV	6	1	6
	87-86-5	Pentachlorophenol		13	7.9	8.2	13	7.9	3	13	7.9	--	--	24	NTV	NTV	3	0.25	3
	85-01-8	Phenanthrene		--	--	--	--	--	--	--	--	--	--	6	NTV	NTV	6	0.01	6
	108-95-2	Phenol		--	--	4600000	--	--	1700000	--	--	--	560000	580	NTV	NTV	580	1	580
	129-00-0	Pyrene		--	--	11000	--	--	4000	--	--	--	2600	15	NTV	NTV	15	0.01	15
	56-55-3	cPAHs	Benzo(a)anthracene	--	--	0.031	--	--	0.018	--	--	--	--	0.31	NTV	NTV	0.018	0.01	0.018
	50-32-8		Benzo(a)pyrene	--	--	0.031	--	--	0.018	--	--	--	--	0.1	NTV	NTV	0.018	0.01	0.018
	205-99-2		Benzo(b)fluoranthene	--	--	0.031	--	--	0.018	--	--	--	--	0.19	NTV	NTV	0.018	0.01	0.018
	207-08-9	cPAHs (cont.)	Benzo(k)fluoranthene	--	--	0.031	--	--	0.018	--	--	--	--	0.19	NTV	NTV	0.018	0.01	0.018
	218-01-9		Chrysene	--	--	0.031	--	--	0.018	--	--	--	--	0.28	NTV	NTV	0.018	0.01	0.018
	193-39-5		Indeno(1,2,3-cd)pyrene	--	--	0.031	--	--	0.018	--	--	--	--	0.0097	NTV	NTV	0.01	0.01	0.01
	53-70-3		Dibenz(a,h)anthracene	--	--	0.031	--	--	0.018	--	--	--	--	0.0067	NTV	NTV	0.0067	0.01	0.01
	n/a		cPAHs TEQ[8]	--	--	0.031	--	--	0.018	--	--	--	--	NTV	NTV	NTV	0.018	PQL[9]	0.018
VOCs	95-50-1	1,2-Dichlorobenzene		--	--	17000	--	--	1300	--	--	--	--	ND Haley Sed	--	1800	1300	1	1,300
	106-46-7	1,4-Dichlorobenzene		--	--	2600	--	--	190	--	--	--	--	5	--	7900	5	1	5
	108-90-7	Chlorobenzene		--	--	21000	--	--	1600	--	--	--	--	No Sed COPC	--	100	100	1	100

Analyte Group	CASRN	Constituent	Protection of Surface Water: 40 CFR Part 131.36[1] — Protection of Aquatic Organisms, Marine Water: Acute (µg/L)	Chronic (µg/L)	40 CFR Part 131.36[1] — Protection of Human Health For Consumption of: Organism Only (µg/L)	Section 304 of the Clean Water Act[2] — Protection of Aquatic Organisms, Marine Water: Acute (µg/L)	Chronic (µg/L)	Section 304 of the Clean Water Act[2] — Protection of Human Health For Consumption of: Organism Only (µg/L)	WAC 173-201A[3] — Protection of Aquatic Organisms, Marine water: Acute (µg/L)	Chronic (µg/L)	WAC 173-340-730[4] — Protection of Human Health (fish consumption), MTCA Method B: Carcino-gen (µg/L)	Non-Carcinogen (µg/L)	Protection of Sediment (SMS and AET values in Table 5-3)[5] (µg/L)	Protection of Vapor Intrusion MTCA Method B[6]: Carcino-gen (µg/L)	Non-Carcinogen (µg/L)	Screening Level (before adjustment for PQL) (µg/L)	PQL[7] (µg/L)	Screening Level (after adjustment for PQL) (µg/L)
Dioxins/Furans	1746-01-6	Dioxin TEQ[8]	--	--	1.4E-08	--	--	5.1E-09	--	--	--	--	TBC	NTV	NTV	5.1E-09	PQL[9]	PQL[9]
Dissolved Metals	7440-38-2	Arsenic[10]	69	36	0.14	69	36	0.14	69	36	--	--	No Sed COPC	NTV	NTV	5	0.5	5 [10]
	7440-50-8	Copper[11]	2.4	2.4	--	4.8	3.1	--	4.8	3.1	--	--	No Sed COPC	NTV	NTV	2.4	0.5	2.4
	7439-92-1	Lead[11]	210	8.1	--	210	8.1	--	210	8.1	--	--	No Sed COPC	NTV	NTV	8.1	1	8.1
	7439-96-5	Manganese [11]	--	--	--	--	--	100	--	--	--	--	No Sed COPC	NTV	NTV	100	0.001	100
	7439-97-6	Mercury	2.1	0.025	0.15	1.8	0.94	0.3	1.8	0.025	--	--	No Sed COPC	NTV	NTV	0.025	0.02	0.025
	740-66-6	Zinc	90	81	--	90	81	26000	90	81	--	--	No Sed COPC	NTV	NTV	81	0.004	81

Notes:

[1]Ambient water quality criteria (AQWC) for the protection of aquatic organisms and protection of human health based on consumption of organisms from 40 CFR part 131.36 (National Toxics Rule).

[2]National recommended water quality criteria for the protection of aquatic organisms and protection of human health based on consumption of organisms from Section 304 of the Clean Water Act.

[3]Water Quality Standards for Surface Waters of the State of Washington, Chapter 173-201A WAC, amended July 1, 2003. Based on protection of aquatic organisms.

[4]MTCA Method B surface water cleanup levels calculated following WAC 173-340-730(3)(b)(iii)(a) and (b) (equations 730-1 and 730-2). Values developed if sufficiently protective health-based criteria/standards have not been established under applicable state and federal laws. Values based on toxicity data from Ecology's CLARC on-line database as of March 2013.

[5]Calculated assuming equilibrium partitioning: Cw (mg/L; porewater) = Sediment Quality Standard (SQS; WAC 173-204-320)/Koc [for organic carbon normalized criteria] and Cw (mg/L; porewater) = Sediment Quality Standard (SQS; WAC 173-204-320)/Koc * foc [for dry weight criteria]. foc assumed to be 0.025 based on Ecology's Draft Sediment Cleanup Users Manual II dated August 2012 (Table 9-1).

[6]Values obtained from Ecology's draft Guidance for Evaluating Soil Vapor Intrusion in Washington State: Investigation and Remedial Action (Ecology Publication #09-09-047), Table B-1.

[7]PQL is lowest available value from Analytical Resources, Inc. (Tukwila, WA) or Frontier Analytical Laboratory (El Dorado Hills, CA).

[8]Dioxins/furans evaluated based on toxicity equivalent (TEQ) concentrations.

[9]PQL not available because constituent concentration is a calculated value. For dioxins/furans, the screening level is shown as "PQL" because the analytical laboratory cannot detect the dioxin and furan congeners at low enough concentrations to meet the risk-based screening level of 5.1E-09 µg/L.

[10]Arsenic groundwater screening level based on background concentration for State of Washington (MTCA Method A Table 720-1).

[11]These analytes are constituents of potential concern for the Cornwall Avenue Landfill site (Cornwall Avenue Landfill RI/FS, Landau 2013) but not the Haley Site.

Shading indicates basis for proposed screening level

-- = no value available

TBC = to be calculated. Because the groundwater screening level for dioxins/furans will be based on the PQL, this pathway will not affect the proposed groundwater screening level selected.

No Sed COPC = Constituent is not a sediment COPC.

NTV = no target value available (SMS values are available for individual cPAHs only).

ND Haley Sed = constituent was not detected in sediment.

Table 5-3

Soil Screening Levels

R.G. Haley Site

Bellingham, Washington

Analyte Group	CASRN	Constituent	Background Concentration[1] (mg/kg)	MTCA Method B Cleanup Levels[2] for Direct Contact - Unrestricted Land Use (WAC 173-340): Carcinogen (mg/kg)	MTCA Method B Cleanup Levels[2] for Direct Contact - Unrestricted Land Use (WAC 173-340): Noncarcinogen (mg/kg)	MTCA Method B Cleanup Levels[3] Protection of Groundwater (Surface Water): Vadose (mg/kg)	MTCA Method B Cleanup Levels[3] Protection of Groundwater (Surface Water): Saturated (mg/kg)	MTCA Method B Cleanup Levels[3] Protection of Groundwater (Sediment - SMS): Vadose (mg/kg)	MTCA Method B Cleanup Levels[3] Protection of Groundwater (Sediment - SMS): Saturated (mg/kg)	MTCA Method B Cleanup Levels[3] Protection of Groundwater (Indoor Air): Vadose (mg/kg)	MTCA Method B Cleanup Levels[3] Protection of Groundwater (Indoor Air): Saturated (mg/kg)	Screening Level (before adjustment for PQL): Vadose (mg/kg)	Screening Level (before adjustment for PQL): Saturated (mg/kg)	PQL[4] (mg/kg)	Screening Level (after adjustment for PQL): Vadose (mg/kg)	Screening Level (after adjustment for PQL): Saturated (mg/kg)
Petroleum Hydrocarbons	n/a	Gasoline-range[5]	--	100[6]		NTV	NTV	NTV	NTV	NTV	NTV	100	100	5	100	100
	n/a	Diesel-range[7]	--	1534		NTV	NTV	NTV	NTV	NTV	NTV	1534	1534	5	1,534	1,534
	n/a	Lube oil-range[7]	--			NTV	NTV	NTV	NTV	NTV	NTV			10		
BETX	100-41-4	Ethylbenzene	--	--	8000	18	1	NTV	NTV	24	1.4	18	1	0.025	18	1
	108-88-3	Toluene	--	--	16000	110	6.4	NTV	NTV	110	6.4	110	6.4	0.025	110	6.4
	1330-20-7	Xylenes (total)	--	--	160000	NTV	NTV	NTV	NTV	2.8	0.16	2.8	0.16	0.003	2.8	0.16
SVOCs	90-12-0	1-Methylnaphthalene	--	35	--	NTV	NTV	0.82	0.042	NTV	NTV	0.82	0.042	0.02	0.82	0.042
	4901-51-3	2,3,4,5-Tetrachlorophenol	--	--	2400	No GW COPC	No GW COPC	No GW COPC	No GW COPC	No GW COPC	No GW COPC	2400	2400	0.006	2,400	2,400
	105-67-9	2,4-Dimethylphenol	--	--	1600	4.51	0.273	0.045	0.0027	NTV	NTV	0.045	0.0027	0.04	0.045	0.04
	95-95-4	2,4,5-Trichlorophenol	--	--	8000	ND Haley GW	ND Haley GW	ND Haley GW	ND Haley GW	NTV	NTV	8000	8000	0.1	8,000	8,000
	88-06-2	2,4,6-Trichlorophenol	--	90.9	80	0.058	0.0033	NTV	NTV	NTV	NTV	0.058	0.0033	0.0063	0.058	0.0063
	91-57-6	2-Methylnaphthalene	--	--	320	NTV	NTV	0.8	0.041	NTV	NTV	0.8	0.041	0.02	0.8	0.041
	534-52-1	4,6-Dinitro-2-methylphenol	--	--	6.4	ND Haley GW	ND Haley GW	ND Haley GW	ND Haley GW	ND Haley GW	ND Haley GW	6.4	6.4	0.67	6.4	6.4
	100-01-6	4-Nitroaniline	--	--	50	ND Haley GW	ND Haley GW	ND Haley GW	ND Haley GW	ND Haley GW	ND Haley GW	50	50	0.33	50	50
	100-02-7	4-Nitrophenol	--	--	--	ND Haley GW	ND Haley GW	ND Haley GW	ND Haley GW	ND Haley GW	ND Haley GW	--	--	0.33	--	--
	83-32-9	Acenaphthene	--	--	4800	65	3.3	0.34	0.017	NTV	NTV	0.34	0.017	0.005	0.34	0.017
	208-96-8	Acenaphthylene	--	--	--	NTV	NTV	1.4	0.069	NTV	NTV	1.4	0.069	0.005	1.4	0.069
	62-53-3	Aniline	--	180	560	ND Haley GW	ND Haley GW	ND Haley GW	ND Haley GW	ND Haley GW	ND Haley GW	180	180	0.67	180	180
	120-12-7	Anthracene	--	--	24000	12000	610	4.5	0.22	NTV	NTV	4.5	0.22	0.005	4.5	0.22
	191-24-2	Benzo(g,h,i)perylene	--	--	--	NTV	NTV	0.62	0.031	NTV	NTV	0.62	0.031	0.005	0.62	0.031
	117-81-7	Bis(2-ethylhexyl)phthalate	--	--	--	4.8	0.24	2.2	0.11	NTV	NTV	2.2	0.11	0.02	2.2	0.11
	85-68-7	Butylbenzylphthalate	--	530	16000	2.3	0.12	0.28	0.014	NTV	NTV	0.28	0.014	0.02	0.28	0.02
	95-48-7	o-Cresol (2-Methylphenol)	--	--	4000	NTV	NTV	0.16	0.011	NTV	NTV	0.16	0.011	0.02	0.16	0.02
	106-44-5	p-Cresol (4-Methylphenol)	--	--	400	NTV	NTV	0.32	0.023	NTV	NTV	0.32	0.023	0.67	0.67	0.67
	n/a	m,p-Cresol (3 & 4-methylphenol)	--	--	400	NTV	NTV	0.32	0.023	NTV	NTV	0.32	0.023	0.67	0.67	0.67
	132-64-9	Dibenzofuran	--	--	80.0	NTV	NTV	0.3	0.015	NTV	NTV	0.3	0.015	0.02	0.3	0.02
SVOCs (continued)	84-66-2	Diethylphthalate	--	--	64000	ND Haley GW	ND Haley GW	ND Haley GW	ND Haley GW	ND Haley GW	ND Haley GW	64000	64000	0.67	64,000	64,000
	206-44-0	Fluoranthene	--	--	3200	88.7	4.4	3.2	0.16	NTV	NTV	3.2	0.16	0.005	3.2	0.16
	86-73-7	Fluorene	--	--	3200	546.2	27.6	0.47	0.024	NTV	NTV	0.47	0.024	0.005	0.47	0.024
	91-20-3	Naphthalene	--	--	1600	138.4	7.3	2.3	0.12	4.8	0.25	2.3	0.12	0.01	2.3	0.12
	86-30-6	n-Nitrosodiphenylamine	--	204	--	0.18	0.0095	0.26	0.013	NTV	NTV	0.18	0.01	0.02	0.18	0.02
	87-86-5	Pentachlorophenol	--	2.5	400	0.047	0.0026	0.38	0.021	NTV	NTV	0.047	0.0026	0.0063	0.047	0.0063
	85-01-8	Phenanthrene	--	--	--	NTV	NTV	2	0.1	NTV	NTV	2	0.1	0.005	2.0	0.10
	108-95-2	Phenol	--	--	24000	2600	180	2.7	0.18	NTV	NTV	2.7	0.18	0.67	2.7	0.67
	129-00-0	Pyrene	--	--	2400	3536.3	177	20	1	NTV	NTV	20	1	0.005	20	1
	56-55-3	cPAHs: Benzo(a)anthracene	--	--	--	0.13	0.0065	2.2	0.11	NTV	NTV	0.13	0.0065	0.005	0.13	0.0065
	50-32-8	cPAHs: Benzo(a)pyrene	--	--	--	0.35	0.017	1.9	0.097	NTV	NTV	0.35	0.017	0.005	0.35	0.017
	205-99-2	cPAHs: Benzo(b)fluoranthene	--	--	--	0.43	0.022	4.6	0.23	NTV	NTV	0.43	0.022	0.005	0.43	0.022
	207-08-9	cPAHs: Benzo(k)fluoranthene	--	--	--	0.43	0.022	4.6	0.23	NTV	NTV	0.43	0.022	0.005	0.43	0.022
	218-01-9	cPAHs: Chrysene	--	--	--	0.14	0.0072	2.2	0.11	NTV	NTV	0.14	0.0072	0.005	0.14	0.0072
	193-39-5	cPAHs: Indeno(1,2,3-cd)pyrene	--	--	--	1.26	0.063	0.7	0.035	NTV	NTV	0.7	0.035	0.005	0.7	0.035
	53-70-3	cPAHs: Dibenz(a,h)anthracene	--	--	--	0.648	0.032	0.36	0.018	NTV	NTV	0.36	0.018	0.005	0.36	0.018
	n/a	cPAHs: cPAHs TEQ[8]	--	0.137	--	NTV	NTV	NTV	NTV	NTV	NTV	0.14	0.137	n/a	0.137	0.137

Dioxins/Furans	1746-01-6	Dioxin TEQ[8]	5.2E-06	0.000013	0.000093	0.00028	0.000014	TBC	TBC	NTV	NTV	0.000013	0.000013	n/a	0.000013	0.000013
Metals	7440-38-2	Arsenic	20	0.67	24	2.9	0.15	No Sed COPC	No Sed COPC	NTV	NTV	20	20	0.5	20	20
	7440-43-9	Cadmium	1	--	80	No GW COPC	No GW COPC	No GW COPC	No GW COPC	No GW COPC	No GW COPC	80	80	0.2	80	80
	7440-47-3	Chromium	48	--	120000	No GW COPC	No GW COPC	No GW COPC	No GW COPC	No GW COPC	No GW COPC	120000	120000	0.5	120,000	120,000
	7440-50-8	Copper[5]	36	--	2960	1	0.053	No Sed COPC	No Sed COPC	NTV	NTV	36	36	0.2	36	36
	7439-92-1	Lead	24	--	250	1600	81	No Sed COPC	No Sed COPC	NTV	NTV	250	81	0.2	250	81
	7439-97-6	Mercury	0.07	--	24	0.026	0.0013	No Sed COPC	No Sed COPC	NTV	NTV	0.07	0.07	0.1	0.07	0.07
	7440-02-0	Nickel[5]	48	--	1600	No GW COPC	No GW COPC	No GW COPC	No GW COPC	No GW COPC	No GW COPC	1600	1600	0.5	1,600	1,600
	7440-66-6	Zinc[5]	85	--	24000	100	5	No Sed COPC	No Sed COPC	NTV	NTV	100	85	1	100	85

Notes:

[1]Metal background values based on Puget Sound Region 90th percentile values, from *Natural Background Soil Metals Concentrations in Washington State* (Ecology Publication #94-115, 1994). Arsenic value is the natural background conentration in Washington State (MTCA Table 740-1). Total dioxins/furans TEQ background value based on Ecology Technical Memorandum #8, Natural Background for Dioxins/Furans in WA Soils, August 9, 2010.

[2] Values based on toxicity data from Ecology's CLARC on-line database as of March 2013 except for IHSs, which are based on toxicity data from Ecology's "CLARC Master Spreadsheet.xlsx" dated May 2014.

[3] Soil values protective of groundwater calculated using Equation 747-1 from WAC 173-340-747. Values for Kd, Koc, and Henry's Law Constant are from CLARC if available; if not, values from EPIWIN were used. For all constituents, values based on published data as of March 2013 except for IHSs which are based on published data as of January 2015.

[4] PQL is lowest available value from Analytical Resources, Inc. (Tukwila, WA) or Frontier Analytical Laboratory (El Dorado Hills, CA)

[5] These analytes are constituents of potential concern for the Cornwall Avenue Landfill Site (Landau 2013) but not the Haley Site.

[6] Soil screening level for gasoline-range hydrocarbons is MTCA Method A cleanup level for unrestricted land use.

[7] Site-specific screening levels were calculated using Equation 740-3 from WAC 173-340-740 using EPH and PAH soil analytical results and Ecology guidance. See text for a discussion on how the median value of 1,534 mg/kg was chosen.

[8] Chemical group evaluated based on toxicity equivalent (TEQ) concentrations.

TBC = to be calculated. Because the dioxins/furans soil screening level will be based on background, this pathway will not affect the proposed soil screening level.

TEQ = Toxicity equivalent concentration

BETX = Benzene, ethylbenzene, toluene, and total xylenes

SVOCs = Semivolatile organic compounds

cPAHs = Carcinogenic polycyclic aromatic hydrocarbons

NA = Not applicable. This analyte was not identified as a constituent of potential concern in groundwater for the Haley Site or the Cornwall Avenue Landfill site (Landau Associates, Inc., 2013 Cornwall Avenue Landfill RI) so these pathways are not applicable.

ND Haley GW = Screening levels for the soil-to-groundwater pathway protective of various receptors are not shown because this analyte was not detected in Haley 2012 Groundwater Samples.

Shading indicates basis for screening level

-- = no value available

NTV = no target value available (surface water, SMS, or indoor air values are not available and/or applicable).

No GW COPC = Constituent is not a groundwater COPC.

No Sed COPC = Constituent is not a sediment COPC.

Table 5-4

Selection of Sediment Indicator Hazardous Substances

R.G. Haley Site

Bellingham, Washington

Analyte	Total # Samples	Maximum Detected Dry-Weight Concentration[1]	Dry Weight Screening Level (LAET/SCO)	Maximum Detected OC-Normalized Concentration[2]	OC-Normalized Screening Level (SCO)	Detection Frequency (%)	Frequency of SL Exceedances (%)	Reporting Limit Exceedance Frequency (%)	Maximum Exceedance Factor (EF) For Detects[3]	Meet Initial IHS Selection Criteria?	GW IHS?	Soil IHS?	Aqueous Phase Mobility (Koc in L/kg)	Proposed IHS Based on Other Considerations?	Comments/Rationale
Initial IHS Selection Criteria							≥10		> 2x SL		**Other IHS Selection Considerations**				
Petroleum Hydrocarbons (mg/kg)															
Diesel-range hydrocarbons	84	37,000	NE	NA	NE	61	NA	NA	NA	NA	No	No	--	No	Petroleum hydrocarbons in sediment are being evaluated based on the total of diesel-range and oil-range hydrocarbons and therefore, includes consideration of this analyte.
Lube oil-range hydrocarbons	84	27,000	NE	NA	NE	81	NA	NA	NA	NA	No	No	--	No	Petroleum hydrocarbons in sediment are being evaluated based on the total of diesel-range and oil-range hydrocarbons and therefore, includes consideration of this analyte.
Total petroleum hydrocarbons (diesel-range + lube oil-range)	84	50,000	260	NA	NE	85	39	0	192	Yes	No	Yes	--	Yes	Petroleum hydrocarbons are a key Haley wood treatment constituent and meet IHS selection criteria in Site soil as well as sediment. Evaluated as sum of detected diesel- and lube oil-range concentrations.
Dioxins/Furans (ng/kg)															
Dioxin TEQ	56	559	4	NA	NE	100	88	NA	140	Yes	Yes	Yes	--	Yes	Dioxins/furans are key Haley constituents and meet IHS selection criteria in other Site media (i.e., groundwater and soil). Evaluated based on toxicity equivalent (TEQ) concentration.
LPAHs															
1-Methylnaphthalene	40	4,700 ug/kg	NE	NA	NE	68	NA	NA	NA	NA	Yes	Yes	2,528	No	Analyte occurs within the footprint of detected concentratrions of phenanthrene and naphthalene.
2-Methylnaphthalene	95	12,000 ug/kg	670 ug/kg	24.2 mg/kg oc	38 mg/kg oc	65	3	1	18	Yes	Yes	Yes	2,478	Yes	Key PAH in soil and groundwater based on detection and exceedance frequency, exceedance factor (potential risk), and geographic footprint. Also one of the more mobile PAHs. Therefore, this analyte will be included as IHS for sediment.
Acenaphthene	101	11,000 µg/kg	500 µg/kg	708.7 mg/kg oc	16 mg/kg oc	56	10	1	44	Yes	Yes	Yes	4,900	Yes	Key PAH in soil and groundwater based on detection and exceedance frequency, exceedance factor (potential risk), and geographic footprint. Also one of the more mobile PAHs. Therefore, this analyte will be included as IHS for sediment.
Acenaphthylene	101	1,500 µg/kg	1,300 µg/kg	76.7 mg/kg oc	66 mg/kg oc	59	2	1	1.2	No	No	No	5,024	No	Analyte does not meet IHS selection criteria. Exceedances of the SL for this analyte occur within the footprint of exceedances for phenanthrene and naphthalene.
Anthracene	101	6,800 µg/kg	960 µg/kg	134.6 mg/kg oc	220 mg/kg oc	74	6	0	7	Yes	No	No	23,000	No	Exceedances of the SL for this analyte occur within the footprint of exceedances for phenanthrene and naphthalene.
Fluorene	101	4,300 µg/kg	540 µg/kg	242.7 mg/kg oc	23 mg/kg oc	62	11	1	8	Yes	No	No	7,700	No	Exceedances of the SL for this analyte occur within the footprint of exceedances for phenanthrene and naphthalene.
Naphthalene	101	8,600 µg/kg	2,100 µg/kg	36.9 mg/kg oc	99 mg/kg oc	75	5	1	4	Yes	No	No	1,200	Yes	Key LPAH in sediment based on detection frequency and geographic footprint. Analyte is detected at a concentration greater than the SL at the only three locations where LPAHs are detected at concentrations greater than the SL and phenanthrene is not detected.
Phenanthrene	101	42,000 µg/kg	1,500 µg/kg	603.4 mg/kg oc	100 mg/kg oc	90	17	0	28	Yes	No	No	16,690	Yes	Key LPAH in sediment based on detection and exceedance frequency, exceedance factor, exceedance factor (potential risk), and geographic footprint. Analyte is detected at a concentration greater than the SL at all but three locations where LPAHs are detected at concentrations greater than the SL.
Total LPAHs	101	61,100 µg/kg	5,200 µg/kg	1187.9 mg/kg oc	370 mg/kg oc	93	15	0	12	Yes	NA	NA	NA	No	Exceedances of the SL for this analyte group occur within the footprint of exceedances for phenanthrene and naphthalene.

Analyte	Total # Samples	Maximum Detected Dry-Weight Concentration[1]	Dry Weight Screening Level (LAET/SCO)	Maximum Detected OC-Normalized Concentration[2]	OC-Normalized Screening Level (SCO)	Detection Frequency (%)	Frequency of SL Exceedances (%)	Reporting Limit Exceedance Frequency (%)	Maximum Exceedance Factor (EF) For Detects[3]	Meet Initial IHS Selection Criteria?	GW IHS?	Soil IHS?	Aqueous Phase Mobility (Koc in L/kg)	Proposed IHS Based on Other Considerations?	Comments/Rationale
Initial IHS Selection Criteria							≥10		> 2x SL		**Other IHS Selection Considerations**				
HPAHs															
Benzo(a)anthracene	101	10,000 μg/kg	1,300 μg/kg	188.5 mg/kg oc	110 mg/kg oc	83	8	0	8	Yes	Yes	Yes	360,000	Yes	Key PAH in sediment based on detection frequency and geographic footprint. Analyte is detected at concentrations greater than the SL at all but three locations where HPAHs are detected at concentrations greater than the SL. Key PAH in soil and groundwater based on detection and exceedance frequency, exceedance factor (potential risk), and geographic footprint. Representative of most mobile of HPAHs.
Benzo(a)pyrene	101	9,100 μg/kg	1,600 μg/kg	176.2 mg/kg oc	99 mg/kg oc	75	7	0	6	Yes	No	No	970,000	No	Exceedances of the SL for this analyte occur within the footprint of exceedances for benzo(a)anthracene.
Benzo(b,k) fluoranthenes	101	12,100 μg/kg	3,200 μg/kg	230.8 mg/kg oc	230 mg/kg oc	81	5	0	4	Yes	No	No	1,200,000	No	Exceedances of the SL for this analyte occur within the footprint of exceedances for benzo(a)anthracene.
Benzo(ghi)perylene	101	600 μg/kg	670 μg/kg	107.7 mg/kg oc	31 mg/kg oc	68	10	0	9	Yes	No	No	1,951,000	No	Exceedances of the SL for this analyte occur within the footprint of exceedances for benzo(a)anthracene and fluoranthene.
Chrysene	101	11,000 μg/kg	1,400 μg/kg	207.7 mg/kg oc	110 mg/kg oc	84	10	0	8	Yes	No	No	400,000	No	Exceedances of the SL for this analyte occur within the footprint of exceedances for benzo(a)anthracene and fluoranthene.
Dibenzo(a,h) anthracene	101	1,300 μg/kg	230 μg/kg	27.3 mg/kg oc	12 mg/kg oc	39	8	3	6	Yes	No	No	1,800,000	No	Exceedances of the SL for this analyte occur within the footprint of exceedances for benzo(a)anthracene and fluoranthene.
Fluoranthene	101	23,000 μg/kg	1,700 μg/kg	423.1 mg/kg oc	160 mg/kg oc	90	15	0	14	Yes	No	No	49,000	Yes	Key HPAH in sediment based on detection and exceedance frequency, exceedance factor (potential risk), and geographic footprint. Analyte is detected at all locations at a concentration greater than the SL where HPAHs are detected at concentrations greater than the SL.
Indeno(1,2,3-cd) pyrene	101	5,300 μg/kg	600 μg/kg	88.5 mg/kg oc	34 mg/kg oc	68	10	0	9	Yes	No	NO	3,500,000	No	Exceedances of the SL for this analyte occur within the footprint of exceedances for benzo(a)anthracene and fluoranthene.
Pyrene	101	22,000 μg/kg	2,600 μg/kg	500 mg/kg oc	1,000 mg/kg oc	90	10	0	9	Yes	No	No	68,000	No	Exceedances of the SL for this analyte occur within the footprint of exceedances for benzo(a)anthracene and fluoranthene.
Total HPAHs	101	99,800 μg/kg	12,000 μg/kg	1,950.4 mg/kg oc	960 mg/kg oc	90	11	0	8	Yes	Total CPAH is an IHS for groundwater	Total CPAH is an IHS for soil	NA	No	Exceedances of the SL for this analyte group occur within the footprint of exceedances for benzo(a)anthracene and fluoranthene.
cPAHs															
cPAH TEQ	101	12,080 μg/kg	21 μg/kg	NA	NE	83	78	14	575	Yes	Yes	Yes	NA	Yes	Key IHS in sediment based on detection and exceedance frequency, magnitude and geographic distribution.
Chlorinated Organics															
1,2,4-Trichlorobenzene	97	ND	31 μg/kg	ND	0.81 mg/kg oc	ND	ND	25	NA	No	No	No	1,700	No	Analyte does not meet IHS selection criteria. No known source associated with Haley activities. Not detected in groundwater or soil at Haley property.
1,2-Dichlorobenzene	96	ND	35 μg/kg	ND	2.3 mg/kg oc	ND	ND	17	NA	No	No	No	380	No	Analyte does not meet IHS selection criteria. No known source associated with Haley activities. Not detected in groundwater or soil at Haley property.
1,3-Dichlorobenzene	96	ND	NE	ND	ND	ND	ND	NA	NA	NA	No	No	375	No	Analyte does not meet IHS selection criteria. No known source associated with Haley activities. Not detected in groundwater or soil at Haley property.
1,4-Dichlorobenzene	96	24 μg/kg	110 μg/kg	NA	3.1 mg/kg oc	2	0	6	<1	No	No	No	620	No	Analyte does not meet IHS selection criteria. No known source associated with Haley activities. Not detected in groundwater or soil at Haley property.
Hexachlorobenzene	100	ND	22 μg/kg	ND	0.38 mg/kg oc	ND	ND	21	NA	No	No	No	80,000	No	Analyte does not meet IHS selection criteria. No known source associated with Haley activities. Not detected in groundwater or soil at Haley property.

Analyte	Total # Samples	Maximum Detected Dry-Weight Concentration[1]	Dry Weight Screening Level (LAET/SCO)	Maximum Detected OC-Normalized Concentration[2]	OC-Normalized Screening Level (SCO)	Detection Frequency (%)	Frequency of SL Exceedances (%)	Reporting Limit Exceedance Frequency (%)	Maximum Exceedance Factor (EF) For Detects[3]	Meet Initial IHS Selection Criteria?	GW IHS?	Soil IHS?	Aqueous Phase Mobility (Koc in L/kg)	Proposed IHS Based on Other Considerations?	Comments/Rationale
Initial IHS Selection Criteria							≥10		> 2x SL		**Other IHS Selection Considerations**				
Phthalates															
Bis(2-ethylhexyl)phthalate	96	940 µg/kg	1,300 µg/kg	32.0 mg/kg oc	47 mg/kg oc	60	0	2	<1	No	No	No	110,000	No	Analyte does not meet IHS selection criteria. No known source associated with Haley activities. Analyte is a soil and sediment COPC and a sediment IHS for the Cornwall Avenue Landfill. Analyte was not detected in sediment samples collected as part of investigation of the Haley Site at a concentration greater than the SL.
Butylbenzylphthalate	100	290 µg/kg	63 µg/kg	11.8 mg/kg oc	4.9 mg/kg oc	16	8	5	5	Yes	No	No	14,000	No	No known source associated with Haley activities. Analyte was not detected in groundwater and was detected once in soil at the Haley Site. Analyte is only present at concentrations greater than the SL at locations where mulitple other analytes (i.e., petroleum hydrocarbons, PAHs, PCP) are also present at concentrations greater than the SL. Therefore, the geographic occurrence of this analyte is within the footprint of other, more prevalent analytes.
Dibutylphthalate	96	190 µg/kg	1,400 µg/kg	9.4 mg/kg	220 mg/kg	10	0	0	<1	No	No	No	1,600	No	Analyte does not meet IHS selection criteria. No known source associated with Haley activities. Analyte is a soil COPC for the Cornwall Avenue Landfill. Analyte was not detected in sediment samples collected as part of investigation of the Haley Site at a concentration greater than the SL. Analyte was not detected in groundwater and soil as part of investigation of the Haley Site.
Diethylphthalate	96	47 µg/kg	200 µg/kg	4.4 mg/kg oc	61 mg/kg oc	5	0	2	<1	No	No	No	82	No	Analyte does not meet IHS selection criteria. No known source associated with Haley activities. Analyte was not detected in sediment samples collected as part of investigation of the Haley Site at a concentration greater than the SL. Analyte was not detected in groundwater and and was detected once in soil at the Haley Site.
Dimethylphthalate	96	590 µg/kg	71 µg/kg	NA	53 mg/kg oc	13	5	5	8	Yes	No	No	32	No	No known source associated with Haley activities. Analyte was not detected in groundwater and soil as part of investigation of the Haley Site.
Di-n-octylphthalate	96	120 µg/kg	6,200 µg/kg	4.6 mg/kg oc	58 mg/kg oc	6	0	0	<1	No	No	No	83,000,000	No	Analyte does not meet IHS selection criteria. No known source associated with Haley activities. Analyte was not detected in sediment samples collected as part of investigation of the Haley Site at a concentration greater than the SL. Analyte was not detected in groundwater and soil as part of investigation of the Haley Site.
Miscellaneous Extractables															
Dibenzofuran	101	3,400 µg/kg	540 µg/kg	281.6 mg/kg oc	15 mg/kg oc	52	8	3	19	Yes	No	No	9,161	No	Dibenzofuran is only present at concentrations greater than the SL at locations where mulitple other PAHs are present at concentrations greater than the SL. Therefore, the geographic occurrence of dibenzofuran is within the footprint of other, more prevalent PAH analytes.
Hexachlorobutadiene	96	ND	11 µg/kg	ND	3.9 mg/kg oc	ND	0	38	NA	No	No	No	54,000	No	Analyte does not meet IHS selection criteria. No known source associated with Haley activities. Analyte was not detected in sediment samples collected as part of investigation of the Haley Site at a concentration greater than the SL. Analyte was not detected in groundwater and soil as part of investigation of the Haley Site.
n-Nitrosodiphenylamine	105	1,700 µg/kg	28 µg/kg	NA	11 mg/kg oc	3	2	14	61	Yes	No	No	1,300	No	Analyte is only present at concentrations greater than the SL at locations where mulitple other analytes (i.e., PAHs, PCP) are also present at concentrations greater than the SL. Therefore, the geographic occurrence of this analyte is within the footprint of other, more prevalent analytes.
Benzoic acid	65	250 µg/kg	650 µg/kg	NA	NA	3	0	14	<1	No	No	No	0.6	No	Analyte does not meet IHS selection criteria. Analyte was not detected in sediment samples collected as part of investigation of the Haley Site at a concentration greater than the SL. No known source associated with Haley activities. Analyte was not detected in groundwater and soil as part of investigation of the Haley Site.
Benzyl alcohol	61	18 µg/kg	57 µg/kg	NA	NA	3	0	44	<1	No	No	No	22	No	Analyte does not meet IHS selection criteria. No known source associated with Haley activities. Analyte was not detected in sediment samples collected as part of investigation of the Haley Site at a concentration greater than the SL. Analyte was not detected in groundwater and soil as part of investigation of the Haley Site.

Analyte	Total # Samples	Maximum Detected Dry-Weight Concentration[1]	Dry Weight Screening Level (LAET/SCO)	Maximum Detected OC-Normalized Concentration[2]	OC-Normalized Screening Level (SCO)	Detection Frequency (%)	Frequency of SL Exceedances (%)	Reporting Limit Exceedance Frequency (%)	Maximum Exceedance Factor (EF) For Detects[3]	Meet Initial IHS Selection Criteria?	GW IHS?	Soil IHS?	Aqueous Phase Mobility (Koc in L/kg)	Proposed IHS Based on Other Considerations?	Comments/Rationale
Initial IHS Selection Criteria							**≥10**		**> 2x SL**		**Other IHS Selection Considerations**				
Phenol															
2,4-Dimethylphenol	95	110 µg/kg	29 µg/kg	NA	NA	20	5	23	4	Yes	No	No	210	No	Analyte is only present at concentrations greater than the SL at locations where mulitple other analytes (i.e., PAHs, PCP) are also present at concentrations greater than the SL. Therefore, the geographic occurrence of this analyte is within the footprint of other, more prevalent analytes.
o-Cresol (2-methylphenol)	95	59 µg/kg	63 µg/kg	NA	NA	18	0	6	<1	Yes	No	No	300	No	Analyte does not meet IHS selection criteria. Additionally, analyte was not detected in groundwater and only detected twice in soil at Haley property.
p-Cresol (4-methylphenol)	96	440 µg/kg	670 µg/kg	NA	NA	47	0	0	<1	No	No	No	300	No	Analyte does not meet IHS selection criteria. Additionally, analyte did not meet IHS selection criteriea for groundwater and soil.
Pentachlorophenol (PCP)	101	4,700 µg/kg	100 µg/kg	NA	NA	60	46	22	47	Yes	Yes	Yes	590	Yes	Pentachloropenol (PCP) is a key Haley wood treatment constituent and meets IHS selection criteria in other Site media (i.e., groundwater and soil) as well as sediment.
Phenol	96	470 µg/kg	420 µg/kg	NA	NA	36	2	1	1.1	No	No	No	29	No	Analyte does not meet IHS selection criteria. Additionally, analyte did not meet selection criteria in groundwater and was not detected in soil at Haley property.
Metals (mg/kg)															
Mercury	34	11.3	0.41	NA	NA	94	47	0	28	Yes	No	No	--	No	Mercury is a Whatcom Waterway soil and sediment COPC. Mercury is a also a Cornwall soil and sediment COPC. No known source associated with Haley activities.

Notes:

Analyte meets initial IHS selection criteria (Exceedance Frequency ≥ 10% or Exceedance Factor > 2)

Analyte identified as an IHS based on both satisfaction of initial selection criteria and consideration of other selection criteria , or on consideration of other selection criteria alone.

[1]The value provided is the maximum detected dry weight concentration of the analyte for the samples with a total organic carbon (TOC) concentration that is less than 0.5 percent or greater than 3.5 percent that are therefore, screened against the Lowest Apparent Effect Threshold (LAET) levels or the maximum detected dry weight concentration for analytes that do not have an organic carbon normalized (TOC-normalized) Sediment Cleanup Objective (SCO) under the Sediment Management Standards.

[2]The value provided is the maximum detected TOC-normalized concentration of the analyte for the samples with a TOC concentration that is greater than or equal to 0.5 percent or less than or equal to 3.5 percent that are therefore, screened against the TOC-normalized SQS levels.

[3]The maximum exceedance factor is the largest of the ratios for the maximum dry weight concentration compared to the dry weight LAET/SQS level or the maximum TOC-normalized concentration compared to the TOC-normalized SCO level.

IHS = indicator hazardous substance

Frequency of SL Exceedances = (# of samples with constituent detected at a concentration greater than SL)/(total # of samples analyzed for constituent)

Exceedance Factor (max) = ratio of maximum detected concentration divided by SL. EFs are rounded to whole numbers except for values between 1 and 2 which are rounded to the nearest tenth.

NE = A screening level has not been established for this analyte.

LAET = Lowest Apparent Effects Threshold

COPC = constituent of potential concern

PAH = polycyclic aromatic hydrocarbons

ND = Not detected

SL = Screening level

RL = Reporting limit

NA = Not applicable

HPAHs = High molecular weight PAH

LPAH = Low molecular weight PAH

TEQ = Toxicity equivalent concentration

TOC = Total organic carbon

ng/kg = nanogram per kilogram

µg/kg = microgram per kilogram

mg/kg = milligram per kilogram

Koc = soil organic carbon-water partitioning coefficient. Lower Koc values correspond to greater aqueous-phase mobility.

Dioxin TEQ is the toxicity-weighted sum of all dioxin and furan congeners expressed as an equivalent 2,3,7,8-TCDD concentration using the World Health Organization (WHO) 2005 congener-specific toxicity equivalency factors (TEFs) for mammals and humans; where congeners are not detected, a value of ½ the detection limit is assumed for the calculation.

Table 5-5

Selection of Groundwater Indicator Hazardous Substances

R.G. Haley Site

Bellingham, Washington

	Analyte	Total # Samples	Maximum Detected Concentra-tion	Screening Level	Detection Frequency (%)	Frequency of SL Exceedances (%)	Reporting Limit Exceedance Frequency (%)	Maximum Exceedance Factor (EF)	Meet Initial IHS Selection Criteria?	Soil IHS?	Sed IHS?	Aqueous Phase Mobility (Koc in L/kg)	Proposed IHS Based on Other Considerations?	Comments/Rationale
	Initial IHS Selection Criteria					≥10		>2x SL		Other IHS Selection Considerations				
	Dioxins/Furans (pg/l)													
	Dioxin TEQ	5	2,430	PQL	100	100	0	PQL	Yes	Yes	Yes	250,000	Yes	Meets IHS selection criteria. Key Haley constituent present in other media.
	Metals (ug/l)													
	Copper	29	2.6	2.4	28	3	0	1.1	No	No	No	--	No	Does not meet selection criteria. Copper is a Cornwall soil, groundwater and sediment COPC and a Cornwall sediment IHS. SL exceedances only in Cornwall monitoring wells.
	Manganese	24	1,440	100	100	92	0	14	Yes	No	No	--	No	Manganese is a Cornwall groundwater IHS. No known association with historical Haley activities. SL exceedances only in Cornwall monitoring wells.
	Mercury	24	20	0.025	4	4	96	800	Yes	No	No	--	No	Mercury is a Cornwall soil and sediment COPC and Whatcom Waterway sediment COC; no known association with historical Haley activities. SL exceedances occur only in Cornwall monitoring wells.
	PAHs (ug/l)													
	1-Methylnaphthalene	50	520	15	80	30	0	35	Yes	Yes	No	2,528	Yes	Key noncarcinogenic PAH based on detection and exceedance frequency and exceedance factor (potential risk) and geographic footprint. Also, one of the more mobile PAHs.
	2-Methylnaphthalene	74	680	15	51	15	0	45	Yes	Yes	Yes	2,478	Yes	Less prevalent occurrence than 1-methylnaphthalene, but retained as groundwater IHS because analyte was Identified as a soil IHS. Also, one of the more mobile PAHs.
	Acenaphthene	50	24	3.3	88	24	0	7	Yes	No	Yes	4,900	Yes	Exceedances fall within the footprint of 1- and 2-methylnaphthalene exceedances and the potential risk (as represented by exceedance factor) is generally less than that posed by 1- and 2-methylnaphthalene. Retained as IHS due to vertical profile in groundwater and to evaluate upland to sediment pathway.
	Benzo(ghi)perylene	50	0.27	0.016	4	4	54	17	Yes	No	No	1,951,000	No	Exceedances fall within the footprint of 1- and 2-methylnaphthalene exceedances and the potential risk (as represented by exceedance factor) posed by these analyes is generally less than that posed by 1- and 2-methylnaphthalene.
	Fluorene	74	26	3	53	16	0	9	Yes	No	No	7,700	No	
	Phenanthrene	50	37	6	88	10	0	6	Yes	No	Yes	16,690	No	
cPAHs	Benzo(a)anthracene	50	0.58	0.018	26	20	42	32	Yes	Yes	Yes	360,000	Yes	Most important individual cPAH based on detection frequency, exceedance factor (potential risk) and geographic footprint. Representative of most mobile cPAHs.
cPAHs	Benzo(a)pyrene	50	0.43	0.018	6	4	54	24	Yes	No	No	970,000	No	Exceedances fall within the footprint of benzo(a)anthracene and/or total cPAH TEQ exceedances and the potential risk (as represented by exceedance factor) posed by these analyes is generally less than that posed by benzo(a)anthracene and total cPAH TEQ.
cPAHs	Benzo(b)fluoranthene	26	0.5	0.018	15	12	54	28	Yes	No	No	1,200,000	No	
cPAHs	Benzo(j,k)fluoranthene	26	0.15	0.018	12	12	54	8	Yes	No	No	1,200,000	No	
cPAHs	Chrysene	50	0.56	0.018	14	10	48	31	Yes	No	No	400,000	No	
cPAHs	Dibenzo(a,h)anthracene	50	0.08	0.01	4	4	54	8	Yes	No	No	1,800,000	No	
cPAHs	Indeno(1,2,3-cd)pyrene	50	0.27	0.01	4	4	54	27	Yes	No	No	3,500,000	No	
cPAHs	cPAH TEQ	50	0.5919	0.018	26	16	42	33	Yes	Yes	No	n/a	Yes	Collectively represents all cPAHs including the individual compounds not selected as IHSs.

Analyte	Total # Samples	Maximum Detected Concentra-tion	Screening Level	Detection Frequency (%)	Frequency of SL Exceedances (%)	Reporting Limit Exceedance Frequency (%)	Maximum Exceedance Factor (EF)	Meet Initial IHS Selection Criteria?	Soil IHS?	Sed IHS?	Aqueous Phase Mobility (Koc in L/kg)	Proposed IHS Based on Other Considerations?	Comments/Rationale
Initial IHS Selection Criteria					≥10		>2x SL		**Other IHS Selection Considerations**				
SVOCs (ug/l)													
Bis(2-ethylhexyl)phthalate	50	3	1	30	28	24	3	Yes	No	No	110,000	No	BEHP is a Cornwall soil and sediment COPC and a Cornwall sediment IHS. No known association with historical Haley activities. Only 2 of 14 exceedances are from monitoring wells located on Haley; the remainder are from Cornwall monitoring wells. Exceedances on Haley fall within the footprint of benzo(a)anthracene and/or total cPAH TEQ exceedances.
Carbazole	50	3.4	1.6	14	6	0	2	Yes	No	No	3,400	No	Exceedances fall within the footprint of 1- and 2-methylnaphthalene exceedances and the potential risk (as represented by exceedance factor) posed by these analyes is less than that posed by 1- and 2-methylnaphthalene.
Dibenzofuran	50	6.1	1.6	28	12	0	4	Yes	No	No	9,161	No	
Pentachlorophenol (PCP)	50	100	3	40	2	48	33	Yes	Yes	Yes	590	Yes	Key Haley wood treatment constituent. Meets selection criteria in this and other media.
TPH (mg/l)													
Gasoline-range hydrocarbons	1	0.33	n/a	100	n/a	n/a	n/a	No	No	No	--	No	Detections fall within footprint of 1- and 2-methylnaphthalene, benzo(a)anthracene and/or total cPAH TEQ exceedances. TPH in groundwater is being evaluated based on individual constituents rather than entire TPH mixture.
Diesel-range hydrocarbons	38	6.9	n/a	55	n/a	n/a	n/a	No	Yes (as sum of diesel- and lube oil-range hydrocarbons)		--	No	
Lube oil-range hydrocarbons	38	0.84	n/a	5	n/a	n/a	n/a	No			--	No	
Analytes Detected with no Exceedances (ug/L)													
1,2-Dichlorobenzene	30	0.36	1,300	13	0	0	<1	No	No	No	--	No	Does not meet selection criteria. Not detected in Haley wells.
1,4-Dichlorobenzene	50	1.4	5	4	0	0	<1	No	No	No	--	No	Does not meet selection criteria. Not detected in Haley wells.
2,3,4,6-Tetrachlorophenol	26	22	320	3.8	0	0	<1	No	No	No	--	No	Does not meet selection criteria. Detected in only one sample (same sample with maximum PCP detection).
2,3,5,6-Tetrachlorophenol	26	10	320	4	0	0	<1	No	No	No	--	No	Does not meet selection criteria. Detected in only one sample (same sample with maximum PCP detection).
2,4,6-Trichlorophenol	50	0.6	5	10	0	0	<1	No	No	No	--	No	Does not meet selection criteria. Exceedances fall within the footprint of PCP exceedances.
Acenaphthylene	74	3.7	13	28	0	0	<1	No	No	No	--	No	Does not meet selection criteria. Exceedances fall within the footprint of 1- and 2-methylnaphthalene, benzo(a)anthracene and/or total cPAH TEQ exceedances.
Anthracene	50	5	9.6	58	0	0	<1	No	No	No	--	No	Does not meet selection criteria. Exceedances fall within the footprint of 1- and 2-methylnaphthalene, benzo(a)anthracene and/or total cPAH TEQ exceedances.
Arsenic	24	2	5	63	0	0	<1	No	No	No	--	No	Does not meet selection criteria. Concentrations less than background level of 5 µg/L.
Benzene	27	0.51	2.4	22	0	0	<1	No	No	No	--	No	Exceedances fall within the footprint of 1- and 2-methylnaphthalene, benzo(a)anthracene and/or total cPAH TEQ exceedances.
Chlorobenzene	24	10	100	75	0	0	<1	No	No	No	--	No	Does not meet selection criteria. Only detected in Cornwall wells at concentrations substantially less than SL.
Ethylbenzene	27	3.1	2,100	19	0	0	<1	No	No	No	--	No	Exceedances fall within the footprint of 1- and 2-methylnaphthalene, benzo(a)anthracene and/or total cPAH TEQ exceedances.
Fluoranthene	50	2	3.3	48	0	0	<1	No	No	Yes	--	No	Exceedances fall within the footprint of 1- and 2-methylnaphthalene, benzo(a)anthracene and/or total cPAH TEQ exceedances.
Lead	24	1	8.1	13	0	0	<1	No	No	No	--	No	Does not meet selection criteria. Lead is a Cornwall soil, groundwater and sediment COPC. No known association with historical Haley activities.
m,p-Cresol	26	43	79	8	0	0	<1	No	No	No	--	No	Does not meet selection criteria. Only two detections (HS-MW-17 and CL-MW-101) are located at opposite ends of Site. Exceedances fall within the footprint of 1- and 2-methylnaphthalene, benzo(a)anthracene and/or total cPAH TEQ exceedances.
Naphthalene	74	32	83	53	0	0	<1	No	No	Yes	--	No	Does not meet selection criteria. Exceedances fall within the footprint of 1- and 2-methylnaphthalene, benzo(a)anthracene and/or total cPAH TEQ exceedances.

Analyte	Total # Samples	Maximum Detected Concentra-tion	Screening Level	Detection Frequency (%)	Frequency of SL Exceedances (%)	Reporting Limit Exceedance Frequency (%)	Maximum Exceedance Factor (EF)	Meet Initial IHS Selection Criteria?	Soil IHS?	Sed IHS?	Aqueous Phase Mobility (Koc in L/kg)	Proposed IHS Based on Other Considerations?	Comments/Rationale
Initial IHS Selection Criteria					**≥10**		**>2x SL**		**Other IHS Selection Considerations**				
N-Nitrosodiphenylamine	50	1	6	2	0	0	<1	No	No	No	--	No	Does not meet selection criteria.
Phenol	50	1.3	580	2	0	0	<1	No	No	No	--	No	Does not meet selection criteria. Exceedances fall within the footprint of 1- and 2-methylnaphthalene, benzo(a)anthracene and/or total cPAH TEQ exceedances.
Pyrene	50	2.7	15	60	0	0	<1	No	No	No	--	No	Does not meet selection criteria. Exceedances fall within the footprint of 1- and 2-methylnaphthalene, benzo(a)anthracene and/or total cPAH TEQ exceedances.
Toluene	27	0.38	15,000	7	0	0	<1	No	No	No	--	No	Does not meet selection criteria. Exceedances fall within the footprint of 1- and 2-methylnaphthalene, benzo(a)anthracene and/or total cPAH TEQ exceedances.
Total Xylenes	27	1.6	310	56	0	0	<1	No	No	No	--	No	Does not meet selection criteria. Exceedances fall within the footprint of 1- and 2-methylnaphthalene, benzo(a)anthracene and/or total cPAH TEQ exceedances.
Zinc	24	50	81	25	0	0	<1	No	No	No	--	No	Does not meet selection criteria. Zinc is a Cornwall soil and sediment COPC. No known association with historical Haley activities.

Notes:

Analyte meets initial IHS selection criteria (Exceedance Frequency ≥ 10% or Exceedance Factor > 2)

Analyte identified as an IHS based on both satisfaction of initial selection criteria and consideration of other selection criteria , or on consideration of other selection criteria alone.

1. Data set comprises 2012 groundwater samples from monitoring wells installed for the Haley RI and two rounds of samples from shoreline monitoring well pairs installed for the Cornwall RI in 2012.

IHS = indicator hazardous substance

Frequency of SL Exceedances = (# of samples with constituent detected at a concentration greater than SL)/(total # of samples analyzed for constituent)

Exceedance Factor (EF) (max) = ratio of maximum detected concentration divided by SL. EFs are rounded to whole numbers except for values between 1 and 2 which are rounded to the nearest tenth.

SL = screening level

COC = constituent of concern

COPC = constituent of potential concern

PAH = polycyclic aromatic hydrocarbons

PQL = practical quantitation limit

TEQ = toxicity equivalent concentration

BEHP = bis(2-ethylhexyl)phthalate

n/a = not applicable

pg/L = picogram per liter

μg/L = microgram per liter

mg/L = milligram per liter

Koc = soil organic carbon-water partitioning coefficient. Lower Koc values correspond to greater aqueous-phase mobility.

Dioxin TEQ is the toxicity-weighted sum of all dioxin and furan congeners expressed as an equivalent 2,3,7,8-TCDD concentration using the World Health Organization (WHO) 2005 congener-specific toxicity equivalency factors (TEFs) for mammals and humans; where congeners are not detected, a value of ½ the detection limit is assumed for the calculation.

Table 5-6

Selection of Soil Indicator Hazardous Substances

R.G. Haley Site

Bellingham, Washington

Analyte	Total # Samples	Maximum Detected Concentration	Screening Level	Detection Frequency (%)	Frequency of SL Exceedances (%)	Reporting Limit Exceedance Frequency (%)	Maximum Exceedance Factor (EF)	Meet Initial IHS Selection Criteria?	GW IHS?	Sed IHS?	Aqueous Phase Mobility (Koc in L/kg)	Proposed IHS Based on Other Considerations?	Comments/Rationale
Initial IHS Selection Criteria					≥10		>2x SL		**Other IHS Selection Considerations**				
BTEX (mg/kg)													
Ethylbenzene	13	10.2	1	23	8	0	10	Yes	No	No	200	No	Soil screening level based on protection of groundwater and ethylbenzene was not detected in groundater at concentrations exceeding the groundwater screening level. Detected ethylbenzene concentrations in soil are also less than the MTCA Method B direct contact SL.
Total Xylenes	13	25.6	0.16	31	23	23	160	Yes	No	No	230	No	Soil screening level based on protection of groundwater and total xylenes were not detected in groundwater at concentrations exceeding the groundwater SL. Total xylene concentrations detected in soil were less than the MTCA Method B direct contact SL.
Dioxins/Furans (ng/Kg)													
Dioxin TEQ	13	98,551	13	100	85	0	7,580	Yes	Yes	Yes	--	Yes	Meets IHS selection criteria. Key Haley constituent present in other media.
Metals (mg/kg)													
Arsenic	6	7.67	20	100	0	0	<1	No	No	No	--	No	The natural background level for arsenic as established in MTCA A Table 740-1 is 20 mg/kg (WAC 173-340-900). Detected arsenic concentrations in soil are less than 20 mg/kg; the maximum detected arsenic concentration in soil is 7.67 mg/kg.
Copper	17	1,030	36	100	59	0	29	Yes	No	No	--	No	Copper is a Cornwall soil, groundwater and sediment COPC and a Cornwall sediment IHS. Ten (10) of the 17 samples tested for copper and included in this data set were on the Cornwall site (AF-MW and AF-SB series). No known copper impacts associated with historical activities on Haley property. Soil screening level based on protection of groundwater and copper exceedances in groundwater occur only in Landau monitoring wells. Detected copper concentrations in soil are less than the MTCA Method B direct contact SL.
Lead	10	89	81	100	20	0	1.1	Yes	No	No	--	No	Lead is a Cornwall soil, groundwater and sediment COPC and a Cornwall sediment IHS. No known impacts associated with historical activities on Haley property. Soil SL based on protection of groundwater and lead was not detected in groundwater at concentrations greater than groundwater SL. Detected lead concentrations in soil are less than the MTCA Method A unrestricted land use SL.
Mercury	10	0.18	0.07	50	40	30	3	Yes	No	No	--	No	Mercury is a Cornwall soil and sediment COPC. No known associated with Haley activities. Soil SL based on protection of groundwater and groundwater only analyzed for mercury in Landau monitoring wells. Detected mercury concentrations in soil are less than the MTCA Method B direct contact SL.
Zinc	10	237	85	100	20	0	3	Yes	No	No	--	No	Zinc is a Cornwall soil and sediment COPC and a Cornwall sediment IHS. No known association with historical Haley activities. Soil SL based on protection of groundwater and zinc was not detected in groundater at concentrations exceeding groundwater SL. Zinc concentrations detected in soil are less than the MTCA Method B direct contact SL.

Analyte	Total # Samples	Maximum Detected Concentra-tion	Screening Level	Detection Frequency (%)	Frequency of SL Exceedances (%)	Reporting Limit Exceedance Frequency (%)	Maximum Exceedance Factor (EF)	Meet Initial IHS Selection Criteria?	GW IHS?	Sed IHS?	Aqueous Phase Mobility (Koc in L/kg)	Proposed IHS Based on Other Considerations?	Comments/Rationale
Initial IHS Selection Criteria					≥10		>2x SL		**Other IHS Selection Considerations**				
PAHs (ug/kg)													
1-Methylnaphthalene	61	870,000	42	89	71	0	20,714	Yes	Yes	No	2,528	Yes	Meets initial IHS selection criteria and is a groundwater IHS. Also one of the more mobile PAHs.
2-Methylnaphthalene	95	1,920,000	41	90	77	1	46,829	Yes	Yes	Yes	2,478	Yes	Key noncarcinogenic PAH based on detection and exceedance frequency and risk ratio (potential risk) and geographic footprint. Also one of the more mobile PAHs.
Acenaphthene	108	75,500	17	75	68	8	4,441	Yes	Yes	Yes	4,900	No	
Acenaphthylene	108	27,800	69	57	37	14	403	Yes	No	No	5,024	No	Exceedances fall within the footprint of 1- and 2-methylnaphthalene exceedances and the potential risk (as represented by exceedance factor) posed by these analyes is generally less than that posed by 1- and 2-methylnaphthalene.
Anthracene	108	35,200	220	57	29	14	160	Yes	No	No	23,000	No	
Benzo(ghi)perylene	108	3,300	31	50	34	25	107	Yes	No	No	1,951,000	No	
Fluoranthene	108	9,600	160	74	45	9	60	Yes	No	Yes	49,000	No	
Fluorene	108	73,300	24	73	63	8	3,054	Yes	No	No	7,700	No	
Naphthalene	108	361,000	120	80	55	3	3,008	Yes	No	Yes	1,200	No	
Phenanthrene	108	140,000	100	86	68	1	1,400	Yes	No	Yes	16,690	No	
Pyrene	108	20,000	1000	81	31	4	14	Yes	No	No	68,000	No	
cPAHs													
Benzo(a)anthracene	108	5,600	6.5	58	57	32	862	Yes	Yes	Yes	360,000	Yes	Most important individual cPAH based on detection frequency, exceedance factor (potential risk) and geographic footprint. Representative of most mobile cPAHs.
Benzo(a)pyrene	108	6,000	17	51	45	30	353	Yes	No	No	970,000	No	Exceedances fall within the footprint of benzo(a)anthracene and/or total cPAH TEQ exceedances and the potential risk (as represented by exceedance factor) posed by these analyes at is generally less than that posed by benzo(a)anthracene and total cPAH TEQ.
Benzo(b)fluoranthene	107	5,000	22	54	46	26	227	Yes	No	No	1,200,000	No	
Benzo(j,k)fluoranthene	108	2,520	22	38	33	33	115	Yes	No	No	1,200,000	No	
Chrysene	108	5,300	7.2	63	60	27	736	Yes	No	No	400,000	No	
Dibenzo(a,h)anthracene	108	890	18	25	19	41	49	Yes	No	No	1,800,000	No	
Indeno(1,2,3-cd)pyrene	108	2,700	35	44	30	27	77	Yes	No	No	3,500,000	No	
cPAH TEQ	107	6,272	137	63	28	17	46	Yes	Yes	No	n/a	Yes	Collectively represents all cPAHs including the individual compounds not selected as IHS.
SVOC (ug/kg)													
2,4,6-Trichlorophenol	100	7.3	6.3	5	2	51	1.2	No	No	No	380	No	Does not meet selection criteria. Soil SL based on protection of groundwater and 2,4,6-trichlorophenol was not detected in groundwater at concentrations exceeding groundwater SL. 2,4,6-trichlorophenol concentrations detected in soil are less than the MTCA Method B direct contact SL.
2,4-Dimethylphenol	74	15,000	40	4	4	64	375	Yes	No	No	210	No	Soil SL based on protection of groundwater and 2,4-dimethylphenol was not detected in groundater. 2,4-dimethylphenol concentrations detected in soil are less than the MTCA Method B direct contact SL.
4,6-Dinitro-2-Methylphenol	60	26,000	6,400	2	2	12	4	Yes	No	No	--	No	Only exceeded SL in one soil sample. Geographic occurrence falls within footprint of other, more prevalent analytes (PAHs and PCP).
Bis(2-Ethylhexyl) Phthalate	80	13,000	110	23	15	49	118	Yes	No	No	110,000	No	BEHP is a soil and sediment COPC for Cornwall and a Cornwall sediment IHS. Geographic occurrence falls within footprint of other, more prevalent analytes (PAHs and PCP).
Butyl benzyl phthalate	59	650	20	2	2	68	33	Yes	No	No	14,000	No	Soil SL based on protection of groundwater and butyl benzyl phthalate was not detected in groundater. Butyl benzyl phthalate concentrations detected in soil are less than the MTCA Method B direct contact SL.
Dibenzofuran	107	14,800	20	17	16	68	740	Yes	No	No	9,161	No	Geographic occurrence falls within footprint of other, more prevalent analytes (PAHs and PCP).
m,p-Cresol	54	850	670	4	4	11	1.3	No	No	No	300	No	Does not meet selection criteria. Soil SL based on protection of groundwater and m,p-cresol was not detected in groundater at concentrations exceeding the groundwater SL. m,p-Cresol concentrations detected in soil are less than the MTCA Method B direct contact SL.
N-Nitrosodiphenylamine	101	66,700	20	14	14	67	3,335	Yes	No	No	1,300	No	Soil SL based on protection of groundwater and n-nitrosodiphenylamine was not detected in groundater. n-Nitrosodiphenylamine concentrations detected in soil are less than the MTCA Method B direct contact SL.
o-Cresol (2-methylphenol)	148	610	20	1	1	74	31	Yes	No	No	300	No	Soil SL based on protection of groundwater and o-cresol was not detected in groundater. O-Cresol concentrations detected in soil are less than the MTCA Method B direct contact SL.
p-Cresol (4-methylphenol)	14	870	670	7	7	57	1.3	No	No	No	300	No	Does not meet selection criteria. Soil SL based on protection of groundwater and p-cresol was not detected in groundater. p-Cresol concentrations detected in soil are less than the MTCA Method B direct contact SL.
Pentachlorophenol (PCP)	147	221,000	6.3	63	57	26	35,079	Yes	Yes	Yes	590	Yes	Key Haley wood treatment constituent. Meets selection criteria in this and other media.

Analyte	Total # Samples	Maximum Detected Concentra-tion	Screening Level	Detection Frequency (%)	Frequency of SL Exceedances (%)	Reporting Limit Exceedance Frequency (%)	Maximum Exceedance Factor (EF)	Meet Initial IHS Selection Criteria?	GW IHS?	Sed IHS?	Aqueous Phase Mobility (Koc in L/kg)	Proposed IHS Based on Other Considerations?	Comments/Rationale
Initial IHS Selection Criteria					≥10		>2x SL		**Other IHS Selection Considerations**				
TPH (mg/kg)													
Gasoline-range hydrocarbons	9	500	100	44	33	0	5	Yes	No	No	--	No	Exceedances fall within footprint of diesel- and lube oil-range exceedances; gasoline-range hydrocarbons is a Cornwall soil COPC.
Diesel-range Hydrocarbons	121	61,800	n/a	89	n/a	n/a	n/a	No	No	No	--	No	Sum of diesel- and lube oil-range hydrocarbons was evaluated by comparing to a site-specific MTCA Method B cleanup level for petroleum hydrocarbons.
Lube Oil-range Organics	121	24,300	n/a	70	n/a	n/a	n/a	No	No	No	--	No	
TPH Sum (diesel-range + lube oil-range)	121	66,105	1,534	93	39	0	43	Yes	No	Yes	--	Yes	Key Haley wood treatment constituent. Meets IHS selection criteria soil and sediment.
Analytes Detected with No Exceedances													
4-Nitrophenol (p-Nitrophenol) (µg/kg)	60	210	No Screening Level Established	2	No Screening Level Established	No Screening Level Established	No Screening Level Established	No	No	No	--	No	One detection at 13 feet bgs (detection frequency of 1.7%). Corresponds with PAH exceedances.
Toluene (mg/kg)	13	0.42	6.4	8	0	0	<1	No	No	No	--	No	One detection at 5 feet bgs. Corresponds with gasoline- and diesel-range hydrocarbon exceedances.
Cadmium (mg/kg)	10	0.6	80	20	0	0	<1	No	No	No	--	No	Maximum detected concentration (0.6 mg/kg) less than Puget Sound background level (1 mg/kg)
Chromium (mg/kg)	16	68.3	120,000	100	0	0	<1	No	No	No	--	No	Maximum detected concentration (68.3 mg/kg) slightly greater than Puget Sound background level (48 mg/kg) and 1,800 less than soil screening level (120,000 mg/kg).
Nickel (mg/kg)	10	55	1,600	100	0	0	<1	No	No	No	--	No	Maximum detected concentration (55 mg/kg) slightly greater than Puget Sound background level (48 mg/kg) and 30 less than soil screening level (1,600 mg/kg).
2,3,4,5-Tetrachlorophenol (µg/kg)	40	2,080	2,400,000	3	0	0	<1	No	No	No	--	No	One detection at 2 feet bgs (detection frequency less than 5%). Corresponds with PCP exceedance.
2,4,5-Trichlorophenol (µg/kg)	114	25,000	8,000,000	3	0	0	<1	No	No	No	--	No	Three detections (detection frequency less than 5%). Corresponds with PCP exceedances.
Aniline	59	200	180,000	2	0	0	<1	Yes	No	No	--	No	Does not meet selection criteria. One minor exceedance of soil SL. Addressed by PAHs and PCP.
4-Nitroaniline (µg/kg)	54	1,400	50,000	2	0	0	<1	No	No	No	--	No	One detection at 4.3 feet bgs (detection frequency less than 5%). Corresponds with PAH exceedances.
Diethyl phthalate (µg/kg)	60	160	64,000,000	2	0	0	<1	No	No	No	--	No	One detection at 28 feet bgs (detection frequency less than 5%). Corresponds with PAH exceedances.

Notes:

Analyte meets initial IHS selection criteria (Exceedance Frequency ≥ 10% or Exceedance Factor > 2)

Analyte identified as an IHS based on both satisfaction of initial selection criteria and consideration of other selection criteria , or on consideration of other selection criteria alone.

IHS = indicator hazardous substance

Frequency of SL Exceedances = (# of samples with constituent detected at a concentration greater than SL)/(total # of samples analyzed for constituent)

Exceedance Factor (EF) (max) = ratio of maximum detected concentration divided by SL. EFs are rounded to whole numbers except for values between 1 and 2 which are rounded to the nearest tenth.

SL = screening level

COPC = constituent of potential concern

PAH = polycyclic aromatic hydrocarbons

PCP = pentachlorophenol

BEHP = bis(2-ethylhexyl)phthalate

RL = Reporting Limit

n/a = Not Applicable

TEQ = Toxicity equivalency concentration

ng/kg = nanogram per kilogram

µg/kg = microgram per kilogram

mg/kg = milligram per kilogram

Dioxin TEQ is the toxicity-weighted sum of all dioxin and furan congeners expressed as an equivalent 2,3,7,8-TCDD concentration using the World Health Organization (WHO) 2005 congener-specific toxicity equivalency factors (TEFs) for mammals and humans; where congeners are not detected, a value of ½ the detection limit is assumed for the calculation.

Koc = soil organic carbon-water partitioning coefficient. Lower Koc values correspond to greater aqueous-phase mobility.