FINAL
Remedial Investigation/Feasibility Study
Cornwall Avenue Landfill
Bellingham, Washington

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Prepared for

Port of Bellingham
Bellingham, Washington

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ABBREVIATION/ACRONYM LIST

AETs	Apparent Effect Threshold Values
ARARs	applicable or relevant and appropriate requirements
BEP	bis(2-ethylhexyl)phthalate
BBP	butylbenzylphthalate
BGS	below ground surface
BNSF	Burlington Northern Santa Fe Railway Company
BTEX	benzene, toluene, ethylbenzene, and xylenes
°C	degrees Celsius
CAP	cleanup action plan
City	City of Bellingham
CFU	colony forming unit
cm	centimeter
cm/s	centimeter per second
cm/yr	centimeter per year
COPC	constituent of potential concern
cPAH	carcinogenic polycyclic aromatic hydrocarbons
CSL	cleanup screening level
CSM	conceptual site model
DCA	disproportionate cost analysis
DGPS	differential global positioning system
DNR	Washington State Department of Natural Resources
Ecology	Washington State Department of Ecology
EIS	Environmental Impact Statement
ESA	Endangered Species Act
FML	flexible membrane liner
FS	feasibility study
ft	feet
ft/day	feet per day
ft^2	square feet
ft^3	cubic feet
ft^3/day	cubic feet per day
GP	Georgia Pacific West
gpm	gallon per minute
H:V	horizontal to vertical
HDPE	high density polyethylene
HPAHs	high molecular weight polycyclic aromatic hydrocarbons
IHS	Indicator Hazardous Substance
IPA	interim placement area
km^2	square kilometer
LEL	lower explosive limit
LFG	landfill gas
LNAPL	light non-aqueous phase liquid
LPAHs	low molecular weight polycyclic aromatic hydrocarbons
m^3	cubic meter
m/sec	meter per second
MFS	minimum functional standards
mg/kg	milligram per kilogram
mg/L	milligrams per liter

MHHW	mean higher high water
mi^2	square mile
mL	milliliter
MLLW	mean lower low water
MNR	monitored natural recovery
MTCA	Model Toxics Control Act
ng/kg	nanogram per kilogram
ng/L	nanogram per liter
NOAA	National Oceanic and Atmospheric Administration
NTU	nephelometric turbidity unit
OC	organic carbon normalized
PAHs	polycyclic aromatic hydrocarbons
PCBs	polychlorinated biphenyls
PCL	preliminary cleanup level
PCP	pentachlorophenol
PLPs	potentially liable parties
Port	Port of Bellingham
ppt	parts per trillion
PQL	practical quantitation limit
PRB	permeable reactive barrier
PSDDA	Puget Sound Dredge Disposal Analysis
RAOs	remedial action objectives
RCRA	Resource Conservation and Recovery Act
RI	remedial investigation
RI/FS	Remedial Investigation/Feasibility Study
SCUBA	self-contained underwater breathing apparatus
SEPA	State Environmental Policy Act
Site	Cornwall Avenue Landfill Site
SL	screening level
SMS	Sediment Management Standards
SPI	sediment profile imaging
SQS	sediment quality standards
SVOCs	semivolatile organic compounds
TBT	tributyl tin
TEQ	toxicity equivalency
TOC	total organic carbon
TPH	total petroleum hydrocarbon
TSS	total suspended solids
USACE	U.S. Army Corps of Engineers
USFWS	United States Fish and Wildlife Service
USGS	U.S. Geologic Survey
VOCs	volatile organic compounds
yd^3	cubic yard
µg/kg	microgram per kilogram
µg/L	microgram per liter

1.0 INTRODUCTION

Under the terms of Agreed Order No. 1778, as amended, the Port of Bellingham (Port) and City of Bellingham (City) have prepared this Remedial Investigation/Feasibility Study (RI/FS) report. The Port and the City have been identified by the Washington State Department of Ecology (Ecology) as potentially liable parties (PLPs) under the Washington State Model Toxics Control Act (MTCA; Chapter 173-340 WAC) for the Cornwall Avenue Landfill Site (Site) in Bellingham, Washington. The Port and the City conducted the RI in accordance with the *Draft Work Plan Supplemental Remedial Investigation, Cornwall Avenue Landfill, Bellingham, Washington* (Landau Associates 2002) and the *Work Plan, Cornwall Avenue Landfill Site, Supplemental RI Groundwater Investigation, Bellingham, Washington* (Landau Associates 2012a).

The RI describes the environmental setting for the Site, identifies potential receptors and develops Site screening levels (SLs), identifies the nature and extent of contamination for affected media, and develops preliminary cleanup levels (PCLs) and indicator hazardous substances (IHS) for the Site. SLs address all detected hazardous substances in all affected media for which promulgated criteria are available. PCLs are refined from the SLs at the end of the RI process based on the RI results. PCLs are considered preliminary cleanup levels because the final cleanup levels are established by Ecology in the cleanup action plan (CAP), which is developed following completion of the RI/FS. The FS develops and evaluates alternatives for cleanup of Site contamination, and presents a preferred cleanup alternative.

1.1 SITE DESCRIPTION

The Site is located south of downtown Bellingham, at the terminus of Cornwall Avenue, adjacent to Bellingham Bay. The Site is also bordered by an active rail line owned by Burlington Northern Santa Fe Railway Company (BNSF), and by the R.G. Haley site. These features are shown on Figures 1-1 and 1-2.

The Site extends across two separate properties, one owned by the City and the other consisting of Washington state lands administered by the Washington State Department of Natural Resources (DNR), as shown on Figure 1-2. Property-related references in this document use the following conventions:

- DNR property or state land: The upland and in-water area owned by the State of Washington seaward of the Inner Harbor Line.
- Cornwall property: The upland area formerly owned jointly by the Port and the City, and now solely by the City.
- BNSF railway mainline: The upland area owned by BNSF.

- The Cornwall landfill, Cornwall Avenue Landfill, or the landfill: The area containing municipal refuse.

Note: For clarity, a project north has been established for the Site at the northeast Cornwall property line (see Figure 1-2). This convention is used throughout the report when referring to the orientation of Site features.

The Site is defined as the area containing refuse; the area containing wood waste within Cornwall property boundaries; the imported sediment stockpiles, and any adjoining areas impacted by hazardous substance releases from the refuse or wood waste, as shown on Figure 1-2. The Site boundaries are described more specifically as follows:

- West and South Site Boundary: These boundaries are set in Bellingham Bay at the western and southern limits of Site-related impacts to sediment. Figures in this report indicate an approximate boundary to the west and south based on the presence of refuse or wood waste. More specifically, the boundaries with respect to defining the area of cleanup will be established at the point where the concentrations of Cornwall site-related contaminants have declined to a level commensurate with the sediment cleanup levels established for the Site.
- North Site Boundary: This boundary is set at the northern limit of refuse or impacts from refuse. Where refuse is absent, this boundary is established at the northern Cornwall property line.
- East Site Boundary: This boundary is set at the eastern edge of the wood waste fill, which generally coincides with the eastern Cornwall property line (i.e., where it adjoins the BNSF railway mainline).

The Site is approximately 16.5 acres in size, including about 13 acres of aquatic lands and 13 acres of uplands. All 3.5 acres of the aquatic lands and approximately 8.4 acres of the uplands are owned by Washington State and managed by DNR; DNR is also a Site PLP. The remaining 4.5 acres of the uplands are owned by the City. The inner harbor line represents the boundary between City-owned land and state-owned land at the Site. Property to the north of the Site is also owned by the City, and is part of the R.G. Haley cleanup site. BNSF owns the property east of the Site for the railway mainline. Figure 1-2 presents the pertinent property boundaries for reference and the approximate Site boundary based on the findings of the RI.

Presently, the only significant features on the Site consist of a stormwater detention basin constructed in 2005 at the south end of the Site, and the interim placement areas (IPAs) located in the western portion of the Site that store stabilized sediment from an interim action conducted in 2011 and 2012. The 2011/2012 interim action is discussed further in Section 3.7 (Interim Action). The Site is largely unpaved, with the exception of a section of asphalt road and other pavement in the northeastern portion of the Site. Current Site features are shown on Figure 1-2.

The R.G. Haley MTCA site is located adjacent and north of the Site. Releases from the R.G. Haley site appear to have impacted soil and groundwater conditions in the northern portion of the Site in an area referred to herein as the overlap area, and refuse from the Site is present in the southwestern portion of the R.G. Haley site uplands. There also appears to be additional overlap between the sites in soil, and sediment. The City is currently conducting an RI for the R.G. Haley site, and is responsible for addressing contamination originating from past wood treating operations at that site. Sections 3.3 (R.G. Haley Site Remedial Investigation/Feasibility Study) and 6.3.2 (Site Interior Groundwater Quality) provide additional information regarding the investigation and environmental conditions in the overlap area. This information is also considered in the FS to ensure that the FS alternatives for this Site do not interfere with or preclude cleanup alternatives for the R.G. Haley site.

Another MTCA site, the Whatcom Waterway sediment cleanup site, borders the Site on the west in Bellingham Bay. That site overlaps the sediment portion of the Cornwall Site. The primary contaminant of concern at the Whatcom Waterway sediment cleanup site is mercury and the required cleanup (under Consent Decree No. 07-2-02257-7) in the area of the Cornwall Site is monitored natural recovery (MNR). Monitoring is expected to begin in 2016 following Phase I implementation of active cleanup measures in other areas of the Whatcom Waterway sediment cleanup site. As discussed in Section 10.2 (Compatibility with R.G. Haley and Whatcom Waterway Remedial Activities), remedial actions for the Cornwall Site will be planned and conducted in coordination with the Whatcom Waterway cleanup activities.

1.2 OBJECTIVES OF THE REMEDIAL INVESTIGATION/FEASIBILITY STUDY

The objective of this RI/FS is to collect, develop, and evaluate sufficient information regarding the Site to enable the selection of a cleanup action (WAC 173-340-350). Specifically, this RI/FS:

- Characterizes the nature and extent of contamination for affected media (i.e., groundwater, sediment, and soil)
- Identifies preliminary cleanup standards for affected media
- Develops and evaluates cleanup action alternatives that protect human health and the environment
- Identifies a preferred cleanup alternative.

This document presents the information collected and the evaluations performed to achieve these objectives.

1.3 REPORT ORGANIZATION

The RI/FS report is organized as follows:

- Section 2.0 (Project Background) presents project background, including a summary of Site history, and a description of previous environmental investigation and interim cleanup action activities.
- Section 3.0 (Remedial Activities) describes the RI activities, including soil, groundwater, surface water, and marine sediment investigations.
- Section 4.0 (Environmental Setting) describes the environmental setting for the Site, including its physical features, geology, hydrogeology, natural resources, and land use.
- Section 5.0 (Development of Site Screening Levels) develops Site SLs for affected media, which are used in Section 6.0 (Nature and Extent of Contamination) to characterize the nature and extent of contamination.
- Section 6.0 (Nature and Extent of Contamination) presents the results of the investigations which delineate the nature and extent of contamination.
- Section 7.0 (Conceptual Site Model) presents the conceptual Site model, including contaminants and sources, and fate and transport processes.
- Section 8.0 (Discussion of Cleanup Standards) presents the development of cleanup standards for the Site, identifies remedial action objectives (RAOs), and identifies potentially applicable laws.
- Section 9.1 (Site Units) identifies specific areas of the Site to be addressed during cleanup activities.
- Section 9.2 (Remedial Action Objectives and Potentially Applicable Laws) identifies the specific goals of the cleanup action to address potential exposure pathways and the State and Federal laws applicable to cleanup of the Site.
- Section 9.3 (Screening of Remedial Technologies) presents the screening of the remedial technologies.
- Section 9.4 (Description of Remedial Alternatives) describes the remedial alternatives for each Site unit.
- Section 9.5 (Feasibility Study Evaluation Criteria) presents the criteria by which the remedial alternatives will be evaluated to determine the preferred alternative.
- Section 9.6 (Evaluation of Alternatives) evaluates the remedial alternatives against the evaluation criteria.
- Section 9.7 (Disproportionate Cost Analysis) presents the disproportionate cost analysis.
- Section 10.0 (Summary and Conclusions) presents the summary and conclusions, including a description of the preferred alternative.

2.0 PROJECT BACKGROUND

This section provides an overview of the history of the Site, including a summary of all environmental investigations conducted at the Site prior to the RI. RI activities are summarized in Section 3.0 (Remedial Activities), and the integrated results of all Site environmental investigations are presented in Sections 4.0 (Environmental Setting) and 6.0 (Nature and Extent of Contamination).

2.1 SITE HISTORY

Historically, the majority of the Site consisted of tide flats and subtidal areas of Bellingham Bay. From about 1888 to 1946, the Site was used for sawmill operations, including log storage and wood debris disposal. Between about 1946 and 1965, the Port held the lease on the state-owned portion, and subleased a portion of the Site to the City from 1953 to 1962. During that time period, the City used the Site for the disposal of refuse. In 1962, the City entered into a lease with another Port tenant (American Fabricators) and continued landfill operations at the Site until 1965. From 1971 to 1985, the Site was leased to Georgia Pacific West (GP) by the Port, including sublease of the state-owned portion of the Site. In 1985, GP purchased a portion of the Site from the Port referred to in previous documents as the "fee-owned portion" of the Site. In January 2005, the Port repurchased the fee-owned property from GP, in conjunction with other waterfront property owned by GP, and in December 2005, the City purchased an ownership interest in the fee-owned portion of the Site from the Port. In 2012, the City acquired the remaining fee-owned portions of the Site from the Port. Additional details regarding the Site history and uses of the Cornwall Avenue Landfill are described in the initial characterization report (Tetra Tech and Historical Research Associates 1995), provided in Appendix A of this report.

Sometime prior to 1953, a wood-framed warehouse was built in the southern corner of the Site, and another smaller wood-framed warehouse was built (date of construction unknown) near the northeastern corner of the Site. The use of the warehouses prior to GP's leasehold is unknown. GP used the warehouses until they were demolished in 2004 and 2005. Because most of the Site investigations were conducted prior to demolition of the GP warehouses, the footprints of the former warehouses are shown on most figures included in this report.

Upon closure in 1965, the landfill was covered with a soil layer of variable thickness, and the shoreline was protected by various phases of informal slope armoring consisting of a variety of rock boulders and broken concrete. Significant shoreline erosion has occurred following closure of the landfill, which resulted in exposure of landfill refuse at the surface and redistribution of landfill refuse onto the adjacent beach area. The toe of the refuse fill slope extends out into Bellingham Bay to some distance beyond the shoreline.

The Site came to public attention in 1992 when a beachcomber reportedly discovered medical waste (including glass blood vials and plastic syringes) along the beach at the toe of the landfill. This discovery led to Ecology's initial Site investigation in 1992, which is discussed later in this section. Subsequent evaluation of the medical waste issue by Whatcom County Health and Human Services (WCHHS 1999) concluded that:

- The medical waste present at the Site was generated 27 to 49 years ago.
- Disposal of medical waste at the Cornwall Avenue Landfill was consistent with Whatcom County Solid Waste Regulations during the years of active landfill operation.
- There is not a potential for pathogens potentially associated with medical waste disposed at the landfill to have survived to the present.
- There is no threat of exposure related to medical waste from prior landfill operation and additional sampling and analyses for pathogens is not necessary.

Based on the Whatcom County Health and Human Services evaluation, the investigation of Site environmental conditions has focused on the environmental parameters discussed in this document.

On the basis of data collected during the initial Site investigation, Ecology performed a site hazard assessment under the Toxics Cleanup Program in 1992. The Ecology site hazard assessment for the Cornwall Avenue Landfill indicated that "... the refuse included household garbage, pulp waste, and other possible waste." A characterization of contaminants and potential post-closure uses for the landfill was initially conducted for the Washington State Attorney General (Tetra Tech and Historical Research Associates 1995), and is provided in Appendix A of this report. The Tetra Tech report provides a detailed description of historical site use and landfilling activities.

Based on the results of the site hazard assessment, Ecology ranked the Site a 2 on a scale of 1 to 5, with 1 being the highest priority. Some of the factors contributing to the ranking included the lack of a landfill liner, leachate collection, and run-on/run-off control; toxic metals detected in the leachate; estimated quantity of waste disposed at the landfill; and the proximity of the Site to populated areas and sensitive environments.

2.2 PREVIOUS SITE INVESTIGATIONS

A number of environmental investigations were conducted at the Site prior to the signing of the Agreed Order and initiation of formal RI activities in 2005. These pre-RI investigations are described below. RI activities conducted subsequent to issuance of the Agreed Order are described in Section 3.0 (Remedial Activities).

In addition to environmental investigations, information obtained during previous geotechnical investigations conducted at the Site is useful in evaluating Site geologic conditions. Therefore, a brief description of these investigations is also provided in this section. Table 2-1 summarizes each of the pre-

RI environmental and geotechnical investigations in chronological order. Elevations for groundwater monitoring wells and seep sampling locations are presented in Table 2-2, and location and elevation data for surface sediment samples are presented in Table 2-3. Applicable results of the pre-RI investigations are integrated with the results of the RI in Sections 4.0 (Environmental Setting) and 6.0 (Nature and Extent of Contamination).

2.2.1 GEOTECHNICAL INVESTIGATIONS

Geotechnical investigations were conducted within or adjacent to the Site in 1960 (Dames & Moore 1960) and in 1985 (Purnell & Associates 1985). Dames & Moore completed five borings (Borings 1 through 5) as part of a geotechnical investigation conducted at and near the Site in 1960. Purnell & Associates completed 14 borings (B-1 through B-14) and 6 test pits (TP-1 through TP-6) and installed piezometers in borings B-2, B-3, B-4, B-5, B-6, and B-12 to evaluate groundwater flow in 1985. The exploration locations for these geotechnical investigations are shown on Figures 2-1 and 2-2 for upland and in-water exploration locations, respectively, and the boring and test pit logs are presented in Appendix B. Generalized environmental impacts were documented during the Purnell & Associates investigation. Notations consisted of an observed oil film near the northeastern corner of the landfill at test pit locations TP-1, TP-2, TP-3, TP-4, and boring B-4. No analytical data were collected as part of this investigation.

2.2.2 INITIAL SITE INVESTIGATION

In 1992, Ecology conducted an initial environmental investigation of the Site (Ecology 1992a), which formed the basis for the site hazard assessment (Ecology 1992b). The investigation consisted of collecting and analyzing four groundwater seep samples at locations E-1 through E-4 within the intertidal zone and two surface sediment samples collected near groundwater seep locations E-2 and E-4, as shown on Figure 2-2.

The seep water samples were analyzed for metals, semivolatile organic compounds (SVOCs), total petroleum hydrocarbons (TPH), and a number of conventional parameters. One or more of the water samples exceeded the marine water quality criteria for a number of heavy metals. The seep samples were not filtered and were described by the analytical laboratory as “turbid and dark in color” (Tetra Tech and Historical Research Associates 1995). The turbidity of the seep samples collected by Ecology may have contributed to the high concentrations of constituents detected. The surface sediment samples were analyzed for metals, volatile organic compounds (VOCs), SVOCs, pesticides, and total polychlorinated biphenyls (PCBs). The Sediment Management Standards (SMS) were exceeded in one or more samples for copper, zinc, lead, bis(2-ethylhexyl)phthalate (BEP), and PCBs. The analytical program did not include analysis for total organic carbon (TOC), so Tetra Tech used an assumed TOC concentration of 1 percent to normalize the sediment analytical results for organics for comparison to the SMS criteria.

2.2.3 EXPANDED SITE INVESTIGATION

An expanded Site investigation was conducted in 1996 to further evaluate environmental conditions (Landau Associates 1997). The investigation included the collection and analysis of groundwater seep samples from three locations (S-1 through S-3) in the intertidal zone and collection of a surface sediment sample from each of the seep sampling locations. The investigation also included a test pit investigation (TP-1 through TP-4) to evaluate the nature of near-surface refuse in the intertidal zone, an assessment of the upland and subtidal cover conditions, and an assessment of shoreline erosion. Expanded Site investigation exploration locations are shown on Figures 2-1 and 2-2 for upland and in-water exploration locations, respectively, and the exploration logs are presented in Appendix B.

The groundwater seep samples were tested for metals, SVOCs, VOCs, pesticides, PCBs, major cations and anions, total cyanide, total phenols, gross alpha/beta radiation, fecal coliform, turbidity, color, hardness, salinity, specific conductance, total dissolved solids, and TPH. One or more seep water samples exceeded the surface water quality standards for a number of metals and fecal coliform. Additionally, the sample from S-2 exceeded the radiochemistry standard for gross beta radiation. The seep samples were not filtered, and although care was taken during collection to minimize turbidity, the turbidity was still significantly higher than that considered acceptable for groundwater samples. The surface water quality exceedances in these samples may have resulted from sample turbidity.

Surface sediment samples were analyzed for total metals, total cyanide, SVOCs, pesticides, PCBs, TOC, grain size, TPH by Ecology Method NWTPH-HCID, and conventional parameters (including total solids, total volatile solids, total sulfides, and ammonia). One or more of the following constituents were detected in each of the sediment samples at concentrations exceeding the SMS Sediment Quality Standards (SQS): silver, copper, lead, BEP, and total PCBs.

Dioxins were not tested for during the Expanded Site Investigation or subsequent investigations because of the low potential for their presence in the waste stream disposed at the landfill. Although GP pulping waste was reportedly disposed at the Site, available information suggests that the material did not likely contain significant concentrations of dioxins. According to GP, pulping waste disposed at another landfill, Roeder Avenue Landfill, primarily consisted of knots and tailing screened out of the pulp prior to bleaching (ENSR 2007). The wastes generated downstream of the bleaching process, which are the wastes most likely to contain dioxins, were handled at other facilities. The Cornwall Avenue Landfill was the refuse disposal facility used by GP prior to construction of the Roeder Avenue Landfill, and GP's disposal practices at the Site were likely the same as those at the Roeder Avenue Landfill. Additionally, the GP chlor-alkali plant was not constructed until 1965, the year the Cornwall Avenue Landfill closed, which further reduces the potential that dioxins were contained in any pulping wastes disposed at the Cornwall Avenue Landfill. Furthermore, the solubility of dioxin/furans is very low and they have a high affinity for soil. Therefore, if dioxin/furans were present in the landfill or in soil at the Site, it is unlikely they would migrate via groundwater to the surface water.

2.2.4 FOCUSED REMEDIAL INVESTIGATION

A focused RI was conducted in 1998 and 1999 by Landau Associates (Landau Associates 2000). The primary objectives identified for the focused RI were to:

- Estimate the flow, direction, and velocity of the groundwater in the upper portion of the aquifer
- Determine whether groundwater is a migration pathway for contaminants from the Site to Bellingham Bay
- Evaluate the extent to which upgradient water quality conditions are affecting the groundwater within the Site
- Evaluate the extent of the contribution to groundwater within the Site from the R.G. Haley site or by previously detected releases near the northeastern corner of the Site.

Five groundwater monitoring wells (MW-1 through MW-5) were installed during the focused RI at the locations shown on Figure 2-1. Boring and well completion logs are presented in Appendix B. Groundwater samples were collected from wells MW-1 and MW-5 during this investigation. MW-1 was analyzed for polycyclic aromatic hydrocarbons (PAHs), diesel- and oil-range petroleum hydrocarbons, copper, lead, zinc, total cyanide, fecal coliform, and turbidity. The groundwater sample collected from well MW-5 was analyzed for PAHs and diesel- and oil-range petroleum hydrocarbons. A strong petroleum odor and heavy sheen were present in soil samples near the water table during the installation of MW-1. The diesel- and oil-range petroleum hydrocarbon detections in the sample from MW-1 and the diesel-range petroleum hydrocarbon detection in the sample from MW-5 exceeded the current MTCA Method A groundwater cleanup levels. Additionally, the copper concentration detected in the sample from MW-1 exceeded the applicable surface water quality standards.

Three groundwater seep sampling devices (S-1, S-2, and S-3) were installed at the Site during the focused RI at the same locations as the 1997 expanded Site investigation seep/sediment sampling locations. The sampling devices were installed to: 1) obtain samples of groundwater seep discharge that are representative of groundwater quality at the point of discharge to Bellingham Bay; and 2) to estimate the potential for a relatively thin sand filter layer (representing a component of intertidal cover material proposed for containment) to improve seep discharge water quality. The seep sampling device construction details are shown on Figure 2-3.

Groundwater seep samples were analyzed for copper, lead, and zinc (total and dissolved), cyanide, fecal coliform, and turbidity. Fecal coliform, copper, and lead were detected in one or more groundwater seep samples at concentrations that exceeded the SLs discussed in Section 5.4 (Groundwater Screening Levels).

2.3 RELATIONSHIP OF REMEDIAL INVESTIGATION/FEASIBILITY STUDY TO OTHER DOCUMENTS

As indicated on Figure 2-1, the R.G. Haley site is located adjacent to the Site. As will be subsequently discussed in this document, there is some overlap of hazardous substances in soils, groundwater, and sediment between the two sites. Because of this overlap, it is important that the remedial actions implemented at the two sites be coordinated to ensure successful remediation at both sites over the long term. The approach to coordinating the Site and R.G. Haley site cleanups is discussed in the FS portion of this document.

Ecology conducted a site hazard assessment during 1992 for the adjacent R.G. Haley site (Ecology 1992c). The R.G. Haley site is a former wood treatment facility located immediately north of the Site. The site hazard assessment identified pentachlorophenol (PCP) and fluorine at levels above MTCA cleanup levels and Ecology ranked the R.G. Haley property a 3 based on these data. The potential impact of the R.G. Haley site on the Site was considered during a previous investigation (referred to as the focused RI), as discussed in Section 6.2.2 (Extent of Petroleum Hydrocarbon Contamination). Data presented in relevant R.G. Haley documents, including the R.G. Haley Interim Cleanup Action Plan (GeoEngineers 2000), Addendum No. 2 to the Interim Cleanup Action Plan (GeoEngineers 2001), the Interim Cleanup Action Report (GeoEngineers 2002), the Draft Final RI/FS Report (GeoEngineers 2007), and RI data collected by GeoEngineers in 2012, were reviewed as part of this RI to evaluate the extent of refuse and petroleum hydrocarbon sheen, as described in Section 6.0 (Nature and Extent of Contamination**).**

The Site is located within The Waterfront District redevelopment area, which is currently undergoing extensive planning efforts to facilitate a transition from historical industrial activities to a mixed-use urban neighborhood. The remedial alternatives developed for the Site need to protect human health and the environment under future land use. As a result, potential future land use, including the development concept presented in The Waterfront District Draft Sub-Area Plan (Port of Bellingham website 2012), is addressed in the FS portion of this document. Environmental review regarding the proposed land use components is being performed under the State Environmental Policy Act (SEPA) by the Port's SEPA responsible official. The Final Environmental Impact Statement (EIS; Blumen Consulting Group, Inc. 2010) and Final EIS Addendum (EA Engineering 2012) were published in conjunction with the Draft Sub-Area Plan in December 2012 all of which are herein collectively referred to as the Waterfront District EIS. The Waterfront District EIS documents help present an understanding of the relationship between the Site and The Waterfront District redevelopment activities.

3.0 REMEDIAL ACTIVITIES

For the purposes of this document, remedial activities consist of those RI and interim action activities conducted at the Site subsequent to execution of Agreed Order No. 1778. RI activities include both activities conducted specifically as part of the Site RI and environmental characterization conducted for other purposes that generated relevant Site environmental data. RI activities conducted as part of the Site RI include the 2002 Site Supplemental RI, the 2008 Ecology sediment investigation, and the 2012 Supplemental RI Groundwater Investigation. Activities not conducted as part of the Site RI that generated relevant Site environmental data include a 2004 Phase II environmental assessment of GP Bellingham operations, a 2008 sediment quality investigation conducted by the City for the proposed Boulevard Park overwater walkway, and RI activities conducted for the R.G. Haley site, at locations at or adjacent to the Site. Interim action activities consisted of the sediment beneficial reuse interim action conducted in 2011/2012 to store stabilized fine-grained sediment that could potentially be used at the Site in the future as contouring fill material. Brief descriptions of RI and interim action activities for each of these remedial activities are presented in this section.

Because the Site is a former solid waste landfill, it is inherently heterogeneous and hazardous substances tend to be distributed sporadically throughout the refuse. As a result, it was conservatively assumed that all of the soil/refuse and wood waste within the landfill exceeds applicable MTCA cleanup levels and requires remediation. Because of the potential for surface soil contamination from the R.G. Haley site to have been conveyed onto the Site by vehicles and stormwater, and for hazardous substances in refuse to have been entrained in cover soil, it was also assumed that Site cover soil contains hazardous substances above applicable MTCA cleanup levels. Consequently, RI soil characterization was focused on delineating the extent of refuse and wood waste, and investigating the extent of petroleum hydrocarbon present on the Site that appears to be associated with the R.G. Haley cleanup site.

The decomposition of solid waste and wood waste typically depletes oxygen in groundwater and leads to reducing (low oxygen) groundwater conditions. The reducing groundwater conditions often cause naturally occurring metals in soils such as iron and manganese to become mobile and enter the dissolved phase. Additional compounds associated with the breakdown of solid waste and wood waste include tannins and lignins, and common cations and anions such as sulfate, chloride, and ammonia, which are often present at concentrations of concern in landfill leachate or groundwater that is in contact with buried waste. Additionally, some hazardous substances disposed of at municipal solid waste landfills can leach into groundwater, such as VOCs and petroleum hydrocarbons. Some hazardous substances that do not readily dissolve into groundwater, such as many SVOCs (including PAHs) and PCBs, are still considered groundwater constituents of potential concern (COPCs) because they have very low cleanup levels that result in criteria exceedances at very low concentrations. As a result, these constituents were considered likely to be present in Site groundwater and groundwater quality characterization was focused on these constituents, although less prevalent constituents were also tested for during various phases of Site groundwater characterization.

3.1 2002 SUPPLEMENTAL REMEDIAL INVESTIGATION ACTIVITIES

A supplemental RI was performed in 2002 to address data gaps identified in the focused RI. The 2002 supplemental RI consisted of a number of activities to better characterize Site soil, groundwater, and sediment quality, which are briefly described below. Supplemental RI activities were conducted in accordance with the Ecology approved supplemental RI Work Plan (Landau Associates 2002), and are described below in sections specific to the media investigated (soil, groundwater, sediment, and storm drain system).

3.1.1 SOIL INVESTIGATION

Soil borings and test pits were completed during the supplemental RI to delineate the extent of petroleum hydrocarbon sheen encountered during previous Site investigation activities. Fourteen test pits (RITP-1 through RITP-14) were excavated in the vicinity of MW-1 and the northeastern corner of the Site. Four soil borings (RISB-1 through RISB-4) were completed in the vicinity of MW-1 by hollow-stem auger due to the presence of paved surfaces, which precluded the use of test pit explorations in these areas. Boring and test pit locations are shown on Figure 2-1. Test pit and boring logs are presented in Appendix B.

The presence of light non-aqueous phase liquid (LNAPL) was observed in test pit RITP-7. A sample of the LNAPL was collected for chemical analyses. No other samples were collected during the soil investigation for analytical testing. The results of this investigation are discussed further in Section 6.2 (Soil Quality).

3.1.2 GROUNDWATER INVESTIGATION

The following activities were performed as part of the 2002 supplemental RI groundwater investigation:

- Installation of two groundwater monitoring wells (MW-9 and MW-10) in the vicinity of MW-1 to evaluate the nature, extent, and source of TPH contamination that was detected in MW-1 during the focused RI.
- Installation of three groundwater monitoring wells (MW-6, MW-7, and MW-8) to characterize the nature and extent of TPH-impacted groundwater originating from the LNAPL previously observed near the northeastern corner of the Site.

- Installation of three groundwater seep sampling devices (RIS-1, RIS-2, and RIS-3) to replace the ones that were destroyed following completion of the focused RI by a detached log boom. The new devices were installed in approximately the same locations as the previous devices.
- Collection and analysis of groundwater discharge samples from the seep sampling devices for two additional monitoring events to evaluate consistency with the focused RI data. The groundwater seep samples were analyzed for the same parameters investigated during the focused RI, including PCBs, total suspended solids (TSS), TOC, and ammonia.
- Sampling of all groundwater monitoring wells and seep sampling devices at the Site for fecal coliform analysis to determine the origin of fecal coliform detections in seep water samples and MW-1 during the focused RI.
- Sampling of most of the groundwater monitoring wells and seep sampling devices at the Site for PCB analyses to evaluate whether groundwater was a potential source of the PCB detections in Site sediment and to compare PCB concentrations at the groundwater/surface water interface to Site SLs.
- Sampling of MW-3 for diesel- and oil-range petroleum hydrocarbon analyses to evaluate if the sheen observed during the installation of MW-3 was of a petroleum origin.
- Sampling of the LNAPL observed during the excavation of test pit RITP-7 in the northeastern corner of the Site for analysis of PAHs, PCBs, diesel- and oil-range petroleum hydrocarbons, and benzene, toluene, ethylbenzene, and xylenes (BTEX).

The groundwater monitoring well and seep sampling locations are shown on Figures 2-1 and 2-2, respectively. Monitoring well boring logs and construction details are presented in Appendix B.

When groundwater is in contact with landfill refuse, it is often evidenced by elevated conventional parameters such as sulfate, nitrate, ammonia, and low levels of VOCs as discussed in Section 3.0 (Remedial Activities).

A heavy sheen was observed in soil samples collected near the water table during the installation of MW-6. This was confirmed by a groundwater sample obtained from this well that also had a petroleum odor and sheen. A slight sheen was observed in soil samples collected near the water table during the installation of MW-8 that was attributed to the refuse. No sheen was observed during the collection of the groundwater sample from this well. Refuse, including glass, plastic, wood, and metal, was observed during the installation of wells MW-7, MW-8, and MW-10.

Following installation, the location and elevation of each monitoring well was determined using a differential global positioning system (DGPS). The elevations for the wells were referenced to existing wells MW-1 and MW-5, which were surveyed using conventional methods. The elevations for all Site groundwater monitoring wells are provided in Table 2-2.

The newer seep sampling devices were installed at the approximate locations of the previous seep sampling devices, with the exception of RIS-1. RIS-1 was located about 50 feet (ft) southwest of the focused RI groundwater seep sampling location (S-1) because of observations made during the 2002 supplemental RI that indicated a stormwater outfall for the Site was located in the immediate vicinity of

S-1, which could affect groundwater seep quality results collected from this location. RIS-3 was also relocated about 75 ft southeast of S-3 because it was the closest active seep location at the appropriate elevation [above about 2 ft mean lower low water (MLLW) elevation].

Following installation, the groundwater seep sampling devices were surveyed using DGPS and referenced to the known elevations of the existing monitoring wells. The location coordinates and elevations for the seep sampling devices are presented in Table 2-2.

3.1.3 SEDIMENT INVESTIGATION

The sediment investigation completed as part of the supplemental RI consisted of collection of six surface sediment samples (SRI-SED-1 through -6) for chemical analysis and a subtidal survey to better delineate the extent of landfill refuse. Similar to previous sediment sampling events, the depth of sediment characterized during the 2002 supplemental RI consisted of the upper 12 centimeters (cm), consistent with studies for the Whatcom Waterway site which show that the depth of bioturbation generally ranges from 10 to 15 cm (RETEC 2006). Sediment samples were collected approximately 25 ft seaward of the 50 percent refuse line identified during a subtidal diver survey, which was also conducted during the 2002 supplemental RI and is described below. Sediment sample locations are shown on Figure 2-2. The coordinates and elevations for sediment sample locations are provided in Table 2-3.

The six surface sediment samples were analyzed for PCBs, BEP, copper, lead, zinc, and TOC. Samples SRI-SED-3 and SRI-SED-5, which were the furthest from the shoreline, were also analyzed for mercury to evaluate the ubiquitous presence of mercury in Bellingham Bay.

Subtidal cover conditions were investigated during the 2002 supplemental RI to determine the extent of exposed refuse at the limits of 50 percent surface debris coverage and the outermost extent of surface refuse. A subtidal survey was conducted on June 5, 2002, by Parametrix, Inc. of Kirkland, Washington, using a boat and a diver with a self-contained underwater breathing apparatus (SCUBA). While swimming toward shore, the diver recorded the depth, substrate, and type of refuse to identify the limits of 0 and 50 percent surface refuse coverage. Location coordinates along the diver transects were recorded using DGPS. This process was repeated along 10 transects until the outer 0 percent and the 50 percent boundaries of the observable subtidal refuse or debris was delineated. Observations regarding the nature and distribution of wood debris were also recorded within the survey area. The results of the diver survey are presented in Sections 4.4.1.2 (Shallow Subtidal Habitat) and 6.4.1 (Extent of Refuse and Wood Debris).

3.1.4 DRAINAGE SYSTEM EVALUATION

A video survey of the integrity of the existing stormwater system was performed by Applied Professional Services, Inc., of Issaquah, Washington, on August 21, 2002 during the 2002 supplemental RI. The video survey consisted of extending a video recorder through the stormwater lines to evaluate alignment, materials of construction, and existing condition. During the survey, the alignment/location of the system features were marked on the ground surface at regular intervals and surveyed using a DGPS. The results of the drainage system evaluation are discussed in Section 4.1.2 (Drainage and Stormwater).

3.2 GEORGIA PACIFIC WEST PHASE II ENVIRONMENTAL ASSESSMENT

In 2004, Aspect Consulting conducted a Phase II environmental assessment of the GP Bellingham operations to support property transfer negotiations with the Port, which included the Site (Aspect Consulting 2004). Six soil borings (AF-SB01, AF-SB02, AF-SB03, AF-SB04, AF-MW-01, and AF-MW-02) were completed and two monitoring wells (AF-MW-01 and AF-MW-02) were installed at the Site. Thirteen soil samples were collected from the borings and tested for metals, BTEX constituents, PAHs, SVOCs, TPH, and PCBs. Groundwater samples were collected for analyses of conventional parameters, dissolved metals, VOCs, alcohols, PAHs, SVOCs, PCBs, and petroleum hydrocarbons (gasoline-, diesel-, and oil-range). The analytical results for the samples collected at the Site by Aspect Consulting are discussed in Section 6.3.2 (Site Interior Groundwater Quality). A more complete description of the activities associated with the overall investigation is presented in the complete Aspect Consulting environmental assessment report.

3.3 R.G. HALEY SITE REMEDIAL INVESTIGATION/FEASIBILITY STUDY

In 2004, GeoEngineers installed a monitoring well cluster pair (CL-MW-1S and CL-MW-1D), and in 2012 installed three additional monitoring wells (CL-MW-101, CL-MW-102, and CL-MW-103) on the Site as part of the R.G. Haley site RI/FS. The purpose of the wells was to evaluate groundwater quality related to releases from the R.G. Haley site. The R.G. Haley Site monitoring wells and boring locations that are on the Site, or in close proximity, are presented on Figure 2-1. Groundwater samples from the well cluster pair were collected on a quarterly basis from June 2004 to September 2005 and analyzed for diesel- and oil-range petroleum hydrocarbons and for PAHs.

In 2012, GeoEngineers conducted an additional investigation for the R.G. Haley cleanup site. Some of these samples were from wells that are located either on the Site or on the R.G. Haley site near the overlap area. The locations of soil borings and groundwater monitoring wells used during the 2012 R.G. Haley site investigations that provide characterization data for the overlap area are shown on Figure 2-1. The GeoEngineers investigation included analyses of groundwater from groundwater monitoring wells MW-1, CL-MW-101, CL-MW-102, CL-MW-103, CL-MW-1H, MW-6, MW-9, HS-MW-19, HS-MW-7, TL-MW-12, and TL-MW-13.

Groundwater samples from each of these wells were analyzed for diesel- and oil-range petroleum hydrocarbons, SVOCs, and PAHs. Groundwater samples collected from CL-MW-101 were analyzed for dioxins and furans; groundwater samples from HS-MW-7 were analyzed for copper; and groundwater samples collected from HS-MW-7 and TL-MW-13 were analyzed for ethylbenzene, toluene, and benzene.

The analytical results for the samples collected on the Cornwall Avenue Site by GeoEngineers are discussed in Section 6.3.2 (Site Interior Groundwater Quality). However, a more complete description of the activities associated with the R.G. Haley site investigations is presented in the R.G. Haley preliminary draft RI/FS (GeoEngineers 2007). Relevant data collected during the R.G. Haley site investigations are included in this document for completeness, and to evaluate the potential impact of R.G. Haley site releases on Site remedy selection. However, these data will be presented and evaluated relative to R.G. Haley site releases and associated remedial alternatives in a public review draft of the R.G. Haley RI/FS scheduled for completion in the spring of 2014.

3.4 2008 ECOLOGY SEDIMENT INVESTIGATION

In September 2008, a sediment investigation was conducted by Hart Crowser, on behalf of Ecology, to further evaluate the extent of refuse and wood debris in the aquatic portion of the Site. The investigation utilized sediment profile imaging (SPI) and plan view photography to survey the presence of refuse and wood debris within the surface sediment, and collection of sediment core samples to survey the presence of refuse and wood debris in the subsurface sediment. A total of 138 locations were photographed using SPI and plan view photography. Subsurface sediment cores were collected at 62 locations distributed throughout the subtidal areas of the Site. The intertidal aquatic area and a portion of the shallow subtidal aquatic area were not fully characterized, due to penetration resistance, vessel draft requirements, and low visibility, which prevented effective application of the investigation methods.

The sediment investigation was conducted as part of a bay-wide investigation funded by Ecology. A complete description of the study is presented in a report prepared by Hart Crowser for Ecology (Hart Crowser 2009). The Site investigation locations are shown on Figure 3-1 and the results are discussed in Section 6.4 (Sediment Quality).

3.5 BOULEVARD PARK OVERWATER WALKWAY SEDIMENT INVESTIGATION

The City conducted an environmental and geotechnical investigation along the alignment of a proposed overwater walkway between Boulevard Park and the Site in 2008. As part of this investigation, the City collected and tested sediment surface and core samples from a number of locations, including a location in close proximity to the southern end of the Site (BLVD-SS-09), as shown on Figure 2-2. The samples were tested for metals, diesel- and oil-range petroleum hydrocarbons, and PCBs.

3.6 2012 SUPPLEMENTAL RI GROUNDWATER INVESTIGATION

Between July and September 2012, supplemental RI activities were conducted to better characterize groundwater at the Site in proximity to its point of discharge to Bellingham Bay. The investigation was conducted in accordance with the Ecology approved work plan (Landau Associates 2012a) and included the installation and development of six pairs of deep and shallow groundwater monitoring wells (12 wells in total), and conducting two monitoring events to collect and analyze groundwater samples from the newly installed wells.

The shoreline monitoring wells were sampled on July 23 and 24 and again on September 24, 2012 All groundwater samples were analyzed for dissolved metals, VOCs, SVOCs, herbicides, pesticides, tannins and lignins, TPH-HCID with follow up analyses for detected hydrocarbon ranges, conventional parameters, and typical field parameters. The results of this investigation are discussed in Section 6.3.3 (Downgradient Perimeter Groundwater Quality).

3.7 INTERIM ACTION

In 2011 and 2012, an interim action was conducted at the Site under a first amendment to Agreed Order No. 1778. The purpose of the interim action was to take advantage of the availability of low cost capping material to reduce infiltration of rainwater through the municipal waste, therefore reducing the discharge of contaminants to Bellingham Bay. The interim action involved placing stabilized fine-grained sediment from a nearby Port dredging project on the landfill surface. The sediment was placed into two stockpiles and covered with a scrim-reinforced liner to prevent stormwater infiltration. Stormwater runoff from the stockpiles was directed to a series of new drainage ditches connected to an existing stormwater detention basin which discharges to the bay. The effect of this action was to significantly reduce the amount of rainwater infiltrating into the solid waste, and thus reduce the flow of contaminated groundwater into Bellingham Bay. The action also reduced the area where people or terrestrial species could come into direct contact with potentially contaminated surface soil or refuse.

Another benefit of the interim action was to acquire material that could potentially be used as part of the final cleanup for low-permeability capping or as fill for contouring final grades. Using this material as part of a capping system, if that is selected as a remedial alternative for this Site, could also result in lower final costs for cleanup.

In summary, the availability of the dredged material presented an opportunity to address some of the environmental concerns at the Site while potentially reducing the overall cost of cleanup. Although this opportunity presented itself before completion of the remedial investigation and feasibility study for the entire Site, containment was anticipated to be an element of the final cleanup action for the Site.

The Port's Gate 3 Floats F & G Replacement and Outer Harbor Maintenance Dredging project (Gate 3 project) included harbor maintenance dredging to restore navigable water depths at the marina entrances, within the berthing areas, and along the navigation channels. The project was conducted under a U.S. Army Corps of Engineers (USACE) permit and removed about 47,500 cubic yards (yd^3) of dredged material. Because of its fine-grained nature and high moisture content, the sediment was stabilized to attain a soil-like consistency prior to transport to the Site.

The Gate 3 sediment was tested for total metals, tributyl tin (TBT), VOCs, SVOCs, pesticides, PCBs, and dioxins/furans. All hazardous substances in the Gate 3 sediment were below applicable regulatory criteria, except for dioxins/furans, which exceeded the concentration allowed by the USACE for open water disposal. Use of the sediment at the Site to reduce infiltration and to potentially reduce future cleanup costs was identified by the Port as a viable alternative to open water disposal and they proposed this to Ecology as an interim action. Following public review of the proposed interim action in June/July 2011 as part of the first amendment to the Agreed Order, construction began in late 2011. The interim action consisted of the following elements:

- Sediment was stabilized prior to placement at the Site using about a 5 percent (by weight) addition of Portland cement, which eliminated free water in the sediment and achieved a workable, soil-like consistency.
- A perimeter berm, stormwater conveyance ditch, and roadway were constructed around the interim action area from existing cover soil and imported clean material.
- A landfill gas collection system was installed beneath the interim action area prior to sediment placement.
- Sediment was graded for stormwater drainage to the existing stormwater basins to provide interim stormwater management.
- A temporary cover consisting of 20-mil scrim-reinforced polyethylene sheeting was placed over the graded material, and beneath the perimeter roadway and stormwater conveyance ditch, to prevent erosion and allow stormwater to be managed as noncontact stormwater.
- Five samples of the stabilized sediment were collected and analyzed from the two interim placement areas to document the concentrations of dioxins/furans in the stockpiles.

Figure 3-2 shows the primary features of the interim action. The design of the interim action is presented in the Interim Action Plan (Landau Associates 2011a), and construction of the interim action is documented in the Interim Action Completion Report (Landau Associates 2012b). The analytical results from the testing of the stabilized sediment are presented in Section 6.2.4 (Interim Action Low Permeability Material). The potential use of the stabilized sediment in applicable cleanup action alternatives is discussed in the FS portion of this report.

4.0 ENVIRONMENTAL SETTING

This section describes the environmental setting of the Site. Information discussed in this section includes physical Site features, Site geology and hydrology, area natural resources, and land/navigational uses.

4.1 PHYSICAL CONDITIONS

Physical conditions of a site are relevant because they have the potential to affect the fate and transport of contaminants. Physical conditions discussed below include the following:

- Site Topography and Bathymetry (Section 4.1.1)
- Drainage and Stormwater (Section 4.1.2)
- Shoreline Features and Erosion (Section 4.1.3)
- Sediment Deposition (Section 4.1.4)
- Surface Water and Circulation Patterns (Section 4.1.5).

4.1.1 SITE TOPOGRAPHY AND BATHYMETRY

The topography and bathymetry of the Site were characterized initially based on 1996 data, but upland topographic conditions were significantly modified in 2004 in conjunction with demolition of the GP warehouse and again during the interim action conducted at the Site in 2012. A topographic survey was conducted as part of the interim action to document placement locations and to calculate the volume of material placed at the Site. Additionally, a bathymetric survey was conducted in 2008 by Anchor Environmental as part of the Whatcom Waterway cleanup action that extended through the in-water portion of the Site. Both current and historical topography and bathymetry are discussed below.

Site topography and bathymetry prior to 2003 are shown on Figure 4-1. The topographic contours are based on a 1996 photogrammetric survey provided by Anchor Environmental. The bathymetric contours are based on soundings collected in 1996 by GP as part of the Whatcom Waterway RI/FS and soundings collected by the USACE in the Whatcom Waterway in 1996. As shown on Figure 4-1, the upland portion of the Site prior to 2003 was relatively flat with a surface elevation of about 14 ft MLLW. The slopes of the intertidal and shallow subtidal zones (above about -10 ft MLLW) range between about 5 Horizontal to 1 Vertical (5H:1V) to 10H:1V, and are generally within 100 to 200 ft of Site uplands. The deeper subtidal zone offshore from the Site has a relatively flat slope of about 20H:1V.

Current Site topography and bathymetry are shown on Figure 4-2. Site upland topography was significantly modified in 2004 in conjunction with the demolition of the GP warehouses and in 2012, during the interim action discussed in Section 3.7 (Interim Action). Demolition of the GP warehouses included grading the Site in the vicinity of the former warehouse locations, and installation of a stormwater detention basin and an outfall at the south end of the Site. These modifications resulted in a significant portion of Site stormwater runoff being directed toward the stormwater detention basin, where it either infiltrates or is discharged to Bellingham Bay. As part of the 2012 interim action, additional surface water drainage features were constructed, as described in Section 4.1.2.5 (Post-Interim Action Drainage and Stormwater Management).

Bathymetric conditions changed appreciably between the 1996 and the 2008 bathymetric surveys. The 2008 bathymetric data indicate that the intertidal and shallow subtidal surface became flatter and more uniform over the 12-year period between surveys. Intertidal and shallow subtidal slopes range from between about 6H:1V to 15H:1V and extend away from the Site uplands for approximately 250 ft. The changes are particularly apparent at the southern end of the Site, where 2008 bathymetric data indicate a significant increase in the mud line elevation from the elevations obtained during the 1996 survey.

4.1.2 DRAINAGE AND STORMWATER

Surface water and stormwater management at the Site was evaluated based on visual reconnaissance of general site drainage conditions and the roof drainage system for the main GP warehouse prior to demolition during the expanded Site investigation and the focused RI, and by a video survey of the stormwater management system during the supplemental RI. However, due to subsequent Site modifications including building demolition and completion of the interim action, characterization of the surface water and stormwater drainage based on these previous surveys does not represent current Site drainage conditions. Therefore, drainage and stormwater conditions are discussed below in terms of pre-demolition, post-demolition, and post-interim action conditions.

4.1.2.1 General Site Drainage

The upland portion of the Site is situated at the base of a bluff to the east and is adjacent to Bellingham Bay to the west. The bluff rises steeply about 60 ft and is a vegetated band of forested land that is bounded by the BNSF railroad right-of-way on the west and Boulevard Street on the east. Stormwater from Boulevard Street and residential areas to the east is intercepted by the City stormwater system and is conveyed for discharge away from the Site. Some portion of the stormwater discharge occurs through an outfall to Bellingham Bay located on the adjoining R.G. Haley property. Stormwater to the west of Boulevard Street either infiltrates or is conveyed via overland flow to the base of the bluff on the east side of the BNSF railroad tracks, where it either infiltrates or is conveyed to the west via a culvert underlying the railroad tracks to the north of the Site, as discussed below.

As previously mentioned, the upland portion of the Site is relatively flat. Prior to demolition of the GP warehouses, surface water was primarily directed toward catch basins in the paved portion of the GP property. However, the remainder of the Site was not graded to promote surface water drainage. As shown on Figure 4-3, flowing water was observed northeast of the Site between the railroad tracks and the hillside that trends northeast-southwest of the Site and near the gravel road that parallels the western side of the former main GP warehouse. The area between the railroad tracks and hillside is not graded to provide adequate drainage. Ponding of water in this area may contribute to recharge of the groundwater in the upper portion of the aquifer upgradient of the Site (Stasney 1997). The contribution of this potential recharge in relation to other sources is discussed further in Section 4.3.1.4 (Groundwater Recharge and Water Balance).

More recent reconnaissance by both Ecology and Landau Associates personnel confirmed the presence of ponded and flowing water on the east side of the BNSF railroad tracks near the northeast corner of the Site, and identified the presence of a culvert that conveys a portion of the surface water to an excavated depression on the west side of the tracks immediately east of the R.G. Haley site fence in the northeast corner of the Site. Surface water has been observed running in the ditch and discharging to the culvert as late as early October, indicating that recharge in this area is not seasonal. The presence of ponded and flowing water during the dry season is indicative of springs or other sources of ongoing recharge to surface water ponding that may contribute to Site groundwater recharge. The relative contribution of this recharge source to the Site is discussed further in Section 4.3.1.4 (Groundwater Recharge and Water Balance).

4.1.2.2 Pre-Demolition Warehouse Roof Drainage

The roof drainage collection system for the main GP warehouse was in a state of disrepair during the focused RI and the supplemental RI. Stormwater runoff from the roof was conveyed to the northwestern side of the warehouse via a series of downspouts that discharged stormwater directly to the ground surface. The ground surface in this area drained toward the building. The downspouts on the southeastern side of the building were connected to an 8-inch-diameter header line. The header line extended underneath the building and discharged stormwater to the ground surface beneath the building near the eastern corner. Relatively large areas of ponded water were observed beneath the warehouse floor at both the northeastern and southwestern sides of the warehouse, consistent with observations of the stormwater discharge from the roof drain system. These conditions contributed to shallow groundwater recharge upgradient of the landfill refuse. It could not be determined from the site reconnaissance performed during the supplemental RI and previous investigations if the roof drainage system for the warehouse was connected to the stormwater management system.

4.1.2.3 Pre-Demolition Stormwater Management System

The stormwater management system located north of the main GP warehouse was evaluated during the supplemental RI based on visual observations and a video survey of the underground piping. The video survey identified the materials of construction and the condition of portions of the stormwater conveyance system that were accessible to the video camera. Four catch basins were observed near the central portion of the Site (CB-1 through CB-4) and two near the warehouse (CB-5 and CB-6). The four catch basins appeared to be connected by stormwater pipelines that appeared to be routed toward Bellingham Bay. This was determined by the direction of the pipeline from catch basin CB-4 which was pointing toward the north.

The majority of the piping between the catch basins near the northern side of the main GP warehouse was accessible. The sediment accumulation in the two catch basins closest to the main GP warehouse (CB-5 and CB-6) prevented a video survey from being performed. The video camera could only travel about 150 ft from the outlet of catch basin CB-4 due to sediment accumulation and the resulting blockage in the pipeline from breaks and joint separations. The stormwater management system is shown on Figure 4-3.

The underground piping inspected during the video survey was constructed of concrete bell and spigot pipe. The stormwater management system appeared to be in a state of disrepair with several areas blocked due to offsets, leaking connections, or cracks in the lines. The numerous gaps observed in the pipelines would be sources of groundwater infiltration from the surrounding landfill material or points of stormwater discharge to the landfill subsurface, depending on the elevation of the piping relative to the groundwater table.

The stormwater outfall to Bellingham Bay was not visible on the shoreline and could not be accessed from the nearest catch basin during the video survey because of sediment accumulation in the pipeline. However, the approximate location of the outfall was determined during the Supplemental RI after a significant upwelling of water [estimated to be 30 gallons per minute (gpm), or greater] was observed near former seep sampling location S-1 during a rainstorm. Although the location was obscured by rock and debris, it appeared to be the outfall location for the GP stormwater system. This conclusion was confirmed based on the following observations:

- Flow was not observed from this location the previous day, which preceded the precipitation event.
- The magnitude of the flow was significantly greater and located higher than that observed at any other seepage location along the beach face.
- The flow rate appeared to be similar to the flow rate observed in the closest accessible manhole.

- The location is consistent with the projected end point of the stormwater conveyance system, based on the results of the video survey.

The approximate location of the stormwater outfall was determined by projecting the video surveyed portion of the pipeline extending from catch basin CB-4 toward the shoreline. The projected location of the stormwater outfall matched the location on the shore where the significant upwelling of water was observed during the rainstorm. This location is likely where the outfall discharges to Bellingham Bay. The projected stormwater discharge line and the apparent location of the stormwater outfall are shown on Figure 4-3. Even though the stormwater pipeline running from the vicinity of the warehouse to the outfall appeared to be in poor condition, the discharge of water from the shoreline bank during a heavy precipitation event was significant enough to indicate that the pipeline has sufficient integrity to convey a portion of the collected stormwater to the outfall.

Based on visual inspections conducted during the supplemental RI, roof drains from the smaller warehouse north of the main GP warehouse may have been connected to the stormwater management system. Two pipelines from catch basins CB-3 and CB-4 extended toward the smaller warehouse but the endpoints of these pipelines could not be accessed during the video survey due to obstructions in the pipelines.

One pipeline extended north from catch basin CB-4. The endpoint of the line could not be observed due to blockage in the pipeline. The material forming the blockage appeared to be a black fine-grained material mixed with fecal matter with the presence of insects. These insects were not seen on footage from other segments of the survey, and may have been attracted by the apparent fecal-containing material. A feature that appeared to be the concrete top of a septic tank was observed during the excavation of RITP-6 and appeared to be in direct alignment with the pipeline that extends north from CB-4. If this feature is a septic tank, the sludge observed in the pipeline may have been leakage from the tank that has entered the pipeline, or the pipeline could be directly connected to the septic tank. Alternatively, the apparent fecal material may originate from a broken sanitary sewer line. Additional discussion of this issue is provided in Section 6.3.1 (Overlap Area Groundwater Quality).

4.1.2.4 Post-Demolition Drainage and Stormwater Management in the Former Main Georgia Pacific West Warehouse Area

As previously indicated, the main GP warehouse was demolished in 2004. Following demolition, the footprint of the warehouse was graded to drain to a stormwater detention basin located along the southeastern side of the former warehouse, parallel to the fence line adjacent to the BNSF railway mainline. The detention basin is designed for the collection and temporary storage of stormwater runoff and allows for emergency overflow to Bellingham Bay during heavy storm events.

It is unlikely that the demolition of the main GP warehouse and construction of the stormwater detention basin significantly affected stormwater runoff or groundwater recharge at the Site. The roof drain system for the former warehouse was not functioning properly prior to demolition, and was discharging stormwater runoff beneath and to the northwest of the building [see Section 4.1.2.2 (Pre-Demolition Warehouse Roof Drainage)]. Thus, in the vicinity of the warehouse, the majority of stormwater runoff infiltrated into the subsurface during both pre- and post-demolition conditions at the Site. The installation of the stormwater detention basin and modifications to topography at the Site directs stormwater runoff toward the southern portion of the Site. As such, groundwater recharge is more appreciable in this area compared to the pre-demolition conditions at the Site.

4.1.2.5 Post-Interim Action Drainage and Stormwater Management

The implementation of the interim action in 2011 and 2012 placed a low permeability cover over about 4.5 acres of the Site where the IPAs and the associated roadways and stormwater ditches were covered or lined with 20-mil scrim-reinforced polyethylene sheeting. The placement of this low permeability cover resulted in a reduction of infiltration of about 35 percent for the upland portion of the Site, and about 65 percent through the portion of the Site where refuse is present.

Figure 4-4 presents the current Site topography and drainage features at the Site, including the excavated depression observed in the northeast corner of the Site that appears to collect the ponded or flowing water adjacent to the BNSF railroad tracks via a corrugated pipe from the east. The figure shows the location of the stormwater detention system constructed following demolition of the main GP warehouse, and conveyances constructed during implementation of the interim action. The stormwater management system in the paved area to the north of the former GP warehouse is still present, although it is in disrepair and does not appear to be functional.

4.1.3 SHORELINE FEATURES AND EROSION

The steep portion of shoreline near the top of the bank is partially protected by informal slope armoring consisting of a variety of rock boulders and broken concrete. Below the steep portions (i.e., the lower intertidal areas), riprap coverage is less dense and absent in some areas. This portion of the shoreline consists predominantly of soil (gravel, sand, and silt) with occasional concrete cobbles and landfill debris. The armoring along the steep portions of the shoreline was placed following closure of the landfill in 1965; however, despite the armoring, significant shoreline erosion has occurred. The erosion resulted in exposure of landfill refuse at the surface and redistribution of landfill refuse onto the beach area. The amount of shoreline erosion since landfill closure has been estimated during previous investigations using aerial photographs from 1969, 1994, and 2007, and a topographic survey of the Site in 2012. During the expanded Site investigation, the distance between the top of the shoreline slope and fixed points at the Site (e.g., permanent building) were measured. The differences between these measurements from the 1969 and 1994 aerial photographs indicated significant shoreline erosion occurred over this time period. The shoreline erosion is estimated to have ranged from approximately 60 ft at the southwestern corner of the landfill to 10 to 30 ft at the northern edge of the landfill between 1969 and 1994. The amount of shoreline accretion or filling at the southeastern tip of the landfill appears to be limited compared to the significant shoreline erosion noted throughout the remainder of the Site. The approximate positions of the landfill shoreline boundaries (assumed to be the top of slope) in 1969 and 1994, which were presented in the expanded Site investigation, are shown on Figure 4-5.

Stasney reviewed the 1969 and 1994 aerial photographs and estimated the shoreline erosion along the southwestern corner of the landfill to be about 125 ft (Stasney 1997). The significant difference between the shoreline erosion estimated by Stasney and that determined in the expanded Site investigation prompted Landau Associates to reevaluate the extent of shoreline erosion during the focused RI. It appears that the primary difference between the two interpretations is that Stasney used the approximate location of the mean high tide as the basis for defining the shoreline, while the top of the shoreline bank was used in the expanded Site investigation. The top of the shoreline bank is considered more reliable for evaluating shoreline erosion because it can be more definitively identified through stereo photographs and is a more consistent feature than mean high tide. As a result, the top of the bank measurements were used in this RI for evaluating shoreline erosion.

A comparison of the location of the top of the shoreline bank in the 1994 aerial photograph to the location/position observed in a 2007 aerial photograph indicates that only limited shoreline erosion occurred between 1994 and 2007. As indicated on Figure 4-5, the shoreline did not retreat more than about 10 ft at any given location during this period and did not change along much of the shoreline, though it did advance slightly waterward at the extreme southeastern corner of the Site.

In 2012, a topographic survey of the Site was conducted following implementation of the interim action. The top of the shoreline slope based on this survey is presented on Figure 4-5. The survey indicates the shoreline has retreated significantly in most locations since the 2007 evaluation. However, a direct comparison of the surveyed location to other approximate shoreline locations presented on Figure 4-5 could exaggerate the actual retreat since the other approximate shoreline locations were based on interpretations from aerial photographs and the new data is from a topographical survey. What is apparent from the comparison of the approximate shoreline locations shown on Figure 4-5 is that significant erosion has occurred along the Site shoreline over the years since the landfill was closed that will likely continue if not addressed by an engineered shoreline erosion protection system.

4.1.4 SEDIMENT DEPOSITION

The results of the 2008 Ecology sediment investigation indicate that significant sediment accumulation has occurred throughout much of the subtidal portion of the Site (deeper than approximately – 4 ft MLLW). Sediment accumulation was observed at 38 of the 43 sediment core locations. Sediment accumulation ranged from 0.5 to 3.5 ft, with an average thickness of 2.0 ft. Based on these observations and the period of time since the landfill was closed (approximately 43 years), the average sedimentation rate for the subtidal portion of the Site is about 1.4 centimeters per year (cm/yr). This rate is similar to the sedimentation rates reported for inner Bellingham Bay, which range from 1.52 cm/yr to 1.77 cm/yr (RETEC 2006).

Sediment deposition is further evidenced by the natural recovery exhibited in sediment core samples tested for mercury and PCBs from sediment sampling location BLVD-09. Sediment core samples show progressively lower concentrations for mercury and PCBs in samples collected from 3 to 4 ft below mudline up to the sediment surface. Mercury concentrations decreased from 3.8 milligrams per kilogram (mg/kg) to 0.4 mg/kg and PCB concentrations decreased from 21.47 mg/kg (organic carbon-normalized; OC) to 4.47 mg/kg.

4.1.5 SURFACE WATER AND CIRCULATION PATTERNS

This section describes watersheds that contribute to Bellingham Bay, regional bottom and surface currents throughout the bay, as well as tidal salinity and temperature information for the bay. Information provided in this section was compiled from information provided in the Whatcom Waterway Site RI/FS report (RETEC 2006). The Whatcom Waterway RI/FS report provides a more complete description of surface water and circulation patterns for Bellingham Bay.

4.1.5.1 Watershed Characteristics

The Bellingham Bay near-shore area is primarily influenced by the drainage from three watersheds: the Nooksack River, Whatcom Creek, and Squalicum Creek. Five other smaller watersheds also contribute water to Bellingham Bay, including the Padden Creek watershed. Whatcom Creek is the closest significant drainage course to the Site and discharges to the bay about 1 mile northeast of the Site as shown on Figure 4-6. Information on the Nooksack River, Whatcom Creek, Squalicum Creek, and Padden Creek watersheds is provided below:

- The Nooksack River Watershed drains approximately 1,500 square kilometers [km^2; 580 square miles (mi^2)] and is the primary source of sediments to Bellingham Bay, with an annual discharge of 650,000 cubic meters [m^3; 7,000,000 cubic feet (ft^3)]. All of the Nooksack flow does not, however, reach Bellingham Bay. Part of it enters Lummi Bay by way of the Lummi River. The Nooksack River is influenced by anthropogenic factors that include agriculture and logging. The discharge to Bellingham Bay is approximately 4.4 miles northwest of the Site.

- The Whatcom Creek Watershed drains an area of approximately 26 km² (10 mi^2). Whatcom Creek flows from Lake Whatcom through the City to Bellingham Bay. The City occupies much of the watershed. Presently, Whatcom Creek is influenced by areas of channelization, vegetation removal, and urban stormwater runoff.
- The Squalicum Creek Watershed drains an area of 65 km² (25 mi^2). Squalicum Creek originates at Squalicum Lake and flows through the City. The creek is influenced by areas of channelization, vegetation removal, and urban stormwater runoff. The discharge to Bellingham Bay is approximately 1.6 miles north-northwest of the Site.
- The Padden Creek Watershed drains an area of 16 km² (6.2 mi^2). Padden Creek originates at Lake Padden and flows entirely within City limits to Bellingham Bay. The primary land uses in the watershed include residential, forestry, agricultural, commercial, and industrial (NSEA website 2008). The discharge to Bellingham Bay is approximately 1.2 miles southwest of the Site.

4.1.5.2 Regional Bottom Currents

Most oceanic water enters Bellingham Bay at depth through the northern end of Rosario Strait between Lummi and Vendovi Islands (Figure 4-6). Some water enters through Bellingham Channel. Exchange of water to the west through Hale Passage is limited by a shallow sill. The residence time for water in Bellingham Bay is typically 4 to 5 days, but varies between 1 and 11 days. The available data indicate that there is a net southward flow throughout Bellingham Bay at depth, largely resulting from the lateral and vertical spreading of the Nooksack River discharge. Overall, bottom currents are relatively consistent throughout the year and typically range from 0.2 to 0.3 meters per second (m/sec). Deep current velocities typically range from 0.04 to 0.18 m/sec in the inner bay and can be as high as 0.40 m/sec. Based on generalized relationships between bottom current velocities and sediment re-suspension thresholds, bottom velocities above approximately 0.3 to 0.4 m/sec may be capable of re-suspending fine-grained sediments (i.e., silt and clay particles). Accordingly, inner Bellingham Bay appears to be primarily a net depositional environment, though periodic re-suspension of sediments in the inner bay is possible, particularly in shallow water areas where bottom velocities can be influenced by wave action. This interpretation is consistent with the predominance of fine-grained sediment textures throughout the inner bay, except in higher-energy shallow-water areas.

4.1.5.3 Regional Surface Currents

Surface currents throughout Bellingham Bay vary primarily in response to wind stress. Winds over the bay are from the south or southwest during much of the year, typical of foul-weather low-pressure systems in winter months, resulting in the forcing of surface water toward the northern part of the bay with return flow along the shorelines of the Lummi Peninsula, Portage Island, and Lummi

Island (Figure 4-6). Fair-weather winds from the west or northwest cause surface flow to the east and south along the eastern shoreline. In response to seasonal wind forcing, both clockwise and counter-clockwise circulation patterns are set up in Bellingham Bay. Salinity distribution maps delineate freshwater discharges from the Nooksack River. The brackish river plume sometimes exits the bay along the western shoreline near Lummi Peninsula and Lummi Island (counter-clockwise circulation), but at other times exits primarily along the eastern shoreline near the City of Bellingham and Post Point where it is then directed southwestward across the bay toward the southern tip of Lummi Island (clockwise circulation). In both configurations, surface water enters Rosario Strait mainly near the southern tip of Lummi Island and Vendovi Island. The compensating inflow of seawater to Bellingham Bay occurs partly via surface waters along the opposite shoreline from the brackish river plume and partly via bottom waters. Typical surface currents range between 0.02 to 0.06 m/sec in the inner bay, reaching maximum velocities of 0.36 m/sec.

4.1.5.4 Tides, Flooding, Storm Surge, and Tsunamis

The mean tidal range within Bellingham Bay is 5.44 ft. According to the National Oceanic and Atmospheric Administration (NOAA), the typical diurnal tidal range is about 8.51 ft (NOAA website 2008). Flooding, storm surge, and tsunamis (in decreasing order of probability of occurrence) may increase the water levels in Bellingham Bay on rare occasions. Additionally, the Port is planning for a 2.4 ft rise in sea level in response to the changing climate over the next 100 years. This estimate is based on a variety of projections made by the University of Washington Climate Impacts Group (University of Washington Climate Impacts Group and the Washington Department of Ecology 2008) and the Inter Governmental Panel on Climate Change (IPCC 2007). As discussed elsewhere in this report, the existing shoreline at the Site is eroding and any cleanup strategy implemented at the Site will include a shoreline stabilization system and finished Site grades designed to accommodate the current estimate of sea level rise.

In the Whatcom Waterway Site RI report, empirical estimates of storm surge were obtained by subtracting the highest observed tide on January, 5 1975 from the predicted tide for that day. The predicted high tide, as obtained from NOAA for January 5, 1975, was 9.6 ft. The actual measured high tide was 10.4 ft above MLLW. The difference is a storm surge of 0.8 ft. The effects of storm surge on final water elevations vary with wind speed, wind direction, and tidal cycle (e.g., storm surges only produce extraordinary water elevations if they occur coincident with a high tide that is already near the maximum for the water body).

Tsunamis are earthquake-generated waves that occur in open water bodies. Results of a modeling study conducted by NOAA and DNR indicate that a magnitude 9.1 earthquake caused by the Cascadia

Subduction Zone located in the Pacific Ocean basin could result in a tsunami wave that could cause a depth of inundation of 0 to 1.6 ft over much of the Site. It should be noted, however, that the study acknowledges limitations and uncertainties associated with the modeling.

4.1.5.5 Salinity, Temperature, and Total Suspended Solids

Salinity varies with depth and varies over time in the top 30 ft of the Bellingham Bay water column. The observed variability is primarily the result of fresh water input, wind-induced circulation, and wind-induced mixing. Because most freshwater comes from the Nooksack River, brackish water (salinity less than about 26 parts per thousand) is most extensively distributed in the northern part of Bellingham Bay, but a lower salinity surface layer has been observed to extend throughout the bay and south of Post Point, which is located to the south of the Site. This surface layer is typically less than 6 ft thick, but high winds may occasionally deepen the surface layer to 12 ft. The deepest waters in Bellingham Bay are similar in character to those of Rosario Strait. Bottom water salinities typically range from 29 to 31 parts per thousand, and are relatively stable throughout the year. Surface salinities in inner Bellingham Bay have been recorded to range from approximately 10 to 25 parts per thousand. Higher surface salinities have been observed during the incoming tide. Deep water salinities in the inner Bellingham Bay area have been recorded in the range of 26 to 30 parts per thousand.

Water temperatures in Bellingham Bay vary with depth and vary over time, primarily as the result of seasonal air temperature changes. Water temperatures range from 8 to 13 degrees Celsius (ºC) and are warmest in the summer and early fall and coldest during winter and spring.

TSS within the inner Bellingham Bay area has been measured at concentrations ranging from 3 to 25 milligrams per liter (mg/L). Deep water TSS concentrations have been measured from between 1 to 32 mg/L. Measured TSS concentrations average approximately 10 mg/L in both surface and deep waters.

4.2 GEOLOGY

Geologic conditions at the Site were characterized using information presented in:

- Previous geotechnical reports (Dames & Moore 1960; Purnell & Associates 1985)
- Information summarized by Stasney (Stasney 1997)
- Information contained in the Draft Final RI/FS report for the R.G. Haley site (GeoEngineers 2007)
- Data from construction of the focused RI and supplemental RI monitoring wells
- Data from the supplemental RI borings and test pits
- Data from the 2008 RI sediment investigation.

The Site geology is discussed from the deepest (oldest) unit to the shallowest unit and is shown on east-west and north-south trending cross sections. The alignments of the cross sections are shown in plan view on Figure 4-7. Figures 4-8 and 4-9 present a north-south trending cross section (A-A') and an east-west trending cross section (B-B') of the Site, respectively. Bedrock underlies the entire Site at varying depths and consists of sandstone and carbonaceous shale of the Chuckanut Formation. The Chuckanut Formation is exposed on the hillside located immediately southeast of the Site and is present at depths beneath the Site that increase toward Bellingham Bay, as shown on Figure 4-8.

Overlying the Chuckanut Formation beneath the Site and Bellingham Bay is glacial marine drift. These sediments were deposited as rising sea levels floated and melted Pleistocene glacial ice (Stasney 1997). Boring log data from Purnell & Associates (1985) and Dames & Moore (1960; Appendix B) indicate that this unit generally consists of gray, silty clay with occasional gravel and marine shells. The top of the glacial marine drift ranges from 20 ft below ground surface (BGS) near the eastern edge of the landfill refuse to about 40 ft BGS near the existing shoreline. The thickness of the glacial marine drift varies from greater than 30 ft thick near the existing shoreline until it tapers out near the eastern extent of the refuse.

Fine-grained sediments deposited in Bellingham Bay by the Nooksack River (Stasney 1997) typically overlie the glacial marine drift. Boring logs indicate that this unit generally consists of green-gray silt, or green-gray silty clay and sandy silt. The silt deposited by the Nooksack River ranges in thickness from about 8 ft near the existing shoreline to near depletion at the eastern edge of the refuse. The top of the Nooksack deposits are encountered at a depth of about 20 ft BGS near the eastern edge of the refuse and at a depth of about 30 ft BGS near the existing shoreline. The Nooksack deposits generally increase in thickness toward Bellingham Bay and become absent toward the northern and eastern portions of the Site. The Nooksack deposits represent the uppermost native deposits underlying the Site and Bellingham Bay.

Sawdust and wood debris overlie the Nooksack deposits and the older units within the southwestern portion of the Site, and generally bounds the eastern edge of the refuse. Wood waste was encountered as shallow as 2 to 3 ft BGS east of the refuse and about 15 ft BGS within the southwestern portion of the Site.

Landfill refuse overlies the wood waste within the southwestern portion of the Site and the Nooksack deposits or Chuckanut Formation within the northeastern portion of the Site. The refuse thickness generally increases toward Bellingham Bay, ranging in thickness from 0 to 40 ft at the eastern Site boundary to the existing shoreline. The top of the refuse was typically encountered between 2 and 5 ft BGS.

Overlying the refuse is the landfill cover soil and traffic surfaces. The cover soil consists primarily of granular material (sand and gravel), wood debris, and occasional areas of cobble ballast.

4.2.1 Geologic / Seismic Hazards

The Bellingham Municipal Code (BMC) Chapter 16.55.410 through .460 identifies geologically hazardous areas as areas susceptible to one or more of the following types of hazards:

- Erosion hazards
- Landslide hazards
- Seismic hazards
- Mine hazards.

The Site is located within an area designated by BMC 16.55.420 and shown on the geologic hazard area maps as being a seismic hazard area expected to have a "very high" response to seismic shaking. The Site is not located in areas identified by the City as having potential landslide, erosion, volcanic, or coal mine hazards, as discussed in the *Critical Area Report* (Landau Associates 2011b).

Seismic hazards include ground shaking and ground motion amplification, ground rupture, liquefaction, lateral spreading, and seismically-induced slope instability. The Puget Sound region contains numerous fault zones, and the Sumas and Vedder Mountain fault system, located northeast of Bellingham near Sumas, is currently considered the closest reported fault zone. However, due to the distance between the Site and this fault zone, ground rupture is not expected to occur at or near the Site.

The entire Puget Sound region lies within a convergent tectonic plate margin known as the Cascadia Subduction Zone. Of particular significance is the Juan de Fuca plate, which is being driven eastward and thrusts beneath the North American plate. The movement of the plates directly affects the seismic activity of the region. The most recent subduction earthquake is reported to have occurred in 1700, and was identified by drowned forest along the Washington coast and by a tsunami that reached Japan. Data suggests that great subduction earthquakes along the northern Cascadia Subduction Zone have an average recurrence interval of approximately 520 years (Goldfinger et al. 2008). However, deep subcrustal earthquakes (such as the 1949 Olympia, 1965 Seattle, and 2001 Nisqually earthquakes) and shallow crustal earthquakes (such as the 1946 Vancouver Island and 1996 Duvall earthquakes) are considered to account for the majority of recent seismic activity in the Puget Sound region.

The U.S. Geological Survey (USGS) and other researchers continue to evaluate the presence and potential effects of fault systems in the Pacific Northwest that could affect seismic hazard assessments in the Bellingham area. Relatively recent research of the Boulder Creek fault near Kendall, Washington; the Sumas and Vedder Mountain faults near Sumas, Washington; and other fault features in northwestern Washington suggests that seismic hazards in the Bellingham area might possibly be greater than previously estimated based on currently available USGS seismic hazard maps and data. However, we currently understand that USGS seismic hazard maps and data have not yet been updated to reflect potential ground shaking from such nearby fault systems due to lack of sufficient information that would be required to make such updates.

The Bellingham area is located within a seismically active area, and moderate to high levels of ground shaking should be anticipated during a significant seismic event. The Site is located over deposits containing relatively soft to loose soils and fill materials that could potentially be susceptible to amplified earthquake ground motions at various frequencies. Consequently, the near-surface materials overlying bedrock at the Site will likely affect the level of earthquake ground shaking felt in the area.

When shaken by a significant earthquake, certain soils may lose strength and temporarily behave as if they were a viscous liquid, a phenomenon known as liquefaction. The seismically induced loss of strength can result in ground surface settlement, embankment instability, sand boils, lateral spreading, loss of bearing capacity for shallow foundations, reduction in vertical and lateral deep foundation capacities, and downdrag forces on deep foundations. Seismically induced liquefaction typically occurs in loose to medium dense, clean to moderately silty sand deposits located below groundwater level; soils exhibiting cohesion are less likely to be susceptible to liquefaction.

The DNR Division of Geology and Earth Resources has published liquefaction susceptibility maps for Washington. The results of the DNR study (Palmer et al. 2004) entitled "Liquefaction Susceptibility and Site Class Maps of Washington State, By County" indicate that the Site is mapped as having a high liquefaction susceptibility (primarily due to the presence of man-made fill in an area expected to have a very high response to seismic shaking).

It is anticipated that limited, discontinuous zones of loose, saturated, sandy fill material, and some loose beach deposits that might possibly be present below fill materials placed along the former shoreline would likely be susceptible to liquefaction during a major seismic event. However, the majority of the native deposits and fill materials identified at the Site are expected to have a relatively low to moderate potential for liquefaction during a design seismic event due to their cohesive properties. The actual magnitude and extent of any such soil liquefaction that might occur at the Site will depend on many factors, including the duration and intensity of the ground shaking during the seismic event, and location-specific soil and groundwater conditions.

Lateral spreading is a phenomenon where lateral ground displacements occur as a result of soil liquefaction. Lateral spreading is typically observed on very gently sloping ground or on virtually level ground adjacent to slopes. Lateral spreading tends to break the upper soil layers into blocks that progressively move down-slope during an earthquake. Large fissures at the head of the lateral spread are common, as are compressed or buckled soil at the toe of the soil mass. Lateral spreading displacements can range from a few inches to tens of feet, depending on the magnitude and duration of the seismic event (Kramer 1996). From accounts of recent large earthquakes, lateral spreading at waterfront facilities typically appears to be more prevalent in upland areas within about 300 ft of the shoreline; however, case histories have documented lateral spreading occurring up to about 1,200 ft from the free-face of the soil mass.

The majority of the native deposits and fill materials identified at the Site are expected to have a relatively low to moderate potential for liquefaction and associated lateral spreading during a design seismic event. A detailed evaluation will be conducted to evaluate geologic hazards including liquefaction, lateral spreading, and slope stability during the design phase for the remedial alternative selected for this Site.

4.3 HYDROGEOLOGY

Hydrogeologic conditions at the Site were evaluated using geologic data from previous investigations, data collected during the RI, and available literature regarding hydrogeologic characteristics of geologic units present at the Site. Soil boring logs and test pit information, along with groundwater analytical data obtained during the focused and supplemental RIs, indicate three principal hydrostratigraphic units can be identified beneath the Site. The three units are described below from shallow to deep.

- The uppermost unit consists of the landfill refuse, sawdust, and wood debris, and other fill materials placed at and near the Site. Groundwater is first encountered in this unit.
- The second unit consists of fine-grained silts and clays of both the Glacial Marine Drift and Nooksack deposits, which form the uppermost aquitard throughout most of the Site.
- The third unit is the sandstone of the Chuckanut Formation. This unit could act as an aquifer within portions of the formation that exhibit limited fracturing. The potential for salt water intrusion from Bellingham Bay likely prohibits the shallow portions of the Chuckanut Formation from being a practicable source of potable water. The hydrogeologic properties of the Chuckanut Formation are discussed further below.

Because of its potential to function as either an aquifer or an aquitard, a literature review was conducted on the hydrogeologic properties of the Chuckanut Formation to assess the potential that it is functioning as an aquifer and contributing recharge to the Site shallow groundwater flow system. Although the literature review did not identify any publications or other information that evaluated the hydrogeologic properties of the Chuckanut Formation in the immediate vicinity of the Site, a limited number of references were identified that either provided general information on the hydrogeologic properties of the Chuckanut Formation, or more detailed information for areas located at distance from the Site.

The references reviewed were generally consistent in their characterization of the hydrogeologic properties of the Chuckanut Formation. A U.S. Geologic Survey (USGS) evaluation of the hydrogeologic conditions in Whatcom County characterized the Chuckanut Formation as a semi-confining unit that is not highly productive, but capable of yielding useable quantities of water locally (USGS 1999). A Western Washington University geology masters thesis that evaluated the hydrogeology of northern Lummi Island collected and evaluated an extensive amount of data on domestic wells completed in the Chuckanut Formation (Sullivan 2005). The Chuckanut Formation was characterized as highly fractured and the primary source of groundwater for northern Lummi Island.

The Lummi Island study also estimated the mean horizontal hydraulic conductivity of the Chuckanut Formation to be 1.1 x 10^{-4} centimeters per second (cm/s), which is in the same range as sandy silt. A 2005 groundwater study conducted in the Lake Whatcom area (Ecology 2005) concluded that the small number of water supply wells that have been successfully developed in the bedrock (including the Chuckanut Formation) supported the conclusion in an earlier evaluation (Newcomb et al. 1949) that bedrock formations in the Lake Whatcom area have a limited capacity for groundwater movement and supply. The 2005 Ecology report went on to say that a significant percentage of the boring logs reviewed from wells completed in bedrock indicate abandonment of the borehole after drilling due to a lack of adequate yield.

All of these references are consistent in identifying that the Chuckanut Formation is capable of producing usable amounts of water for domestic purposes, but generally exhibits a low bulk permeability. Based on the observations of surface water flow and ponding along the base of the exposed Chuckanut Formation bluff discussed in Section 4.1.2.1 (General Site Drainage), it appears that the Chuckanut Formation exhibits localized areas of discharge near the base of the bluff. These observations are consistent with the literature and indicate that the Chuckanut Formation likely functions as a semi-confining unit with localized areas of discharge, rather than as an aquitard.

Figure 4-10 is an elevation contour map of the surface underlying the refuse/wood debris fill, which forms the uppermost hydrostratigraphic unit. The surface underlying the refuse/wood debris unit is considered an aquitard where the Nooksack or Glacial Marine Drift deposits are present in the western portion of the Site and a semi-confining unit where the Chuckanut Formation is the underlying geologic unit in the eastern portion of the Site. As discussed above, the Chuckanut Formation likely conveys some groundwater via fracture flow, but its bulk hydraulic conductivity is significantly lower than that of the refuse/wood debris fill, and as such, it functions as a semi-confining unit.

As Figure 4-10 illustrates, the surface underlying the refuse/wood debris unit dips steeply downward from the northeastern corner of the Site, flattens out near the north-central portion of the Site, and then dips steeply downward in the southwestern portion of the Site (and presumably in the northwestern portion of the Site, although data regarding the depth of refuse in this area is not available). The contact surface appears to influence the groundwater flow direction in the northeastern corner of the Site, as discussed in the following section. The uppermost hydrostratigraphic unit is of primary interest for evaluating groundwater conditions at the Site and will be addressed in the remainder of this section.

4.3.1.1 Saturated Thickness, Flow Direction, and Tidal Influence

The depth to groundwater observed at the Site varied between 4 to 16 ft BGS during the supplemental RI activities and is shallower during the wet season. The saturated thickness of the uppermost hydrostratigraphic unit ranges from about 2 ft at the eastern edge of the Site to almost 30 ft at some locations along the shoreline in the southern portion of the Site. The saturated thickness of the uppermost hydrostratigraphic unit is generally thinner in the northern portion of the Site and thicker in the southern portion of the Site, as shown on Figure 4-10.

Groundwater elevations measured from 10 monitoring wells on August 21, 2002; 19 wells on August 14, 2012; and 23 wells on September 26, 2012 are provided in Table 4-1. The 2012 groundwater elevations are considered more accurate than the 2002 data because a recent elevations survey documented up to 1.2 ft of change in well reference elevations due to settlement for wells that were installed prior to the 2012 supplemental RI activities, as documented in Table 4-1. Because the wells installed in 2002 (MW-6 through MW-10) were surveyed using one of the wells installed in 1998 for the reference elevation, the water elevations calculated for the 2002 water level gauging are likely only approximate due to changes in the elevation of monitoring wells MW-1 through MW-5 between 1998 and 2002. A groundwater contour map based on the elevation data from the September 2012 monitoring round is shown on Figure 4-11. From the August 2012 elevation data, the direction of groundwater flow in the uppermost hydrostratigraphic unit was determined to be generally to the west. In the northern portion of the Site, adjacent to the R.G. Haley site, groundwater flow is toward the southwest with a relatively steep hydraulic gradient (0.006 ft/ft) compared to the gradient in the southern portion of the Site (0.003 ft/ft). The higher hydraulic gradients in the northern portion of the Site correlate to an average saturated thickness of about 8 ft, while the flatter hydraulic gradient in the southern portion of the Site correlates to an average saturated thickness of about 23 ft. Thus, the variation in hydraulic gradient for these two areas is partially related to the variation in saturated thickness rather than variations in recharge and/or hydraulic conductivity.

It should be noted that these hydraulic gradients and saturated thicknesses are based on dry season recharge conditions, which result in flatter gradients and lower saturated thicknesses than would be anticipated during the wet season. Based on precipitation data from the Western Regional Climate Center (Desert Research Institute 2012), the average monthly recharge for Bellingham in the wet season

(October through March) is 4.06 inches compared to an average monthly precipitation of 1.83 inches in the dry season (April through September). Thus, wet season precipitation is about 2.2 times greater than dry season precipitation, and a similar increase in a combination of hydraulic gradient and saturated thickness would be anticipated for wet season measurements because precipitation is the primary source of recharge to shallow Site groundwater [as discussed in Section 4.3.1.4 (Groundwater Recharge and Water Balance)].

The tidal influence on groundwater was evaluated during the 1998 focused RI using elevation data obtained from wells MW-1, MW-2, and MW-3, as summarized in Table 4-2, and from MW-11 through MW-16 shallow and deep wells in the 2012 supplemental RI as summarized in Table 4-3. Water elevations for MW-1, MW-2, and Bellingham Bay collected between March 15 and 20, 1999 are presented on Figure 4-12. Water elevations for MW-2, MW-3, and Bellingham Bay collected between June 26 and July 13, 1998 are shown on Figure 4-13. The groundwater elevation in MW-2 fluctuated as much as 0.3 ft and corresponded with tidal fluctuations, while minor fluctuations in the groundwater elevation were observed at MW-3. Tidal influences were not observed for the groundwater elevations in MW-1, as shown on Figure 4-12. Groundwater levels in wells MW-11 through MW-16 fluctuated by up to 0.17 ft between high and low tides on July 30, 2012, although the fluctuations were generally less than 0.1 ft, as presented in Table 4-3 and shown on Figure 4-14.

4.3.1.2 Hydraulic Conductivity

Hydraulic conductivity of the uppermost hydrostratigraphic unit was estimated from the data collected in 1998 using a technique for estimating transmissivity in tidally-influenced aquifers. Transmissivity using this technique is computed from the following equation (Ferris 1951):

$$T = (x^2 \, S \, t_0)/(4\pi \, t_1^2)$$

where:

- T = transmissivity (L^2/t)
- S = storativity (dimensionless)
- x = distance from well to subaqueous outcrop (L)
- t_0 = time between tidal maxima or minima in Bellingham Bay (t)
- t_1 = time lag between the occurrence of the maxima or minima in Bellingham Bay and in the monitoring well (t).

This evaluation utilized the electronic data collected during the focused RI for MW-2 and Bellingham Bay, as presented on Figure 4-13 and in Table 4-2. It should be noted that the elevations presented in Table 4-2 are incorrect because an incorrect reference elevation was used to convert groundwater gauging data to elevations. However, the analysis is based on time lag and change in elevation, so an accurate reference elevation is not needed for the analysis.

The time (t_0) between tidal maximum and minimum in Bellingham Bay was computed using water elevation data from June 26 to July 12, 1998, as presented in Table 4-2. The time lag (t_1), or difference between the maxima or minima of a cyclical tidal fluctuation, was also computed for this same time period and is listed in Table 4-2. The time lag determined by the tidal minima was used for estimating t_1 because it was more consistent than the lag time for the tidal maxima. The distance from MW-2 to the mean tidal level of Bellingham Bay adjacent to the Site was estimated at 75 ft. Aquifer storativity/specific yield was assumed to be 0.05. Borehole logs and depth to groundwater measurements for MW-2 provided an estimate of 20 ft for the aquifer saturated thickness (B) in the MW-2 vicinity.

Based on the 1998 focused RI data and assumptions described above, the transmissivity is estimated to be about 510 square feet (ft^2)/day. This yielded a value for the hydraulic conductivity (K) of 25 ft per day (ft/day) (9×10^{-3} cm/s) using the relationship K = T/B.

Based on generally accepted hydrogeologic references (Driscoll 1986; Freeze and Cherry 1979), a hydraulic conductivity of 9×10^{-3} cm/s is typical of clean, medium sand. A review of over 40 Site boring logs indicate that the refuse unit is predominantly composed of refuse in a silty sand matrix and wood waste is primarily composed of sawdust. Although some zones of courser soil and larger dimension wood waste are present, these courser zones appear to be limited in extent. Based on textural composition of the refuse and wood waste materials, the estimated hydraulic conductivity appears to be on the upper end of what would be expected for functionally silty sand.

4.3.1.3 Groundwater Flow

The groundwater average linear velocity (v) is estimated from the equation:

$$v = Ki/n$$

where:

K = hydraulic conductivity (L/t)

i = hydraulic gradient (dimensionless)

n = effective porosity (dimensionless).

The Site was divided into northern and southern flow regimes for estimating groundwater flow because of the significant difference in hydraulic gradient and saturated thickness in the northern and southern portions of the Site. The hydraulic gradient for the Site was estimated from the groundwater elevation difference between the 7.5 ft and 8.5 ft contours in the northern flow regime and between the 6.5 ft and 7.5 ft contours in the southern flow regime, as shown on Figure 4-15. The distance between the subject elevation contours is about 180 ft in the northern flow regime and about 320 ft in the southern flow regime. This indicates a hydraulic gradient across the northern flow regime of about 0.006 and about 0.003 in the southern flow regime, as shown on Figure 4-15.

As previously discussed, these gradients are based on dry season water elevation data. If the saturated thickness is assumed to remain unchanged, the wet season gradients would be about 2.2 times the dry season gradients, or between 0.013 in the northern flow regime and about 0.0066 in the southern flow regime. Because saturated thickness increases during the wet season, these represent upper bound estimates of the wet season hydraulic gradient.

Assuming an effective porosity of 0.25 yields an estimate for the average linear velocity of about 0.6 ft/day in the northern flow regime and 0.3 ft/day in the southern flow regime during the dry season. During the wet season, the upper bound estimate of average linear velocity is about 1.3 ft/day and 0.7 ft/day for the northern and southern flow regimes, respectively.

Groundwater flow can be estimated from Darcy's Law:

$$Q = KiA$$

where:

$Q =$ groundwater flow (L^3/t)

$K =$ hydraulic conductivity (L/t)

$A =$ cross-sectional area perpendicular to flow (L^2)

$i =$ hydraulic gradient (dimensionless).

Based on the saturated thicknesses estimated on Figure 4-10, the average saturated thicknesses for the areas over which the hydraulic gradients were estimated are 8 ft and 23 ft for the northern and southern flow regimes, respectively. Based on a cross-sectional width of 450 ft for the northern flow regime and 650 ft for the southern flow regime, the cross-sectional areas are estimated to be 3,600 ft^2 and 15,000 ft^2, respectively, as illustrated on Figure 4-15. Based on the estimated hydraulic conductivity of 25 ft/day, the groundwater flow for the northern and southern flow regimes are estimated to be 540 cubic feet per day (ft^3/day; 2.8 gpm) and 1,125 ft^3/day (5.8 gpm), for a total estimated dry season flow rate of 1,660 ft^3/day (8.6 gpm).

As previously discussed, precipitation during the wet season is about 2.2 times greater than during the dry season, and a similar relationship between wet season and dry season groundwater flow likely exists because precipitation appears to be the primary source of recharge to Site groundwater [see Section 4.3.1.4 (Groundwater Recharge and Water Balance)]. As a result, groundwater flow during the wet season is estimated to be about 19 gpm, and the average groundwater flow rate is estimated to be about 14 gpm based on the average of wet season and dry season flow. The estimated average groundwater flow rate of 14 gpm is used in the next section for the water balance evaluation.

The above estimate of groundwater flow does not account for groundwater recharge from precipitation that occurs downgradient from the portion of the upland area used to estimate hydraulic gradients and cross sectional areas (i.e., downgradient of the 7.5 ft groundwater elevation contour for the northern flow regime). The contributory recharge areas for the northern and southern flow regime groundwater flow estimates are shaded on Figure 4-15, and the un-shaded upland area on Figure 4-15 is the portion of the Site for which precipitation recharge is not accounted for in the groundwater flow estimate. Total groundwater flow at the point of discharge to surface water is estimated in the following section based on the estimated groundwater recharge for the entire upland area that contributes to Site groundwater flow.

4.3.1.4 Groundwater Recharge and Water Balance

Groundwater recharge appears to be predominantly from the infiltration of precipitation, although a portion of the recharge may be coming from fracture zones in the Chuckanut Formation, as discussed earlier in this section. A water balance is conducted in this section to evaluate the relative contribution of potential sources of recharge to Site groundwater.

Recharge from precipitation is estimated by calculating the amount of precipitation over the drainage basin for the Site. The estimated Site drainage basin is shown on Figure 4-16, and encompasses the upland portion of the Site and the area upgradient of the Site to Boulevard Street to the east. This area is estimated to be 16.4 acres, and is designated Area A_1 on Figure 4-16. However, as shown on Figure 4-15, the area over which groundwater flow was estimated does not include a portion of the upland area near the shoreline. So, for water balance estimating purposes, the smaller area that is consistent with the area used to estimate groundwater flow (12.4 acres) was used for the water balance evaluation, and is designated Area A_2 on Figure 4-16.

Based on MTCA Equation 747-5, the estimated groundwater recharge resulting from infiltration within the area relevant to the water balance estimate is 15.7 gpm, based on the following:

- Upland Area A_2: 12.4 acres (540,000 ft^2)
- Annual Precipitation: 35 inches/year
- Precipitation Infiltration: 70 percent
- Groundwater Recharge from Infiltration = (540,000 ft^2)(35 inches/year)(0.70)(1 ft/12 inches)(7.48 gallons/ft^3)(1 year/365 days)(1 day/1,440 minutes) = 15.7 gpm.

Based on the average groundwater discharge rate of 14 gpm estimated in Section 4.3.1.3 (Groundwater Flow), recharge from precipitation is slightly greater than the estimated groundwater discharge, although the difference of about 10 percent is not significant considering the approximate nature of many of the input parameters that go into estimating both groundwater recharge from precipitation and groundwater discharge. Based on the water balance, precipitation is the dominant source, if not the sole source, of Site groundwater recharge. However, some of the precipitation that falls in the portion of the Site drainage basin upgradient from the Site may infiltrate into the Chuckanut Formation and then discharge via springs and seeps near the base of the bluff on the east side of the BNSF railroad tracks, as were observed during reconnaissance of the bluff area.

The total Site recharge to groundwater from precipitation that ultimately discharges to Bellingham Bay is estimated to be 21 gpm based on the entire Site drainage basin area (Area A_1 = 16.5 acres) and MTCA Equation 747-5. As previously discussed, this represents the average recharge and would be significantly lower in the dry season and higher in the wet season. Based on the estimated relationship that wet season recharge is 2.2 times the dry season recharge, the wet season recharge for the entire Site is estimated to be about 29 gpm and the dry season recharge is estimated to be about 11 gpm.

The amount of groundwater recharge that originates upgradient of the Site from the area between the eastern edge of the Site to Boulevard Street to the east is estimated to be about 5.8 gpm based on Equation 747-5 and an estimate of 4.6 acres for this area, designated Area A_3 on Figure 4-16. Thus, about 28 percent of Site groundwater recharge is estimated to originate upgradient of the Site.

4.3.1.5 Groundwater Use

Ecology has determined that groundwater at the Site is classified as nonpotable in accordance with WAC 173-340-720(2) as discussed further in Section 5.0 (Development of Site Screening Levels). Drinking water supply wells are not present at the Site or in the Site vicinity. Drinking water to the Site is currently supplied by the City of Bellingham.

4.4 NATURAL RESOURCES

This section summarizes information on natural resources in the Cornwall Avenue Landfill Site area, including fish and wildlife, existing habitats, and plant and animal species.

4.4.1 TYPES AND FUNCTIONS OF HABITATS

Information provided in this section about the types of habitats found in the Bellingham Bay area was obtained from the Whatcom Waterway RI/FS (RETEC 2006) and the Waterfront District EIS. Additional detail is available in the complete RI/FS and EIS reports.

Most of the habitats in Bellingham Bay are used by a variety of marine and terrestrial species for feeding, reproduction, rearing, and refuge, as well as providing habitat or passage for various fish species (both bottom fish and pelagic species such as salmon). The different elevations of habitat are discussed below in three groups: intertidal, shallow subtidal, and deep subtidal. Although separated by only a few feet, these three strata have distinct soil textures and support varying plant and animal communities. Each stratum has two types of substrata: sand/mud/cobble and gravel/rocky shore. The habitat typically found in these strata is summarized here to preface more detailed descriptions of fish and wildlife habitat in Bellingham Bay.

4.4.1.1 Intertidal Habitat

As described in Section 4.1.3 (Shoreline Features and Erosion), substantial amounts of riprap (predominantly concrete slabs and other concrete debris with occasional logs) are present along most of the shoreline at the steep portion of the shore face near the top of the bank. Below the steep portion of the shore face (below about 9 ft MLLW), riprap coverage is typically less dense and is absent in some areas. Soil (gravel, sand, and silt), with occasional concrete cobbles and landfill debris is predominant in the lower intertidal areas of the landfill shore face. The habitat typically found in these strata includes native eelgrass and benthic organisms, although an eelgrass survey for Bellingham Bay conducted in 1999 did not identify eelgrass in the intertidal zone at the Site (Marine Resources Consultants 1999). Also, except for rock crabs present beneath riprap or other large surface material, shellfish or other benthic organisms were not observed in the intertidal zone during previous investigations.

4.4.1.2 Shallow Subtidal Habitat

Native eelgrass is typically more common within the shallow subtidal zone (-4 to -10 ft MLLW). This is true for the shallow subtidal zone at the Site, where intertidal and subtidal surveys conducted in 1996, 2002, and 2008 have identified areas of eelgrass at the southwestern and northwestern ends of the Site. The locations where eelgrass was identified during these surveys are as shown on Figure 4-17. An eelgrass survey of Bellingham Bay conducted in 1999 identified a 0.28-acre patch of eelgrass near the southwestern corner of the Site. A 2008 eelgrass survey conducted by Grette Associates for a City project in the vicinity of the Site indicates that the eelgrass present at the southwestern end of the Site is the northern extreme of a continuous eelgrass bed that extends over 2400 ft to the south along the shoreline. The results of the 2008 Grette Associates eelgrass survey indicate that the eelgrass bed observed in 1999 significantly expanded during the 9-year interim period.

Mudflats within the shallow subtidal zone of Bellingham Bay typically support epibenthic prey that is consumed by juvenile salmon migrating through the area. The substrate within this elevation can also provide suitable habitat for Dungeness crab mating and egg brooding (RETEC 2006).

4.4.1.3 Deep Subtidal Habitat

In deep subtidal habitat with a sand or mud bottom, native eelgrass can still be relatively common at elevations between -10 and -20 ft MLLW; however, below -20 ft MLLW, light is limited and eelgrass and macroalgae are less prevalent (RETEC 2006). A limited amount of eelgrass was observed at depths greater than elevation -10 ft MLLW at the northwestern end of the Site, as indicated on Figure 4-17. The eelgrass bed at the southwestern end of the Site does not extend to depths below elevation -10 ft MLLW.

Some varieties of hard-shell clams are less abundant with increased depth, while the geoduck clam tends to be more abundant in deeper water. The substrate within this elevation can provide suitable habitat for Dungeness crab mating and egg brooding. The substrate and water column are also used for feeding by a variety of fish, including sub-adult and adult juvenile salmon. Most portions of the Site consist of subtidal habitat with sand or mud bottom.

4.4.1.4 Upland Habitat

The upland habitat of the Site is sparse. The Site consists of a soil cover over the former landfill area and traffic surfaces. The cover soil consists primarily of granular material (sand and gravel), wood debris, and occasional areas of cobble ballast. The stormwater detention basin is located in the southeastern corner of the Site. Intermittent vegetation is present near the shoreline, but the interior of the site is largely devoid of vegetation, aside from sparse grass groundcover established following the demolition of the GP warehouse. Although the Site may not provide quality habitat for significant plant or animal species, a steep and forested hillside is located east of the Site and east of the BNSF railroad tracks, which could potentially provide limited habitat for the plant and animal species discussed below. This hillside is located between the BNSF railway mainline and adjacent residential development to the east.

4.4.2 Plant and Animal Species

As documented in the Whatcom Waterway Site RI/FS and the Waterfront District EIS, the Bellingham Bay area is utilized by a wide range of plant and animal species. The significant plant and animal species are summarized below.

4.4.2.1 Plants

Vegetation at the Site consists of weedy herbaceous species such as red clover (*Trifolium pratense*), curly dock (*Rumex crispus*), yarrow (*Achillea millefolium*), Canada thistle (*Cirsium arvense* – Class C noxious weed), common tansy, and various grasses. A row of Himalayan blackberry with some interspersed native shrubs and small trees is present along the shoreline. The hillside east of the Site contains a 150-ft-wide band of native deciduous and evergreen trees and shrubs bordered by Boulevard Street on the east. The hillside rises beyond Boulevard Street into an established residential neighborhood with mature landscaping.

4.4.2.2 Fisheries and Invertebrate Resources

As reported in the Whatcom Waterway RI/FS, documented fisheries resources for Bellingham Bay include the following:

- **Surf Smelt and Sand Lance:** Surf smelt and Pacific sand lance are common fish that spawn in the high intertidal portions of coarse sand and gravel beaches. Surveys by the Washington Department of Fish & Wildlife have documented spawning beaches in Bellingham Bay.
- **Pacific Herring:** Pacific herring spawn in inland marine waters of Puget Sound between January and June in specific locations. There is typically a 2-month peak within the overall spawning season. Herring, which deposit their eggs on marine vegetation such as eelgrass and algae in the shallow subtidal and intertidal zones between 1 ft above and 5 ft below MLLW, are known to congregate in the deeper water of Bellingham Bay. However, only relatively low-density spawning deposition occurs in Bellingham Bay.
- **Salmonids:** Bellingham Bay is used extensively by anadromous salmon species. Each of the streams flowing into Bellingham Bay is used by one or more of the following species: coho, chum, Chinook, pink, sockeye, steelhead, cutthroat, and bull trout. The Nooksack River has the largest salmon runs in Bellingham Bay, followed by Squalicum and Whatcom creeks. Concentrations of chum, coho, and Chinook salmon along the shoreline and in offshore waters in Bellingham Bay peak annually about mid-May. Juvenile coho and Chinook salmon appear to have different migration habits. Coho remain in the bay for approximately 30 to 35 days, while Chinooks remain about 20 days.
- **Groundfish:** Several species of groundfish occur in both shallow and deep waters in Bellingham Bay for part or all of their life. Detailed information on groundfish species and their timing and use of Bellingham Bay is not available. Key characteristics of groundfish occurring in northern Puget Sound are generally applicable to Bellingham Bay.

Bellingham Bay supports a variety of marine invertebrates, ranging from infauna (worms, clams, and small ghost shrimp that penetrate benthic sediments) to epibenthic plankters (organisms such as very small crustaceans that move off the substrate surface) to larger invertebrates such as oysters, crabs, and shrimp.

- **Clams, Geoduck, and Oysters:** The predominant bivalves in Bellingham Bay are intertidal and subtidal hard-shell clams. Intertidal shell clam types include butter, littleneck, horse, and soft-shell clams and cockles. Subtidal clam resources consist of butter, littleneck, and horse clams. Native oyster and Pacific geoduck are also known to occur in Bellingham Bay. Shellfish densities are relatively low along the eastern shore of Bellingham Bay. Geoduck is only present in a handful of locations in the Bay.
- **Shrimp:** Seven species of pandalid shrimp, including, pink, coonstripe, dock, and spot shrimp, occur in nearshore and deeper waters of Bellingham Bay. Coonstripe shrimp have been observed in intertidal areas immediately offshore of the Site, and this species is common around piers and floats.

- **Crab:** Crab trawls conducted for the Puget Sound Dredge Disposal Analysis (PSDDA) investigations indicate that the predominate crab resources in Bellingham Bay are the non-edible purple or graceful crab, the edible red rock crab, and the edible Dungeness crab. The highest densities of rock crab occur in relatively shallow water (30 to 45 ft below MLLW) in areas extending from the Lummi Peninsula to inner Bellingham Bay. Rock and Dungeness crab are likely to occur in shallower waters of Bellingham Bay not sampled as part of the PSDDA investigations. Dungeness crab is generally abundant in most areas of Bellingham Bay. The northern and eastern shorelines of Bellingham Bay serve as nursery/rearing areas for juvenile Dungeness crab. A shell substrate is a preferred habitat for the first 8 to 10 weeks after larvae settle. However, other substrates, such as small cobbles and gravel, algae, and eelgrass, are also recognized as important rearing habitat for juvenile crab.

4.4.2.3 Sea Birds and Marine Mammals

The greater Bellingham Bay area and its shallow estuarine habitats support a number of birds in all seasons. Although Bellingham Bay is not used extensively by large populations of waterfowl, wintering populations tend to be 10 to 15 times larger than summer populations for migratory species. Bellingham Bay is located on the flight path between the Fraser River estuary and Skagit Bay, and is used as a stopover for seabirds and waterfowl migrating between these two areas. Waterfowl sited in Bellingham Bay include brant, snow geese, mallard, widgeon, green-winged teal, and pintail. Bellingham Bay is also used as an over-wintering area for diving birds such as scoter and golden eye. A variety of both natural and man-made habitats provide protection from winter storms to migrant and wintering birds. Glaucous-winged gulls use inner Bellingham Bay for resting and foraging. Pigeon guillemonts use the shoreline area in and around the Whatcom Waterway for nesting and foraging.

Limited information is available on the presence and residence time of marine mammals in Bellingham Bay. Bay-wide, several species have been reported: the harbor seal, sea lions, Orca whale, gray whale, and harbor porpoise. As described below, the local population of Orca whale is listed as endangered under the Endangered Species Act (ESA). The other marine mammals are not threatened or endangered species under ESA, but they are protected from hunting under the Marine Mammal Protection Act. Seals and sea lions have been noted using the Site shoreline for resting areas. Migrating gray whales have been noted to enter Bellingham Bay and to feed in subtidal areas of Puget Sound. Orca whales are occasionally observed in and near Bellingham Bay, though they are more typically observed in Rosario Strait and near the San Juan Islands.

4.4.2.4 Threatened or Endangered Species

Under the ESA, a species likely to become extinct is categorized as "endangered." A species likely to become endangered within the foreseeable future is categorized as "threatened." This section provides information on the occurrence of threatened and endangered bird, fish, and marine mammal species in Bellingham Bay. In addition to the species discussed below, priority habitat and species data 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.

- **Marbled Murrelet:** Open water concentrations of marbled murrelets have been recorded in the central portion of Bellingham Bay. Murrelets forage in the marine environment typically up to 2 miles near a coastline. The species forages year round in waters generally less than 90 ft deep, sometimes congregating in well-defined areas where food is abundant. These birds generally do not utilize shallower waters less than 30 ft deep. Marbled murrelets reportedly feed on a wide variety of prey, including sand lance, Pacific herring, and other marine taxa such as crustaceans. Murrelets require old growth or mature forest composed of conifers, including Douglas fir, western red cedar, Sitka spruce, and western hemlock. There are no known nest sites along the shoreline of Bellingham Bay, and no clear association between these birds and the Site.
- **Puget Sound Chinook Salmon:** On March 16, 1999, NOAA Fisheries added nine West Coast salmon to the Endangered Species List. Of the nine listed species, one occurs within the vicinity of the Site; Puget Sound Chinook salmon was listed as a threatened species. Two races of Chinook salmon (spring and fall) are found in Bellingham Bay. The timing of adult migration to freshwater differs between these two races, but the timing of the return of adult fish, spawning, and emigration of juveniles overlap. Fall Chinook is the most common run of Chinook salmon observed in Puget Sound. Juvenile fall Chinook generally emigrate to the estuary between February and August as sub-yearlings (within the first year after being spawned) or as yearlings. Individual fish may only use Bellingham Bay for a period of days to a few weeks before heading into the greater Puget Sound estuary. They may use the estuaries and intertidal areas between April and November for further rearing and growth. As juvenile fish move into neritic habitats, they preferentially consume emergent insects and epibenthic crustaceans in salt marsh habitat or decapod larvae, larvae, and other prey.
- **Puget Sound Steelhead:** Puget Sound steelhead occur in Whatcom Creek, Squalicum Creek, and the Nooksack River. 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.
- **Bull Trout:** Bull trout, listed as a threatened species under the ESA by the U.S. Fish and Wildlife Service (USFWS), are a member of the North American salmon family. Bull trout occur in the Nooksack River, and presumably spend some time in Bellingham Bay. Many are resident to a single stream; others migrate on a fluvial (i.e., spawn in headwaters streams and live downstream in larger rivers) or adfluvial basis (spawn in streams but live in lakes). Bull trout tend to prefer cold, clear waters (no more than 64°F).
- **Orca Whales:** On November 15, 2005, NOAA Fisheries announced its decision to list the North Pacific Southern Resident Orca whale (*Orcinus orca*) population as endangered under the ESA. The listing was effective on February 6, 2006 (50CFR 223/224). The listing is specific to the three resident whale pods (J, K, and L pod) with spring through fall ranges in Puget Sound and the Straits of Georgia and Juan de Fuca. A number of factors have been identified by NOAA Fisheries as having resulted in the listing of these Orca whales as endangered. Sound and disturbance from vessel traffic, toxic chemicals which accumulate in

top predators, and uncertain prey availability (primarily salmon) all have been identified as concerns for the continued survival of this population. The small number of whales in this group, and relatively slow rate of population recovery since a 20 percent population decline during the 1990s, also puts this historically small group at risk of extinction during a catastrophic event such as an oil spill or disease outbreak. Because Orcas do not frequent near-shore areas with shallow water depths, the marine portion of the Site does not constitute favorable habitat for these whales.

- **Bocaccio, Yelloweye, and Canary Rockfish:** 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. The marine habitat conditions at the Site generally are unfavorable for the rockfish species discussed below since 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.
  - Adult bocaccio rockfish are most commonly found at water depths ranging from 160 to 820 ft, but sometimes inhabit waters as shallow as 40 ft. Bocaccio rockfish are rare in the North Puget Sound, where the Site is located.
  - Adult yelloweye rockfish are most commonly found at water depths ranging from 300 to 590 ft and are not known to inhabit waters less than 80 ft 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 ft. This species is highly associated with rocky or coarse sediment habitats. Canary rockfish are relatively common in the North Puget Sound.

4.4.2.5 Other Terrestrial Animals

Other terrestrial animals likely present at and near the Site are those typically found in urban settings, such as robins, pigeons, woodpeckers, raccoons, squirrels, possums, rats, mice, and moles. These terrestrial animals are not believed to be present at the Site itself in significant numbers, because of the low quality of habitat, but are likely common in the adjoining forested hillside and in the residential area with mature landscaping. Deer scat and hoof prints have been observed near the Site.

4.5 HISTORIC AND CULTURAL RESOURCES

Historic and cultural resources for this Site were evaluated by the Port as part of the Waterfront District redevelopment project and are presented in the Waterfront District EIS. The area comprising the Site historically consisted of tide flats, with the shoreline generally corresponding with the bottom of the bluff area. Dating back from pre-history to the 19th century, the Bellingham waterfront was traditionally occupied by ancestors of the present-day Lummi Nation and Nooksack Indian Tribe. The settlement and subsistence of communities throughout this region were similar in many ways, primarily in the seasonal cycle of congregation at winter villages. Winter villages were usually located along protected coastlines, where activities such as shellfish gathering and fishing could be pursued. European settlement took hold on Bellingham Bay during the 1850s, and the Bellingham waterfront has since been primarily a shipping and industrial area.

No archaeological cultural resources have been identified in the area of the Site. Although no known archaeologically significant cultural resources were identified, the Site is located in a potentially archaeologically-sensitive landscape that once included tideflats or beach areas. The bluff area east of the Site and the area below the bluffs were noted as having the potential to retain archaeological resources. However, usage of the Site for the disposal of wood waste and refuse, then as an industrial area with warehouse buildings has likely resulted in the removal, destruction, or burial of any cultural resources that may have been present near the historical shoreline near the railroad alignment. Additionally, the area immediately below the bluff is occupied by the BNSF railway mainline, the construction of which likely displaced or buried cultural resources that may have been present near the original shoreline for Bellingham Bay. More recent historical uses of the Site are discussed in the initial characterization report (Tetra Tech and Historical Research Associates 1995), provided in Appendix A of this report.

4.6 LAND AND NAVIGATION USE

Land use planning activities for the Site and surrounding areas are currently underway as part of the Waterfront District master planning, as described in Draft Sub-Area Plan (Port of Bellingham website 2012). The Waterfront District planning efforts are being performed by the Port and the City, and anticipate an area-wide rezoning from industrial to a mix of light industrial and mixed-use. Environmental review has been performed under SEPA by the Port's SEPA-responsible official and is documented in the Waterfront District EIS.

The Waterfront District extends from the southern end of the Site to the northern end of the I&J Waterway, as shown on Figure 4-18. The Site is part of the Cornwall Beach planning area which is currently anticipated to include a significant amount of open park space and habitat. Additional development in the Site vicinity may include residential mixed use and a small amount of goods and services associated with the residences and park. Other property uses could include mixed use development or light industrial or commercial use.

Navigation uses offshore of the Site are largely transitory, with vessels coming into and traveling out of the Whatcom Waterway or to the Bellingham Shipping Terminal and barge docking area located northwest of the R.G. Haley Site. Vessels are generally not anchored offshore of the Site and there are no permanent dock structures or mooring dolphins at the Site. It is not anticipated that docks or other in-water structures will be constructed as part of Site redevelopment, except an over-water walkway from Boulevard Park to the southern end of the Site uplands proposed by the City. The over-water walkway would connect Boulevard Park with a City park constructed on a portion of the Site uplands, which is one of the land use alternatives for the Waterfront District redevelopment. The walkway is currently under design and the proposed alignment is shown on Figure 4-17. Site redevelopment is discussed further in Section 9.3.1 (Integration of Remedial Alternatives with Future Development).

5.0 DEVELOPMENT OF SITE SCREENING LEVELS

This section develops Site screening levels (SLs) for use in evaluating the nature and extent of contamination, which is discussed in Section 6.0 (Nature and Extent of Contamination). Site SLs have been developed for those constituents detected in one or more of the Site media (groundwater, soil, and sediment). The SLs are based on potential contaminant exposure pathways, potential receptors, and applicable regulatory criteria, which are discussed below.

The SLs for media of potential concern that are adequately protective of the potential receptors and exposure pathways identified herein were developed in accordance with MTCA requirements, subject to the limitations of the currently available data, and Site-specific considerations. SLs for sediment, groundwater, and soil are presented in Tables 5-1, 5-2, and 5-3, respectively. Note that although surface water is a potentially affected medium, it is addressed through the development of groundwater SLs that are protective of surface water rather than developing surface water SLs directly.

Some of the hazardous substances detected in affected media at the Site are associated with releases from the R.G. Haley site. Diesel- and oil-range petroleum hydrocarbons, and wood treatment-related SVOCs such as PCP and carcinogenic polycyclic aromatic hydrocarbons (cPAHs), appear to be related to releases at the R.G. Haley site. Although SLs are developed herein for these constituents for the purposes of interpreting the RI data, cleanup levels for hazardous substances released from the R.G. Haley site will be developed by Ecology during the cleanup process for that site. As a result, the SLs developed herein for hazardous substances associated with the R.G. Haley site may differ from values developed during the R.G. Haley cleanup process.

Both wood waste and municipal solid waste degrade anaerobically in landfills, creating a reducing groundwater environment that generates ammonia as part of the nitrogen cycle, and mobilizes some metals such as manganese that are naturally present in the surrounding soil. These hazardous substances, and other hazardous substances detected in affected Site media such as heavy metals, PCBs, non-carcinogenic PAHs, and VOCs, are associated with the Cornwall Avenue Landfill Site.

By its nature of use as a municipal waste landfill, Site soil is assumed to be contaminated and RI characterization was focused on other media of potential concern (i.e., groundwater and marine sediment). So, while soil SLs were developed for those hazardous substances detected in the limited number of soil samples collected at the Site, it is understood these do not likely represent the full range of soil contaminants at the Site, and will not be used to define areas requiring cleanup. Areas assumed to exceed cleanup standards and therefore require cleanup include those containing refuse and wood waste, beneficial reuse sediment, and cover soils, as described further in Section 5.5 (Soil Screening Levels).

5.1 POTENTIAL EXPOSURE PATHWAYS

Potential exposure pathways must be identified for both human and environmental impacts. The potential exposure pathways are presented below, along with an indication of whether or not the exposure pathway is potentially complete:

- **Ingestion of groundwater – incomplete pathway.** As discussed in Section 4.3.1.5 (Groundwater Use), Ecology has determined that Site groundwater is not considered a potable water source.
- **Groundwater discharge to surface water – potential pathway.** Discharge of contaminated groundwater to surface water could affect receptors in surface water or sediment.
- **Groundwater discharge through marine sediment – potential pathway**. Discharge of contaminated groundwater through marine sediment prior to discharge to surface water could affect sediment quality, which in turn could affect benthic organisms through uptake of contaminants contained in sediment.
- **Direct human contact with soil – potential pathway.** Potential pathways include exposure to subsurface soil along the shoreline, in areas with limited soil cover, and during construction that involves intrusive activities. Currently, access to the Site is restricted.
- **Direct terrestrial contact with soil – potential pathway**. Terrestrial receptors have the potential to contact subsurface soil during current and future exposure scenarios.
- **Leaching from soil to groundwater – potential pathway.** Soil contaminants can leach to groundwater in unpaved areas where stormwater can infiltrate through shallow contaminated soil or at locations where soil contamination is in direct contact with groundwater.
- **Soil erosion and discharge to marine sediment or surface water – potential pathway**. The upland portion of the Site exhibits ongoing erosion along the shoreline, resulting in the release of refuse and wood waste to Site sediment and surface water. The potential also exists for soils inland from the shoreline to be eroded and transported in storm water runoff to Site sediment and surface water.
- **Soil vapor discharge to indoor and ambient air – potential pathway.** Soil vapor has the potential to migrate and expose indoor and ambient air receptors to VOCs for future use exposure scenarios.
- **Direct human contact with sediment – potential pathway.** The current potential exposure pathway includes contact with surface sediment and the future potential exposure pathway includes contact with dredged sediment during construction.
- **Uptake of contaminants in sediment by benthic organisms – potential pathway.** Potential exposure pathways include uptake of contaminants in sediment by benthic organisms.
- **Higher trophic level organism (seals, birds) consuming aquatic organisms – potential pathway.** Potential exposure pathway consists of higher trophic level organisms consuming benthic, epibenthic, or fish organisms, which can bioaccumulate contaminants present in sediment and/or contaminants present in groundwater discharging from the Site.
- **Human consumption of seafood – potential pathway.** Potential exposure pathways include human ingestion of benthic, epibenthic, or fish organisms, which can bioaccumulate contaminants present in sediment and/or contaminants present in groundwater discharging from the Site.

As mentioned in Section 4.3.1.5 (Groundwater Use), Ecology has determined that the uppermost groundwater in fill at the Site is classified as nonpotable. This determination is in accordance with WAC 173-340-720(2)(d) as follows:

> (2)(a) *The ground water does not serve as a current source of drinking water.* [Drinking water to the Site is currently supplied by the City. Drinking water supply wells do not exist at the Site or in the Site vicinity.]
>
> (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, at concentration which exceed ground water quality criteria published in chapter 173-200 WAC.* [RI work at the Site indicates that contaminated groundwater occurs primarily in the uppermost water-bearing zone. This zone occurs in manmade fill placed in Bellingham Bay and in the upper part of the underlying native sediments. The uppermost water-bearing zone discharges directly into Bellingham Bay. Contaminated groundwater in the uppermost water-bearing zone will not flow laterally inland toward a current or potential future source of drinking water because any inland aquifer would be hydraulically upgradient. Similarly, contaminated water in the uppermost water-bearing zone will not flow vertically downward into deeper current or potential future source of drinking water, because groundwater flow between aquifers at the shoreline is upward, reflecting increasing hydraulic heads with depth.]
>
> (2)(d) *Even if ground water is classified as a potential future source of drinking water under (b) of this subsection, 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 nonpotable for the purposes of this section if each of the following conditions can be demonstrated. These determinations must be for reasons other than that the groundwater or surface water has been contaminated by a release of a hazardous substance at the site.*
>
> (i) *There are known or projected points of entry of the ground water into the surface water.* [RI work at the Site indicates that groundwater enters Bellingham Bay.]
>
> (ii) *The surface water is not classified as a suitable domestic water supply source under chapter 173-201A WAC.* [Bellingham Bay is a marine surface water body and does not classify as a suitable domestic water supply under Chapter 173-201A WAC.]
>
> (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.* [RI work at the Site indicates that groundwater is hydraulically connected to Bellingham Bay. It is not practicable to utilize Site groundwater for water supply due to the potential for drawing saline water into the water-bearing zone (salt water intrusion).]

As a result, groundwater as a source of drinking water is not carried forward for the development of Site SLs.

5.2 POTENTIAL RECEPTORS

There is currently a potential for exposure to human and ecological receptors at the Site. Potential human receptors are:

- **Site upland recreational visitor/general public.** Potential exposure of Site visitors or individuals to contaminants in surface soil can occur through ingestion, dermal contact, or inhalation of particulates.
- **Site aquatic recreational visitor/fisher.** Potential exposure of Site visitors and seafood gatherers/fishers to contaminants in marine sediment can occur through ingestion or dermal contact with contaminated sediment, or ingestion of benthic, epibenthic, or fish organisms containing bioaccumulative compounds originating from Site marine sediment. Current exposure could occur to beachcombers and shellfish gathers in the intertidal zone. Because all viable remedial alternatives include either complete removal of contaminated soil and marine sediment or shoreline stabilization, future exposure is limited to seafood consumption of epibenthic organisms or fish.
- **Site construction workers.** Potential exposure of future Site construction workers to contaminants in surface and subsurface soil can occur through ingestion, dermal contact, or inhalation of particulates, through dermal contact with groundwater, and through inhalation of soil vapors. The Port maintains internal controls to ensure that workers conducting excavations at the Site receive appropriate training and monitoring. Potential exposure to contaminants in sediment could occur through ingestion and dermal contact during sediment dredging.
- **Site residential, commercial, or industrial occupants.** Structures could be occupied by residential, commercial, or industrial parities under future development scenarios. Occupants could be exposed to volatile contaminants (if present) and methane that could migrate into buildings via soil gas, particularly for redevelopment and/or remedial action activities that include construction of a low permeability cap.

Ecological receptors may also currently be exposed to affected Site media. Potential ecological receptors include:

- **Benthic/epibenthic organisms.** Based on data from the Whatcom Waterway RI/FS, benthic macro-invertebrates most actively colonize the upper 12 cm of sediment in Bellingham Bay (RETEC 2006).
- **Aquatic species.** Fish species potentially use marine surface water that is potentially affected by Site groundwater discharge.
- **Terrestrial plants and animals.** Future land use at the Site could include mixed residential/retail, parks, or industrial uses. Development for all of these potential future uses will include low permeability covers and/or clean soil caps, which will preclude contact of terrestrial plants and animals with refuse or contaminated soil, and appropriate institutional controls. Implementation of a cleanup for this Site is anticipated to occur by 2015. As a result, the Site qualifies for an exclusion under WAC 173-340-7491(1) and terrestrial plants and animals are not considered potential receptors for the Site.

5.3 SEDIMENT SITE SCREENING LEVELS

Site SLs for sediment were developed based on SMS cleanup standards, and are presented in Table 5-1. The SMS cleanup standards (Chapter 173-204 WAC) marine chemical criteria can range from the SQS (the level expected to cause no adverse effects to biological resources and does not pose a significant health threat to humans) to the cleanup screening level (CSL; the level expected to cause only minor adverse effects to human health or biological resources). The SQS marine chemical criteria were selected as the SLs for Site sediment. Both SQS and CSL criteria for detected constituents are presented in Table 5-1, and in conjunction with the analytical results, in Section 6.4 (Sediment Quality).

Some SQS and CSL marine chemical criteria are presented "carbon normalized" (OC), or expressed on a TOC basis. To normalize concentrations to TOC, the dry weight concentration is divided by the decimal fraction representing the percent TOC content of the sediment. In cases where TOC was not available for a particular sample, an average value for the Site (2.8 percent) was used for comparative purposes. As shown in Table 5-1, metals and phenol are evaluated on a dry weight basis, and PAHs, phthalate esters, and PCBs are evaluated on an OC basis. Ecology recommends the use of dry weight equivalents to the SMS OC SQS and CSL criteria be considered along with the OC criteria for marine sediment samples that have TOC concentrations less than 0.5 percent or greater than 3.5 percent, because lower TOC values tend to elevate the reporting limits above the SMS criteria and higher TOC values may not result in adequately protective SLs. Additionally, dry weight criteria are available for some hazardous substances that do not have SMS OC criteria. As a result, the Apparent Effects Threshold values (AETs), which are the dry weight equivalents to the SMS SQS and CSL criteria, are also presented in Table 5-1.

The current SMS regulations do not contain numeric criteria to address three of the potential exposure pathways associated with sediment identified in Section 5.1 (Potential Exposure Pathways): 1) human consumption of seafood, 2) human direct contact with sediment, and 3) higher trophic level organism (seals, birds) consuming benthic organisms. However they do contain narrative criteria stating that Ecology may determine the criteria, methods, and procedures necessary to protect human health on a case-by-case basis. The primary concern with these potential exposure pathways are bioaccumulative effects of certain compounds.

The revised SMS regulations that go into effect on September 1, 2013 provide for establishing SLs protective of human health by selecting the highest of: a background concentration, a risk-based concentration or the practical quantitation limit (PQL). In the absence of a background concentration and sufficient data to calculate a risk-based concentration, the PQL will be used for PCBs in sediment.

PCBs are considered the only constituent present in Site sediment that requires the development of a sediment SL to address human health for bioaccumulative affects. The PQL for PCBs in sediment recommended in Ecology's Sediment Sampling and Analysis Plan Appendix (Ecology 2008) is 6 micrograms per kilogram (µg/kg) dry weight. When adjusted by the average TOC value for this Site of approximately 2.8 percent, the resulting carbon normalized value comparative to the PQL is 0.21 mg/kg. Other constituents considered to be bioaccumulative include arsenic, cadmium, lead, mercury, and cPAHs. The bioaccumulative affects of arsenic are addressed by selecting the natural background concentration of arsenic (11 mg/kg; DMMP et al. 2009) as the SL for marine sediment, and based on this SL, there were no exceedances of the arsenic SL in sediment at the Site. For mercury, previous studies for the Whatcom Waterway have determined that the 0.41 mg/kg SQS for mercury adequately addresses all sediment exposure pathways and receptors, including human consumption of seafood and protection of higher trophic level species. Cadmium, lead, and cPAHs SLs addressing potential bioaccumulative affects were not developed for the RI/FS because a SL has already been established for another bioaccumulative constituent, PCBs, which serves as a surrogate for these other bioaccumulatives in the development and evaluation of cleanup alternatives. However, all bioaccumulatives will need to be considered during development of the CAP, and cleanup levels based on bioaccumulative affects may be developed for cadmium, lead and cPAHs at that time.

Sediment SLs protective of direct human contact were not developed for the Site because direct human contact will be prevented under all remedial alternatives. Because the Site shoreline is currently eroding, all remedial alternatives other than complete removal would require shoreline stabilization that will isolate contaminated sediment in the intertidal and shallow subtidal zones from direct human contact. Because of the high energy marine environment present at the Site, stabilization will require erosion protection measures that would prevent penetration of the capping system by excavation using hand equipment. Further, institutional controls would prohibit excavation in any manner without proper health and safety protocols to prevent direct human contact with contaminated marine sediment.

In addition to the chemical parameters presented in Table 5-1, physical criterion has been established for Site sediment that is considered protective of aquatic organisms. The physical criteria for the sediment SLs consist of the following Site-specific criteria for refuse and wood debris in the aquatic environment that Ecology considers adequately protective of benthic organisms (Kovacs 2008):

- No more than a 1 ft thickness of sediment where wood debris (sawdust or wood chips) constitutes greater than 50 percent of the sediment by volume
- No detectable refuse
- No less than 1 ft of clean sediment cover over sediment that exceeds the above criteria for wood debris and refuse.

This criterion is discussed in greater depth in Section 8.1.3 (Sediment Cleanup Standards).

5.4 GROUNDWATER SCREENING LEVELS

Site SLs protective of the potential receptors identified in Section 5.2 (Potential Receptors) were developed for those constituents detected in groundwater during the RI activities and previous investigations. The constituents detected include metals, SVOCs, VOCs, PCBs, ammonia, and petroleum hydrocarbons.

As discussed in Section 5.1 (Potential Exposure Pathways), Site groundwater is considered nonpotable. As a result, groundwater SLs were developed based on groundwater discharge to adjacent marine surface water and sediment. Applicable federal and state groundwater cleanup criteria protective of marine surface water were used to develop the SLs, except for total petroleum hydrocarbons.

Since surface water criteria have not been established for total petroleum hydrocarbons, MTCA Method A cleanup levels for groundwater were used for these constituents for evaluation of risk to human health, as provided for in WAC 173-340-730(3)(b)(iii)(C). The Method A groundwater cleanup levels for petroleum hydrocarbons are not applicable to surface water for protection of aquatic life. Consequently, risk to aquatic species was evaluated with respect to individual constituents of TPH, such as naphthalene. The applicability of the Method A groundwater cleanup levels to protection of surface water is discussed further in the context of petroleum hydrocarbon distribution near the shoreline in groundwater in Section 6.3.3.2 (Downgradient Perimeter Groundwater Quality).

The most stringent of the applicable federal and state criteria were selected as the groundwater SL. These criteria were then adjusted upward, if necessary, such that the criteria are not below PQLs or background concentrations. The potentially applicable regulatory criteria and the selected Site groundwater SLs are presented in Table 5-2.

Groundwater SLs for a few detected constituents were adjusted upward to the PQL, specifically indeno(1,2,3-cd)pyrene, BEP, PCP, and PCBs. The only groundwater SL adjusted upward for background was arsenic. The MTCA Method A groundwater cleanup level for arsenic of 5 micrograms per liter (μg/L) is based on natural background for Washington State. Arsenic is a naturally occurring element present in soil throughout Washington State, and as such is commonly present in groundwater aquifer matrices.

The groundwater SLs developed above consider protection of sediment recontamination by applying the SLs developed for marine sediment in Section 5.3 (Sediment Site Screening Levels), which address both protection of benthic organisms and human health. Additionally, standard MTCA Method B surface water levels used as the basis for developing Site groundwater SLs were adjusted downward to account for a higher fish/shellfish consumption rate developed for the Whatcom Waterway sediment cleanup for protection of recreational/tribal fishers.

A number of VOCs and SVOCs that do not have promulgated cleanup criteria were detected in Site groundwater at low concentrations, primarily during the 2012 supplemental groundwater sampling activities. The concentrations of these constituents are near the method reporting limits and are orders of magnitude lower that the concentrations of more ubiquitous hazardous substances present in Site groundwater, such as manganese and ammonia. As a result, any cleanup actions that adequately address COPCs such as manganese and ammonia will result in concentrations below the PQL for these hazardous substances that lack applicable cleanup criteria. As a result, groundwater SLs were not developed for these hazardous substances.

5.5 SOIL SCREENING LEVELS

Soil SLs protective of the potential receptors identified in Section 5.2 (Potential Receptors) were developed for those constituents detected in soil during the RI activities. Only limited Site soil data were collected because landfill refuse is by nature a very heterogeneous material and for the purposes of Site cleanup is assumed to be contaminated. One of the distinguishing features of landfill cleanups under MTCA, as compared to MTCA cleanups at other sites, is that landfills are assumed to contain hazardous substances at concentrations above applicable cleanup levels. As such, there is no need to establish the existence and concentration of constituents of concern in the refuse and it is understood that individual SLs or cleanup levels are not necessary because the entire mass of refuse (and wood waste in this case) is to be treated as exceeding cleanup levels, as previously noted. Additionally, as requested by Ecology, cover soils across the Site will be assumed contaminated unless proven otherwise through additional sampling based on the close proximity of wood treating operations at the nearby R.G. Haley site which may have resulted in contamination of surface soils at the Site. However, limited soil data were collected during the course of the RI, primarily for purposes other than the Site RI (e.g., Aspect Consulting), and soil SLs were developed to evaluate these ancillary soil data.

The constituents detected in surface and subsurface soils include metals, SVOCs, VOCs, PAHs, and petroleum hydrocarbons. MTCA Method B standard formula values for direct contact were used in developing Site SLs for soil to provide a conservative basis for evaluating Site soil quality. MTCA soil concentrations protective of surface water quality, calculated using the 3-phase partitioning model (equation 747-1), were also used in developing Site SLs for soil. Method A soil cleanup levels for unrestricted site use were used as soil SLs for TPH. The most stringent of the above criteria, adjusted for soil background concentrations or the PQL, as appropriate, were identified as soil SLs for the Site. SLs were not developed for protection of terrestrial species because all remedial alternatives developed in the FS will consist of complete removal or include a separation layer between contaminated soil and overlying clean soil to prevent terrestrial species from contacting contaminated soil. The potentially applicable criteria and selected soil SLs are presented in Table 5-3.

Some hazardous substances were also present in the stabilized sediment imported and stockpiled on the Site, as discussed in Section 3.7 (Interim Action). Imported stabilized sediment contains PAHs, metals, BEP, and dioxins/furans. SLs were developed for all of these hazardous substances. For dioxins/furans, an SL protective of groundwater was not developed because all of the remedial alternatives evaluated in the FS [see Section 9.0 (Feasibility Study)] either completely remove the dioxins/furans-bearing sediment or isolate it from the environment in a manner that largely eliminates leaching. Additionally, dioxins/furans have a low solubility in water and are unlikely to be leachable at detectable concentrations, as described further in Section 7.2.1.

Although the soil to vapor pathway is acknowledged as a potential exposure pathway, Site SLs protective of this potential pathway were not developed. The extensive refuse and wood debris present at the Site generates a sufficient amount of methane gas that landfill gas will need to be managed as part of any cleanup action that includes a low permeability cover, including buildings.

Landfill gas is a decomposition product of solid waste and contains methane and other organic and inorganic gases. It is therefore defined under MTCA as a hazardous substance (WAC 173-340-200). MTCA also requires that cleanup standards be set if air emissions at a site pose a threat to human health or the environment [WAC 1730340-750(1)(A)]. Emissions at the Cornwall Landfill may pose a potential threat, as methane has been detected, and other VOC contaminants may be present.

MTCA does not provide cleanup levels for methane or landfill gas, because the reference doses and cancer potency factors necessary to calculate cleanup levels are not available. In lieu of cleanup levels, MTCA does establish an explicit upper bound, based on explosivity, for any air cleanup level that might be developed – "Standard Method B air cleanup levels shall not exceed ten percent (10%) of the lower explosive limit for any hazardous substance or mixture of hazardous substances" [WAC 173-340-750(3)(b)(iii)]. MTCA also invokes closure requirements under applicable landfill closure regulations, and establishes those under Chapter 173-304 WAC as the minimum. The following specific requirements from Chapter 173-304 WAC could apply to the Cornwall Landfill [WAC 173-304-460(2)(b)(i)]:

- The concentration of explosive gases cannot exceed 25% of the lower explosive limit (LEL) in site structures. The LEL for methane is 5% by volume.
- The concentration of explosive gases cannot exceed the LEL in the subsurface at or beyond the property boundary.
- The concentration of explosive gases cannot exceed 100 ppmv of hydrocarbons (expressed as methane) in off-site structure.

The standard point of compliance is ambient air throughout the Site, and in structures on and off the Site large enough for a person to fit into. Although personal exposure monitoring during work at the

Site has not indicated that ambient air is impacted, the potential risk will be addressed as part of Site cleanup and redevelopment by installation of a landfill gas mitigation system. As such, hazardous substances in soil vapor will be addressed in conjunction with methane gas as part of Site cleanup.

Soil SLs for the protection of marine sediment were considered because of the potential for soil in the vicinity or the shoreline to continue eroding into Bellingham Bay and contaminating marine sediment. However, because all remedial alternatives will either remove all contaminated soil from the Site or contain upland soil in conjunction with stabilizing the shoreline, the potential for soil erosion to marine sediment following implementation of the Site final cleanup action will be eliminated. Additionally, any remedial alternatives that do not remove all contaminated soil from the Site will also include institutional controls requiring the maintenance of a containment system in perpetuity. As a result, soil SLs protective of marine sediment were not developed for the Site.

6.0 NATURE AND EXTENT OF CONTAMINATION

This section describes Site environmental conditions, including groundwater, soil, and sediment quality, and the extent of refuse and wood waste throughout the upland and in-water portions of the Site. The environmental conditions were evaluated based on analytical results for soil, groundwater, and sediment generated during the RI and pre-RI activities and the results of Site cover assessments (i.e., extent of exposed landfill refuse) conducted during the RI and pre-RI investigations.

6.1 CONSTITUENTS OF POTENTIAL CONCERN

As discussed in Section 3.0 (Remedial Activities), soil, refuse, and wood waste within the landfill is assumed to contain hazardous substances above applicable MTCA soil cleanup levels and extensive soil quality testing was not conducted during the RI. As a result, a comprehensive list of COPCs was not developed for Site soil, although soil COPCs are identified for those constituents that have been detected at the Site at concentrations exceeding the Site SLs. These include dioxins/furans present in the interim action material stockpiled on the Site as well as the constituents detected in Site soil and refuse.

In addition to those compounds typically associated with landfills, some constituents detected during the RI activities are attributable to the R.G. Haley site, such as petroleum hydrocarbons in the diesel and oil ranges, SVOCs (such as PCP and cPAHs), and dioxins/furans. Contamination at the Site that appears to be associated with the R.G. Haley site will be addressed during cleanup of that site, although cleanup activities for the two sites will be coordinated to ensure that Cornwall Site cleanup does not preclude any remedial actions that may be selected for the R.G. Haley site, and vice versa.

In order to conduct a complete and comprehensive evaluation of Site environmental conditions, all detected compounds having concentrations above the SLs established for this Site are presented herein as COPCs. COPCs have been identified based on a comparison of detected constituents in Site groundwater, soil, and sediment samples to the Site SLs presented in Section 5.0 (Development of Site Screening Levels). Constituents exceeding the Site SLs in one or more of the samples have been identified as COPCs with one exception. Because samples for total metal analyses are not filtered, there is potential for soil particulates containing metals to be entrained in these water samples. As a result, total metal concentrations may not be representative of actual groundwater conditions. Therefore, metals with total concentrations in groundwater exceeding the Site SL, but with dissolved concentrations in groundwater below the Site SL, were not identified as COPCs.

The constituents detected in soil at the Site during RI activities are presented in Table 6-1 and the constituents detected in groundwater are presented in Table 6-2. The results of an underwater survey of sediment conditions at the Site are presented in Table 6-3 and the results of chemical analyses of sediment samples are presented in Tables 6-4 and 6-5. Laboratory analytical results are provided in Appendices C, D, and E. The constituents detected in soil on the R.G. Haley site near the overlap area with the Site are presented in Table 6-6 and the analytical results for the interim action material placed on the Site are presented in Table 6-7. The constituents exceeding the Site SLs, the apparent source of the constituent (if other than this Site), and the media containing the exceedance are listed below:

Soil

- Refuse and wood waste
- Metals (copper, chromium, , mercury, nickel, and zinc)
- Dioxins/furans in stabilized sediment stockpiled on the Site
- SVOCs (BEP, di-n-butyl phthalate, and n-nitrosodiphenylamine)
- (R.G. Haley) – PAHs (cPAHs and naphthalenes)
- (R.G. Haley) –PCP
- (R.G. Haley) – Diesel-, and oil-range petroleum hydrocarbons
- (R.G. Haley) – Dioxins/furans in cover soil.

Groundwater

- Metals (copper and lead)
- Conventionals (manganese, fecal coliform, and NH_3 – ammonia)
- PCBs
- (R.G. Haley) – PAHs (cPAHs and naphthalene)
- (R.G. Haley) – Diesel- and oil-range petroleum hydrocarbons

Sediment

- PCBs
- Metals (copper, silver, lead, mercury, and zinc)
- SVOCs (BEP, dimethylphthalate)
- (Whatcom Waterway) – Mercury

6.2 SOIL QUALITY

As previously mentioned, except for the soil investigation conducted in 2004 by Aspect Consulting and the soil samples collected by GeoEngineers during RI activities conducted for the adjacent R.G. Haley cleanup site, the quality of Site soil was not evaluated through chemical analyses during the RI. Instead, as described in Section 5.5 (Soil Screening Levels), it is assumed that refuse poses a threat to human health or the environment through direct contact or release to the environment, and will be addressed in general accordance with regulatory requirements for solid waste landfills. As such, the extent of refuse and wood waste is the primary basis for delineating the extent of Site soil contamination, as discussed in Section 6.2.1 (Extent of Refuse and Wood Waste).

The majority of soil chemical analyses were conducted on samples collected from the portion of the Site affected by releases from the R.G. Haley site, and the majority of soil SL exceedances are associated with petroleum hydrocarbons and other wood treating-related chemicals. The extent of petroleum contamination at the Site (based on the visual presence of sheen) is presented in the soil quality section of this report because it was primarily characterized as part of the test pit and soil boring exploration program conducted during the supplemental RI rather than the groundwater characterization element. Discussion regarding the impact of petroleum hydrocarbon-impacted soil on groundwater is generally discussed in Section 6.2.2 (Extent of Petroleum Hydrocarbon Contamination) and petroleum hydrocarbon impacts on groundwater quality are discussed in greater detail in Section 6.3.1 (Overlap Area Groundwater Quality).

Chemical analytical results for COPCs in soil unrelated to petroleum hydrocarbons, including wood treating chemicals associated with releases from the R.G. Haley site, are discussed in Section 6.2.3 (Non-Petroleum Hydrocarbon Soil Analyses).

6.2.1 Extent of Refuse and Wood Waste

The extent of exposed refuse in the upland portion of the Site was evaluated during the expanded Site investigation and the focused RI. During these investigations, no exposed refuse was observed at the surface of the upland portion of the Site. The extent of *in situ* landfill refuse and wood waste in the upland portion of the Site was estimated from the interpretation of boring logs and test pits. The approximate limits of *in situ* landfill refuse, the observed thickness at boring and test pit locations, and the approximate depth to the base of refuse are shown on Figure 6-1.

Based on the estimated areal extent and thickness of refuse, the total volume of refuse in the upland portion of the Site is estimated to be about 215,000 yd^3. Approximately 80,000 yd^3 of refuse is estimated to be present in the marine portion of the Site, as discussed in Section 6.4 (Sediment Quality).

As indicated on Figure 6-1, the approximate upland boundary of landfill refuse extends from the northwestern side of the former main GP warehouse to the northwestern side of the former buildings on the R. G. Haley site. Although other types of fill material such as sawdust, wood debris, and soil are present, no landfill refuse has been observed beyond this lateral boundary. Approximately 7.2 acres of the upland area are located within the landfill refuse boundary. The thickness of landfill refuse in the upland portion of the Site generally increases toward Bellingham Bay, with a maximum observed refuse thickness of 38 ft at Dames & Moore boring location 5. Although this location is outside the limits of what is generally considered upland, the thickness of refuse at this location likely provides a good estimate of the maximum refuse thickness for the upland portion of the Site, near Bellingham Bay. The depth to the base of refuse in the upland portion of the Site generally ranges from 8 to 40 ft BGS.

The estimated thickness of wood waste (including sawdust and wood debris) is also presented on Figure 6-1. The wood waste is often comingled with refuse and was observed throughout most of the Site including the area north of the former GP warehouse, farther inland than refuse was observed. In this area, wood waste thickness is variable, ranging from not present to a thickness greater than 16 ft. The total volume of wood waste in the upland portion of the Site is estimated to be about 94,000 yd^3. The volume of wood waste in the marine portion of the Site was not estimated because data regarding wood waste thickness in this area are limited and the difficulty in differentiating between wood waste originating from Site releases and other sources in the marine environment.

Landfill cover thickness generally ranges between 2 and 5 ft, as shown on Figure 6-2. Landfill cover generally consists of granular material (sand and gravel), wood debris from log decking operations, occasional patches of cobble ballast, and limited areas of asphalt paving. In addition to the existing landfill cover depicted on Figure 6-2, a significant portion of the uplands area containing refuse is now under the cover of the interim placement material and liner, as described in Section 6.2.4 (Interim Action Low Permeability Material).

6.2.2 Extent of Petroleum Hydrocarbon Contamination

Petroleum hydrocarbon soil contamination in the diesel and oil ranges detected at the Site appears to be associated with the adjacent R.G. Haley cleanup site to the north. The extent of petroleum hydrocarbon contamination was delineated based on visual observations during the supplemental RI and the results of soil quality data collected by others (Aspect Consulting and GeoEngineers), and groundwater quality monitoring data [discussed in Section 6.3 (Groundwater Quality)]. For the purposes of this RI, petroleum hydrocarbon results are discussed by petroleum product fractions (gasoline-, diesel-, or oil-range) for clarity because the diesel-range fraction is the dominant fraction detected.

A total of 22 soil samples collected from the petroleum hydrocarbon-affected area by Aspect Consulting and GeoEngineers were tested for petroleum hydrocarbons. Additionally, over 30 test pits, borings, and monitoring wells were completed in this area that were used in evaluating the extent of petroleum hydrocarbon sheen. Results for constituents detected in the Aspect Consulting and GeoEngineers soil samples are summarized in Table 6-1 and compared to the soil SLs. A complete summary of analytical results for the Aspect Consulting soil samples is provided in Appendix C.

As indicated on Figure 6-3, the extent of the visibly-impacted soil covers a large area, and its distribution is consistent with groundwater quality results. The majority of this area is to the north and east of the landfill boundary, and hydraulically upgradient or cross-gradient, although it extends a significant distance south of the boundary between the two sites to the east of the refuse. It should be noted that Figure 6-3 does not show the full extent of impacted soil on the R.G. Haley site because the intent is to show where impacted soil is contiguous between the two sites, and not to show the full extent of soil contamination on the R.G. Haley site.

A review of the petroleum hydrocarbon analytical results in Table 6-1 indicates that diesel-range petroleum hydrocarbons are the dominant hydrocarbon range present in the area affected by the R.G. Haley site. Diesel-range petroleum hydrocarbons were detected above the SL in six of eight borings from which soil samples were tested for petroleum hydrocarbons in the petroleum hydrocarbon-affected area, and oil-range petroleum hydrocarbons were detected above the SL in three of eight borings. Gasoline-range petroleum hydrocarbons samples were detected above the SL in two of three soil borings from which soil samples were tested for this petroleum hydrocarbon range within the petroleum hydrocarbon-affected area, although the ratio of gasoline-range to diesel-range concentrations suggest that the gasoline-range detections may be associated with the lower molecular weight fraction of the diesel-range contamination rather than a gasoline release.

An isolated area of nonaqueous product was observed in the central portion of the Site, near the northern corner of the former main GP warehouse that appears to be unrelated to the sheen observed in the northeastern portion of the Site. During the supplemental RI, a black, highly viscous liquid that had a similar appearance to Bunker C fuel oil was observed at RITP-12. The material was 2 to 4 inches thick and was contained within a wood structure located above the water table at about 4 ft BGS. The excavation exposed a portion of the wooden structure about 3 ft by 3 ft. The extent of the wooden structure was unknown because it was left intact and backfilled with the excavated materials. A sample of the black liquid was collected and allowed to sit overnight in an open container under a vented hood. By the next morning the liquid had dried to a hard, brittle material that appeared to be a plastic. As such, the black viscous material does not appear to be a petroleum hydrocarbon product and its composition is unknown.

It should also be noted that minor sheen associated with refuse solids, rather than the petroleum hydrocarbon contamination associated with the R.G. Haley site, was encountered during the RI and previous investigations in some wells and test pits. In some instances, the sheen appeared to be biogenic and not associated with petroleum hydrocarbons. These locations were not included within the petroleum hydrocarbon sheen area delineated on Figure 6-3, but are bounded by the groundwater monitoring wells installed during the supplemental RI, as discussed in Section 6.3 (Groundwater Quality).

As previously discussed, the source of the petroleum hydrocarbon impact in the northern portion of the Site does not appear to be related to Site releases. Petroleum hydrocarbon contamination is contiguous with the petroleum hydrocarbon contamination found on the southern portion of the R.G.

Haley site. As shown on Figure 4-11, current groundwater elevation data indicate that the groundwater flow direction in the petroleum hydrocarbon-affected area is primarily to the west, which does not have as much of a southerly direction of flow as the distribution of the petroleum hydrocarbon contamination would suggest. However, petroleum hydrocarbon contamination releases likely occurred over decades of operation, and historical groundwater flow in the northeast corner of the Site was likely very different during operation of the R.G. Haley facility. The wood treating wastewater seepage pit where wood treating wastes were discharged was located near the northeast corner of the Site, which would have caused a groundwater mound near the boundary between the two sites, resulting in a more southerly direction of groundwater flow in this portion of the Site, as well as discharge of wood treating wastes to the south onto the Site.

It is also important to note that the Bellingham Bay shoreline was historically located much farther to the east prior to landfilling operations. Petroleum hydrocarbon contamination in LNAPL form tends to spread out laterally along the shoreline in tidally influenced groundwater flow systems. This migration pathway would likely have resulted in southerly direction to LNAPL migration from the R.G. Haley site onto the Site during historical shoreline conditions. A detailed evaluation of the nature and extent of contamination associated with the R.G. Haley site will be conducted in a forthcoming R.G. Haley-specific RI/FS.

6.2.3 Non-Petroleum Hydrocarbon Soil Analyses

This section describes the analytical results for soil samples collected at the Site for analyses other than petroleum hydrocarbons. These analyses include metals, BTEX, PAHs, SVOCs, and PCBs. Some of these analytes appear to be related to releases associated with wood treating activities at the R.G. Haley site (e.g., PCP and cPAHs) and other analytes are reflective of soil/refuse quality. Analytical results for soil samples collected on the R.G. Haley site near the overlap area between the two sites are presented in Table 6-6 to provide a basis for better correlating those COPCs that originate from the R.G. Haley site. Wood treating and non-wood treating analytes are discussed separately below.

As shown in Table 6-6, PAHs, including cPAHs, in conjunction with diesel-range petroleum hydrocarbons, are indicative of releases from the R.G. Haley site. In addition, dioxins/furans were detected in concentrations as high as 98,550 nanograms per kilogram (ng/kg) on the R.G. Haley site. PCP was not detected in any Site soil samples collected from locations outside of the petroleum hydrocarbon-affected area shown on Figure 6-3. cPAHs above the soil SL were detected at one location (AF-SB02) outside of the petroleum hydrocarbon-affected area, but cPAHs are ubiquitous in the environment so its presence at the Site is not considered anomalous.

Analytes detected in Site soil at concentrations exceeding the soil SLs that appear to be unrelated to releases from the R.G. Haley site include certain heavy metals (chromium, copper, mercury, nickel, lead, and zinc). However, the Site soil SLs for heavy metals are all driven by the protection of surface water, and with the exception of copper, the groundwater SLs were not exceeded in groundwater samples considered representative of Site groundwater quality [see Section 6.3 (Groundwater Quality)]. The only SVOC detected above the soil SLs that does not appear to be associated with R.G. Haley releases is a single exceedance of the n-nitrosodiphenylamine at AF-MW-02. No BTEX or PCB analytes were detected above the Soil SLs.

6.2.4 Interim Action Low Permeability Material

As described in Section 3.7 (Interim Action), an interim action was implemented to store fine-grained sediment at the Site which could potentially be used for cap or sub-cap material during future cleanup at the Site, and which significantly reduces the amount of surface water infiltrating through the soil cover where it could contact landfill refuse and then discharge to Bellingham Bay.

Three sediment samples were collected prior to dredging to characterize the sediment for possible open water disposal and five samples of stabilized sediment were collected from the interim placement areas. The pre-dredging samples were tested for heavy metals, TBT, SVOCs, pesticides, PCBs, dioxins/furans, and conventional parameters, and the stabilized sediment samples were analyzed for dioxins/furans. The results for detected constituents are summarized in Table 6-7. Sample locations from the interim placement areas are shown on Figure 3-2.

No TBT, PCBs, or pesticides were detected in the pre-dredging sediment samples. One non-PAH SVOC (BEP) was detected at a concentration below the soil SL. A number of heavy metals were detected at concentrations above the soil SLs based on protection of groundwater, but the concentrations are similar to those detected in Site soil/refuse that do not appear to have impacted groundwater quality. A number of PAHs were detected in the pre-dredging sediment samples. The concentrations of two cPAHs [benzo(a)anthracene and chrysene] were above the soil SL, but the toxicity equivalency (TEQ) value for the sample with those detections remains below the SL. The concentration of dioxins/furans in the pre-dredging samples ranged from 6.2 to 27.3 ng/kg TEQ and averaged 14.7 ng/kg, which slightly exceeds the soil SL of 11 ng/kg. The dioxin concentrations for the stabilized sediment samples ranged from about 9.5 to 21.9 ng/kg TEQ and averaged 13.9 ng/kg. These results demonstrate that the dioxin/furan concentrations for the stabilized sediment samples are consistent with the dioxin/furan concentrations for the pre-dredge sediment samples.

6.3 GROUNDWATER QUALITY

For the purposes of this report, groundwater quality is categorized and discussed below in terms of location relative to the Site. Section 6.3.1 (Overlap Area Groundwater Quality) discusses groundwater quality in the overlap area between the R.G. Haley site and the Site in the northeast portion of the Site. Section 6.3.2 (Site Interior Groundwater Quality) discusses groundwater quality in the interior portion of the Site outside of the overlap area, and Section 6.3.3 (Downgradient Perimeter Groundwater Quality) discusses groundwater quality at the downgradient perimeter of the Site near the point of groundwater discharge to Bellingham Bay. Section 6.3.3 (Downgradient Perimeter Groundwater Quality) also discusses the results of groundwater seep sampling, which provides additional groundwater quality data at the point of groundwater discharge to surface water during low tide. However, the shoreline monitoring wells installed in 2012 are primarily relied upon for evaluation of groundwater quality near its point of discharge to surface water.

Concentrations of constituents detected in groundwater samples from monitoring wells on the Cornwall property are provided in Table 6-2. Concentrations of constituents detected in groundwater samples collected from monitoring wells located on the R.G. Haley site near the property line separating the R.G. Haley and Cornwall properties are presented in Table 6-8. Figures 6-3, 6-4, and 6-5 provide plan views of the Site with the concentrations of petroleum hydrocarbons, NH_3-ammonia, and manganese plotted for all wells that have been tested for these constituents during RI activities.

6.3.1 OVERLAP AREA GROUNDWATER QUALITY

This section describes groundwater quality observed in the overlap area portion of the Site, where groundwater quality appears to be primarily impacted by the adjacent R.G. Haley site. Monitoring wells MW-1, MW-5, MW-6, CL-MW-101, CL-MW-102, CL-MW-103, CL-MW-1S, CL-MW-1D, CL-MW-1H, and AF-MW-02 are located in the overlap area portion of the Site, as indicated on Figure 6-3.

Groundwater samples from this portion of the Site were analyzed for diesel- and oil-range petroleum hydrocarbons (each well); PAHs and SVOCs (each well except CL-MW-1D); BTEX (MW-1, MW-5, MW-6, and HS-MW-7); VOCs (AF-MW-02); PCBs (MW-1 and MW-5); and fecal coliform (MW-1, MW-5 and MW-6). Investigations in this area have focused on these constituents based on the elevated concentrations observed during sampling in 1996 and 1998. Although the groundwater appears significantly impacted by releases of petroleum and other hydrocarbons, it is assumed that since groundwater in this area is in contact with refuse, it is also likely impacted by elevated concentrations of ammonia, manganese, and other leachate compounds.

The concentration of diesel-range petroleum hydrocarbons detected was above SLs at each of the groundwater monitoring locations sampled in this area, except at MW-1 and MW-5. The concentration of oil-range petroleum hydrocarbons detected was above the SL at MW-1, CL-MW-1S, and CL-MW-1D. Fecal coliform was detected above the SL at MW-5. PAHs were detected above the SL at CL-MW-1S, CL-MW-101, CL-MW-103, CL-MW-6, and CL-MW-1H. Other monitored parameters were below the SLs. The following paragraphs summarize the results of groundwater analyses for this area.

Detected diesel-range petroleum hydrocarbons in this area ranged in concentration from 740 to 41,000 micrograms per liter (μg/L) and detected oil-range petroleum hydrocarbons ranged in concentration from 500 to 104,000 μg/L. The SL for diesel- and oil-range petroleum hydrocarbons is 500 μg/L, as discussed in Section 5.4 (Groundwater Screening Levels). As shown on Figure 6-3, the concentrations of these petroleum hydrocarbon-related constituents are higher in this portion of the Site than elsewhere at the Site and the only portion of the Site where the petroleum hydrocarbon concentrations exceeded the SLs, which is consistent with the documented release of nonaqueous phase liquid and dissolved-phase petroleum hydrocarbon contamination from the adjacent R.G. Haley site. Trace LNAPL was observed in samples collected from CL-MW-1S, which is the probable cause of the more elevated diesel-range petroleum hydrocarbon concentrations at this location. As evidenced in the monitoring results plotted on Figure 6-3 and discussed in Sections 6.3.2 (Site Interior Groundwater Quality) and 6.3.3 (Downgradient Perimeter Groundwater Quality), concentrations of these constituents decrease with distance from this area, and are mostly below laboratory reporting limits at the downgradient perimeter of the Site uplands. Additionally, petroleum hydrocarbon sheen was consistently observed in explorations completed in this area.

The oil-range petroleum hydrocarbon SL was only exceeded at one location (CL-MW-1) in both the deep and shallow wells at that location. Oil-range petroleum hydrocarbons were detected above the SLs in four of five samples collected from CL-MW-1S, and in one of five samples collected from CL-MW-1D. The oil-range petroleum hydrocarbon concentration at CL-MW-1D (580 μg/L) only slightly exceeded the SL of 500 μg/L. The oil-range petroleum hydrocarbon concentrations at CL-MW-1S were all quite elevated, with the highest detected concentration of 104,000 μg/L. The diesel-range petroleum hydrocarbon concentrations at CL-MW-1S were also quite elevated, and both diesel- and oil-range concentrations at this location appear to be associated with the presence of LNAPL in the CL-MW-1S samples. Oil-range petroleum hydrocarbon concentrations are shown on Figure 6-3, and indicate a more limited distribution than diesel-range petroleum hydrocarbons, which is consistent with a more limited source and lower migration potential in both LNAPL and dissolved form.

PCP was detected multiple times in MW-6, at a maximum concentration of 78.5 μg/L. PCP detections from other wells on the Site were below the SL of 10 μg/L. The highest concentration of PCP detected in groundwater monitoring wells on the R.G. Haley property was 1,350 μg/L at TL-MW-10.

The concentration at MW-6 is significantly higher than other detections on the Site, and based on these data and the location of MW-6 relative the R.G. Haley site, the limited PCP groundwater contamination present in the overlap area appears to be related to releases from the adjacent R.G. Haley site.

PAHs were detected above the SL in groundwater samples from CL-MW-1S, Cl-MW-101, CL-MW-103, CL-MW-6, and CL-MW-1H on the Site. At CL-MW-6 and CL-MW-1S, the total cPAH (TEQ) concentration exceeds the Site SL of 0.018 µg/L. The PAH detections are consistent with the petroleum hydrocarbons confirmed in groundwater in this area, and with the analytical results of the LNAPL sample, as discussed below. The presence of PAHs is also consistent with groundwater analytical results for the R.G. Haley site, which also exhibited the detection of several PAHs, including cPAHs, as indicated in Table 6-8. These results are consistent with the R.G. Haley site being the source of PAH groundwater contamination detected in Site groundwater.

In addition to the groundwater samples, the LNAPL collected from the water table in test pit RITP-7, also located upgradient of the landfill refuse, was tested for PAHs, PCBs, BTEX, and diesel- and oil-range petroleum hydrocarbons. The LNAPL that was observed over most of the petroleum hydrocarbon-impacted area during the Supplemental RI was limited to a thin sheen. The LNAPL accumulation on the water table (about 0.25 inch) in test pit RITP-7 was sufficient to allow collection of a sample. As indicated in Table 6-9, the LNAPL sample was 99 percent (990,000 mg/kg) diesel, which is consistent with the individual compounds detected in the LNAPL sample. A number of short chain PAHs, ethylbenzene, and xylenes were detected in the LNAPL sample, all of which are present in diesel fuel. PCBs were not detected in the LNAPL sample.

Dioxins/furans were detected at CL-MW-101 during an investigation conducted by GeoEngineers in 2012 for the R.G. Haley site at a total dioxin/furan TEQ of 0.004 nanograms per liter [ng/L, or parts per trillion (ppt)], as summarized in Table 6-2. Based on the detected concentration being very low, and the extremely low solubility of dioxins and furans in water, detections of dioxins and furans are potentially due to minute amounts of dioxin-containing soil particles being entrained in the groundwater sample, rather than actual dissolved concentrations. The field measurement of turbidity in this groundwater sample was reportedly 7.2 nephelometric turbidity units (NTUs). Although this turbidity measurement is not excessively high, it does suggest that soil particles were present and given the low detection and reporting limits achieved for dioxin and furan analysis, may impart a high bias to the sample result. Dioxins/furans were detected in groundwater from the R.G. Haley site near the overlap area between the sites at HS-MW-10 (which is located in approximately the same location as the more recently installed HS-MW-19) at a concentration of 0.117 ng/L, as presented in Table 6-8. Based on these data, dioxin/furan groundwater contamination, if not an artifact of the sampling process, appears to result from the R.G. Haley site.

Fecal coliform was detected in the sample collected from MW-5 at 19,000 colony forming unit per one hundred milliliter (CFU/100 mL), which is significantly above the Site SL of 14 CFU/100 mL. The source of elevated fecal coliform detected at MW-5 is unknown. It is not clear whether the GP warehouses or the R.G. Haley site were served by sanitary sewer. Discussions with City personnel indicate that available City drawings do not show a sanitary sewer connection to either the R.G. Haley site or the GP warehouse facilities, and that a sewer trunk line is not present in close proximity to the Site. However, GP paid for sewer service which suggests that service was provided but the connection is not documented. As described in Section 4.1.2.3 (Pre-Demolition Stormwater Management System), a structure that appeared to be a septic tank was encountered during excavation of test pit RITP-6, located just east of MW-5. Leakage from a septic tank or sanitary sewer conveyance line would be a likely source for the elevated fecal coliform detections in the groundwater sampled from MW-5. As indicated in Section 4.1.2.3 (Pre-Demolition Stormwater Management System), the biogenic conditions encountered in the stormwater drainage system near MW-5 also suggest the possible impact from a septic tank or sewage conveyance line leakage or failure. Although the source of upgradient fecal coliform is unknown, it appears to be unrelated to the former landfilling activities associated with the Site. Because the GP warehouse and other former Site structures have been demolished, and the Site is currently vacant, it is unlikely that ongoing releases of sewage, or other potential anthropogenic sources of fecal coliform, are occurring.

6.3.2 Site Interior Groundwater Quality

For the purposes of this report, we discuss groundwater quality conditions for this portion of the Site in terms of being upgradient of the shoreline wells and downgradient of the overlap area. During the natural degradation of both refuse and wood in the subsurface, oxygen is consumed and reducing conditions are created while the soil microbes break down the organic content in both refuse and wood. Under reducing conditions, some metals, which might otherwise be bound within the soil matrix, become mobile in the dissolved phase. Manganese and iron are metals commonly found in soil that become soluble when reduced and thus would be anticipated to be present in groundwater at the Site. Groundwater within the landfill refuse may be additionally impacted by contaminants that were disposed of with the refuse leaching into groundwater.

Site interior groundwater quality was evaluated based on data from monitoring wells MW-3, MW-4, MW-7 through MW-10, and AF-MW01. Figure 2-1 shows the locations for each of these monitoring wells. It should be noted that evaluation of Site groundwater quality was primarily focused on evaluated groundwater quality near the point of groundwater discharge to surface water, and in evaluating the extent of petroleum hydrocarbon impact in the overlap area. As a result, groundwater quality data for the interior portion of the Site is limited, which is reflected in the limited discussion presented in this section.

Groundwater monitoring wells in the interior of the Site were sampled during one or more of the following sampling events: 1) 1998 during the focused RI, 2) 2002 as part of the supplemental RI, 3) 2004 as part of the Phase II environmental site assessment for GP, and 4) 2004, 2005, and 2012 as part of the R.G. Haley site RI. Groundwater samples collected in this area have been analyzed for diesel- and oil-range petroleum hydrocarbons and VOCs (each well, except MW-4), dissolved metals (AF-MW01), PAHs and SVOCs (AF-MW01 and MW-7), and PCBs and fecal coliform (each well except AF-MW01). Analytical results for these wells are presented in Table 6-2.

Petroleum hydrocarbons in the diesel and oil ranges were only detected above the reporting limit at interior well MW-7, where diesel was detected at 409 µg/L. This location is downgradient from the overlap area, so the detection is consistent with upgradient groundwater quality. BTEX components were not detected in any of the samples tested for BETX or VOCs. However, a number of gasoline-related VOCs were detected at low concentrations in the sample collected from AF-MW-02, which is on the edge of the overlap area. Based on the gasoline-related VOC analytical results, it does not appear that significant releases of gasoline-range petroleum hydrocarbons occurred at the Site.

At AF-MW01, arsenic and nickel were detected below SLs, iron was significantly elevated but does not have an associated SL, and manganese was elevated above the SL of 100 µg/L. Iron and manganese concentrations are commonly associated with refuse and wood waste sites due to the reduced groundwater oxidation state typically associated with these types of waste. As a result, elevated iron and manganese groundwater concentrations are consistent with Site usage.

PAHs and SVOCs were below reporting limits at most locations, and where it was detected, concentrations were below the SLs at all interior wells.

PCBs were not detected in the groundwater samples collected from interior wells MW-3, MW-8, MW-9, and MW-10. PCBs were detected at a concentration of 0.053 µg/L in a sample collected from MW-7, which is above the total PCB SL of 0.025 µg/L. The detection of Aroclor 1254 in the sample from MW-7 may be an artifact of the sample turbidity (50 NTUs), and as such, may be biased high. This conclusion is supported further by the absence of Aroclor 1254 detections in groundwater samples collected from MW-8 and seep sampling device RIS-1, both of which are located downgradient of MW-7. These considerations strongly suggest that the PCB detection in MW-7 is not the source of PCBs detected in the surface sediment.

The fecal coliform concentration detected in the sample collected from MW-4 (820 CFU/100 mL) is significantly above the site SL of 14 CFU/100 mL, but lower than the detections at MW-5 discussed in Section 6.3.1 (Overlap Area Groundwater Quality). The source of the elevated fecal coliform level at this location is unknown, but may be attributed to the accumulation of bird fecal matter on the ground surface near the well. The main GP warehouse also had a significant accumulation of bird fecal matter on the roof and stormwater run-off from the roof likely contributes to groundwater recharge in the MW-4 vicinity. Fecal coliform was also detected in a sample collected from MW-10 at a concentration of 41 CFU/100 mL, which is above the SL of 14 CFU/100 mL. A specific source for the fecal coliform detection at MW-10 has not been identified. However, it could be attributed to the same source causing the high fecal coliform detections at MW-5, given the relative position of these wells, direction of groundwater flow, and the highly elevated level of fecal coliform detections in MW-5. It is unlikely that the fecal coliform detections are associated with landfill activities since fecal coliform bacteria could not survive in the subsurface for the 40+ years that have elapsed since the landfill was closed.

6.3.3 DOWNGRADIENT PERIMETER GROUNDWATER QUALITY

Groundwater quality near the point of groundwater discharge to surface water was evaluated based on seep and monitoring well data collected during several Site investigations. Section 6.3.3.1 (Downgradient Perimeter Groundwater Seep Quality) provides a summary of previous groundwater seep characterization results. Groundwater seep characterization data were collected during a number of Site investigations, but only the data collected during the 2002 Supplemental RI are discussed because these samples are considered the least affected by particulates (turbidity), and as a result the most representative. Section 6.3.3.2 (Downgradient Perimeter Groundwater Quality) provides a summary of groundwater quality as evaluated during the 2012 supplemental groundwater investigation. This investigation provides the most comprehensive characterization of groundwater at the Site and based on the close proximity to the discharge to surface water (point of compliance), provides the most relevant data for assessing the Site's impact on human health and the environment.

Because the seep sampling data were collected more than 10 years ago and were not collected from conventional monitoring devices, the 2012 groundwater monitoring well data are considered more representative of Site groundwater quality conditions, and are the primary data relied upon for evaluation of Site groundwater quality near its point of discharge to surface water. However, the monitoring wells installed for the 2012 groundwater investigation were installed at least 20 ft from the shoreline, and water level and specific conductance data from these wells indicate very limited interaction between the monitoring wells and marine surface water. Because hydrodynamic dispersion in close proximity to a tidally influenced shoreline tends to influence the concentration of constituents dissolved in groundwater prior to entry into the surface water body, the groundwater data from the 2012 monitoring wells represents a conservatively high estimate of COPC concentrations at the point of entry to surface water.

6.3.3.1 Downgradient Perimeter Groundwater Seep Quality

Groundwater seep quality was evaluated during Ecology's initial Site investigation in 1992, the expanded Site investigation in 1996, the focused RI in 1998, and the supplemental RI in 2002. Sample results from each of the seep sampling events are presented in Table 6-2. Samples collected from groundwater seeping from the uplands into the marine waters at the shoreline provide an opportunity to characterize groundwater at the location where groundwater discharges to Bellingham Bay. However, flow conditions and contaminant concentrations from groundwater seeps likely vary with time, season, and the complex interaction between the tide and groundwater. Based on these interactions, the analytical data from seep samples may not represent best-case or worst-case conditions, but some intermediate point in the range of concentrations. Seep sampling was conducted during low tide, in order to increase the probability that samples represent worst-case conditions, and dilution from marine water is limited.

Seep sampling methods were improved during each successive investigation to reduce the level of turbidity in the seep samples; high turbidity generally results in analytical results that are biased high for those constituents that tend to partition to soil, which is apparent in the data collected in Ecology's initial 1992 investigation (seep samples E-1 through E-4), the 1996 expanded Site investigation (seep samples S-1 through S-3), and the focused RI (seep samples S-1 through S-3). As a result, the evaluation of groundwater seep quality from the two rounds of sampling conducted during the 2002 supplemental RI (seep samples RIS-1 through RIS-3), the most recent seep sampling events, are assumed to best represent groundwater seep quality and form the basis of the discussion below.

Groundwater seep samples were analyzed for total and dissolved metals, petroleum hydrocarbons, PCBs, cyanide, fecal coliform, ammonia, and additional conventional and field parameters.

During the 2002 supplemental RI, total copper exceeded the SL in one of two samples collected from each of the three sampling locations (RIS-1, RIS-2, and RIS-3), with a maximum concentration of 7 µg/L compared to the SL of 2.4 µg/L. The copper SL was only exceeded in one of the two dissolved copper samples collected from RIS-2 during the Supplemental RI, and the detected concentration of 5 µg/L was only slightly greater than the copper SL.

No SVOCs (including PAHs) were detected above the site SLs during early investigation phases, and as a result, SVOCs were not tested for during the supplemental RI. Similarly, most conventional parameters were not tested for following the early Site investigation phases, except as discussed below for cyanide, fecal coliform, and nonionic ammonia (NH_3-ammonia).

Groundwater seep sample RIS-3 obtained during the first monitoring event of the supplemental RI (July 17, 2002) was the only sample from either sampling event in which total cyanide was detected at a concentration above the laboratory reporting limit. The detected concentration was 0.008 mg/L, which is significantly below the SL of 16 mg/L.

Fecal coliform was not detected in any of the seep water samples collected during the supplemental RI, but was detected in concentrations up to 300 CFU/100 mL in a number of samples collected during previous investigations. The variability in fecal coliform concentrations suggests that there is not a continuous source, which supports the conclusion that the presence of fecal coliform in seep samples is related to the presence of bird droppings or marine mammals along the shoreline, which are transitory in nature.

NH_3-ammonia was detected in all groundwater seep water samples collected during both monitoring events of the supplemental RI at concentrations ranging from 0.036 to 0.060 mg NH_3/L, which exceed the SL of 0.035 mg NH_3/L. However, these concentrations are significantly lower than the NH_3-ammonia concentrations up to 0.636 mg NH_3/L detected in the 2012 groundwater monitoring event, which supports the conclusion that hydrodynamic dispersion is reducing the concentrations of COPCs as groundwater migrates towards its point of discharge to surface water.

PCB Aroclor 1242 was detected in the groundwater seep samples collected from RIS-1 and RIS-2 in the second supplemental RI monitoring event at concentrations of 0.14 and 0.16 μg/L, respectively. There is no Site SL for Aroclor 1242, but both concentrations slightly exceed the total PCB site SL of 0.1 μg/L.

The absence of Aroclor 1242 detections in any of the groundwater monitoring well samples tested for PCB and the trace detections in two of six groundwater seep samples collected during the supplemental RI suggest that the detected Aroclor 1242 concentrations in sediment samples are not the result of groundwater discharge from the Site. Aroclor 1242 was previously detected in a sediment sample collected from the RIS-2 vicinity during the expanded Site investigation. PCB detections in groundwater seep samples may be the result of particulates entrained in the samples. Even though suspended solids concentrations were relatively low at 6.6 mg/L and 6.3 mg/L for RIS-1 and RIS-2, respectively, a minor amount of suspended solids would cause a significant increase in the detected Aroclor 1242 concentrations in a water sample.

Diesel- and oil-range petroleum hydrocarbons were tested for in groundwater samples collected from groundwater seep sample location RIS-1 and RIS-2 during the supplemental RI due to their location downgradient from the upland petroleum hydrocarbon contamination in the northeastern area of the Site, but petroleum hydrocarbons were not detected in these samples. These results indicate that the petroleum hydrocarbon-contaminated soil in the northeastern portion of the Site does not appear to be affecting groundwater quality at the point of discharge to surface water.

Both field and laboratory turbidity measurements were obtained for the seep samples collected during the supplemental RI (RIS-1, RIS-2, and RIS-3 locations). The laboratory turbidity values were significantly higher than the not detected field measurements for these samples. The reason for this discrepancy is not known, but likely results from a calibration or sensor failure of the field equipment. As a result, the laboratory turbidity measurements should be relied on for evaluating turbidity of the seep samples collected during the supplemental RI.

Based on the results of groundwater seep sampling, only ammonia, manganese, copper, and perhaps PCBs were considered to be present at elevated concentrations. Previous rounds suggested that other analytes might also be present at elevated concentrations, including gross beta radioactivity, phenols, and phthalates. Gross beta radioactivity appears to result from the presence of naturally occurring radioactive potassium present in marine surface water, and analytes such as phenols and phthalates appear to result from elevated turbidity present in the earlier seep sampling rounds.

6.3.3.2 Downgradient Perimeter Groundwater Quality

During a supplemental RI investigation conducted in 2012, two rounds of groundwater sampling were conducted for six shallow and deep monitoring well pairs (MW-11S, D through MW-16S, D). The locations of these monitoring wells are shown on Figure 2-1. Groundwater samples collected during these sampling events were analyzed for dissolved metals, VOCs, SVOCs, herbicides, pesticides, tannins and lignins, TPH-HCID with follow up analyses for detected hydrocarbon ranges, conventional parameters, and typical field parameters.

This supplemental investigation was the most complete groundwater quality monitoring conducted at the Site based on the comprehensive list of analyses, and the number and location of the wells. As such, data collected during these two sampling events represent the best characterization of groundwater near the point of discharge to Bellingham Bay. Because these wells are all located at least 25 ft from the shoreline, the concentrations detected in groundwater samples collected from these wells provide a conservatively high estimate of COPC concentrations that discharge to surface water. Groundwater data from other wells near the shoreline (MW-2, MW-3, and MW-8) also provide additional characterization of downgradient groundwater quality at greater distance from the shoreline. The analytical results for these wells are presented in Table 6-2.

The results of the two sampling events in 2012 were similar. Also, the water quality is fairly uniform across the length of the landfill perimeter and at the two sampled depth intervals (shallow and deep). The sampling events indicate only two constituents, manganese and NH_3-ammonia, are consistently above SLs. One additional exceedance was observed in the groundwater sample from MW-11S during the July 2012 event. The concentration of dissolved copper at this location was

2.6 µg/L, which is just above the SL of 2.4 µg/L. During the subsequent sampling event in September 2012, the detected concentration of dissolved copper was 0.9 µg/L, which is below the SL.

Herbicides and pesticides were not detected during either of the two sampling events. Except for the copper detection discussed above, the detected concentrations of dissolved metals were below SLs.

Gasoline-, diesel-, and oil-range petroleum hydrocarbons, and VOCs were below SLs. A single detection of gasoline-range petroleum hydrocarbons (330 µg/L) at MW-13D and a single detection of diesel-range petroleum hydrocarbons (200 µg/L) at MW-15S were the only petroleum hydrocarbon detections in the shoreline monitoring wells. Both of these detections occurred in the first round of monitoring and concentrations were below reporting limits in the second round of monitoring. Based on these results, and the lack of petroleum hydrocarbon detections in any of the seep samples, the petroleum hydrocarbon SLs based on the Method A groundwater cleanup level are considered protective for both human health and aquatic organisms.

The detected concentrations of ammonia ranged from 0.001 to 0.636 mg NH_3/L. The SL for ammonia is 0.035 mg NH_3/L, based on chronic aquatic water quality criteria. Ammonia was detected in samples from each location at concentrations above the SL except MW-11D, MW-15S, and MW-15D, where it was detected, but below the SL. Ammonia is a common constituent associated with landfill leachate and with sewage or septage. Both of these potential sources are present at, or in the immediate vicinity of, the Site.

The detected concentrations of manganese ranged from 0.072 to 1.430 mg/L. Detections were above the SL of 0.1 mg/L at each well during both events, with the exception of MW-11D. As mentioned previously in this report, manganese is naturally occurring in soils in this area and becomes mobile in the dissolved phase under reducing conditions, such as those associated with wood waste or landfill refuse. Because of the distance of the wells from the shoreline and the increase in the oxidation state of groundwater that generally occurs in closer proximity to the shoreline due to hydrodynamic dispersion, the manganese concentration is anticipated to be significantly lower than measured in the monitoring wells at the point of groundwater discharge to surface water.

Based on the analytical results from both seep sampling devices and monitoring wells, groundwater near the point of discharge to surface water can be summarized with the following characteristics:

- Conductivity between 2,000 and 3,000 µS/cm (likely elevated by the adjacent marine water)
- Dissolved oxygen typically less than 1 mg/L (likely increases in close proximity to shoreline)
- TOC between 10 and 25 mg/L
- Biological oxygen demand between 10 and 100 mg/L
- Tannins and lignins ranging from 1 to 40 mg/L (likely due to the wood waste)

- Sulfur species dominated by sulfate, with lesser sulfide
- Ammonia between 0.005 to 0.29 mg NH_3/L
- Manganese between 0.1 and 1.5 mg/L, and other dissolved metals (iron, copper, lead, zinc)
- Low-level non-carcinogenic PAHs
- BEP
- Low-level VOCs (including benzene, chlorobenzene, styrene, 4-isopropyltoluene, etc.)
- Low level gasoline-range petroleum hydrocarbons
- Fecal coliform (not detected in the last two rounds of seep sampling)
- PCBs (likely the result of entrained particulates).

6.4 SEDIMENT QUALITY

Sediment quality was evaluated based on chemical data and the surficial extent of landfill refuse and wood debris. The chemical assessment focused on surface sediment, although limited subsurface sediment core data were also evaluated. The assessment of the surficial extent of refuse and wood debris was based on surface and shallow subsurface observations.

6.4.1 EXTENT OF REFUSE AND WOOD DEBRIS

The extent of refuse and wood debris in Site surface and subsurface sediment was delineated based on observations from the following explorations:

- Two offshore borings (Dames & Moore borings 2 and 3)
- Four test pits excavated along the shoreline during the expanded Site investigation
- Two subtidal SCUBA reconnaissance surveys conducted during the expanded Site investigation and the supplemental RI
- Subtidal SPI and cores collected during the 2008 Ecology sediment investigation.

The locations of each of these explorations are shown on Figure 6-6. The data collected by divers during the supplemental RI are presented in Table 6-3. Results for the SPI and core sampling conducted in the 2008 sediment investigation are provided in Appendix E. The 2008 sediment investigation was relied on to a greater extent than previous investigations because it was the most recent and the most comprehensive evaluation conducted to evaluate the extent of refuse and wood debris in Site sediment.

The extent of refuse and wood debris based on the above investigations is shown on Figure 6-6. Note that the line delineating the extent of refuse and wood debris excludes location RGH-07 (at the northern end of the Site) from the affected area. This location is excluded because the identification of refuse at this location is based on the presence of a single piece of black plastic and refuse was not encountered at any nearby locations. Additionally, black plastic was not a common component of refuse in the 1950s and 1960s when the landfill was active.

As previously mentioned in Section 5.3 (Sediment Site Screening Levels), Ecology also established the following Site-specific criteria for refuse and wood debris in the aquatic environment that it considers a potential threat to benthic organisms (Kovacs 2008):

- No more than a 1-ft thickness of sediment where wood debris (sawdust or wood chips) constitutes greater than 50 percent of the sediment by volume
- Any detectable refuse
- Less than 1 ft clean sediment cover over sediment that exceeds the above criteria for wood debris and refuse.

Locations where these criteria were exceeded are shown on Figure 6-7. A comparison of the extent of refuse and wood debris on Figure 6-6 with the area over which the criteria for protection of benthic organisms is exceeded on Figure 6-7 indicates that the criteria for protection of benthic organisms is exceeded over a much smaller area. This difference in area is the result of significant deposition of recent sediment over the refuse and wood debris, such that most of the deep subtidal affected area is covered by at least 1 ft of clean sediment, which is indicative of natural recovery processes.

6.4.2 CHEMICAL ASSESSMENT

The chemical assessment of surface sediment quality was based on the analytical results for the following 25 sediment samples:

- Two sediment samples (E-2 and E-4) collected during the initial Site investigation (Ecology 1992a)
- Three sediment samples (S-1, S-2, and S-3) collected during the expanded Site investigation (Landau Associates 1997)
- Four sediment samples (HC-SS-19, HC-SS-20, HC-SS-21, HC-SS-28) from the Site vicinity collected during the Whatcom Waterway RI/FS (Anchor Environmental and Hart Crowser 1999)
- Six sediment samples collected during the supplemental RI (SRI-SED-1, SRI-SED-2, SRI-SED-3, SRI-SED-4, SRI-SED-5, and SRI-SED-6)
- Three sediment samples (SRI-2, SRI-2, and SRI-3) collected as part of the R.G. Haley site RI (GeoEngineers 2007).
- One surface sediment sample (BLVD-SS-09) and six subsurface samples (BLVD-SC-09-0-2’, BLVD-SC-09-2-3’, BLVD-SC-09-3-4’, BLVD-SC-09-4-6’, BLVD-SC-09-6-8’, and BLVD-SC-09-8.5-9.7’) collected as part of the City’s investigation for the proposed overwater walkway that would link the Site to Boulevard Park to the southwest.

The locations of the above-referenced surface sediment samples are shown on Figure 6-6. Analytical results for the detected constituents are summarized in Table 6-4. Applicable data have been organic carbon normalized (OC) for comparison to the Site SLs in Table 6-5. TOC was not analyzed during Ecology's initial Site investigation, so these data were carbon normalized using TOC concentrations measured during the expanded Site investigation for samples collected in the proximity of the original Ecology sampling locations. The PCB results for the subsurface sediment samples were carbon normalized using the TOC concentration measured from the surface sediment sample (BLVD-22-09) at that location.

A quantitative evaluation of sediment quality was conducted by comparing the analytical results for the sediment samples to the SLs developed in Section 5.3 (Sediment Site Screening Levels). As described in that section, the sediment SLs are based on SMS SQS criteria, except for PCBs, which is based on the PQL. Samples that exceeded the SMS CSL or AET criteria are indicated in Table 6-4 and Table 6-5 and on Figure 6-8.

For PCBs, the SL is based on the PQL of 0.006 mg/kg, which, based on the average organic carbon content of sediment samples collected at the Site, is equivalent to a value of 0.21 mg/kg OC. The sediment PCB results are presented in Tables 6-4 and 6-5 and compared to SLs based on dry weight and carbon normalized values. Because the PCB SL is based on the PQL, the PCB SL is essentially exceeded at any location where PCBs are detected.

The SLs were exceeded for one or more constituents in 20 of the 25 samples. The constituents that were detected at concentrations exceeding the SQS criteria include copper, lead, mercury, silver, zinc, PCBs, BEP, and butylbenzylphthalate (BBP). The lead, zinc, and BBP SLs were exceeded once, and in different samples; BEP and copper SL exceedances occurred in two samples; and the mercury SL was exceeded in five surface sediment samples and five core samples. The presence of mercury at concentrations exceeding the SQS is likely associated with the Whatcom Waterway site and not a release from the Site. PCBs were detected, and exceeded the SL, in 11 of the 12 surface sediment samples and all three of the core samples tested for PCBs. Analytical results for the seven constituents detected above their site SLs are presented on Figure 6-8. Detections of other constituents including cadmium, chromium, phenols, 4,4-DDD and -DDT, low molecular weight polycyclic aromatic hydrocarbons (LPAHs), high molecular weight polycyclic aromatic hydrocarbons (HPAHs), phthalates, cyanide, ammonia, and sulfide were below Site SLs.

While the Cornwall Avenue Landfill may be a source of some contaminants to sediment associated with the wave-reworked material along the landfill shore face, the landfill does not appear to be a significant source of contaminants to Bellingham Bay sediments beyond the immediate vicinity of the Site boundary. This conclusion is supported by the following information:

- With the exception of PCBs, the constituents that exceeded the Site SLs in landfill-associated surface sediment samples (copper, lead, zinc, silver, mercury, BEP, and BBP) did not exceed the SLs at the supplemental RI locations located beyond the extent of refuse in sediment.

- None of the constituents tested in the surface sediment, except PCBs, exceed the Site SLs by a factor of 2 or greater at more than one location. The zinc concentration exceeded its SL by a factor of 5.2 at sampling location E-2 and the BBP concentration at sampling location SRI-1 exceeded the SQS by a factor of 2.4.
- With the exception of PCBs, all of the sediment samples that exhibited more than one SL exceedance were collected from the intertidal zone or close proximity to the uplands.

Although the PCB SL was exceeded at numerous locations due to the use of the PQL as the SL, the concentrations are generally low, with only two samples exceeding the current SMS SQS or CSL criteria. Additionally, the distribution of PCB concentrations does not indicate a significant source of PCBs in the landfill. For example, the second highest sediment PCB concentration detected in Site sediment (16.2 mg/kg OC at S-3) was collected in the immediate vicinity of a location where PCBs were below reporting limits (E-4). Similarly, the highest PCB concentration detected in sediment (24.6 mg/kg OC at E-2) was collected adjacent to a location with a much lower concentration (5.8 mg/kg OC at S-2). Other concentrations generally ranged from about 1 mg/kg OC to about 4.5 mg/kg OC, which translates to a PCB dry weight range of about 0.03 mg/kg to about 0.14 mg/kg based on an organic carbon concentration of 3 percent.

Although not generally considered a contaminant in sediment, sulfide was observed to be significantly elevated in sample S-3. The specific cause of the high sulfide concentration is unknown. Elevated levels of sulfide in surface sediment commonly occur in an anaerobic environment and may originate from the anaerobic activity associated with wood debris present in the vicinity of sampling location S-3.

Sediment core data from location BLVD-SC-09 provides a basis for assessing the extent to which natural recovery processes are occurring in the Site vicinity. Seven core samples were collected at this location, extending in approximately 2 ft increments from the surface to a depth of 9.7 ft below mud line. Mercury was the only constituent tested for in every core sample. The mercury concentration was highest in the 3 to 4 ft core sample (3.8 mg/kg) and showed a consistently decreasing concentration in shallower core samples, with a concentration of 0.8 mg/kg in the 0 to 2 ft core. PCBs were only tested for in the upper three cores, but also showed a consistently decreasing concentration in shallower sediment, with PCB concentrations decreasing from 21.47 mg/kg OC in the 3 to 4 ft sample to 3.2 mg/kg OC in the 0 to 2 ft sample. The significant and consistent decrease in COPC sediment concentration from depth to the surface clearly demonstrates that natural recovery processes are occurring and that significant sediment accumulation is occurring at the Site.

Based on the analytical results from marine sediment characterization, marine sediment quality can be summarized with the following characteristics:

- Heavy metals generally above sediment SLs in near-shore surface sediment

- Mercury above sediment SLs in most surface sediment samples (likely originating from the Whatcom Waterway site)
- BEP above the sediment SL and low level concentrations of other phthalates in near-shore surface sediment
- PCBs above the sediment SL through marine sediment (based on PQL as SL)
- Low level pesticide detections (4,4-DDD and -DDT) in near-shore surface sediment
- Low level PAH detections
- Cyanide, sulfide, ammonia, and phenols (consistent with presence of refuse and wood waste).

6.5 SURFACE WATER AND AIR QUALITY

The surface water and air quality were not evaluated as potentially affected environmental media for the Site RI. The absence of surface water bodies within the upland portion of the Site deemed it unnecessary to perform a surface water assessment. Air quality was not assessed because it is not considered a significant concern under the present ground cover at the Site.

The only potential air quality issue associated with the Site that has been identified is landfill gas emissions resulting from the decomposition of refuse and wood debris. The age of the landfill and high permeability of the existing landfill cover would indicate that the current air emissions are likely minimal and diffuse. During the interim action conducted in 2011 and 2012, a significant portion of the Site was covered with a low-permeability material and a flexible membrane liner (20 mil scrim reinforced polyethylene) as described in Section 3.7 (Interim Action). Based on the potential for landfill gas production, although it is expected to be minimal, a passive landfill gas ventilation system was installed beneath the low permeability material. For the purposes of this RI/ FS, it is assumed that the existence of degrading landfill refuse and wood waste at the Site is sufficient to require landfill gas control as part of any cleanup alternative implemented at the Site that includes a low permeability cap installed over significant portions of the Site. An assessment of landfill gas generation and gas quality will be conducted at the Site in order to design the landfill gas control system and to evaluate the potential emissions. This evaluation will be conducted as part of the remedial design process and presented in the Engineering Design Report in accordance with requirements under a Consent Decree.

7.0 CONCEPTUAL SITE MODEL

The conceptual Site model (CSM) was developed based on historical land use, environmental data, and the contaminant fate and transport processes that control the migration of contaminants in the natural environment. A schematic representation of the Site CSM is presented on Figure 7-1, and the following sections discuss the factors affecting the CSM, including contaminants and sources present at the Site, the nature and extent of contamination, fate and transport processes, exposure pathways and receptors, and source control efforts.

The RI conclusions are also presented at the end of this section.

7.1 CONTAMINANTS AND SOURCES

The chemical contaminants detected in groundwater at the Site at concentrations exceeding SLs are primarily metals (copper, nickel, lead, and manganese), fecal coliform, ammonia, petroleum hydrocarbons, SVOCs (including PCP and PAHs), and PCBs. In addition, refuse and wood debris present at the Site could generate methane gas. The source of these contaminants is the Cornwall Avenue Landfill and the historical wood product industrial activities that preceded the landfill, with the following exceptions or clarifications:

- PCP contamination, petroleum hydrocarbon contamination, and related contamination (i.e., SVOCs and cPAHs) primarily originate from wood treating activities that occurred on the R.G. Haley site and which have migrated onto the Cornwall Site.
- Fecal coliform contamination in groundwater beneath the upland portion of the Site appears to be associated with releases of raw sewage or septage from damaged sanitary sewer lines or septic tanks that are no longer in service. Bird droppings associated with the roof of the former GP warehouse are also possible historical sources of fecal coliform.
- Fecal coliform detected in groundwater seep samples collected at the shoreline may be attributable to birds or other marine mammals that frequent the shoreline. Fecal coliform was not detected in samples collected during the supplemental RI from the two most recent rounds of seep sampling, so previous fecal coliform SL exceedances likely resulted from particulates entrained in the seep samples.
- Ammonia is likely a secondary contaminant associated with refuse and wood waste decomposition and not a direct release of ammonia at the Site.
- Manganese in groundwater is likely a secondary contaminant associated with reduced groundwater conditions typically associated with refuse and wood debris.
- Copper concentrations in upgradient groundwater (MW-1) appear to be at least partially the result of elevated particulates entrained during sampling, and may also result from natural background conditions or minor, unidentified sources. Only one of 24 downgradient groundwater samples exceeded the SL for copper (MW-11S). During the second round of sampling from this well, the concentration was below the SL.

- Lead in groundwater seep samples and surface sediment likely originates from refuse, although the limited extent of lead contamination in both media suggests that only a limited source is present. Additionally, dissolved lead was not detected above the SLs in the samples collected during the two rounds of supplemental RI seep sampling or the two rounds of 2012 supplemental RI groundwater sampling, indicating that lead in groundwater likely results from particulates entrained in the earlier seep samples.

The results of soil, groundwater, and sediment investigations are discussed in detail in Section 6.0 (Nature and Extent of Contamination). A summary of the distribution of constituents detected above SLs is discussed below and shown on Figure 7-2. The extent of contamination in the upland portion of the Site primarily includes the area upgradient of the landfill where soil and groundwater have been impacted by petroleum hydrocarbon contamination (and related compounds) from the R.G. Haley site, and areas of buried refuse and wood debris. The extent of the petroleum hydrocarbon contamination and refuse/wood waste are shown on Figure 7-2. The extent of petroleum hydrocarbon contamination, primarily in the diesel range, is defined by the area over which groundwater or soil exceed applicable Site SLs, which is essentially equal to the area where visible sheen was observed during Site investigation activities. As previously discussed, the R.G. Haley site is the primary source of petroleum hydrocarbon, PCP, and PAH contamination at the Site.

The extent of landfill refuse present in the upland portion of the Site is depicted on Figure 7-2. Due to its heterogeneous nature, specific contaminant sources within the refuse have not been identified. However, PCB, metals, and ammonia contamination observed in Site groundwater and sediment is assumed to originate from refuse present in the landfill, and it is possible that dioxins/furans could be present in the refuse. Fecal coliform contamination in the uplands portion of the Site appears to be related to sanitary sewer or septage releases, and possibly bird droppings, and not releases specific to historical Site activities. The fine-grained, stabilized sediment placed at the Site during the Interim Action contains dioxins/furans at concentrations above the SL, and low concentrations of some heavy metals and cPAHs that exceed the SLs based on protection of groundwater, as discussed in Section 6.2.4 (Interim Action Low Permeability Material). The extent of contamination associated with hazardous substances contained in the stabilized sediment is limited to the IPAs where the material is stored. As shown on Figure 6-1, wood waste is present throughout most of the upland portion of the Site. Although explorations have not been advanced in the southeast portion of the Site, it is anticipated that wood waste is also present in this area due to the extensive wood products industrial history of the Site.

The constituents detected in sediment at concentrations exceeding the Site SLs consist of metals (copper, silver, zinc, lead, and mercury), PCBs, BEP, and BBP. As shown on Figure 7-2, landfill refuse and wood debris are present at distances of up to about 350 ft from the shoreline. As discussed in Section 6.4.1 (Extent of Refuse and Wood Debris), the extent of wood debris and landfill refuse in sediment that represents a potential threat to benthic organisms based on Site-specific criteria established by Ecology is more limited due to the deposition of clean sediment over most subtidal areas of the Site, as is shown on Figure 7-2. Concentrations of most constituents above the Site SLs in sediments are sporadic and no constituent exceeded its Site SL at more than two locations except PCBs. With the exception of a single exceedance of BBP, PCBs, and possibly cPAHs, the extent of surface sediment containing constituent concentrations above the Site SLs does not extend beyond the area that represents a potential threat to benthic organisms based on the presence of wood debris and landfill refuse. Because the PCBs SL is based on the PQL, and PCBs were detected in all but one sediment sample tested for PCBs, the in-water Site boundary is considered an estimate. Because of its low concentrations relative to the SQS criteria, HPAHs (including cPAHs) were not tested for extensively in sediment. As discussed in Section 5.3 (Sediment Site Screening Levels), the cPAHs concentrations are generally low relative to PCBs and achievement of the PCB SL is assumed to also address potential human exposure to cPAHs. So the Site boundary, as determined by PCBs, is assumed to also bound the extent of Site cPAHs contamination in the aquatic portion of the Site.

7.2 FATE, TRANSPORT, AND ATTENUATION PROCESSES

This section provides an overview of the fate, transport, and attenuation processes that likely affect the migration of contaminants in the various media present at the Site. As discussed in the following sections, the primary fate and transport processes include:

- Leaching of contaminants from refuse by infiltrating precipitation
- Leaching of contaminants by groundwater in direct contact with refuse
- Migration of affected groundwater to potential receptors
- Migration of soil gas (methane and petroleum hydrocarbon vapors)
- Wave erosion and redistribution of refuse, wood debris, and associated chemical contaminants in the aquatic environment
- Erosion and transport of refuse/wood waste in stormwater runoff.

In addition to the naturally occurring processes described below, anthropogenic processes could affect the fate and transport of the contaminants at the Site in the future. These processes could include earthwork related to construction activities where contaminated soil is redistributed vertically or laterally during excavation of the subsurface, installation of future subsurface utilities that could act as a preferential transport pathway for contaminated groundwater and landfill gas migration, or recontamination from non-point sources (stormwater and atmospheric deposition). Propeller wash and anchor drag are also anthropogenic processes that may cause the redistribution of contaminated sediment or refuse in the aquatic portion of the Site, although these processes are unlikely to be significant under currently anticipated future land use scenarios.

7.2.1 UPLAND SOIL

The transport of contaminants in soil generally occurs through two primary mechanisms at the Site. Contaminants that partition to soil can be transported by erosion, either via stormwater runoff or by wave erosion along the shoreline. In the case of petroleum hydrocarbon contamination, transport in soil can also occur through the migration of LNAPL downward through the unsaturated zone and laterally on top of the water table surface in the downgradient direction of groundwater flow, or laterally along a low permeability contact (e.g., the Nooksack Deposits) under unsaturated or intermittently saturated conditions. Intermittent groundwater fluctuations in areas with LNAPL may result in the development of a smear zone where LNAPL becomes sorbed onto soil particles over the depth range that groundwater fluctuates. Soil petroleum hydrocarbon concentrations generally exceed cleanup levels wherever residual or free-phase LNAPL is present.

Attenuation processes in soil vary by the chemical characteristics of the contaminant. Many contaminants partition to soil and attenuate with distance from the source. Other contaminants undergo biological degradation. Petroleum hydrocarbon soil contamination typically attenuates rapidly with distance from the source due to both partitioning and biological degradation (i.e., natural attenuation). The transport of heavy metals in soil is limited for most metals due to their affinity for adhering to soil. However, some metals convert to more soluble forms under reducing conditions and migrate with groundwater, as discussed below. Fecal coliform attenuates rapidly from its source because fecal coliform require a nearby source of fecal matter to remain viable. Additional contaminant transport can occur through anthropogenic activities, such as excavation or grading, which have the potential to relocate contamination to greater depths, unaffected areas, or to offsite locations.

The migration of petroleum hydrocarbons in LNAPL form requires an ongoing LNAPL source as a driving force, which appears to be lacking for the portion of the R.G. Haley release located on the Site based on no observations of LNAPL in the groundwater monitoring wells constructed in 2012 along the shoreline at the Site. As a result, migration of petroleum hydrocarbon LNAPL appears to be limited, which is consistent with observations in 2007 at the R.G. Haley site (GeoEngineers 2007). The degradation of petroleum hydrocarbon LNAPL is quite slow, even at sites with ideal, high redox potential. Given the low redox potential due to refuse and wood debris decomposition, the degradation of petroleum hydrocarbon LNAPL is anticipated to be quite slow.

The mobility of dioxins/furans in the stabilized sediment was evaluated in the Interim Action Work Plan (Landau Associates 2011a). The evaluation considered two mechanisms for migration of dioxin/furans contained in the fine-grained sediments stored on the property associated with the Site: 1) mobilization caused by infiltration of precipitation through the material and 2) a rise in sea level causing groundwater to rise and inundate the material. Each of these mechanisms involve water coming into contact with and leaching dioxins/furans from the material, entering the groundwater flow system, and discharging to surface water. The potential impacts of this migration pathway to groundwater were evaluated using the MTCA three phase partitioning model [WAC 173-340-747(5)]. Based on the high affinity of dioxins/furans to partition to soil particles and the low hydraulic conductivity of the fine-grained sediments, it was estimated that groundwater impacts from infiltration through the material would be less than that from the infiltration of precipitation through soil containing natural background concentrations of dioxins/furans for soil in Washington State. It was also estimated that the concentration of dioxins/furans would need to be about twice the maximum concentration measured in the fine-grained sediments to adversely affect surface water quality, even in the event that the material was inundated continuously by rising groundwater (Landau Associates 2011a).

7.2.2 GROUNDWATER

Other than shoreline erosion, groundwater is the primary transport media for upland contaminant migration at the Site. Because the upland portion of the Site is not completely capped with a low permeability material, and refuse and wood debris are in direct contact with groundwater, leaching of contaminants to groundwater is ongoing. In particular, contaminants that are mobilized, or created, by the decomposition of refuse and wood debris (such as manganese and ammonia) will continue to be generated for many years. However, the average concentrations of these compounds measured upgradient of the point of discharge to surface water exceed the Site SL by much less than an order of magnitude in almost all instances, which suggests that the groundwater SLs can likely be achieved at the shoreline through actions that significantly decrease groundwater flow rates.

The transport of heavy metals in groundwater typically occurs in a dissolved form, although metals can also migrate in colloidal (particulate) form. Most metals transported in groundwater attenuate rapidly with distance from the source primarily through absorption. However, certain metals, such as iron and manganese, transform to soluble ionic forms under low oxidation reduction potential conditions, such as those present at landfill sites.

The attenuation of heavy metals and petroleum hydrocarbons is heavily influenced by hydrodynamic dispersion in a tidally-influenced groundwater regime such as that present near the Site shoreline. Hydrodynamic dispersion in groundwater subjected to tidal fluctuations is greatly increased due to the mixing of surface water and groundwater in the vicinity of the shoreline; the fluctuation in groundwater elevation also causes "tidal pumping" of soil gas in the unsaturated zone. Tidal pumping results in greater air/soil gas exchange and a more oxygen-rich subsurface environment, which in turn supports greater absorption or precipitation for most metals and greater aerobic decomposition of petroleum hydrocarbons.

The transport of petroleum hydrocarbons in groundwater occurs in the aqueous phase. Transport is affected by various processes, including absorption, dispersion, and biological decomposition. These attenuation factors are collectively referred to as natural attenuation, and tend to be most effective in an aerobic (oxygen-rich) environment. Refuse and wood debris landfills are generally depleted of oxygen, and as a result, it would be expected that natural attenuation would be relatively limited at this Site. However, microbial populations that are well adapted to anoxic environments are generally present in landfill refuse and will provide some attenuation via biological decomposition, although at a slower rate.

7.2.3 SOIL VAPORS

The migration of petroleum hydrocarbon vapors and methane gas produced by the decomposition of the refuse and wood debris represents a migration pathway of potential concern. Petroleum hydrocarbon LNAPL that contains VOCs, such as gasoline and diesel, also release contaminants to soil vapor. Vapor phase migration can be exacerbated at sites containing refuse or wood debris due to the generation of methane gas, which acts as a driving force for vapor-phase migration and can cause soil gas to migrate significant distances. Under the current permeable soil cover and land use conditions, vapors can migrate vertically upward and diffuse to the atmosphere. This condition was maintained after implementing the 2011/2012 sediment beneficial reuse interim action by installing a passive landfill gas control ventilation as part of that action. However, the management of soil vapors will be additionally considered for future development and remedial scenarios.

7.2.4 SEDIMENT

Primary fate and transport mechanisms in the aquatic environment include shoreline erosion due to wave action, bioturbation, and deposition of clean sediment. Bioturbation is the mixing (or displacement) of sediment caused by the natural activities of aquatic organisms (e.g., benthos). Past studies in Puget Sound have demonstrated benthic organisms are generally found within the uppermost 10 cm of the sediments (Ecology 2008). Studies for the Whatcom Waterway site show the depth of bioturbation for much of Bellingham Bay ranges from 10 to 15 cm (RETEC 2006), and the predominantly biologically active zone is assumed to be 12 cm. The burrowing activity of the benthic organisms may cause mixing of underlying contaminated sediments with clean surface sediments, or vice-versa. Bioturbation can act as either a contaminant transport or attenuation mechanism, depending on a number of factors, such as the rate of clean sediment deposition, the level of biological activity, and the nature and extent of contamination. Some organisms may burrow deeper than 10 or 15 cm, such as ghost shrimp

(*Neotrypaea californiensis*), which are commonly noted as one of the deepest burrowers. Ghost shrimp typically burrow to depths of approximately 40 cm. These organisms are present at the Whatcom Waterway site area and occur throughout Pacific coastal waters (RETEC 2006); therefore, there is potential for their presence in intertidal areas at the Site.

As described in Section 4.1.3 (Shoreline Features and Erosion), substantial shoreline erosion has occurred since closure of the landfill. This erosion has caused transport of landfill refuse, and likely wood debris, to the intertidal and subtidal portions of the Site. Bioturbation has caused intermixing of recently deposited clean sediment with underlying contaminated sediment, reducing the concentration of contaminants in surface sediment.

The primary transport mechanism for contaminated sediment at this Site is wave erosion. The amount of erosion due to waves varies with water depth. In relatively shallow water depths (e.g., less than 10 to 15 ft), wind-driven waves can produce increases in bottom velocities that can resuspend settled sediment, and thus cause sediment transport and redistribution. The Site is located in an unprotected area and, therefore, is exposed to prevailing offshore winds, increasing the likelihood of storm waves that may result in resuspension of settled sediment. The impact of Site wave erosion is evidenced by the significant amount of shoreline retreat that has occurred since the landfill was closed and the presence of refuse in surface sediment. However, wave erosion has decreased significantly in recent years, as discussed in Section 4.1.3 (Shoreline Features and Erosion).

The most effective process for attenuation in sediment is sediment deposition. This process involves burial of the contaminated surface sediment over time by natural deposition of clean sediment such that the depth of the contaminated sediment is below the biologically active zone, thereby reducing risk to benthic organisms. As discussed in Section 4.1.4 (Sediment Deposition), the results of the 2008 Ecology sediment investigation indicate that significant sediment accumulation has occurred throughout much of the subtidal portion of the Site. This was further evidenced in the sediment core data from location BLVD-SC-09, discussed in Section 6.4.2 (Chemical Assessment). The data from this location indicate a significant and consistent decrease in COPC sediment concentration from depth to the surface, and clearly demonstrate the natural recovery occurring through sediment accumulation at the Site. The deposition of recent, clean sediment has occurred in sufficient quantities to establish a clean surface sediment layer over most of the affected subtidal area, consistent with natural recovery processes.

Other attenuation processes in sediment include long-term weathering and transformation processes. However, weathering tends to be relatively slow compared to deposition and contaminant burial. Contaminant weathering in sediments consists of dilution, volatilization, chemical transformation, biotransformation and biodegradation, and sorption. Although slow, these processes contribute to the permanent reduction of contaminant concentrations and bioavailability. Shoreline erosion in the intertidal zone remains a transport mechanism of concern for the aquatic portion of the Site and will be considered for all remedial scenarios in the FS.

7.3 REMEDIAL ACTIONS COMPLETED TO DATE

Source control activities address the elimination of releases from historical property usage or activities at adjacent properties that resulted in contamination of affected media. The potential sources of contamination identified at the Site include refuse placed in the former municipal landfill, wood debris in upland or marine portions of the Site, and releases associated with historical wood treating operations on the R.G. Haley site. Actions taken to control these sources are described below.

7.3.1 LANDFILL REFUSE AND WOOD DEBRIS

Following closure, the landfill was covered with a soil layer of variable thickness, and the shoreline was protected by various phases of informal slope armoring consisting of a variety of rock boulders and broken concrete. In addition to the soil layer covering the surface of the landfill, an additional approximately 47,500 yd^3 of fine-grained sediment was brought to the property during 2011/2012 interim action, as described in Section 3.7 (Interim Action). Despite the shoreline armoring, significant shoreline erosion occurred, which resulted in exposure of landfill refuse at the surface and redistribution of landfill refuse in the intertidal and subtidal areas throughout the Site. Some shoreline armoring remains in place and thereby may reduce the amount of landfill refuse actively eroding into the aquatic environment. Natural deposition of sediment is also occurring in the subtidal portion of the Site, as discussed in Section 4.1.4 (Sediment Deposition), thereby capping the refuse and wood debris in this area with clean sediment such that the depth of the refuse and wood debris is below the biologically active zone.

7.3.2 R.G. HALEY SITE

The R.G. Haley site was a former wood treatment plant that used large quantities of P-9 carrier oil with and without PCP additive. P-9 carrier oil was reportedly released to several portions of the R.G. Haley site, including sediment. Additionally, contamination in the form of LNAPL has migrated to the south onto the Cornwall Avenue Landfill Site.

Process wastewater, including PCP-contaminated drainage fluid, was reportedly discharged to the former seepage pit. The former seepage pit was located in the southwestern corner of the R.G. Haley site, in close proximity to the Cornwall Avenue Landfill Site's northeastern property line. In July 1985, approximately 80 tons of contaminated material from the seepage pit and adjacent area was removed and disposed off site, and the excavation was backfilled with granular fill and paved with asphalt (GeoEngineers 2007).

Oil recovery from the subsurface at the R.G. Haley site has been implemented since 2000. Between 2000 and 2007, approximately 270 gallons of oil was recovered from the subsurface. Additionally, a steel sheetpile wall was constructed along the shoreline on the R.G. Haley site in 2002 to minimize shoreline erosion and further releases of LNAPL to the marine environment. About 100 yd^3 of petroleum-contaminated sediment was excavated in conjunction with installation of the sheetpile wall. The R.G. Haley RI/FS report (GeoEngineers 2007) provides additional information regarding source control activities for the R.G. Haley site, and source control efforts after 2007 will be described in an upcoming draft of the RI/FS report for that site.

7.4 REMEDIAL INVESTIGATION CONCLUSIONS

The RI has identified contaminants present at the Site, affected media, potential receptors and exposure pathways, and the fate and transport of the contaminants at the Site, and a comprehensive CSM has been developed based on this information. This CSM (summarized on Figure 7-1) allows for the development of cleanup levels that will be protective of human health and the environment. Although additional studies may be required as part of remedial design, sufficient information has been obtained to develop and evaluate remedial alternatives, and select a final cleanup action. The following contaminants and sources are addressed in the FS:

- Refuse and wood debris in upland and aquatic portions of the Site
- Metals, PCBs, and ammonia in Site groundwater
- Methane, petroleum hydrocarbons, and possibly VOCs in soil gas
- Metals, PCBs, cPAHs, BEP, and BBP in sediment.

Petroleum hydrocarbons and the associated PAHs and SVOCs resulting from releases from the R.G. Haley site are not specifically addressed in the FS. However, the selection of the preferred remedial alternative for this Site will consider the coordination of the cleanup activities for the two sites in order to prevent impacting cleanup activities related to the R.G. Haley site releases.

8.0 DISCUSSION OF CLEANUP STANDARDS

This section identifies regulatory cleanup requirements through the development of Site-specific PCLs based on remedial action objectives (RAOs) and consideration of potentially applicable laws and regulations. The PCLs are based on the SLs developed in Section 5.0. PCLs are refined from the SLs based on the findings of the RI, including considerations such as frequency of detection and potential exposure pathways. As discussed in Section 1.0, PCLs are considered preliminary because the final cleanup levels will be selected by Ecology and presented in the CAP. The screening summary for detected groundwater constituents is presented in Table 8-1, PCLs for groundwater and sediment are shown in Table 8-2, and the screening summary for detected sediment constituents is presented in Table 8-3.

8.1 SITE CLEANUP STANDARDS

Affected Site media include soil, groundwater, and sediment. Cleanup standards consist of cleanup levels and the point(s) of compliance where the cleanup level will be achieved for each affected media. The following sections present PCLs and points of compliance for affected Site media. PCLs were set for groundwater and sediment, but not soil, as described below and summarized in Table 8-2. Final cleanup levels will be developed for the Site by Ecology in the cleanup action plan (CAP).

8.1.1 SOIL CLEANUP STANDARDS

Due to its nature as a waste material and inherent heterogeneity, the refuse was not characterized for soil quality during the RI. Rather, the refuse is assumed to be contaminated for the purposes of the RI/FS and constituent-specific soil PCLs were not developed. Because of the potential for intermixing, or impacts from previous Site industrial activities and activities on the adjacent R.G. Haley site, existing Site cover soil is also considered potentially contaminated and will be addressed in the same manner as refuse and wood waste in the FS. This is also true for the interim action sediment brought to the property; it too is contaminated. All of the cleanup alternatives developed in the following section [Section 9.0 (Feasibility Study)] address the contaminated soil/refuse/wood waste either by completely removing it or by isolating it from the environment. As a result, cleanup levels protective of direct contact, leaching, and erosion are not necessary, and have not been established.

The development of soil cleanup standards typically includes consideration of the vapor migration pathway if VOCs are present in soil. However, because the Site contains refuse and wood debris that will continue to generate low levels of methane for many years, landfill gas (LFG) control will be an element of any Site cleanup action that includes containment. As a result, any VOCs present in Site soil will be addressed by the methane gas control system, which will eliminate the soil vapor as a potential exposure pathway for the Site. Consequently, soil cleanup levels protective of the vapor migration pathway were not developed for the Site.

The point of compliance for soil in WAC 173-340-740(6) is throughout the Site. MTCA recognizes that for those cleanup actions that involve containment of hazardous substances, the soil cleanup levels will typically not be met throughout the Site [WAC 173-340-740(6)(f)]. However, MTCA also recognizes that such cleanup actions may still comply with cleanup standards. The determination of the adequacy of soil cleanup will be based on the remedial action alternative's ability to comply with groundwater cleanup standards for the Site, to meet performance standards designed to minimize human or environmental exposure to affected soil, and to provide practicable treatment of affected soil. Performance standards to minimize human and environmental exposure to affected soil may include institutional controls that limit activities that interfere with the protectiveness of the remedial action. Specific actions are described in subsequent sections of this report.

8.1.2 GROUNDWATER CLEANUP STANDARDS

Site groundwater PCLs are based on groundwater discharge to surface water (Bellingham Bay). MTCA allows for the application of groundwater cleanup criteria based on the protection of adjacent surface water if releases of hazardous substances occur to groundwater that has an extremely low probability for use as a future drinking water source [WAC 173-340-720(1)(c)]. As discussed in Section 4.3.1.5 (Groundwater Use), Ecology has determined that Site groundwater is non-potable in accordance with WAC 173-340-720(2). As a result, the use of PCLs protective of marine surface water is appropriate for the Site.

The groundwater PCLs are based on the same criteria used for the development of the SLs in Section 5.4 (Groundwater Screening Levels). As such, the groundwater PCLs are the most stringent of the following criteria adjusted to the PQL or background concentration (as appropriate): 1) federal (40 CFR 131.36) and state (MTCA) surface water criteria based on human consumption of fish, and 2) federal (40 CFR 131.36) and state (Chapter 173-201A WAC) acute and chronic water quality criteria. Since surface water criteria have not been established for total petroleum hydrocarbons, MTCA Method A cleanup levels for groundwater were used for these constituents for evaluation of risk to human health, as provided for in WAC 173-340-730(3)(b)(iii)(C). The Method A groundwater cleanup levels for petroleum hydrocarbons are not specifically referenced as applicable to surface water for protection of aquatic life. As such, Method A groundwater PCLs may not be appropriate screening criteria for demonstrating protection of aquatic organisms if petroleum hydrocarbons are broadly distributed near the point of groundwater discharge to surface water. As discussed in Section 6.3.3 (Downgradient Perimeter

Groundwater Quality), petroleum hydrocarbons were not found to be present in most wells near the shoreline at this Site.

The point of compliance for groundwater is typically throughout the Site when groundwater is considered a potential source of potable drinking water. If groundwater discharge to surface water represents the highest beneficial use, MTCA provides for a conditional point of compliance at the point of discharge of groundwater to the surface water receiving body. The conditional point of compliance is acceptable under MTCA for properties abutting surface water with the following conditions [WAC 173-340-720(7)(d)(i)]:

A. Contaminated groundwater is entering, and will continue to enter, surface water even after implementation of the selected cleanup action

B. If it is not practicable to meet the cleanup level at a point within the groundwater before entering the surface water within a reasonable restoration timeframe

C. A mixing zone is not used to demonstrate compliance

D. Groundwater discharges are provided with all known available and reasonable methods for treatment before being released to surface waters

E. Groundwater discharges shall not result in violations of the sediment quality values published in Chapter 173-204 WAC

F. Groundwater and surface water monitoring shall be conducted to assess the long-term performance of the selected cleanup action

G. Notice of proposal of the conditional point of compliance shall be mailed to DNR and the USACE inviting comments on the proposal.

Conditions A and B are currently met based on the information provided in the RI. A mixing zone will not be proposed to achieve compliance with groundwater cleanup standards, addressing condition C. The FS will evaluate, and integrate as applicable, all known available and reasonable methods of groundwater treatment into the remedial alternatives to address condition D. The groundwater cleanup levels will consider protection of marine sediment quality to address condition E. Groundwater and surface water quality compliance monitoring will be included in all remedial alternatives developed in the FS to address condition F. Required notice will be provided to the USACE and DNR once a final cleanup action is selected for the Site, if the selected remedy requires a conditional point of compliance, to address condition G.

Based on these considerations, it is anticipated that the downgradient edge of the Site, as close as technically possible to the point of entry of groundwater to Bellingham Bay, will be established as the conditional point of compliance for Site groundwater. The achievement of groundwater cleanup levels will be measured at the conditional point of compliance using a network of groundwater monitoring wells located at the downgradient edge of the Site.

The data collected in 2012 from the groundwater monitoring wells located near the downgradient edge of the Site were used to develop the screening criteria summary presented in Table 8-1. As indicated in Table 8-1, there were exceedances of one or more of the water quality criteria for copper, manganese, and NH_3-ammonia. Each of these is identified as a Site indicator hazardous substance (IHS) based on exceedance of the SL with the exception of copper, as discussed below. The most stringent of the applicable criteria is identified as the PCL for groundwater at the Site and is summarized in Table 8-2.

Fecal coliform was detected in groundwater seep samples, but was not carried forward as an IHS because it appears to be unrelated to the Site and appears to originate from non-landfill sources, as discussed in Section 6.3.1 (Overlap Area Groundwater Quality). In addition, fecal coliform bacteria were not detected in any of the seep groundwater samples collected during the supplemental RI.

The maximum detected groundwater concentration of copper in the downgradient perimeter wells was 2.6 µg/L. This value only slightly exceeds the PCL for dissolved copper of 2.4 µg/L and is below the concentration of 7.2 µg/L detected in an upgradient well. Based on the low frequency of exceedance (1 of 24, or 4 percent) and considering the maximum detection only slightly exceeds the SL, copper was not carried forward as an IHS.

A number of VOCs and SVOCs that do not have promulgated cleanup criteria were detected in Site groundwater at low concentrations, primarily during the 2012 supplemental groundwater sampling activities. As discussed in Section 5.4 (Groundwater Screening Levels), the concentrations of these constituents are near the method reporting limits and are orders of magnitude lower that the concentrations of groundwater IHS such as manganese and ammonia. As a result, any cleanup actions that adequately address established groundwater IHS will result in concentrations below the PQL for these hazardous substances that lack applicable cleanup criteria. As a result, groundwater PCLs were not developed for these COPCs and they are not carried forward as Site IHS.

It is important to note that petroleum hydrocarbons and specific compounds associated with petroleum hydrocarbon contamination are not identified as IHS for groundwater (or soil) even though extensive petroleum hydrocarbon sheen was observed within and upgradient of the Site. Petroleum hydrocarbon detections in groundwater upgradient of the Site have exceeded MTCA groundwater Method A cleanup levels for diesel- and oil-range petroleum hydrocarbons. As discussed in Section 6.3.1 (Overlap Area Groundwater Quality), the petroleum hydrocarbon contamination appears to originate from the R.G. Haley site. Although the petroleum hydrocarbon sheen appears to originate from an offsite source, its presence should not compromise the effectiveness of any of the alternatives evaluated for cleanup of the Site.

Petroleum hydrocarbon constituents were not detected above SLs in groundwater monitoring wells located along the downgradient perimeter of the upland portion of the Site. Gasoline-range petroleum hydrocarbons were detected at a concentration of 330 μg/L in one groundwater sample collected from MW-13D, which is below the SL of 800 μg/L based on protection of human health. Regulatory criteria for gasoline-range petroleum hydrocarbons protective of marine organisms are not available, so it is not known whether the groundwater SL is adequately protective of marine organisms. However, gasoline-range petroleum hydrocarbons were not detected in the 28 other groundwater and seep samples tested for this analyte, including the other sample collected from MW-13D, for a frequency of detection of about 3.5 percent. Based on a frequency of detection of less than 5 percent, and a detected concentration less than the SL, gasoline-range petroleum hydrocarbons was not carried forward as a Site IHS for groundwater.

8.1.3 SEDIMENT CLEANUP STANDARDS

The sediment PCLs are based on the chemical criteria identified for the sediment SLs discussed in Section 5.3 (Sediment Site Screening Levels) and the Site-specific physical criteria for refuse and wood debris coverage considered protective of benthic organisms presented in Section 6.4.1 (Extent of Refuse and Wood Debris). The SQS and bioaccumulative SLs are the primary chemical criteria for the sediment PCLs. The physical criteria for the sediment PCLs consist of the following Site-specific criteria for refuse and wood debris in the aquatic environment that Ecology considers adequately protective of benthic organisms (Kovacs 2008):

- No more than a 1 ft thickness of sediment where wood debris (sawdust or wood chips) constitutes greater than 50 percent of the sediment by volume
- No detectable refuse
- No less than 1 ft of clean sediment cover over sediment that exceeds the above criteria for wood debris and refuse.

The sediment analytical data were compared to SQS values to identify sediment IHS and PCLs, except that PCB analytical data were also compared to the sediment PQL as a conservative approach to addressing the bioaccumulative characteristics of this IHS, as previously discussed in Section 5.4 (Groundwater Screening Levels). The constituents detected in sediment at the Site are compared to applicable levels in Table 8-3.

The IHS identified for marine sediment at the Site are copper, cadmium, lead, silver, zinc, BEP, cPAHs, and PCBs since these constituents were detected at least once in sediment samples at concentrations exceeding the Sediment PCLs, or in the case of cadmium, lead, and cPAHs, are carried forward as IHS based on their bioaccumulative affects although the PCB PCL is being used as a surrogate to address all bioaccumulative compounds for the purposes of the RI/FS. As stated in Section 5.3 (Sediment Site Screening Levels), all bioaccumulatives will need to be considered during development of the CAP, and cleanup levels based on bioaccumulative affects may be developed for cadmium, lead, and cPAHs at that time. A complete list of IHS and PCLs identified for sediment at the Site are summarized in Table 8-2.

The point of compliance for sediment chemical criteria is the predominantly biologically active zone, which is considered the upper 12 cm of sediment, as discussed in Section 7.2.4 (Sediment). The point of compliance for the physical criteria is the upper 1 ft (30.5 cm), as identified in the third bullet above.

9.0 FEASIBILITY STUDY

The purpose of this section is to develop and evaluate a range of cleanup action alternatives and identify the preferred alternative for Site cleanup. MTCA has established requirements for selecting a cleanup action and the expectations for cleanup action alternatives in WAC 173-340-360 and 173-340-370. This section begins with a discussion of the interdependent relationship between the Site Units requiring cleanup, then establishes RAOs and potentially applicable laws relevant to the cleanup of this Site, and develops cleanup alternatives to meet the RAOs.

9.1 SITE UNITS

The Site contains two separate and distinct affected areas that warrant designation and evaluation as independent Site Units. The Site Units are the Upland Site Unit and the Marine Site Unit, as identified on Figure 9-1. Alternatives are presented to clean up each Site Unit and a preferred alternative is developed as a Site-wide cleanup alternative which achieves RAOs for both Site Units.

Although the environmental settings of the two Site Units are separate and distinct, the primary sources of contamination, refuse and wood waste, are contiguous between the two Site Units. As a result, the cleanup actions selected for each Site Unit are interdependent and must be integrated for an effective Site-wide cleanup action. Additionally, implementation of some cleanup action elements may need to be sequenced in a specific manner to be effective. The interrelationship between, and coordination of, the Upland and Marine Site Unit cleanup alternatives are discussed as appropriate in the applicable sections of the FS. The physical factors, land and navigation use, and natural resource value for each Site Unit is described below.

9.1.1 UPLAND SITE UNIT

The Upland Site Unit is the approximately 12 acres of upland generally bounded by Bellingham Bay, the property boundary to the north (except where refuse extends beyond the northern property boundary as shown on Figure 9-1), and the landward limit of refuse and wood debris as shown on Figure 9-1. The Site is currently zoned light industrial. However, the Port and the City have developed a draft subarea plan for the Waterfront District redevelopment area that includes the property associated with the Site and other areas along the waterfront (Port of Bellingham, City of Bellingham 2010). The zoning within the vicinity of the Site will be updated to a "commercial mixed use" designation, contingent on final development of the subarea plan. The draft subarea plan anticipates that the majority of the Site (and surrounding properties) will be converted to a large park with pedestrian trails, open space, and ancillary structures such as restrooms as well as parking and vehicle access. Although not currently planned, the commercial mix-use zoning could allow for a combination of parkland and mixed use (residential condominiums, retail stores, and office parks) for the City-owned portion of the Site and the adjacent property to the southeast. Under the final 2013 Shoreline Master Program (Bellingham, City of nd.), the designated use of the Cornwall Avenue Landfill Site includes recreational parks and open spaces. The cleanup action alternatives developed herein are based on future property use as recreational parkland and open space. However, each of the alternatives presented are compatible with the various potential land uses mentioned above without significant modifications to the conceptual details.

The upland habitat of the Site is sparse, as discussed in Section 4.4.1.4 (Upland Habitat). The Site consists of a soil cover over the former landfill area and adjacent Site upland area containing wood debris. The cover soil consists primarily of granular material (sand and gravel), wood debris, and occasional areas of cobble ballast. A stormwater detention basin is located in the southeastern corner of the Site. Several catch basins remain at the Site as shown on Figure 4-4, although the system is in disrepair. These remaining features of the older surface water management system will be abandoned during cleanup of the Site. Little vegetation is present on the upland portion of the Site that would impact selection or implementation of cleanup at the Site. Section 3.7 (Interim Action) provides details concerning the low permeability material that is being temporarily stored at the Site. The 2011/2012 interim action included the placement of low-permeability material at the Site which will be evaluated in this FS as a potential media to use as capping and grading material for cleanup of the Site. As discussed in Section 4.1.3 (Shoreline Features and Erosion), the shoreline has changed significantly over the years, based on changes in the approximate location of the top of slope above the beach area.

It is likely that without additional shoreline stabilization, erosion forces would continue to rework the shoreline area, exposing and causing the migration of buried refuse. Shoreline stabilization is discussed as part of the Marine Site Unit, but stabilization features will be extended above mean higher high water (MHHW) along the shoreline, so it will extend into the Upland Site Unit.

9.1.2 MARINE SITE UNIT

The Marine Site Unit is the approximately 11.6 acre area of intertidal and subtidal aquatic lands where landfill refuse and wood debris have come to be located. Sediment within this area exceeds either surficial marine sediment physical criteria based on the protection of benthic organisms, or the sediment PCLs (chemical criteria). As shown on Figure 9-1, the estimated boundary of the Marine Site Unit extends in some locations greater than 300 ft from the shoreline. The actual distance from the shoreline may be greater than shown, when exceedances of the cleanup levels for PCBs and other bioaccumulatives are considered. Further evaluation will be completed during the design phase to define the in-water boundary of this unit.

Current and anticipated future use and navigation in the Marine Site Unit includes private and commercial maritime activities associated with the Whatcom Waterway and recreational maritime uses along the Bellingham Bay waterfront. Navigation use offshore of the property is characterized primarily by transitory vessels traveling the Whatcom Waterway. Vessels are generally not anchored offshore of the property and there are no permanent dock structures or mooring dolphins.

As described in Section 4.4.1.1 (Intertidal Habitat), the intertidal zone is composed primarily of riprap, concrete debris, and other informal shoreline stabilization materials, which provides minimal habitat for marine species other than rock crabs. The shallow subtidal portion of the Marine Site Unit contains a significant area of native eelgrass at the southern end of the Site, and a limited amount of eelgrass near the northern Site boundary, as described in Section 4.4.1.2 (Shallow Subtidal Habitat) and shown on Figure 9-1. Mudflats within the shallow subtidal zone may support epibenthic prey that is consumed by juvenile salmon migrating through the area and may provide potentially suitable habitat for Dungeness crab mating and egg brooding (RETEC 2006). Some varieties of clams and shrimp may be present in the shallow subtidal zone. The subtidal substrate and water column are also used for feeding by a variety of fish, including sub-adult and adult juvenile salmon. More detailed natural resource information can be found in Section 4.4 (Natural Resources).

9.2 REMEDIAL ACTION OBJECTIVES AND POTENTIALLY APPLICABLE LAWS

The RAOs identify the goals that must be achieved by a cleanup alternative in order to achieve cleanup standards and provide adequate protection of human health and the environment. The RAOs must address all affected media and a cleanup alternative must achieve all RAOs to be considered a viable cleanup action. The characterization of Site conditions presented in Section 6.0 (Nature and Extent of Contamination), the preliminary cleanup standards developed in Section 8.1 (Site Cleanup Standards), and the review of applicable or relevant and appropriate requirements (ARARs) have culminated in the development of RAOs for the Site.

9.2.1 REMEDIAL ACTION OBJECTIVES

RAOs can be either action-specific or media-specific. Action-specific RAOs are based on actions required for environmental protection that are not intended to achieve a specific chemical criterion. Media-specific RAOs are based on the PCLs developed in Section 8.1 (Site Cleanup Standards).

The action-specific and media-specific RAOs identified for the Site are as follows:

RAO-1: Prevent erosion of refuse along shoreline: Previous investigations confirmed the presence of exposed landfill materials on the Site shoreline and within the intertidal and subtidal zones. A primary goal of the Site cleanup is to prevent further erosion of landfill refuse along the shoreline. The containment alternatives must effectively prevent continued erosion of the landfill slope along the Bellingham Bay shoreline.

RAO-2: Prevent direct contact with refuse and contaminated soil: If refuse or contaminated soil (including existing cover soil and stockpiled sediment) remains on Site, direct contact with humans and terrestrial species or erosion and transport in stormwater runoff must be prevented.

RAO-3: Prevent use of shallow Site groundwater for potable purposes: Shallow Site groundwater that comes into contact with, or is affected by, refuse is not appropriate for use as potable water, and its use for such purposes must be prevented.

RAO-4: Control LFG/VOCs: Methane generated by the degradation of landfill materials may accumulate under a landfill cap designed to prevent the infiltration of water; this gas must be managed by a LFG control system. The age of the Site (no waste has been placed in the landfill for over 40 years) is such that gas generation is expected to be minimal. This RAO will also address potential human exposure to VOCs in soil gas associated with petroleum hydrocarbons released from the R.G. Haley site, or any other sources of VOCs that may be present in Site soil vapor.

RAO-5: Prevent exposure of marine biota to sediment that exceeds the sediment PCLs: Marine biota in the predominantly biologically-active zone must be protected from sediment that exceeds the preliminary sediment cleanup standards to protect marine biota, and in the case of PCBs, protect human health for individuals that consume affected marine biota.

RAO-6: Prevent exposure of aquatic organisms to contamination originating from groundwater or surface water that exceeds the groundwater PCLs: Aquatic organisms must be protected from groundwater that discharges to surface water with concentrations of contaminants that exceed the groundwater PCLs.

Additional considerations that will be evaluated when selecting a remedy for the Site include:

- Compatibility with anticipated future Site uses, including public park and/or commercial/residential development.
- Restoration of public access and marine habitat function to the shoreline, to the extent practicable.
- Retain and enhance existing eelgrass beds, to the extent practicable.
- Compatibility with planned or potential cleanup actions for the R.G. Haley and Whatcom Waterway sites.

The RAOs for the Upland Site Unit are to mitigate risks associated with Site contaminants for the potential exposure pathways and migration routes. Specifically, the RAOs that are applicable to the Upland Site Unit include the following:

- RAO-2: Prevent direct contact with refuse
- RAO-3: Prevent use of shallow Site groundwater for potable purposes
- RAO-4: Control LFG/VOCs
- RAO-6: Prevent exposure of aquatic organisms to contamination originating from groundwater or surface water that exceeds the groundwater PCLs.

The RAOs that are applicable to the Marine Site Unit include the following:

- RAO-1: Prevent erosion of refuse along shoreline

- RAO-2: Prevent direct contact with refuse
- RAO-5: Prevent exposure of marine biota to sediment that exceeds the sediment PCLs
- RAO-6: Prevent exposure of aquatic organisms to contamination originating from groundwater or surface water that exceeds the groundwater PCLs.

9.2.2 POTENTIALLY APPLICABLE STATE AND FEDERAL LAWS

The extent to which each alternative meets these objectives will be determined by applying the specific evaluation criteria identified in MTCA and SMS. In accordance with MTCA, all cleanup actions conducted under MTCA must comply with applicable state and federal laws [WAC 173-340-710(1)]. MTCA defines applicable state and federal laws to include legally applicable requirements and those requirements that are relevant and appropriate (collectively referred to as the ARARs). This section provides a brief overview of potential ARARs for Site cleanup.

The primary ARARs are cleanup standards under the SMS and MTCA cleanup levels and procedures for implementation of a cleanup under MTCA. Other potential ARARs include the following:

- Washington Chemical Contaminants and Water Quality Act and Washington Water Pollution Control Act and the following implementing regulations: Water Quality for Surface Waters (Chapter 173-201A WAC) and SMS (Chapter 173-204 WAC).
- Minimum Functional Standards for Solid Waste Handling (MFS; Chapter 173-304 WAC): these regulations contain typical closure requirements that are relevant based on the waste disposal history of the Site.
- Resource Conservation and Recovery Act (RCRA) and Subtitle C regulations, to the extent that any hazardous wastes are discovered during the cleanup action. RCRA regulations may be applied in the overlap area with the R.G. Haley cleanup site for any listed wastes that are present related to R.G. Haley operations.
- Washington Hazardous Waste Management Act and Dangerous Waste Regulations, to the extent that any dangerous wastes are discovered during the cleanup action.
- Clean Water Act, with respect to water quality criteria for surface water (Bellingham Bay) and in-water work associated with dredging or sediment capping.
- Shoreline Management Act, with respect to construction activities during the cleanup action.
- Dredge and fill requirements under CFR 320-330 and Hydraulic Code Rules under Chapter 220-110 WAC.
- ESA, due to listing of Puget Sound Chinook and the potential listing of Coastal/Puget Sound bull trout.
- Critical Areas Ordinance of the City of Bellingham (Bellingham Municipal Code Chapter 16.55 Critical Areas).

The current refuse regulations, Criteria for Municipal Solid Waste Landfills (Chapter 173-351 WAC), are not an ARAR for the Site because the current solid waste regulations specifically reference the

MFS as the applicable regulations for landfills that did not accept waste after October 9, 1991 [WAC 173-351-010(2)(b)].

MTCA, Water Quality Standards for Surface Waters, SMS, and the Clean Water Act were considered in the development of cleanup standards [Section 8.1 (Site Cleanup Standards)]. RCRA Subtitle C and Dangerous Waste Regulations are not expected to apply unless dangerous wastes are discovered or generated during the cleanup action. Dangerous wastes are not known to be present at the Site. The Shoreline Management Act, dredge and fill requirements, and Hydraulic Code Rules may apply during the implementation of a particular cleanup action but do not directly influence the evaluation of the cleanup alternatives.

The MFS landfill closure requirements (Chapter 173-304 WAC) were considered during development and evaluation of the cleanup alternatives. WAC 173-304-407 identifies closure and post-closure requirements for landfills. These requirements include the following:

- The facility shall be closed in a manner that minimizes the need for further maintenance, and controls, minimizes, or eliminates threats to human health and the environment from post-closure escape of solid waste constituents, leachate, landfill gases, contaminated rainfall, or waste decomposition products to the ground, groundwater, surface water, and the atmosphere.
- Post-closure activities include groundwater monitoring; surface water monitoring; gas monitoring; and maintenance of the facility, facility structures, and monitoring systems for their intended use for a period of 20 years or as long as necessary for the facility to stabilize (i.e., little or no settlement, gas production, or leachate generation) and to protect human health and the environment; and until monitoring of groundwater, surface water, and gases can be safely discontinued.

A draft biological evaluation will be prepared for USACE review and approval as part of the permitting process for the selected cleanup remedy. The USACE-approved draft biological evaluation will be submitted to NOAA Fisheries and USFWS concurrently to address ESA requirements.

9.3 SCREENING OF REMEDIAL TECHNOLOGIES

The purpose of the FS is to develop and evaluate cleanup action alternatives to enable an appropriate cleanup action to be selected for the Site. This FS complies with the requirements under MTCA for performance of an FS (WAC 173-340-350) and selection of a cleanup action (WAC 173-340-360). Additionally, it is consistent with the Bellingham Bay Comprehensive Strategy and meets the Bellingham Bay Action Team's objectives for contaminated Site cleanup, habitat restoration, and integrated land use.

Under MTCA, the development of a cleanup action alternative requires that technologies capable of meeting cleanup requirements are screened, and then assembled into remedial alternatives that achieve all of the RAOs. These are then evaluated and compared and a preferred alternative is identified. Section 8.0 (Discussion of Cleanup Standards) presents the cleanup requirements for the Site and Section 9.1 (Site

Units) identifies the site units for which cleanup alternatives will be developed. This section describes pertinent considerations for the development of cleanup alternatives for the Site, reviews a range of potentially applicable cleanup technologies, and selects various technologies to be retained for development of cleanup alternatives in Section 9.4 (Description of Remedial Alternatives).

In this section, the range of potential technologies available for remediation of Site contaminants is reviewed and screened to identify a short-list of potentially applicable technologies for further evaluation. MTCA regulations place a preference on the use of permanent cleanup methods such as removal, disposal, or treatment, relative to those that manage contaminants in-place using institutional controls and/or containment. This preference is reflected in the MTCA and SMS evaluation criteria, and the comparative analysis of remedial alternatives. Retained technologies to be carried forward in development of remedial alternatives are summarized in Section 9.4 (Description of Remedial Alternatives).

Ecology will ultimately select a cleanup action alternative that complies with MTCA and SMS, and the PLPs will implement that cleanup action through a consent decree or agreed order. Subsequent redevelopment activities will be required to maintain the integrity of the cleanup action and comply with institutional controls, as applicable. The identified potentially applicable technologies screened are summarized in the following sections.

9.3.1 INTEGRATION OF REMEDIAL ALTERNATIVES WITH FUTURE DEVELOPMENT

One of the key screening considerations for selecting potential remedial technologies for the Site is the ability to integrate the cleanup with future development options, as previously identified in Section 9.2.1 (Remedial Action Objectives). This section is presented to provide a point of reference for the screening of technologies.

The property associated with the Site is located at the southern boundary of the Waterfront District redevelopment area, as shown on Figure 4-18. As shown on the figure, the property associated with the Site is planned for development as a public park and open space area. Development as a park could include restrooms and possibly small businesses such as food service or recreational equipment, so indoor air quality is a consideration. Property redevelopment would also include paved roadway and parking areas that would need to be integrated with capping of park vegetated areas. This plan for development was recently confirmed by the City and Port in their adoption of the waterfront plan depicted in Figure 4-18. However, redevelopment is still in the planning stages and could conceivably change to include other uses such as mixed use, commercial, or industrial. As a result, the technologies and resulting remedial alternatives must be sufficiently flexible to apply to a number of potential future property uses.

All cleanup alternatives must be compatible with redevelopment plans for the Site property. This requires that applicable cleanup elements, such as capping and LFG control, be considered and are integrated into the development design once a development plan is selected. Detailed design and construction of the upland portions of the selected cleanup action may or may not be performed concurrently with the design and construction of redevelopment components. Therefore, institutional controls and restrictive covenants may be required to ensure that future redevelopment activities are properly integrated with capping and LFG control systems.

9.3.2 Screening of Upland Remedial Technologies

The RAOs applicable to the Upland Site Unit are RAO-2 (prevent direct contact with refuse where it is potentially exposed along the shoreline), RAO-3 (prevent use of shallow Site groundwater for potable purposes), RAO-4 (control LFG/VOCs), and RAO-6 (prevent exposure of aquatic organisms to groundwater that exceeds the groundwater PCLs). The remedial technologies or response actions screened for consideration in development of cleanup action alternatives for the Upland Site Unit are presented in the following sections.

9.3.2.1 Capping

Capping would be achieved by placing a low permeability cap over the upland portion of the Site to limit potential future human exposure to refuse and contaminated soil and groundwater, and to minimize surface water infiltration and groundwater recharge at the Site. The cap could be constructed of a low-permeability soil cap, a flexible membrane liner (FML) system, pavement, and/or buildings. The cap would be designed to provide surface water drainage and erosion control by sloping final ground surfaces toward drainage features that would provide conveyance and discharge to Bellingham Bay. The capping and stormwater controls would extend throughout the upland Site Unit to mitigate exposure routes and to minimize surface water recharge to groundwater.

A soil cap would consist of low permeability soil cover system placed throughout the Site to provide a physical barrier to direct contact with refuse and contaminated soil (RAO-1). The use of a fine-grained soil or sediment to construct the soil cap would significantly reduce stormwater infiltration and reduce groundwater flow and associated discharge of contaminated groundwater to surface water (RAO-6).

Similarly, a low permeability cap consisting of asphalt, an FML system, or buildings, would provide a physical barrier to prevent direct contact with refuse and contaminated soil (RAO-1), and significantly reduce stormwater infiltration and associated discharge of contaminated groundwater to surface water (RAO-6).

These approaches to upland capping (low permeability soil, FML system, pavement and buildings) are carried forward as remedial technologies for further evaluation. Any capping system implemented at the Site would also include the abandonment of the surface water control system components near the former GP Warehouse building. This includes the catch basins, tight-line conveyance system, and potential outfall shown on Figure 4-4. For each capping system discussed herein, it is assumed that 15 percent of the Site upland area will be covered with pavement or buildings, and the remaining 85 percent (455,520 ft^2) will be covered with the capping system.

9.3.2.2 Landfill Gas Management

If areas of refuse or wood debris are capped with low permeability materials, a LFG management system will be needed to ensure methane gas and potentially VOCs present in soil vapor do not pose a risk of accumulation or migration (RAO-4). LFG management typically consists of horizontal collection piping embedded in high permeability backfill and located below the low permeability cap section. Active gas management systems that generate a vacuum to remove subsurface gasses are typically reserved for sites that generate significant amounts of LFG, and passive (self-venting) systems are typically used at sites that do not generate large amounts of gas. Because landfilling has not occurred for over 40 years, and the current redevelopment plans are for primarily parks and open space, it is anticipated that a passive gas control system will be adequate for the Site. The final selection of passive gas control or active gas control will be made during the system design based on the selected cleanup action, the final development plan selected for the Site, and on field data obtained during the final design. LFG management is carried forward as a remedial technology for further evaluation.

9.3.2.3 Groundwater Extraction and Treatment

Groundwater treatment technologies that require groundwater extraction would be located along the shoreline to extract groundwater impacted by the refuse and wood waste. Extraction of groundwater near the shoreline would necessitate the installation of a barrier wall along the shoreline to prevent marine water intrusion. The installation of a barrier wall along the shoreline is considered infeasible because of the presence of large obstructions such as concrete debris within the refuse that would likely preclude the installation of a continuous barrier. Without a barrier wall, extracted groundwater would be composed primarily of marine water drawn from the bay rather than contaminated groundwater. Both the quantity and quality of marine water would result in treatment of extracted groundwater being impracticable.

The installation of a barrier wall at the current shoreline would not address impacts on surface water quality from refuse and wood waste waterward of the shoreline, so a barrier wall would not be fully effective unless it was installed beyond the limits of Site refuse and wood waste in the marine portion of the Site. Installation of a barrier wall at the limits of refuse and wood waste in the aquatic portion of the Site would require converting a large aquatic area to uplands, which is not considered protective of marine habitat.

Based on these considerations, groundwater extraction and treatment is not carried forward as a potential remedial technology for further evaluation.

9.3.2.4 Groundwater Shoreline Filter Treatment

Groundwater treatment through filtration by porous media (i.e., a sand filter) near the groundwater/surface water interface would provide treatment by removing particulates entrained in groundwater. Additionally, a porous filter zone at the groundwater/surface water interface would increase hydrodynamic dispersion induced by tidal fluctuation, thus decreasing the concentration of groundwater IHS prior to discharge to surface water. A properly designed granular filter layer would provide filtration treatment for metals and organic compounds such as PCBs, which tend to partition heavily to particulates. Additionally, IHS that are mobilized by reducing (low oxygen) conditions, such as manganese, would transition to the solid phase due to the presence of highly oxygenated marine surface water within the filtration zone. The highly oxygenated marine surface water is also anticipated to provide a reduction in ammonia concentrations. Thus, shoreline filtration would assist in meeting RAO-6.

The granular filter layer would be designed based on Site specific conditions with a higher hydraulic conductivity and more homogeneous composition than the adjacent refuse to increase the hydrodynamic dispersion that naturally occurs in the pore water of near-shore soil and sediment near the groundwater/surface water interface. Depending on the characteristics of the local aquifer and receiving water, tidally-averaged dispersion ratios at the sediment/water interface in Puget Sound can range from a low of 3:1 (surface water:groundwater) to more than 10:1 (e.g., refer to D-Street, Great Western Chemical, and Southwest Harbor RI reports on file at Ecology). The construction of a highly permeable, homogeneous filter layer would significantly improve the mixing of marine water and groundwater.

The average concentrations of ammonia and manganese in seep samples are about 50 percent of concentrations measured in the shoreline wells, indicating about a 2:1 (surface water:groundwater) dispersion factor without the benefit of a shoreline filter layer. An additional reduction ratio of between about 2:1 to 3:1 will be required at the shoreline to achieve the groundwater PCLs. The combination of reduced contaminant flux and improved hydrodynamic dispersion near the surface water/groundwater interface through use of a granular filter layer are established engineering concepts for improving groundwater quality prior to discharge to surface water, and are considered capable of achieving the additional concentration reduction required to achieve the groundwater PCLs. As a result, groundwater treatment through sand filtration is carried forward as a remedial technology for further evaluation.

9.3.2.5 Groundwater Permeable Reactive Barrier

Permeable reactive barriers (PRBs) can be used as an *in situ* groundwater treatment technology. PRBs are design to intercept the flow of contaminated groundwater and are filled with media which reacts with dissolved contamination, allowing treated groundwater to flow freely downgradient. A PRB installed along the shoreline could potentially treat groundwater flowing from the upland Site Unit toward Bellingham Bay, prior to its discharge to surface water. PRBs are typically filled with a reactive media such as zero-valent iron, with a relatively high hydraulic conductivity and reaction kinetics that can quickly react with the contacting water as it passes through. PRBs are typically installed into a trench elongated in the direction perpendicular to groundwater flow, often in conjunction with an impermeable barrier system to direct groundwater flow to the PRB zone in what is referred to as a "funnel and gate" system.

Construction of such a system would be subject to the same constructability issues as the continuous barrier discussed in the previous section. Additional concerns include the lack of appropriate reactive media for treatment of groundwater IHS (manganese and ammonia), that the barrier cannot be placed completely downgradient of the refuse, and the effective useful life of reactive media submerged in a marine environment is expected to be short. Based on these concerns, a PRB is not considered feasible for groundwater treatment and is not carried forward as a remedial technology for further evaluation.

9.3.2.6 Offsite Surface Water Interception and Diversion

Surface water ponding and flow was observed upgradient of the northeast corner of the Site through most of the year, as discussed in Section 4.1.2.1 (General Site Drainage). Based on groundwater elevations in the northeast portion of the Site, it appears that surface water infiltration upgradient of this area is recharging Site groundwater. Intercepting and diverting surface water in this area would reduce the amount of surface water infiltrating into the Site and would in turn reduce the amount of contaminated groundwater discharging to surface water (RAO-6). Intercepting and diverting surface water in this area is technically implementable but may be subject to administrative complications because the property is offsite and owned by BNSF. However, offsite surface water interception and diversion is carried forward for further evaluation because the administrative implementability issues are not considered insurmountable.

9.3.2.7 Groundwater Diversion Barrier

Installation of an upgradient groundwater diversion barrier system would reduce the amount of groundwater flowing into the Site and would in turn reduce the amount of contaminated groundwater discharging to surface water (RAO-6). A groundwater diversion barrier system would intercept shallow groundwater at the eastern upgradient boundary of the property along the BNSF railway alignment and divert the water to a surface water discharge point before it would be affected by contact with Site soil and refuse. Because the Chuckanut Formation bedrock is present at shallow depth in this location, a groundwater diversion barrier would not extend to a significant depth below ground surface, and would not eliminate groundwater recharge originating from the Chuckanut Formation. The groundwater diversion barrier technology is carried forward as a remedial technology for further evaluation. However, it should be noted that the interception and diversion of offsite surface water discussed in the previous section could reduce the need for, and effectiveness of, a groundwater diversion barrier.

9.3.2.8 Soil Treatment

Treatment of Site soil is not considered as a viable cleanup technology because the heterogeneous nature of refuse and wood debris at the Site precludes the effective treatment of such a large volume. As a result, soil treatment is not carried forward for further evaluation.

9.3.2.9 Removal and Offsite Disposal

Physical removal (excavation) and offsite disposal of the upland refuse and any associated contaminated soil would achieve all Site RAOs by removing the primary contaminant sources and the secondary contaminated media (i.e., groundwater). Standard excavation techniques would be used for removal, although the physical setting and large volume of material requiring removal would result in significant implementability issues. Because refuse is present as a continuum extending into the Marine Site Unit, upland removal would need to be implemented in conjunction with a sediment removal action. Removed refuse, wood debris, and contaminated soil would be disposed of at a licensed solid waste disposal facility. Removal and offsite disposal of upland refuse and contaminated soil is carried forward as a remedial technology for further evaluation.

9.3.2.10 Institutional Controls

This technology would utilize restrictive covenants to achieve RAO-2 and RAO-3, by preventing Site activities that could lead to direct human contact with contaminated soil or groundwater, or the ingestion of contaminated groundwater. Institutional controls are not considered a stand-alone remedial alternative, but would be an integral part of any containment alternatives. As a result, institutional controls are carried forward as a remedial technology for further evaluation.

9.3.2.11 Compliance Monitoring

Compliance monitoring is not considered a stand-alone remedial alternative, but is a required element of any cleanup action conducted under MTCA. Compliance monitoring would be conducted to verify that cleanup standards for affected media are achieved, and once achieved, are maintained. Compliance monitoring could be applied to all affected upland media (soil, groundwater, soil vapor), and could also be applied to the performance of certain cleanup technologies (e.g., physically monitoring the integrity of a low permeability cap). Compliance monitoring is carried forward as a remedial technology for further evaluation.

9.3.3 Screening of Marine Site Unit (Sediment) Remedial Technologies

The RAOs applicable to the Marine Site Unit are RAO-1 (prevent erosion of refuse along the shoreline), RAO-2 (prevent direct contact with refuse where it is potentially exposed along the shoreline), RAO-5 (prevent exposure of marine biota to sediment that exceeds the sediment PCLs), and RAO-6 (prevent exposure of aquatic organisms to contamination originating from groundwater or surface water that exceeds the groundwater PCLs). The remedial technologies or response actions screened for consideration in development of cleanup action alternatives for the Marine Site Unit are presented in the following sections.

9.3.3.1 Shoreline Stabilization

Shoreline stabilization is incorporated as an integral part of the overall strategy for each of the remedial alternatives that include containment as part of the alternative. Stabilization of the shoreline is necessary to permanently contain the landfill refuse, protect the landfill against further wave erosion, and provide an environmental cap over contaminated sediment in the intertidal and shallow subtidal zones. Stabilization technologies include stabilization with granular rock materials or soft bank technologies. Shoreline stabilization would prevent erosion of refuse and wood debris along the shoreline (RAO-1), prevent direct contact with refuse within the intertidal zone (RAO-2), and prevent exposure of marine biota to contaminated sediment within the intertidal and shallow subtidal area (RAO-5).

The wind wave analysis conducted for the design of the Coast Guard improvements on the I&J Waterway (Baker 1997) indicated that peak waves entering the Site from the south/southwest can achieve heights of about 7 ft under 100-year storm conditions. The Site is relatively protected from waves originating from the south/southwest but there is direct exposure to waves originating from the northwest, which is the direction from which many severe storms and associated wind waves originate. As a result, any erosion control system for the Site will need to be designed to withstand high energy wave action.

Although shoreline stabilization using typical materials such as large rock (riprap) is effective in preventing erosion and can be designed to provide public water access, the resulting surface contacting the open water has limited habitat value. Shoreline stabilization using soft bank technologies may not provide as much protection from erosion as typical stabilization technologies and is known to be unstable in high energy environments, but is considered potentially applicable for the Site due primarily to the greater habitat value and improved shoreline esthetics. Soft bank technologies are typically considered for aquatic environments where erosion can be controlled with less protective measures than a fully armored face. Some long-term regular maintenance and replenishment of beach materials is typically necessary to address the ongoing erosion that would be expected. Soft bank technologies are usually designed to respond dynamically to storm waves and do not generally provide the same degree of design certainty as conventional shoreline stabilization (i.e., riprap and seawalls). Permanent containment of refuse is a fundamental requirement at the Site, so soft bank technologies must be applied with caution. It may be necessary to incorporate additional engineering controls into the design that otherwise would not be required under less critical applications. Shoreline stabilization technologies are carried forward as remedial technologies for further evaluation.

9.3.3.2 Sediment Capping

Placement of a layer of clean soil or sediment over contaminated sediment creates a predominantly biologically active zone unaffected by Site contamination. The cap material would provide a clean stratum for colonization by benthic organisms, thus preventing exposure of marine biota to contaminated sediment (RAO-5). Sediment capping can consist of a thin layer cap (typically less than 1 ft thick) or an engineered cap of greater thickness. A thin layer cap is primarily intended to expedite natural recovery processes while an engineered cap is intended to maintain a thicker, stable layer of clean material over contaminated sediment. Both thin layer and engineered capping are widely accepted technologies for addressing sediment contamination and are carried forward as remedial technologies for further evaluation.

9.3.3.3 Monitored Natural Recovery

Sediment natural recovery is the remedial technology through which sediment quality improves though a number of natural processes. For example, data for the Whatcom Waterway MTCA site indicate that the combination of source removal, sedimentation, and bioturbation in the upper 12 cm (5 inches) of sediment have resulted in natural recovery of mercury-contaminated sediment associated with former releases from the GP chlor/alkali facility to Bellingham Bay (Patmont et al. 2004). Monitoring of natural recovery processes through physical and/or chemical monitoring is a necessary component of natural recovery when it is used as a remedial technology to ensure that cleanup standards are achieved and maintained.

As discussed in Section 4.1.4 (Sediment Deposition), the results of the 2008 Ecology sediment investigation indicate that sediment accumulation, which is the most significant component of natural recovery, is occurring at the Site at an average rate of 1.4 cm/yr throughout much of the subtidal portion of the Marine Site Unit. This accumulation rate is generally consistent with the sedimentation rates that have been measured in inner Bellingham Bay (RETEC 2006). Thus, available data support the conclusion that sediment accumulation is occurring within Bellingham Bay, including the vicinity of the Site, and that natural recovery is a viable remedial technology to achieve RAO-5 for the portion of the Marine Site Unit that is not addressed through shoreline stabilization or sediment capping. As a result, monitored natural recovery (MNR) is carried forward as a remedial technology for further evaluation. The outer boundary of where MNR will be applied will at a minimum extend to the limits of refuse or wood waste, but will extend farther, as necessary, to encompass surface sediment where PCB concentrations exceed the sediment cleanup level established for the Site.

9.3.3.4 Removal and Offsite Disposal

Physical removal (dredging) and offsite, upland disposal of the contaminated sediment and associated landfilled materials from the Marine Site Unit would achieve all RAOs applicable to the Marine Site Unit. Standard dredging techniques would be used and dredged affected media would be disposed of at a licensed solid waste facility. As previously indicated in Section 9.3.2.9 (Removal and Offsite Disposal), refuse and wood debris are contiguous between the Upland and Marine Site Units, and complete removal for both Site Units would be required for effective implementation. Although subject to a number of implementability issues, removal and offsite disposal of contaminated sediment is carried forward as a remedial technology for further evaluation.

9.4 DESCRIPTION OF REMEDIAL ALTERNATIVES

The remedial alternatives evaluated in this FS utilize cleanup response actions specified in MTCA as appropriate for addressing hazardous substances [WAC 173-340-350(8)(c)(i)(C)] and which were chosen to be carried forward after initial screening [Section 9.3 (Screening of Remedial Technologies)]. This section describes these remedial alternatives with sufficient detail to provide the reader with a conceptual understanding of the design intent for comparing the various alternatives, and to provide an adequate basis for developing the cost estimates for each alternative. The alternatives were developed based on professional judgment and experience, cleanup actions implemented for similar sites, and applicable scientific and engineering principles and practices. The basic design assumptions used in developing these alternatives are for the purposes of cost and feature comparison for the FS, and may vary from the final design. Additional design-phase data collection, detailed engineering, design, and permitting will be required once a remedial alternative is selected by Ecology, and these activities may significantly affect the final design for the selected remedy.

For each alternative, this section provides the following information:

- A description of the cleanup actions, including habitat and land use and navigation considerations relevant to the cleanup action
- A discussion of how each alternative would meet the RAOs for the Site.

As indicated in Section 9.3.1 (Integration of Remedial Alternatives and Future Development), it is anticipated that future Site use will be primarily as a public park, with potential ancillary uses such as public restrooms, food services and/or park-related commercial services. However, future property use is still in the planning stages, so other potential future uses are possible. Because the remedial alternatives evaluated must be compatible with the final selected property use, alternatives will be kept sufficiently general such that they could be implemented for a wide variety of future uses. However, for cost estimating purposes, future use is assumed to be as a public park to allow development of remedial alternative costs for FS evaluation purposes.

The development of alternatives presented herein considers the potential impact on the R.G. Haley site, and the potential impact of the R.G. Haley site on the Site remedial alternatives with the recognition that close coordination will be required between the two sites during cleanup implementation. The Site alternatives are developed to be compatible with a wide range of potential remedies for the R.G. Haley site, although the range of alternatives ultimately evaluated were not limited by the proximity of the R.G. Haley site. Additionally, the Marine Site Unit overlaps with the Whatcom Waterway cleanup site in an area of that site designated for MNR under a MTCA consent decree. Each of the alternatives presented herein for cleanup of the Marine Site Unit will be at least as protective as this measure, and would be implemented carefully to not disturb the natural recovery process occurring at the Whatcom Waterway site. Additionally, long-term compliance monitoring for the Site will be coordinated with the Whatcom Waterway and R.G. Haley sites in order to provide for efficient data collection.

The following sections provide a more detailed description of the cleanup alternatives developed for the Site, including the assumptions and rationale used for developing these cleanup alternatives. Four remedial alternatives were developed for the Site using a combination of the remedial technologies discussed in Section 9.3 (Screening of Remedial Technologies). The alternatives are summarized in Tables 9-1, the evaluation of the reasonable restoration time frame for the Upland and Marine Unit alternatives are presented in Tables 9-2 and 9-3, respectively, and a summary of costs are provided in Table 9-4. Detailed cost estimates costs for each alternative are included in Appendix F. There are several technologies that would be implemented at the Site under each of the containment Alternatives 1, 2, and 3. These technologies would not be required if Alternative 4 is implemented because Alternative 4 includes the excavation and removal of all refuse and wood debris from the Upland and Marine Site Units. The costs for operation and maintenance of the capping systems have not been estimated for this evaluation. Periodic inspections would be a necessary component of each of the containment alternatives, as well as repairs to the cap if damage is observed. These costs would be essentially equivalent for each of the containment alternatives, would be small in comparison to the cost of Alternative 4, and therefore, would not impact the selection of the preferred alternative. The four cleanup alternatives and the technologies that are common to each of the containment alternatives are summarized in the list below and discussed in the following sections:

- **Technologies that would be included as a part of cleanup Alternatives 1, 2, or 3:**
  - Upland Site Unit (protection for direct contact, soil vapor, erosion)
    - Low permeability upland cap (to reduce stormwater infiltration)
    - Upland stormwater and erosion control (reduce infiltration and prevent erosion)
    - Passive LFG control (to mitigate accumulation of LFG)
    - Institutional controls (to prevent Site usage or activities that could lead to direct contact with contaminated soil or groundwater, or the ingestion of contaminated groundwater).
    - Actions to improve the BNSF property drainage (reduce infiltration).
    - Proper abandonment of the former stormwater system in the northeast portion of the Site, including catch basins and the subsurface tight-line conveyance system.
  - Marine Site Unit (intertidal and subtidal sediment areas and surface water)
    - Shoreline stabilization (prevent erosion and sediment toxicity).
    - Capping of intertidal and shallow subtidal beach area (limit human and benthic contact, bioaccumulation risks).
- **Alternative 1: Containment with Low Permeability Cap, Shoreline Stabilization, and Subtidal Sediment Monitored Natural Recovery**
  - Implement technologies listed above that are common to each alternative
  - Upland cap: Low permeability soil cap plus buildings, and/or pavement
  - Subtidal sediment remediation: MNR.
- **Alternative 2: Containment with Low Permeability Cap and Liner, Shoreline Stabilization with Sand Filter, Sediment Cap, and Monitored Natural Recovery**
  - Implement technologies listed above that are common to each alternative

- Upland cap: Low permeability soil cap with scrim reinforced liner plus buildings, and/or pavement
- Surface water protection: Shoreline sand filter treatment layer
- Subtidal sediment remediation: Thin layer sand cap and MNR.

- **Alternative 3: Two-Layer Upland Cap, Upgradient Groundwater Interception, Shoreline Stabilization with Sand Filter, Engineered Sediment Cap, and Monitored Natural Recovery**
  - Implement technologies listed above that are common to each alternative
  - Upland cap: Two layer cap (FML and low permeability soil cap), buildings, and/or pavement
  - Surface water protection: Shoreline sand filter treatment layer, upgradient groundwater diversion barrier system
  - Subtidal sediment remediation: Engineered sediment cap, with MNR beyond limits of cap.
- **Alternative 4: Waste Removal**
  - Landfill and wood waste excavation and removal
  - Shoreline armoring or stabilization.

9.4.1 ALTERNATIVE 1: CONTAINMENT WITH LOW PERMEABILITY CAP, SHORELINE STABILIZATION, AND SUBTIDAL SEDIMENT MONITORED NATURAL RECOVERY

The primary components of this cleanup alternative include covering the Upland Site Unit with a low permeability cap, stabilizing the shoreline in the intertidal zone, and implementing MNR for sediment remediation in the subtidal zone. Figure 9-2 shows a plan view of the Site and indicates where each of these technologies would be implemented at the Site. Figure 9-3 provides a conceptual cross section through both upland and marine Alternative 1 primary elements. The figures also illustrate other features of this alternative, including surface water management to reduce infiltration and LFG control to prevent the accumulation and mitigate migration of gas. Compliance monitoring would be conducted to evaluate the long-term integrity of the cleanup action and institutional controls would be implemented to restrict property usage and prevent human contact with contaminants in the subsurface.

Alternative 1 achieves all applicable RAOs through a combination of containment, institutional controls, and compliance monitoring.

- *RAO-1 (Prevent erosion of refuse along shoreline)* is achieved by installing a shoreline stabilization system.
- *RAO-2 (Prevent direct contact with refuse)* is achieved by constructing a cap over the Upland Site Unit consisting of low-permeability soil with the inclusion of a non-woven geotextile separation layer to prevent contact with plants, soil biota, or burrowing wildlife at the surface, pavement, or buildings; installing a shoreline stabilization system that will act as a cap over

the intertidal and shallow subtidal portions of the Marine Site Unit; and implementing institutional controls.

- *RAO-3 (Prevent use of shallow Site groundwater for potable purposes*) is achieved by implementing institutional controls.
- *RAO-4 (Control LFG/VOCs*) is achieved by installing a passive LFG control system beneath the low permeability upland cap.
- *RAO-5 (Prevent exposure of marine biota to sediment that exceeds the sediment PCLs)* is achieved in the intertidal zone shallow subtidal zones by the installation of a shoreline stabilization system that will provide containment of wood debris and refuse, and in the deeper subtidal zone by implementing MNR.
- *RAO-6 (Prevent exposure of aquatic organisms to contamination originating from groundwater or surface water that exceeds the groundwater PCLs)* is achieved through a combination of components of the cleanup action alternative. Groundwater recharge will be reduced by installing an upland low permeability cap with surface grading, and onsite and offsite surface water control measures. This reduction in groundwater recharge will result in a decrease in the flux of groundwater discharge to surface water and the associated exposure of aquatic organisms to affected groundwater.

The following sections provide additional details of the cleanup action elements associated with Alternative 1.

9.4.1.1 Upland Site Unit

The elements of Alternative 1 associated with the Upland Site Unit consist of installation of a low permeability soil cap, stormwater control both on the Site and on BNSF property upgradient of the northeast corner of the Site, and LFG control throughout the Site. These remedial action elements are discussed in the following sections.

Low Permeability Cap and Stormwater Control

A low permeability cap would be installed throughout the Upland Site Unit as part of Alternative 1, as shown on Figure 9-2. For the purposes of estimating cost for the cap system, we assume that 15 percent of the total area of the Upland Site Unit will be covered by buildings or pavement. Conceptual design details of the cap are presented on Figure 9-3. The thickness of the various layers making up the capping system and the materials of construction presented in this FS are provided in general terms consistent with a conceptual design to provide an understanding of the system functionality and cost. The actual details of the cap, including layer thicknesses and materials of construction would be developed during the design process if this alternative is selected for implementation. Under Alternative 1, the containment capping system would include the following elements from ground surface to the depth of buried refuse and wood debris:

- **Surface cover**: The surface of the Upland Site Unit would consist of a layer of topsoil approximately 1 ft thick, asphaltic pavement with a base course material, or buildings. A surface cover thickness of 1 ft is a typical minimum thickness for landfill covers and will be used in the FS for cost estimating purposes. We note that vegetative plantings at this Site may be quite different than for other landfill cover systems. As a result, the actual thickness of this layer (and others) will be determined during the design phase and may need to be thicker than 1 ft. It is likely, under the current redevelopment plans, that the majority of the Site uplands surface cover would be topsoil vegetated to support property usage as an open park. Paved areas would be limited and may include surface parking or paved sidewalks. Buildings would also be limited and may include small structures located at the Site to support park functions such as facilities maintenance or public restrooms.

- **Drainage layer:** A drainage layer would be located beneath the surface cover to provide drainage for water that infiltrates through topsoil or pavement to prevent saturation of the low permeability soil layer. The drainage layer could be constructed from geocomposite materials or granular fill, as determined during the remedial design. For the purposes of this FS conceptual design and for cost estimating purposes, we assume the drainage layer would be approximately 1 ft thick and consist of granular fill material.

- **Separation Layer:** A separation layer would be placed between the drainage layer and the underlying low permeability soil layer, if the low permeability layer is constructed using the stabilized fine-grained sediments placed at the Site during the 2011/2012 interim action. The layer would serve to provide physical separation between the drainage layer and the underlying low permeability soil layer. Because the fine grained sediment contains low concentrations of dioxins and furans, the separation layer is included to prevent direct contact with the underlying low permeability soil during any post-construction intrusive activities by alerting would-be excavators in the future that they are encountering the low permeability layer and so they could implement procedures to minimize direct contact with, or unintentional disturbance of, the material. For the purposes of cost estimating, we assume the separation layer will be constructed of a non-woven geotextile.

- **Low permeability layer**: In areas not covered with buildings or pavement, a layer of low permeability soil would be installed beneath the drainage and separation layers which would largely prevent stormwater infiltration into the underlying refuse and wood debris. The soil would need to demonstrate permeability characteristics equivalent to a 2-ft-thick layer of soil with a hydraulic conductivity of $1x10^{-6}$ cm/s to meet the requirements for landfill closure under the MFS for solid waste handling (Chapter 173-304 WAC), which is considered an ARAR for the Site due to its historical use as a solid waste landfill. The fine-grained sediment stored at the Site as part of the 2011/2012 interim action meet this criteria, exhibiting a hydraulic conductivity of $4x10^{-7}$ cm/s for cement stabilized sediment tested during design of the interim action (Landau Associates 2011a).

- Because of the relatively flat Site grades, granular soil would be imported and placed to create adequate grades for stormwater drainage. The amount of soil required to establish drainage would be reduced through the use of the interim action sediment discussed in the previous bullet.

- **Gas control layer:** A gas control layer would be placed just below the low permeability layer in order to provide a ventilation pathway for LFG or VOCs rising from the subsurface. This layer could be constructed from geocomposite materials or granular fill, as determined during the remedial design. For the purposes of this FS conceptual design and for cost estimating purposes, we assume the gas control layer would be approximately ½ ft thick and consist of granular fill material, and that perforated 2-inch SDR-11 high density polyethylene (HDPE) would convey gases collected from this layer to the atmosphere via LFG vents.

The existing soil cover, low permeability layer, and import fill would be graded to provide adequate drainage and prevent stormwater ponding, and the surface cover of topsoil would support re-vegetation. In order to provide adequate drainage, a 1.5 percent slope toward drainage features would be established. Drainage would be partially provided using the low-permeability layer while maintaining a minimum thickness in that layer of 2 ft to minimize infiltration. It is estimated that approximately 27,000 yd^3 of additional soil would be need to be imported to establish adequate drainage. These actions would significantly reduce surface water infiltration through improved stormwater interception and increased evapotranspiration from the vegetative cover. Stormwater management would consist of stormwater interception, treatment (as applicable), and conveyance to surface water discharge to Bellingham Bay. Stormwater actions such as regrading, lining of ditches, and tight line conveyance of stormwater would be made to the BNSF property stormwater drainage system to intercept, convey, and discharge surface water that currently accumulates in ponds and ditches near the railroad tracks, discussed in Section 4.1.2.1 (General Site Drainage) and shown on Figure 4-4. The existing Site stormwater system would be decommissioned as part of the redevelopment activities.

The surface grading, placement of topsoil, and stormwater management system associated with construction of the low permeability cap and ancillary buildings and paved surfaces would significantly reduce stormwater infiltration. Based on the low hydraulic conductivity of the stabilized sediment (4×10^{-7} cm/s), the material would provide an excellent low permeability layer for the cover system, and would be located below a separation layer and at least 2 ft of clean cover soil which will limit future potential for direct contact. For the purposes of this FS, we have conservatively assumed that surface water infiltration within the Upland Site Unit would be reduced by approximately 90 percent by the Alternative 1 soil capping system described above.

Based on the average groundwater recharge rate of 15.7 gpm resulting from infiltration of precipitation at the Site estimated in Section 4.3.1.4 (Groundwater Recharge and Water Balance), the estimated reduction in groundwater recharge expected after installing a low-permeable soil cover that reduces infiltration by 90 percent would be 14.1 gpm (15.7 gpm X 0.90). Based on the average groundwater discharge rate for the entire Site drainage basin of 21 gpm estimated in Section 4.3.1.3 (Groundwater Flow), this low permeability cap would reduce groundwater recharge through the landfill by about 67 percent. Recharge would be further reduced by the stormwater actions on the BNSF property, although the amount by which these actions would reduce groundwater recharge is difficult to quantify. These reductions of groundwater recharge would improve groundwater quality near the point of discharge to Bellingham Bay by reducing the rate of Site contaminated groundwater discharge to Bellingham Bay.

While the reduction in groundwater flow alone may not be sufficient to achieve groundwater PCLs at the point of discharge to surface water, the reduction in groundwater discharge rate will also increase hydrodynamic dispersion near the shoreline, particularly with the installation of the shoreline stabilization system. So while it is likely that implementing Alternative 1 would achieve the PCLs for groundwater at the point of compliance, a level of uncertainty exists regarding the degree of hydrodynamic dispersion that could be expected and the reduction in concentrations of ammonia and manganese that it would provide.

LFG Control

Because it has been more than 40 years since landfill closure, it is expected that current LFG generation rates are minimal. However, the low permeability cap could result in the accumulation and possible migration of LFG. As a result, a LFG management system would be installed throughout the Site which provides for the collection of and passive ventilation of LFG and potentially other VOCs that may be in the soil gas.

During the remedial design phase, LFG monitoring and LFG generation potential modeling would be conducted to evaluate whether active or passive gas control is needed and whether air emissions would meet Northwest Air Pollution Control Authority guidelines and MTCA air quality standards. For the purposes of estimating costs, it was assumed that a passive gas collection and atmospheric venting system would be constructed as part of this cleanup alternative.

9.4.1.2 Marine Site Unit

The elements of Alternative 1 associated with the Marine Site Unit consist of installation of a shoreline stabilization system and MNR beyond the limits of the shoreline stabilization system. These remedial action elements are discussed in the following sections.

Shoreline Stabilization

Alternative 1 would include shoreline stabilization in the intertidal and shallow subtidal zone as shown on Figures 9-2 and 9-3. Portions of Alternative 1 overlap with portions of the R.G. Haley cleanup. Because sediment dredging may be conducted as part of the R.G. Haley cleanup in areas that would be subject to shoreline stabilization as part of Alternative 1, the R.G. Haley sediment dredging activities would need to be implemented in advance of Alternative 1 at the northern end of the Site. The manner in which cleanup for the two sites will be coordinated is discussed further in Section 10.2 (Compatibility with R.G. Haley and Whatcom Waterway Remedial Activities).

The shoreline stabilization system would be designed to prevent shoreline erosion, which could cause exposure to, or possibly the migration of, refuse buried beneath the shoreline. The system would be constructed throughout the intertidal and shallow subtidal zones to an elevation of -10 ft MLLW to ensure that the stabilization system would remain stable under high wave action during extreme low tides. The stabilization system would also serve as a cap and biotic barrier over the sediment that is most impacted by Site releases due to shoreline erosion resulting from wave action.

Detailed engineering, design, and permitting of the shoreline stabilization system will be required to ensure that the system can provide adequate protection from significant wave action during winter storms to effectively contain the buried refuse and wood debris. The stabilization system would be developed to balance the need for the rock size to be large enough to resist detachment from wave action while also meeting federal in-water permitting requirements. The use of soft bank technologies would be considered during remedial design, particularly at the southern end of the Site where the shoreline is partially protected from winter storms. The use of soft bank technologies in this area could minimize the loss of eelgrass habitat and better support its re-establishment following construction.

For the purposes of FS cost estimating purposes, it is assumed that the shoreline stabilization system would consist of gravel and riprap and be approximately 3 ft thick. We assume a nominal 6-inch layer of gravel would be placed over the revetment rock to fill the rock interstices and enhance the habitat value of the shoreline stabilization system. The shoreline stabilization layer would extend from above the extreme high water elevation (about 13 ft MLLW) to the approximate boundary between deep and shallow subtidal habitat zones (-10 ft MLLW), although the thickness would be decreased from the extreme low water elevation (about -4 ft MLLW) to the -10 ft MLLW elevation.

The existing landfill slope above the shoreline would be re-graded, as necessary, to ensure slope stability and facilitate construction of the shoreline stabilization system. The shoreline stabilization system would be constructed during low tides using conventional upland construction equipment in conjunction with marine-based equipment for the lower intertidal and subtidal portions. A slope stability analysis was not conducted, but the relatively flat slope (5H:1V) used for the FS, and the course nature of the existing riprap and landfill materials, suggest that slope stability under static or dynamic conditions, including liquefaction, would not be an issue. Additional slope stability analyses would be performed during the remedial design phase.

The construction of the shoreline stabilization system would move the landfill slope farther seaward so that the intertidal and shallow subtidal zones would be resituated accordingly. This would result in a loss of up to about 0.14 acre of deep subtidal habitat, although the area of intertidal and shallow subtidal habitat would remain relatively unchanged. Some of this potential aquatic habitat loss could be avoided by reshaping and grading of the shoreline prior to installation of the shoreline stabilization system, although it would be undesirable to significantly disturb the relatively stable zone of reworked refuse and soil currently exposed in the intertidal zone. The sediment habitat would be significantly enhanced through the intertidal capping and containment of exposed refuse and contaminated sediment, and through the placement of the gravel over the riprap. Habitat components of the cleanup action, including any required mitigation resulting from loss of aquatic habitat, would be addressed during the design and permitting phase of the cleanup.

The relatively low concentrations of groundwater IHS, and the low organic content and permeable nature of the shoreline stabilization system, support the conclusion that recontamination of the intertidal and shallow subtidal sediment cap materials by groundwater would not occur. In addition to promoting hydrodynamic dispersion, containing refuse and wood debris, and providing erosion protection, the shoreline stabilization layer would provide a 3-ft cap over contaminated sediment in the intertidal and shallow subtidal zone between about elevations +13 ft and -4 ft MLLW, and a stabilization layer of decreasing thickness between about elevations -4 ft and -10 ft MLLW. The rock would also provide a barrier to deep burrowing benthic biota commonly found in the intertidal zone.

Monitored Natural Recovery

Alternative 1 would include MNR in the deep subtidal zone as shown on Figure 9-2. Because sediment dredging may be conducted as part of the R.G. Haley cleanup in areas that would be subject to MNR as part of Alternative 1, the R.G. Haley sediment dredging activities would need to be implemented in advance of Alternative 1 at the northern end of the Site. The manner in which cleanup for the two sites will be coordinated is discussed further in Section 10.2 (Compatibility with R.G. Haley Preferred Remedial Action).

Natural sediment deposition is expected to eventually create a cap over the entire deep subtidal area that currently exceeds the PCLs or Site-specific physical criteria for protection of benthic organisms. The subtidal area outside the limits of the shoreline stabilization system that requires additional natural recovery to achieve the sediment chemical or physical criteria is shown on Figure 9-2 and represents approximately 229,000 ft^2 (5.3 acres), although the exact limits would be defined during remedial design. As discussed in Section 4.1.4 (Sediment Deposition), sufficient sediment deposition to achieve the sediment physical criteria has already occurred over a significant portion of the deep subtidal area, and sediment accumulation at other locations in Bellingham Bay support the conclusion that natural recovery is a viable technology for sediment cleanup. As shown on Figure 9-2, the shoreline stabilization system will extend over almost the entire area where the extent of refuse and wood debris are not protective of aquatic organisms. With the exception of PCBs, the shoreline stabilization system will cover and contain all sediment IHS concentrations exceeding the sediment PCLs. As a result, MNR would be focused on demonstrating natural recovery for PCBs.

MNR would consist of conducting periodic sediment monitoring to confirm that natural recovery is occurring and that the sediment physical criteria and the Site sediment PCLs are achieved throughout the Marine Site Unit. Sediment compliance monitoring would consist of sediment coring or similar techniques to determine the thickness of clean sediment cover over refuse and wood debris to evaluate whether a minimum 1-ft cover thickness has been achieved, and to monitor the recovery of sediment quality with respect to PCB concentrations. For FS cost estimating purposes, it is assumed that 10 shallow core samples would be collected to monitor the accumulation of clean sediment thickness and 12 surface sediment samples would be collected to monitor surface sediment quality. It is assumed for cost estimating purposes that only PCBs would be tested for in surface sediment samples.

Sediment compliance monitoring would be conducted immediately following construction of the shoreline stabilization system, and at 5-year intervals thereafter, until the sediment physical and chemical criteria are achieved throughout the Marine Site Unit. The length of time required to achieve the sediment physical criteria is not known, but is estimated to be about 15 to 20 years, based on the extent to which natural recovery has already occurred at the Site. As a result, up to five sediment compliance monitoring events are assumed for FS cost-estimating purposes.

Contingent remedial measures, such as additional capping, would be evaluated if natural recovery monitoring does not demonstrate that sufficient sediment deposition would occur within a reasonable time frame to achieve physical and chemical MNR goals, or if natural recovery was not occurring in portions of the Marine Site Unit.

9.4.1.3 Compliance Monitoring and Institutional Controls

Compliance monitoring would be conducted to evaluate compliance with MTCA requirements WAC 173-340-440 (4)(B) and WAC 173-340-410, which require compliance monitoring for all cleanup actions for the following three purposes:

- **Protection monitoring** to confirm that human health and the environment are adequately protected during construction, operation, and maintenance associated with the cleanup action.
- **Performance monitoring** to confirm that the cleanup action has attained cleanup standards and any other performance standards.
- **Confirmational monitoring** to confirm the long-term effectiveness of the cleanup action once the cleanup standards and other performance standards have been attained.

Compliance monitoring and institutional controls would apply to both Upland and Marine Site Units. Compliance monitoring would include chemical monitoring of groundwater, LFG, and sediment, and physical monitoring of the Site cap and shoreline stabilization system, as described below.

Groundwater and surface water quality would be evaluated at the point of compliance for long-term groundwater compliance performance and confirmational monitoring. Specific details of the sampling and analysis program, including number and location of monitoring stations, frequency of sampling, quality assurance objectives, and complete list of analytes, would be documented in a compliance monitoring plan that would be developed during the remedial design phase. For FS cost estimates, it is assumed that eight new groundwater monitoring wells would be installed at the shoreline, the wells would be installed at an angle to allow monitoring as close as practicable the groundwater/surface water interface.

Monitoring of the LFG control system may be required, depending on the results of LFG emissions survey conducted during remedial design. The level of effort required for LFG monitoring, if required, is anticipated to be of limited scope and duration due to the low LFG generation potential of the Site.

For the purposes of the FS, it is assumed that both groundwater and LFG would be monitored on a quarterly basis for 2 years, followed by 3 years of semiannual monitoring following construction of the upland cap. Groundwater samples would be tested for all groundwater IHS and LFG would be tested for VOCs and methane. The need for groundwater or LFG compliance monitoring would be evaluated by Ecology at the conclusion of the 5-year monitoring period.

It is assumed for FS cost-estimating purposes that physical monitoring of the upland landfill cap and the shoreline stabilization system would be performed annually. Compliance monitoring is an integral part of MNR, as described above. For the purposes of FS cost estimating, we assume that bathymetric surveys of the Marine Site Unit would be conducted in conjunction with natural recovery monitoring activities on 5-year intervals. Through continued maintenance and repair as necessary, the design life for Alternatives 1 through 3 is expected to be extended to perpetuity. For the purposes of conducting a comparison between the Alternatives, we estimate the cost for maintenance and repair based on a project life of 20 years, although these activities will likely be required for a longer period.

Institutional controls for the upland portion of the Site would include a restrictive covenant for the Site to prevent activities that could compromise the integrity of the cleanup action or otherwise result in unacceptable risks to human health or the environment. The restrictive covenant would prevent the use of groundwater for potable purposes and would place restrictions on intrusive activities that could result in releases of hazardous substances or exposure of workers to contaminated media. The low permeability cover and LFG management systems are integral to the effectiveness of the cleanup action, so the restrictive covenant would also be written to provide that the low permeability cover and the LFG management system are properly protected and maintained. The restrictive covenant would be filed as a deed restriction with Whatcom County, would be binding on the owner's successors and assignees, and would impose limits on property conveyance.

Institutional controls for the Marine Site Unit would be required to prevent damage to the shoreline stabilization system and the clean sediment cover created through natural recovery. Institutional controls would include prohibitions on activities that could breach the shoreline stabilization system within any soft bank portion of the system. Additionally, vessel activity within the Marine Site Unit would likely need to be managed to prevent damage by boat prop wash, anchoring, or similar activities to the shoreline stabilization system and clean sediment cover achieved through natural recovery.

Specific monitoring requirements, contingency response actions, and required institutional controls would be prepared as part of the remedial design activities.

9.4.2 Alternative Two: Containment with Low Permeability Cap and Liner, Shoreline Stabilization with Sand Filter, Sediment Cap, and Monitored Natural Recovery

Alternative 2 increases the level of protection over Alternative 1 through the inclusion of a scrim-reinforced liner above the low permeability soil layer, the placement of a thin layer sediment cap in the area shown on Figure 9-4, and a shoreline sand filter treatment layer in the shoreline stabilization system. As with Alternative 1, portions of Alternative 2 overlap with portions of the R.G. Haley cleanup, and because sediment dredging may be conducted as part of the R.G. Haley cleanup in these areas of overlap, the R.G. Haley sediment dredging activities would need to be implemented in advance of Alternative 2 at the northern end of the Site. The manner in which cleanup for the two sites will be coordinated is discussed further in Section 10.2 (Compatibility with R.G. Haley and Whatcom Waterway Remedial Activities).

Alternative 2 achieves all applicable RAOs through a combination of containment, enhanced hydrodynamic dispersion, institutional controls, and compliance monitoring. Alternative 2 achieves applicable RAOs in a manner similar to Alternative 1, but includes additional measures presented in bold text below:

- *RAO-1 (Prevent erosion of refuse along shoreline)* is achieved by installing a shoreline stabilization system.
- *RAO-2 (Prevent direct contact with refuse)* is achieved by constructing a cap that includes soil and a scrim-reinforced polyethylene layer over the Upland Site Unit, installing a shoreline stabilization system that will act as a cap within the intertidal and shallow subtidal areas, and implementing institutional controls.

- *RAO-3 (Prevent use of shallow Site groundwater for potable purposes*) is achieved by implementing institutional controls.
- *RAO-4 (Control LFG/VOCs*) is achieved by installing a passive LFG control system beneath the low permeability layer of the soil cap.
- *RAO-5 (Prevent exposure of marine biota to sediment that exceeds the sediment PCLs)* is achieved **by constructing a sediment thin layer cap that would extend to the limits of refuse and wood debris,** and by implementing a MNR program in the area outside the limits of this cap.
- *RAO-6 (Prevent exposure of aquatic organisms to contamination originating from groundwater or surface water that exceeds the groundwater PCLs)* is achieved through a combination of components of the cleanup action alternative. Groundwater recharge will be reduced by installing an **upland low permeability cap with scrim-reinforced liner,** surface grading, surface water control measures, **and by constructing a sand filter treatment layer along the shoreline of the Site designed to increase hydrodynamic dispersion and aeration in the intertidal and shallow subtidal zones.**

The following sections provide additional details of the cleanup actions associated with Alternative 2.

9.4.2.1 Upland Site Unit

A low permeability soil cap would be installed throughout the Upland Site Unit as part of this cleanup action Alternative. The area of coverage shown on Figure 9-4, and the conceptual design details of the cap presented on Figure 9-5 are the same as those described for Alternative 1, except that the geotextile separation layer would be replaced with scrim-reinforced polyethylene layer to further reduce infiltration and provide a more durable physical separation layer. As discussed in Section 9.4.1 (Alternative 1: Containment with Low Permeability Cap, Shoreline Stabilization, and Subtidal Sediment Monitored Natural Recovery), the low permeability soil cap is anticipated to provide adequate containment of the buried refuse and wood debris, and reduce groundwater recharge from stormwater at the Site.

As with the other alternatives, the thickness of the various layers making up the system and the materials of construction presented in this FS are provided in general terms consistent with a conceptual design to provide an understanding of the system functionality and a basis for cost estimating. The actual details of the cap, including layer thicknesses and materials, would be developed during the design process if Alternative 2 is selected for implementation. For the purposes of the FS, we assume the liner placed above the low-permeability soil will be a scrim-reinforced polyethylene liner with a thickness of 20 mils. A conceptual cross section of the two-layer capping system is provided on Figure 9-5.

It is anticipated that the use of a scrim-reinforced polyethylene layer would result in the cover system reducing infiltration at least 95 percent, thereby reducing infiltration by 14.9 gpm (15.7 gpm x 0.95). Based on the average groundwater discharge rate for the entire Site drainage basin of 21 gpm estimated in Section 4.3.1.3 (Groundwater Flow), this low permeability cap would reduce groundwater recharge through the landfill by about 71 percent.

Sand Filter Treatment Layer

As part of Alternative 2, a sand filter treatment layer would be installed along the shoreline to provide filtration for groundwater discharging to Bellingham Bay. For the purposes of the FS, it is assumed that the sand filter treatment layer would include approximately 1 ft of clean sand placed on the intertidal slope as a filtration layer beneath the shoreline stabilization system. A nonwoven geotextile layer would be placed above the sand filter layer to provide separation between the sand filter and the overlying shoreline stabilization material to ensure that the filter media is not eroded through the large stabilization media pore spaces. It is anticipated that well-graded sand from an upland borrow source would be used for the filter material. The appropriate material gradation and thickness for the granular filter layer requires a detailed analysis that will be performed during the remedial design phase. The gradation and thicknesses for the intertidal granular filter layer identified in this FS are preliminary conceptual designs that were developed for estimating cleanup costs.

The sand filter treatment layer would provide filtering of the groundwater prior to entering Bellingham Bay to reduce suspended particles, increase hydrodynamic dispersion near the groundwater/surface water interface by providing a higher permeability and more heterogeneous media for mixing of groundwater and surface water, and enhanced aeration (oxidation) of groundwater prior to entry of surface water by increasing the intermixing of oxygen-rich surface water with groundwater. Based on the groundwater quality data and the anticipated effectiveness of the upland cap, a relatively thin and highly permeable granular filter layer should be adequate to achieve cleanup standards. However, the composition and thickness of the sand filter layer would be evaluated during remedial design. Additionally, the groundwater compliance monitoring system would be integrated into the sand filter treatment layer to provide more representative samples of groundwater at the groundwater/surface water interface.

In combination with the approximately 71 percent reduction in groundwater discharge caused by the low permeability soil cap, a shoreline filter appears likely to reduce NH_3-ammonia and dissolved manganese concentrations to below PCLs. In addition to the reduction in contaminant concentration due to hydrodynamic dispersion, the filter would enhance groundwater treatment by increasing the residence time at the intertidal zone interface where dissolved oxygen levels are higher due to aeration caused by wave or tidal action. Aeration is a common method of reducing both ammonia (Patoczka and Wilson 1984; Jamieson et al 2003) and dissolved manganese (Raveendran 2001) concentrations in water by promoting nitrification of NH_3-ammonia to nitrate or nitrite and oxidizing manganese to an insoluble form. Anticipated loading would be calculated during the final design to further refine the layer thickness required.

9.4.2.2 Marine Site Unit

Alternative 2 would include the basic shoreline stabilization system and MNR components of Alternative 1, plus a thin layer sediment cap beyond the shoreline stabilization system.

Thin Layer Cap

To meet the chemical PCLs and sediment physical criteria in the subtidal zone, Alternative 2 would include constructing a thin layer sand cap over the area shown on Figure 9-4, and implementing MNR. The thin layer sand cap would extend from the boundary of the shoreline stabilization system at about elevation -10 ft MLLW to the outer limit of the extent of refuse and wood debris.

The purpose of a thin layer cap is primarily to accelerate and enhance natural recovery rather than to provide a stable, engineered cap that would isolate contaminated sediment from overlying biological activity and other natural or anthropogenic activities that could expose contaminated sediment to the predominantly biologically active zone. For FS cost estimating purposes, a minimum thickness of 6 inches is assumed for the thin layer cap. Because we anticipate difficulty in spreading a uniform layer of sand beneath the water, our cost estimate includes an additional volume of sand equivalent to 20 percent of the total volume necessary to achieve a minimum thickness of 6 inches. Construction of such a cap would immediately increase the quality of deep subtidal aquatic habitat and provide a clean sediment stratum appropriate for colonization by marine benthic organisms throughout the area affected by Site refuse and wood debris. In combination with the shoreline stabilization system, which would effectively provide a cap over the intertidal and shallow subtidal zone, a thin layer cap in the deep subtidal zone would bring the total sediment capping area to about 11.6 acres.

The target area for the thin layer cap is shown on Figure 9-4. For the purposes of the FS and cost estimating, we assume the cap will generally consist of sand. During the remedial design phase, specific gradation requirements for the thin layer cap material would be developed.

The shoreline stabilization system would cover most of the eelgrass beds shown on Figure 9-4, and the thin layer cap would cover the remainder of the eelgrass beds at the northern end of the Site. The thin layer capping material would provide a cleaner, more receptive substrate for eelgrass colonization than the existing surface sediment containing refuse or wood debris near the surface, so the eelgrass beds covered by the thin layer cap should be quickly recolonized.

Similar to shoreline stabilization, subtidal capping will need to be coordinated with implementation of the R.G. Haley cleanup. Sediment dredging associated with the R.G. Haley cleanup would need to be implemented in advance of Site subtidal capping.

Monitored Natural Recovery

MNR would be implemented similar to Alternative 1. Because a thin layer cap would be installed rather than an engineered containment cap, there is some potential that erosion, bioturbation, or anthropogenic activities could expose underlying contaminated sediment. As a result, MNR would be implemented throughout the thin layer cap area, and extending farther offshore to evaluate MNR effectiveness in reducing PCB concentrations.

9.4.2.3 Compliance Monitoring and Institutional Controls

The compliance monitoring conducted as part of Alternative 2 would be the similar to that for Alternative 1 in Section 9.4.1.3 (Compliance Monitoring and Institutional Controls), including the scope for both physical and chemical monitoring. Specific monitoring requirements, contingency response actions, and required institutional controls would be prepared as part of the remedial design activities.

9.4.3 ALTERNATIVE 3: TWO-LAYER UPLAND CAP, SHORELINE STABILIZATION WITH SAND FILTER, ENGINEERED SEDIMENT CAP, AND UPGRADIENT GROUNDWATER INTERCEPTION

Alternative 3 is similar to the first two alternatives, but uses a two-layer upland cap (addition of a FML), provides a thicker, engineered containment sediment cap in the subtidal area, and includes the addition of a groundwater diversion barrier at the upgradient boundary of the Site to further reduce groundwater flow through the landfill and contaminated groundwater discharge to Bellingham Bay. The primary components of Alternative 3 are shown in plan view on Figure 9-6, and a conceptual cross section for the Site is provided on Figure 9-7.

Alternative 3 achieves all applicable RAOs through a combination of containment, enhanced hydrodynamic dispersion, groundwater diversion, institutional controls, and monitoring. Alternative 3 achieves applicable RAOs in a manner similar to Alternative 2, and additional measures that are not a part of Alternative 2 are presented in bold in the text below:

- *RAO-1 (Prevent erosion of refuse along shoreline)* is achieved by installing a shoreline stabilization system.
- *RAO-2 (Prevent direct contact with refuse)* is achieved by constructing a cap over the Upland Site Unit, installing a shoreline stabilization system that will act as a cap within the intertidal and shallow subtidal areas, and implementing institutional controls.

- *RAO-3 (Prevent use of shallow Site groundwater for potable purposes*) is achieved by implementing institutional controls.
- *RAO-4 (Control LFG/VOCs*) is achieved by installing a passive LFG control system beneath the low permeability layer of the soil cap.
- *RAO-5 (Prevent exposure of marine biota to sediment that exceeds the sediment PCLs)* is achieved by **constructing an engineered sediment containment cap that would extend to the limits of the extent of refuse and wood debris,** and by implementing a MNR program in the area outside the limits of this cap.
- *RAO-6 (Prevent exposure of aquatic organisms to contamination originating from groundwater or surface water that exceeds the groundwater PCLs)* is achieved through a combination of components of the cleanup action alternative. Groundwater recharge will be reduced by installing an upland two-layer low permeability cap with surface grading and surface water control measures, **by constructing an upgradient groundwater diversion barrier,** and by constructing a sand filter along the shoreline of the Site.

The following sections provide additional details of the cleanup actions associated with Alternative 3.

9.4.3.1 Upland Site Unit

The components of the Upland Site Unit for Alternative 3 are the same as for Alternative 2, except for the addition of the upgradient groundwater diversion barrier. A two-layer low permeability cap would be installed throughout the Upland Site Unit as part of this cleanup action Alternative as shown on Figure 9-6. Conceptual design details of the cap are the same as would be implemented under Alternative 2. As discussed for Alternative 2, we have conservatively assumed that surface water infiltration within the Upland Site Unit would be reduced by approximately 98 percent by the two-layer low permeability cap, and it would reduce groundwater recharge through the landfill by about 73 percent. Additional components of Alternative 3 that are equivalent to Alternative 2 include grading the Site to promote drainage, actions to the BNSF property stormwater drainage system to prevent accumulation of surface water ponds observed near the railroad tracks, installation of a sand filter along the shoreline, and LFG control.

Alternative 3 includes the addition of an upgradient groundwater diversion barrier system to further reduce groundwater recharge through the landfill. The groundwater interception and diversion system would be constructed along the alignment shown on Figure 9-6. Conceptual details of the system are provided on Figure 9-7. The groundwater interception and diversion system could only be installed to a maximum depth of the contact with the Chuckanut Formation and would not be effective in intercepting any groundwater recharge originating from this unit.

The upgradient diversion barrier would consist of a groundwater interception trench backfilled with coarse soil such as pea gravel, with a low permeability cutoff wall on the downgradient side of the trench, as shown on Figure 9-7. Intercepted groundwater would be discharged to surface water near the southern end of the Site. Because the diversion barrier would extend into the petroleum hydrocarbon-affected area associated with the R.G. Haley site to the north, LNAPL recovery and/or groundwater treatment may be needed prior to discharging intercepted groundwater to Bellingham Bay, although the trench should be isolated from the petroleum hydrocarbon contamination following completion of the trench. For cost estimating purposes, it is assumed that treatment of groundwater from the trench will not be required.

As discussed in Section 4.3.1.4 (Groundwater Recharge and Water Balance), approximately 5.8 gpm of recharge through the landfill originates from rainfall in the portion of the drainage basin located upgradient of the Site. Assuming an upgradient groundwater interception system could capture and divert approximately 80 percent of this flow, the potential reduction in Site groundwater recharge that can be achieved by the system is about 4.6 gpm, representing approximately 22 percent of the estimated 21 gpm of Site groundwater discharge. However, a portion of this groundwater recharge would likely be eliminated by the stormwater actions identified for the BNSF property. The combination of the upgradient groundwater diversion barrier and the low permeability cap is estimated to reduce the amount of groundwater discharge by 20 gpm for Alternative 3, or about 95 percent of the currently estimate rate of groundwater discharge.

9.4.3.2 Marine Site Unit

The primary difference between Alternatives 2 and 3 for the Marine Sediment Unit is the installation of an engineered containment cap in the deep subtidal area rather than a thin layer cap. Additionally, the scope of MNR would be reduced because the cap would provide greater physical separation between contaminated sediment and the predominantly biologically active zone. Alternative 3 is discussed in the following sections.

Shoreline Stabilization and Sediment Engineered Cap

Alternative 3 would include constructing the same shoreline stabilization system (with sand filter) that would be included in Alternative 2, as shown on Figures 9-6 and 9-7. Alternative 3 differs from Alternative 2 in the type of cap constructed outboard of the shoreline stabilization system. Instead of a 6-inch-thick thin layer cap intended to enhance and accelerate natural recovery, Alternative 3 would include a thicker, engineered cap to provide a higher degree of assurance that contaminated sediment would be contained below the predominantly biologically active zone.

As with Alternative 2, the sediment cap placement would occur below elevation -10 ft MLLW, which is the elevation separating the shallow and deep subtidal zones. As a result, capping in the subtidal area would slightly increase the amount of shallow subtidal habitat by raising the mudline elevation. Because shallow subtidal habitat is considered to have greater value than deep subtidal habitat, sediment capping represents an improvement in aquatic habitat. Because the cap is located in the deep subtidal zone, it would not likely be affected by wave action or vessel prop wash, so it could be constructed from materials ranging in gradation from clay to coarser sand and gravel. Specific borrow sources and gradation requirements would be evaluated during remedial design. Sources of clean sediment could be either clean dredge material from periodic maintenance dredging of locations such as the Squalicum Channel or the Snohomish River, or from an upland borrow source. For the FS conceptual design, it was assumed that the cap would be constructed of sand with an average thickness of 18 inches, although cap thickness would be further evaluated during remedial design.

Monitored Natural Recovery

The scope of MNR would be reduced because MNR monitoring within the sediment capping zone would not be required. But, monitoring beyond the sediment cap would be required for PCBs to evaluate the effectiveness of natural recovery in achieving the PCB cleanup level. For FS cost estimating purposes, it was assumed that monitoring for natural recovery would include six monitoring stations monitored on the same frequency as Alternatives 1 and 2.

9.4.3.3 Compliance Monitoring and Institutional Controls

The compliance monitoring and institutional controls implemented as part of Alternative 3 would be similar to the compliance monitoring described for Alternatives 1 and 2 described above. The only difference would be that physical monitoring of the cap thickness could require slightly longer cores to evaluate cap thickness. Specific monitoring requirements, contingency response actions, and required institutional controls would be prepared as part of the remedial design activities.

9.4.4 ALTERNATIVE 4: WASTE REMOVAL

In this cleanup alternative, the refuse, wood debris, and contaminated soil present at the Site would be removed from the Upland and Marine Site Units, and transported off site to a licensed solid waste disposal facility. The approximate limits of excavation are shown on Figure 9-8 and the conceptual details of the remedial alternative are presented on Figure 9-9. Alternative 4 achieves all RAOs by removing all contaminated media from the Site, thereby eliminating the source. Because all refuse would be removed from the Site under this cleanup alternative, institutional controls and compliance monitoring would not be necessary.

The excavation volume is estimated based on complete removal of the refuse, wood debris, and associated contaminated soil or sediment, as discussed in Section 6.2.1 (Extent of Refuse and Wood Waste). We estimate the upland excavation will remove approximately 430,000 yd^3 of refuse, wood debris, and soil. The excavation would extend throughout the Upland Site Unit where refuse and wood debris is present, wherever practicable. Excavation boundaries may require modification in areas such as the eastern boundary of the Site near the BNSF railroad alignment. The estimated volume of excavation is based on the total depth of observed refuse and wood debris, and includes a significant portion of intermixed and cover soil. We assume all soil excavated would be considered contaminated. The estimated volume of required excavation does not include the approximately 47,500 yd^3 fine-grained sediments that are stored at the Site. Including this volume would increase the estimated cost for Alternative 4 by about 10 percent, and this additional volume was not included in the estimated costs for the alternative to avoid influencing the cost considerations for this alternative in the disproportionate cost analysis (DCA) process.

The depth of refuse and wood debris in the Marine Site Unit is highly variable and not well documented except near the shoreline, where it is estimated to extend to an average depth of approximately 30 ft. Although the actual volume of sediment dredging would be evaluated during the remedial design process, for the purposes of the FS, it is estimated that approximately 150,000 yd^3 of material would be dredged to completely remove the refuse and wood waste from the Marine Site Unit. Dredge sediments would be stockpiled on a barge to allow dewatering prior to transport and disposal.

It is possible that some of the excavated waste would require pretreatment before it could be accepted at a solid waste facility. For the purposes of cost estimation, it is assumed that 90 percent of the waste excavated would be accepted without treatment, 10 percent of the waste would require onsite stabilization prior to disposal at a solid waste facility, and that none of the waste would require disposal at a hazardous waste landfill. Preliminary estimates of the waste used in this Section are based on available data and would be further evaluated during the remedial design.

The excavation and dredging would significantly modify the location of the shoreline. The shoreline would be reconstructed using clean sand fill and the shoreline stabilized within the intertidal and shallow subtidal zones. For the purpose of cost estimating, the conceptual design includes reconstructing the shoreline slopes to establish a 10H:1V grade within the intertidal zone, and 5H:1V below MLLW. It is additionally assumed for FS cost estimating purposes that the shoreline would be stabilized using traditional materials such as gravel and riprap, although soft bank technologies would be evaluated during remedial design. Alternative 4 has the potential for significant short-term water quality and sediment impacts resulting from the release of contaminants during removal, which may affect its ability to achieve

RAO-5 and RAO-6 during construction. This issue is further discussed in Section 9.6 (Evaluation of Alternatives).

Alternative 4 would result in an increase of approximately 7 acres of marine habitat, primarily in the subtidal zone. Because all refuse would be removed from the Site under this cleanup alternative, institutional controls and long-term compliance monitoring would not be necessary following construction. As discussed for the other Marine Site Unit alternatives, Site sediment excavation/dredging would need to be conducted in coordination with cleanup of the R.G. Haley site.

9.5 FEASIBILITY STUDY EVALUATION CRITERIA

This section presents a description of the evaluation criteria against which the alternatives are evaluated. As previously discussed in Section 9.4 (Description of Remedial Alternatives), all cleanup action alternatives for each Site Unit achieve the applicable RAOs presented in Section 9.2 (Remedial Action Objectives and Potentially Applicable Laws). MTCA specifies the evaluation criteria against which cleanup action alternatives are compared. However, additional evaluation criteria specified in SMS are applicable to sediment cleanup sites. As a result, the alternatives developed for the Upland Site Unit will be evaluated against MTCA criteria, and the alternatives developed for the Marine Site Unit will be evaluated against both MTCA and SMS criteria. Both MTCA and SMS require that cleanup alternatives be compared to a number of criteria to evaluate the adequacy of each alternative in achieving the intent of the regulations, and as a basis for comparing the relative merits of the developed cleanup alternatives. Most of the evaluation criteria are identical between MTCA and SMS, although SMS identifies two evaluation criteria not specified in MTCA.

9.5.1 THRESHOLD REQUIREMENTS

As specified in WAC 173-340-360(2)(a), all cleanup actions are required to meet the following threshold requirements:

- Protection of human health and the environment
- Compliance with cleanup standards specified under MTCA
- Compliance with applicable state and federal laws
- Provisions for compliance monitoring.

9.5.2 REQUIREMENT FOR PERMANENT SOLUTION TO THE MAXIMUM EXTENT PRACTICABLE

WAC 173-340-200 defines a permanent solution as one in which cleanup standards can be met without further action being required at the Site or at any other site involved with the cleanup action, other than the approved disposal site of any residue from the treatment of hazardous substances. Ecology recognizes that permanent solutions may not be practicable for all sites and provides criteria for determining whether a cleanup action is permanent to the "maximum extent practicable" in WAC 173-340-360(3)(f). These criteria include:

- ***Overall protectiveness*** of human health and the environment, including the degree to which Site risks are reduced, the risks during implementation, and the improvement of overall environmental quality
- ***Permanent reduction in toxicity, mobility, and volume of hazardous substances***, including the reduction or elimination of hazardous substance releases and sources of releases
- ***Cleanup costs,*** including capital costs and operation and maintenance costs
- ***Long-term effectiveness***, including the degree of certainty that the alternative will be successful, the long-term reliability, the magnitude of residual risk, and the effectiveness of controls required to manage treatment residues and remaining waste
- ***Management of short-term risks***, including the protection of human health and the environment during construction and implementation
- ***Implementability***, including consideration of whether the alternative is technically possible; the availability of necessary offsite facilities, services, and materials; administrative and regulatory requirements; scheduling, size, and complexity of construction; monitoring requirements; access for construction, operations, and monitoring; and integration with existing facility operations
- ***Consideration of public concerns,*** which will be addressed through public comment on this RI/FS report and the CAP that will be subsequently developed by Ecology.

Ecology provides guidance for a DCA procedure [WAC 173-340-360(3)(e)] to determine whether a cleanup action is permanent to the maximum extent practicable. The purpose of the DCA is to determine if the incremental increase in cost of a cleanup alternative over that of a lower cost alternative is justified by the incremental increase in benefits to human health and the environment. If the incremental increase in costs is determined to be disproportionate to the benefits, the more expensive alternative is considered impracticable and the lower cost alternative is determined to be permanent to the maximum extent practicable. This process provides a mechanism for balancing the permanence of the cleanup action with its costs, while ensuring that human health and the environment are adequately protected.

9.5.3 REQUIREMENT FOR A REASONABLE RESTORATION TIME FRAME

WAC 173-340-360(4)(b) specifies that the following factors be considered in establishing a reasonable time frame:

- Potential risks to human health and the environment
- Practicability of achieving a shorter restoration time frame
- Current use of the Site, surrounding areas, and associated resources that are, or may be, affected by releases from the Site

- Potential future use of the Site, surrounding areas, and associated resources that are, or may be, affected by releases from the Site
- Availability of alternate water supplies
- Likely effectiveness and reliability of institutional controls
- Ability to control and monitor migration of hazardous substances from the Site
- Toxicity of the hazardous substances at the Site
- Natural processes that reduce concentrations of hazardous substances and have been documented to occur at the Site or under similar Site conditions.

9.5.4 REQUIREMENT FOR CONSIDERATION OF PUBLIC CONCERNS

Consideration of public concerns is an inherent part of the Site cleanup process under MTCA (refer to WAC 173-340-600). This RI/FS report was issued for public review and comment, and Ecology determined which changes to the RI/FS report were needed in response to public comments. A similar process will occur for the CAP, prior to implementation of the final cleanup action, as specified in WAC 173-340-380.

9.5.5 SEDIMENT MANAGEMENT STANDARDS EVALUATION CRITERIA

In addition to the MTCA evaluation criteria described above, SMS requires that sediment cleanup alternatives be evaluated for the improvement in overall environmental quality or net environmental benefit, and for environmental impacts. Net environmental benefit includes benefits to the environment such as restoration of water and sediment quality, habitat and fisheries, and public benefits such as public access, recreation, aesthetics, and future land use. Environmental impacts include such factors as construction-related water and sediment quality impacts, loss of habitat value or acreage, and restrictions to land use or access. Net environmental benefit will be addressed by a separate evaluation criterion for the Marine Site Unit in Section 9.7.1.2 (Marine Site Unit).

9.6 EVALUATION OF ALTERNATIVES

This section provides an evaluation of the cleanup alternatives with respect to the MTCA and SMS criteria discussed in Section 9.5 (Feasibility Study Evaluation Criteria). A DCA of the alternatives is presented in Section 9.7 (Disproportionate Cost Analysis).

9.6.1 THRESHOLD REQUIREMENTS

In order for a cleanup alternative to meet the threshold requirements, it must adequately protect human health and the environment, comply with cleanup standards, comply with state and federal laws, and provide for compliance monitoring. Compliance with the threshold requirements for a cleanup action under MTCA is presumed by definition to be protective of human health and the environment once the cleanup action meets the cleanup standards for all affected media. Also, any cleanup action performed in accordance with the requirements of MTCA (and SMS) is assumed to be in compliance with cleanup standards and applicable state and federal laws. The following sections identify how the cleanup alternatives for each Site Unit comply with the threshold requirements.

9.6.1.1 Upland Site Unit

The potential exists for human health to be impacted under current Site conditions through direct contact with subsurface refuse during intrusive activities, or along the shoreline as additional shoreline erosion occurs. The primary potential impacts to the environment associated with the Upland Site Unit are continued release of refuse and wood debris to the aquatic environment from shoreline erosion and the discharge of contaminated groundwater (impacted through contact with the refuse) to Bellingham Bay. The current impacts will be addressed by the cleanup alternatives carried forward for evaluation.

The four Upland Site Unit alternatives comply with the threshold requirements as follows:

- ***Protection of human health and the environment*** – Alternatives 1, 2, and 3 protect human health and the environment through 1) physical containment of refuse, 2) reduction of contaminant concentrations in groundwater at the proposed conditional point of compliance by a reduction in groundwater discharge, and 3) institutional controls, and groundwater compliance monitoring. Alternatives 2 and 3 also reduce groundwater contaminant concentrations at the preliminary conditional point of compliance through groundwater treatment (filtration) and enhanced hydrodynamic dispersion provided by the sand filter layer. Alternative 3 further reduces contaminated groundwater discharge through installation of an upgradient groundwater diversion barrier. Alternative 4 provides protection of human health and the environment through complete soil, refuse, and wood waste removal and disposal at an offsite licensed solid waste facility.
- ***Compliance with cleanup standards*** – Through the various cleanup technologies and administrative controls employed, and achievement of the applicable RAOs, it is anticipated that Alternatives 1 through 4 would all comply with MTCA soil and groundwater cleanup standards. Alternatives 1, 2, and 3 would comply with cleanup standards through containment and the use of a conditional point of compliance for groundwater, and Alternative 4 would achieve cleanup standards through removal and offsite disposal.
- ***Compliance with applicable state and federal laws*** – Through identification of ARARs in Section 9.2 (Remedial Action Objectives and Potentially Applicable Laws) and compliance with MTCA and SMS regulations, Alternatives 1 through 4 all comply with applicable state and federal laws.
- ***Provisions for compliance monitoring*** – Protection monitoring will be provided for Alternatives 1 through 4 through health and safety protocols outlined under a Site-specific health and safety plan. Groundwater quality monitoring and LFG collection system monitoring would provide both performance and confirmation monitoring for Alternatives 1 through 3. Alternative 4 would include soil quality monitoring for performance and confirmation monitoring after completion of the excavation.

9.6.1.2 Marine Site Unit

The potential exists for human health to be impacted under current Site conditions through direct contact with refuse and contaminated sediment within the intertidal zone, and through the ingestion of marine organisms affected by contaminated sediment. The primary impact to environmental receptors is contact with contaminated sediment and affected groundwater or surface water. The current impacts will be addressed by the cleanup alternatives carried forward for evaluation.

Each alternative addresses threshold requirements for the Marine Site Unit as follows:

- ***Protection of human health and the environment*** – Alternative 1 protects human health and the environment through physical containment in the intertidal and shallow subtidal zones, and through natural recovery in deep subtidal areas of the Marine Site Unit. Alternatives 2 and 3 protect human health and the environment through physical containment of refuse in the intertidal and shallow subtidal zones, and through capping of refuse and wood debris and natural recovery in the deep subtidal zone. Alternative 4 protects human health and the environment through physical removal of contaminated sediment, refuse, and wood debris, and disposal at an offsite licensed solid waste facility.
- ***Compliance with cleanup standards*** – Through the various cleanup technologies, and achievement of the applicable RAOs discussed in Section 9.2.1 (Remedial Action Objectives), Alternatives 1 through 4 would each be in compliance with MTCA and SMS cleanup standards. Alternative 1 would comply with cleanup standards through containment and natural recovery, and Alternatives 2 and 3 would comply through containment, groundwater filtration, and natural recovery. Alternative 4 would achieve cleanup standards through removal and offsite disposal.
- ***Compliance with applicable state and federal laws*** – Through identification of ARARs, as discussed in Section 9.2.2 (Potentially Applicable State and Federal Laws) and compliance with MTCA and SMS regulations, Alternatives 1 through 4 would each be in compliance with applicable state and federal laws.
- ***Provisions for compliance monitoring*** – Protection monitoring would be provided for Alternatives 1 through 4 through health and safety protocols outlined under a Site-specific health and safety plan. Sediment natural recovery monitoring and/or cap monitoring, and bathymetric surveys would provide both performance and confirmation monitoring for Alternatives 1, 2, and 3 conducted under a Site-specific compliance monitoring plan. Alternative 4 would include sediment quality monitoring for performance and confirmation monitoring after completion of the removal action.

9.6.2 REQUIREMENT FOR A REASONABLE RESTORATION TIME FRAME

MTCA identifies a number of factors to be considered when establishing a reasonable restoration time frame, as described in Section 9.5.3 (Requirement for a Reasonable Restoration Time Frame). A cleanup action is considered to have achieved restoration once cleanup standards have been met. An evaluation of the cleanup alternatives with regard to achieving a reasonable restoration time frame is presented in Tables 9-2 and 9-3, for the Upland and Marine Site Units, respectively, and restoration time frames for each of the alternatives is summarized in Table 9-5. However, the practicability of achieving a shorter restoration time frame is addressed as part of the DCA evaluation presented in Section 9.7 (Disproportionate Cost Analysis). All the cleanup alternatives achieve restoration in a reasonable time frame.

9.6.2.1 Upland Unit

It is anticipated that each of the alternatives described in Section 9.4 (Description of Remedial Alternatives) would achieve restoration within the time frame criteria listed in Section 9.5.3 (Requirement for a Reasonable Restoration Time Frame), as presented in Table 9-2 and 9-5. Alternatives 1 through 3 could be constructed in a single construction season, and would immediately achieve soil cleanup standards. It may require 1 or more years following construction for these alternatives to achieve groundwater cleanup standards, depending on the length of time required to achieve post-construction steady state groundwater conditions. Specifically, Alternatives 2 and 3 are expected to achieve groundwater cleanup standards within 1 to 2 years, and Alternative 1 within 3 to 5 years (Alternative 1 does not have the shoreline sand filter). Alternative 4 would likely require multiple years to construct because of the large excavation volume, but should achieve restoration upon completion of construction, provided the cleanup action does not cause sediment contamination through releases during the removal process. The restoration time frame for Alternative 4 is expected to be 4 to 5 years.

9.6.2.2 Marine Site Unit

It is anticipated that each of the alternatives described in Section 9.4 (Description of Remedial Alternatives) would achieve restoration within the time frame criteria listed in Section 9.5.3 (Requirement for a Reasonable Restoration Time Frame), as presented in Table 9-3 and 9-5. Alternatives 1 through 3 could each be constructed within a single construction season. Alternative 1 is anticipated to achieve sediment cleanup standards in shallow subtidal areas within 3 to 5 years, and within 10 to 20 years within the deep subtidal zone where MNR is applied. Alternative 2 would be similar to Alternative 1, but with increased protection in intertidal and shallow subtidal zones because of improved groundwater quality resulting from the installation of a sand filter layer, and increased protection in the subtidal zone where a sediment cap would be placed. It is anticipated that cleanup would be achieved within 1 to 2 years (immediately following construction) in the shallow subtidal zone and the portion of the deep subtidal zone that is capped. The remainder of the deep subtidal zone is anticipated to achieve protection within 10 to 15 years, slightly shorter than Alternative 1 because capping a portion of the deep subtidal zone should accelerate the effectiveness of MNR. The restoration timeframe is anticipated to be the same for Alternative 3 as Alternative 2. Alternative 4 is anticipated to achieve cleanup immediately following construction (4 to 5 years), which is similar to the restoration timeframe for Alternatives 1 through 3 for the intertidal and shallow subtidal zones, but 5 to 15 years shorter than Alternatives 1 through 3 in the deep subtidal zone. However, redistribution and contamination of post-construction sediment surface could extend the restoration time frame by 10 to 20 years, resulting in a similar restoration time frame as to the other alternatives.

9.6.3 PERMANENT SOLUTIONS TO THE MAXIMUM EXTENT PRACTICABLE

As described in Section 9.5.2 (Requirement for Permanent Solution to the Maximum Extent Practicable), MTCA requires that cleanup actions be permanent to the maximum extent practicable, and identifies a number of criteria to determine which remedial alternative achieves this requirement. The evaluation of whether a given remedial alternative is permanent to the maximum extent practicable is addressed through a DCA, which is presented in Section 9.7 (Disproportionate Cost Analysis).

9.7 DISPROPORTIONATE COST ANALYSIS

As discussed in Section 9.5.2 (Requirement for a Permanent Solution to the Maximum Extent Practicable), MTCA requirements for remedy selection include the requirement to use permanent solutions to the maximum extent practicable. MTCA defines permanent cleanup actions as those in which cleanup standards are met without further action being required. MTCA specifies that the evaluation of whether a cleanup action uses permanent solutions to the maximum extent practicable be based on a DCA consistent with the requirements of WAC 173-340-360(3)(e). In a DCA analysis, cleanup alternatives are arranged from most to least permanent based on the criteria specified in WAC 173-340-360(3)(f).

The DCA then compares the relative environmental benefits of each alternative against those provided by the most permanent alternative evaluated. Costs are disproportionate to benefits if the incremental cost of the more permanent alternative exceeds the incremental benefits achieved by the lower cost alternative [WAC 173-340-360(3)(e)(i)]. The costs for each cleanup alternative is summarized in Table 9-4. Alternatives that exhibit disproportionate costs are considered "impracticable." Where the benefits of two alternatives are equivalent, MTCA specifies that Ecology select the least costly alternative [WAC 173-340-360(e)(e)(ii)(C)].

The DCA is performed in the following sections, using the information presented in Section 9.6 (Evaluation of Alternatives). The alternatives are first compared to the most permanent cleanup alternative for each Site Unit, and the benefits of each alternative are ranked under the criteria of the DCA [WAC 173-340-360(3)(f)] in Section 9.7.1 (Comparative Evaluation of Alternatives). The costs are then compared against these benefits and the relationship between the costs and benefits is determined in

Section 9.7.3 (Disproportionate Cost Analysis). This analysis then determines which alternative is permanent to the maximum extent practicable for each Site Unit.

Relative rankings for the alternatives within each Site Unit were determined by assigning a value on a scale from 1 to 10, where 10 is the highest benefit/value, for each criterion, multiplying each value by a weighting factor, and summing the weighted values to determine an overall alternative benefit ranking score. Weighting factors are based on Ecology input provided for other feasibility studies conducted on Port of Bellingham sites. The six evaluation criteria and associated weighting factors are:

- Protectiveness: 30 percent
- Permanence: 20 percent
- Long-term effectiveness: 20 percent
- Short-term risk management: 10 percent
- Implementability: 10 percent
- Considerations of public concerns: 10 percent.

Additionally, net environmental benefit must be included as an evaluation criterion for the Marine Site Unit. Net environmental benefit is the environmental gains in quality attained by remediation efforts, minus the environmental injuries caused by those actions. To accommodate this additional criterion, net environmental benefit is given a weighting factor of 10 percent, and the weighting factor for long-term effectiveness is reduced to 10 percent.

9.7.1 COMPARATIVE EVALUATION OF ALTERNATIVES

The DCA is based on a comparative analysis of the alternatives for each Site Unit against the six permanence evaluation criteria plus the net environmental benefit criteria for the Marine Site Unit. For each Site Unit, relative rankings for the evaluation criteria of each alternative are discussed below and summarized in Table 9-5.

9.7.1.1 Upland Site Unit

The following provides the comparative evaluation of the alternatives for the Upland Site Unit and compares Alternatives 1 through 3 to the most permanent alternative, Alternative 4.

Protectiveness of Human Health and the Environment

All four alternatives for the Upland Site Unit are protective of human health and the environment. However, there are relative degrees of protectiveness based on the technologies used to achieve that protectiveness. Alternative 4 achieves protection through the removal of contaminated soil and refuse. Alternatives 1 through 3 achieve protection through containment, stormwater management, compliance monitoring and institutional controls, and, in the case of Alternative 3, a groundwater diversion system. Although removal and offsite disposal is not inherently more protective than the other technologies, it does provide a higher level of certainty that protectiveness will be maintained in the long term. Although it is anticipated that each Alternative would achieve groundwater cleanup standards, a slightly increased level of groundwater flow reduction and greater level of hydrodynamic dispersion is achieved by Alternative 2 over Alternative 1, and additional groundwater flow reduction is achieved by Alternative 3 over Alternative 2. As a result, incremental increases in the level of protectiveness are achieved progressing from Alternative 1 to Alternative 3.

Based on these factors, Alternative 4 was ranked the highest for protectiveness with a ranking of 9 based on the complete removal of contaminated soil. Although placement of low permeability caps provides a high degree of certainty for protectiveness, Alternatives 1 through 3 are ranked slightly lower because they also rely on institutional controls to achieve cleanup. Alternatives 1 through 3 were given rankings of 4, 6, and 7, respectively, because of the slightly higher level of redundancy in effort achieved through addition of the shoreline sand filter layer for Alternative 2 and the upgradient groundwater diversion and two-layer low permeability cap under Alternative 3.

Permanence

Although none of the cleanup alternatives provide a permanent reduction in the toxicity or volume of hazardous substances, all alternatives provide a permanent reduction in mobility. Alternative 4 is considered the most permanent alternative because it removes the source material from the Site and contains it in an engineered landfill. Alternatives 1 through 3 each provide a permanent reduction in mobility through containment of refuse and a reduction in contaminated groundwater discharge to Bellingham Bay.

The integrity of the capping and containment systems associated with Alternatives 1 through 3 can be effectively maintained under the future land use options being considered for the Site. Regardless of future land use, the remedial actions associated with these three alternatives can be easily integrated into Site development and maintained in the long term. The permanence of Alternatives 1 through 3 will be further ensured through institutional controls that establish development and operational requirements for perpetuity. Alternative 4 was ranked highest for permanence (9) based on the waste being placed in a more secure setting, thus reducing the long-term mobility. Alternative 1 receives a ranking of 5, slightly less than the ranking of 6 for Alternatives 2 and 3 based on the greater durability of the liners used for the separation layer in the capping system. Alternatives 2 and 3 are both assigned a ranking of 6 because they will achieve approximately the same level of permanence, but significantly less than that provided by complete removal.

Effectiveness Over the Long Term

The four upland cleanup alternatives have varying degrees of certainty regarding long-term effectiveness. Alternative 4 has the highest certainty for long-term effectiveness because all refuse would be removed from the Site. Alternative 3 has the highest level of long-term effectiveness of the three containment alternatives because it provides the greatest reduction in groundwater discharge to surface water. Alternative 2 provides less of a reduction in the rate of groundwater discharge to surface water as compared to Alternative 3. Alternative 1 is similar to Alternative 2, but does not include the shoreline sand filter treatment layer that would further reduce contaminant concentrations at the point of groundwater discharge to surface water.

Alternatives 1 through 3 would prevent direct human contact with landfill refuse and would progressively increase the reduction of groundwater flow and contaminant concentrations discharging to Bellingham Bay. The concentrations of IHS in groundwater will decrease due to reduced groundwater flow and contaminant flux, increased hydrodynamic dispersion, and to some degree, geochemical reactions (primarily oxidation) near the tidal interface.

Based on these factors, Alternative 4 is ranked the highest for long-term effectiveness (10) because removal of contamination sources (refuse and soil) will eliminate any potential for a release to the environment in the future, although there is some potential that low levels of contamination would be redistributed into the aquatic environment during removal. Alternative 3 received a lower ranking of 7 for long-term effectiveness because onsite containment does not provide the same level of long-term effectiveness as removal. Alternatives 1 and 2 received lower rankings of 5 and 6, respectively, because the lower levels of groundwater recharge and hydrodynamic dispersion (as applicable) reduce the long-term effectiveness of the alternatives.

Management of Short-Term Risks

Alternatives 1 through 3 are all ranked high (9, 9, and 8, respectively) for short-term risk management because these alternatives require minimal disturbance of the landfill contents and consist primarily of placing an engineered layer of protective materials over impacted soil and refuse. Alternative 3 has slightly higher short-term risk than Alternatives 1 and 2 due to the construction of the hydraulic barrier system, which has a higher construction risk and a greater risk of releasing hazardous substances during construction.

The short-term risks for implementation of Alternative 4 are high because of the high potential for environmental releases to Bellingham Bay during implementation, and that it will likely require multiple construction seasons to implement. This will extend the duration for short-term risks and increase the potential for sediment recontamination in the Marine Site Unit from heavy stormwater runoff and wave action. While these short-term risks can be managed over the multiple construction seasons, it may not be possible to completely mitigate them. Additionally, the removal and offsite disposal of more than 500,000 yd^3 of refuse and contaminated sediment represents a significant potential for vehicle accidents or spills during transport to the waste disposal facility. Therefore, Alternative 4 is ranked low (2) for short-term risk management.

Implementability

Alternatives 1 through 3 would be implemented using common construction techniques employed for earthwork. Alternative 2 is identical to Alternative 3, except for the addition of the upgradient groundwater diversion barrier and the FML in Alternative 3. Alternative 4 would likely require extensive groundwater management and specialized equipment to reach the excavation depths required. There are a limited number of contractors capable of implementing a project of this magnitude within the physical setting present at the Site. Additionally, Alternative 4 may be subject to permitting difficulties due to the significant potential for water quality impacts, including the release of hazardous substances to the marine environment. The scope of Alternative 4 is such that it may not be possible to obtain adequate funding to implement the project, so its administrative implementability is uncertain.

Alternatives 1 and 2 are ranked 9 for implementability because they require the least amount and lowest difficulty of construction, and do not pose significant administrative implementation. Alternative 3 is given a ranking of 7 due to the additional complexity associated with implementation of the groundwater diversion system. Alternative 4 is ranked lowest (3) for implementability due to the volume and location/depth of refuse and soil that would need to be removed and managed appropriately.

Consideration of Public Concerns

Each alternative considers public concerns by responding to public comments received on the RI/FS and CAP documents as part of the cleanup process under MTCA. Based on public comment on the RI/FS report, upland Alternative 3 received a ranking of 9, followed by Alternative 4 with a ranking of 6. Alternatives 1 and 2 were given rankings of 2 and 3, respectively.

Comparison of Overall Benefits (Relative Benefit Scores)

Based on higher overall scores in the areas of protectiveness, permanence, and long-term effectiveness, Alternative 4 has the highest weighted score. The rank and relative benefit scores for each Upland Site Unit alternative under this scenario are presented in Table 9-5, and are as follows:

Alternative 1 Relative Benefit Score: 5.2

Alternative 2 Relative Benefit Score: 6.3

Alternative 3 Relative Benefit Score: 7.1

Alternative 4 Relative Benefit Score: 7.6

9.7.1.2 Marine Site Unit

The following provides the comparative evaluation of the alternatives for the Marine Site Unit and compares Alternatives 1 through 3 to the most permanent alternative, Alternative 4.

Protectiveness of Human Health and the Environment

Each of the alternatives for the Marine Site Unit are protective of human health and the environment. Alternative 1 achieves protection through MNR and shoreline stabilization. Alternatives 2 and 3 achieve protection through MNR, sediment capping, and shoreline stabilization. Alternative 4 achieves protection through the dredging and removal of contaminated sediment. Alternative 4 provides a higher level of certainty that protectiveness will be achieved, although there is some potential to redistribute contamination during dredging.

Alternative 4 was ranked the highest for protectiveness with a ranking of 9 based on the complete removal and offsite disposal of contaminated sediment, but with recognition of the potential for some contaminant redistribution and resulting surface sediment contamination. Alternatives 1 through 3 are given rankings of 5, 7, and 8 respectively for overall protectiveness. Alternative 1 is given the lowest ranking based on the additional time required to achieve sediment cleanup standards solely through natural recovery. However, natural recovery is the selected remedial action for the portion of the Whatcom Waterway site that extends onto the aquatic portion of the Site, so it has already been accepted by Ecology as effective in this area. Alternative 2 is ranked lower than Alternative 3 because a thin layer cap may not provide the same level of protectiveness as an engineered containment cap, although natural recovery processes have already been demonstrated to be occurring at the Site, so a thin layer cap is considered protective of human health and the environment and would achieve cleanup standards more rapidly than Alternative 1.

Permanence

Although none of the cleanup alternatives provide a permanent reduction in mobility, all four cleanup alternatives result in a permanent remedy provided that containment remedies (Alternatives 1 through 3) are adequately maintained over the long term. Alternative 4 is considered the most permanent alternative because it results in the complete removal and offsite disposal of refuse, wood debris, and contaminated sediment from the Marine Site Unit, and provides a reduction in contaminant mobility through placement in an engineered landfill. Alternatives 1 through 3 would provide permanent remedies, although Alternative 1 is more dependent on natural processes than and the other alternatives since it does not include placement of a cap in the subtidal zone.

Alternative 4 is given a permanence ranking of 9. It does not receive the highest benefit score because it does not permanently reduce the volume or toxicity of the hazardous substances and there is a potential for redistribution of contaminated sediment onto clean surface sediment during dredging. Although engineering controls used during dredging will minimize contaminant redistribution and associated residual sediment contamination, complete elimination of contaminant redistribution for such a large excavation/dredging project subject to high wave energy is likely infeasible. Alternatives 1 through 3 receive lower rankings of 6, 7, and 7, respectively, because they provide no reduction in volume of waste and contaminated media and minimal reduction in toxicity (through treatment of groundwater at the shoreline). Alternative 1 is given a lower ranking than Alternative 2 and 3 because of its reliance solely on natural recovery to achieve and maintain cleanup standards beyond the limits of the shoreline stabilization system.

Effectiveness Over the Long Term

Alternatives 1 through 4 are considered effective over the long term because each will achieve sediment cleanup standards in a reasonable restoration time frame and containment or removal of contamination sources (refuse and wood debris) would eliminate the potential for future release to the environment. Although Alternative 4 would achieve cleanup standards quickly, there is a significant potential for residual surface sediment contamination following implementation of Alternative 4 from suspension and redistribution of contaminants during dredging.

Alternative 4 receives the highest ranking (9) for long-term effectiveness. Alternatives 1 through 3 receive lower rankings (5, 8, and 8, respectively) for long-term effectiveness because onsite containment is not a high-preference technology; the ranking for Alternative 1 is lower than Alternatives 2 and 3 because of the time required to achieve sediment cleanup standards based solely on MNR beyond the shoreline stabilization system, and Alternatives 2 and 3 are ranked at 8 because they are expected to provide the same level of effectiveness over the long term.

Management of Short-Term Risks

The short-term risks associated with implementation of Alternatives 1 through 3 are minimal given that these alternatives will require limited disturbance of refuse, contaminated sediment, or wood debris. The most significant short-term risks for these alternatives would result from potential releases of contaminants to Bellingham Bay during installation of the shoreline stabilization system. Additionally, some short-term risk to marine biota would result from the water quality impacts, and benthic and epibenthic biota would be impacted resulting from the placement of the sediment thin layer and engineered caps associated with Alternatives 2 and 3, respectively.

There is significantly greater short-term risk associated with Alternative 4 than the other two alternatives due to the large volume of refuse, wood debris, and contaminated sediment that would be excavated/dredged from the marine environment. Alternative 4 construction activities would result in the potential exposure of workers to hazardous substances, and potential release of hazardous substances to Bellingham Bay. Additionally, transport of large volumes of dredged material on public roadways or via barge poses potential risk of spills and accidents.

Alternative 1 is ranked highest (9) for short-term risk management and Alternatives 2 and 3 are ranked slightly lower (8). Alternative 4 is given a lower score (2) because it presents significant potential short-term risks during implementation because large volumes of contaminated materials would be excavated/dredged from the intertidal and subtidal zones over multiple construction seasons.

Implementability

The cleanup technologies utilized by Alternatives 1 through 3 (shoreline stabilization and sediment capping) use common upland and marine equipment and methodologies applied to numerous environmental and marine engineering projects. As such, Alternatives 1 through 3 are considered highly implementable.

Alternative 4 would be implemented using common dredging techniques and equipment, but the magnitude and complexity of the alternative makes it subject to a number of engineering implementability issues associated with removing such a large volume of refuse, wood waste and sediment from the marine environment, including water quality issues, spreading contamination through suspension and redistribution, and conducting such a large scale dredging project in a near shore, high wave energy environment.

Administrative implementability, including permitting and cost, would also be a significant project challenge for Alternative 4. Permitting for such a large scale dredging project could be difficult because of the potential impacts to water quality and threatened or endangered species protected under the ESA. Additionally, the cost of Alternative 4 is such that it may not be possible to obtain adequate funding to implement.

Alternative 1 is ranked the highest (10) for implementability because it requires minimal construction and does not pose any significant administrative implementation issues. Alternatives 2 and 3 are ranked slightly lower (9) due to the potential difficulties in placing the sediment cap and controlling surface water quality impacts (turbidity). Alternative 4 is given a low score of 4 for the reasons discussed above.

Consideration of Public Concerns

Public comment on the RI/FS report did not result in a clear preference for one or more of the Marine Site Unit alternatives. As a result, all the alternatives are given a ranking of 10 for consideration of public concerns.

Net Environmental Benefit

Each alternative would provide a net environmental benefit through achieving sediment cleanup standards. Alternative 1 achieves a net environmental benefit through containment of refuse and contaminated sediment in the intertidal and shallow subtidal zones, and natural recovery in the deep subtidal zone. About 0.8 acres of the eelgrass bed at the southern end of the Site and about 0.2 acres of the eelgrass bed at the northern end of the Site would be covered by the shoreline stabilization system associated with Alternatives 1, 2 and 3, resulting in a net loss of about 1.0 acre of eelgrass beds. The eelgrass beds in this area would not likely re-colonize unless soft bank methods are used for shoreline stabilization. Alternatives 2 and 3 achieve a net environmental benefit through containment in the intertidal zone and sediment capping in the subtidal zone. An approximate additional 0.1 acre of the eelgrass bed at the northern end of the Site would be covered by the sediment cap associated with Alternatives 2 and 3, resulting in a net loss of an additional 0.1 acre of eelgrass beds, although the eelgrass is expected to quickly repopulate the area after the cap has been applied. Additionally, the thicker engineered cap associated with Alternative 3 would provide a modest increase in shallow habitat receptive to eelgrass colonization, so Alternative 3 would provide a slightly greater net environmental benefit than Alternative 2.

Alternative 4 achieves a net environmental benefit through the removal of refuse, wood debris, and contaminated sediment from the marine environment, and by the creation of about 7 acres of new aquatic habitat. Although cleanup construction would cause significant disruption of existing marine habitat, Alternative 4 would create and improve the most marine habitat of the three alternatives developed for the Marine Site Unit.

Alternative 4 is given the highest net environmental benefit ranking (9) based on the significant amount of aquatic habitat improved and created, and in consideration of the significant disruption to existing eelgrass beds and benthic organisms. Alternative 3 is given the next highest net environmental benefit ranking (7) because it creates a modest amount of new shallow subtidal habitat, which is of greater net environmental benefit than deep subtidal habitat. Alternative 1 is given a slightly lower net environmental benefit score (5) than Alternative 2 (6) because will not achieve sediment cleanup standards as quickly without a thin-layer cap to enhance natural recovery.

Comparison of Overall Benefits (Relative Benefit Scores)

Based on higher scores in the areas of short-term risk, implementability, and net environmental benefit, Alternative 3 received the highest overall weighted score. The rank and relative benefit scores for each Marine Site Unit alternative are as follows:

Alternative 1 Relative Benefit Score: 6.6

Alternative 2 Relative Benefit Score: 7.6

Alternative 3 Relative Benefit Score: 8.0

Alternative 4 Relative Benefit Score: 7.9

9.7.2 COST

This section presents the estimated costs for each alternative, subdivided by Site Unit. Itemized costs are provided in Appendix F and the costs are summarized in Table 9-4. The following sections briefly summarize the estimated costs for use in the DCA, for the Upland and Marine Site Units, respectively.

9.7.2.1 Upland Site Unit

Estimated present worth costs related to the Upland Site Unit for each alternative are as follows:

Alternative 1: $5,100,000

Alternative 2: $5,700,000

Alternative 3: $6,900,000

Alternative 4: $53,700,000

These estimated cleanup costs are consistent with an order of magnitude cost estimate and are based on an assumed present worth factor of 3 percent.

9.7.2.2 Marine Site Unit

Estimated present worth costs related to the Marine Site Unit for each alternative are as follows:

Alternative 1: $3,100,000

Alternative 2: $3,400,000

Alternative 3: $3,800,000

Alternative 4: $24,500,000

These estimated cleanup costs are consistent with an order of magnitude cost estimate and are based on an assumed present worth factor of 3 percent.

9.7.3 DISPROPORTIONATE COST ANALYSIS

As required by MTCA for remedy selection, the costs and benefits associated with the evaluated remedial alternatives are compared using a DCA. The DCA compares the relative environmental benefits of each alternative against those provided by the most permanent alternative evaluated. Costs are disproportionate to benefits if the incremental cost of the most permanent alternative exceeds the incremental degree of benefits achieved over the lower cost alternative [WAC 173-340-360(3)(e)(i)]. Alternatives that exhibit such disproportionate costs are considered “impracticable.” Where the benefits of two alternatives are equivalent, MTCA specifies that Ecology select the lower cost alternative [WAC 173-340-360(3)(e)(ii)(C)].

The estimated costs presented in Section 9.7.2 (Cost), and the benefits presented in Section 9.7.1 (Comparative Evaluation of Alternatives), are summarized for each alternative in Table 9-5. Table 9-5 also summarizes the overall benefits and costs for each alternative using the relative benefit scores developed in Section 9.7.1 (Comparative Evaluation of Alternatives). The benefit/cost ratio for each alternative, which is a relative measure of the cost effectiveness of the alternative, is also presented in Table 9-5. The cost benefit ratio is calculated by dividing the comparative overall benefit by the cost of the alternative; the alternative cost is first divided by $5,000,000 for scaling purposes. The comparative benefit, cost, and benefit/cost ratio for each alternative, grouped by Site Unit, are graphically presented on Figure 9-10.

9.7.3.1 Upland Site Unit

Consistent with MTCA requirements, the composite benefit and cost of each remedial alternative for the Upland Site Unit are compared to those for the most permanent alternative, Alternative 4. Alternative 4 makes the greatest use of high-preference technologies and represents the most permanent remedial alternative evaluated in this FS. As such, Alternative 4 represents the benchmark against which the incremental costs and benefits of the other alternatives are evaluated.

Alternative 4 receives a composite benefit ranking of 7.6 (out of 10.0). Because this remedy uses the most permanent remedial technologies of those evaluated for this FS, it receives high benefit rankings for overall protectiveness, permanence, and long-term effectiveness. However, Alternative 4 receives low benefit rankings for short-term risk management and implementability, due to the difficulty and risk associated with the removal of large volumes of refuse, contaminated soil, and wood debris from the upland portion of the Site. Alternative 4 receives a higher composite benefit ranking than Alternative 3.

However, its incremental increase in benefit over Alternative 3 is about 7 percent while the increase in cost is almost 700 percent. As a result, the cost for Alternative 4 is considered substantial and disproportionate to the incremental benefit provided relative to Alternative 3, and, consistent with WAC 173-340-360(3)(e), upland Alternative 4 is considered impracticable. As a result, Alternative 4 was eliminated from further consideration for cleanup of the Upland Site Unit and the remaining upland alternatives were compared to Alternative 3.

Alternative 2 received a lower composite benefit ranking than Alternative 3 (6.3 and 7.1, respectively). Both remedial alternatives are ranked high for overall protectiveness, short-term risk management, and implementability but are ranked slightly lower for permanence and long-term effectiveness because they primarily rely on containment to achieve and maintain cleanup standards. Alternative 3 has a significantly higher ranking for consideration of public concerns (9) than Alternative 2 (3), which accounts for the majority of the difference in the composite benefit ranking between these two alternatives. However, the estimated cost for Alternative 2 is $5,700,000, compared to an estimated cost of $6,900,000 for Alternative 3, which represents about a 21 percent increase in cost to achieve less than a 13 percent increase in composite environmental benefit. Additionally, the benefit/cost ratio for Alternative 2 (5.53) is higher than for Alternative 3 (5.14). As a result, the cost for Alternative 3 is considered substantial and disproportionate to the incremental benefit provided relative to Alternative 2, and, consistent with WAC 173-340-360(3)(e), upland Alternative 3 is considered impracticable.

Alternative 1 receives a composite benefit ranking of 5.2, which is about 18 percent lower than for Alternative 2 (6.3). Alternative 1 receives a lower benefit ranking for overall protectiveness, long-term effectiveness, and consideration of public concerns based on Alternative 2 including a sand filter treatment layer and a slightly lower permeability capping system. The estimated cost of Alternative 1 is $5,100,000, so the incremental increase in cost for Alternative 2 ($600,000) is about 12 percent, and the benefit/cost ratio for Alternative 1 (5.10) is about 8 percent lower than Alternative 2 (5.53). Because the benefit/cost ratio for Alternative 1 is substantively lower than Alternative 2, and the incremental increase in cost between Alternative 1 and Alternative 2 ($600,000) is relatively small, the potential reduction in cost achieved by Alternative 1 is not considered substantial or proportionate to the lower environmental benefit achieved by this alternative. Alternative 2 is, therefore, considered permanent to the maximum extent practicable for the Upland Site Unit.

9.7.3.2 Marine Site Unit

Consistent with MTCA requirements, the composite benefit and cost of each remedial alternative for the Marine Site Unit are compared to those for Alternative 4, the most permanent alternative for the Marine Site Unit. Alternative 4 makes the greatest use of high-preference technologies and represents the most permanent remedial alternative evaluated in this FS. As such, Alternative 4 represents the benchmark against which the incremental costs and benefits of the other alternatives are evaluated.

Alternative 4 receives a composite benefit ranking of 7.9. Because this remedy uses the most permanent remedial technologies of those evaluated for this FS, it receives high benefit rankings for overall protectiveness, permanence, long-term effectiveness, and net environmental benefit. However, this alternative receives low benefit rankings for short-term risk management and implementability due to the difficulty and risk associated with the removal of large volumes of refuse, contaminated soil, and sediment from the marine and near-shore environments.

Although Alternative 4 is considered the most permanent, it receives a lower equivalent composite benefit ranking score than Alternative 3 because of the significant short-term risk and implementability concerns. Because the overall benefit score is lower and the cost is almost 7 times higher, the cost of Alternative 4 is clearly substantial and disproportionate to the cost of Alternative 3 given that the overall benefit score is actually lower. As a result, Alternative 4 was eliminated from further consideration.

Alternative 3 received a composite benefit ranking of 8.0, which is about 5 percent higher than Alternative 2 (7.6). The increase in benefit ranking is due to its slightly higher permanence and net environmental benefit rankings based on the use of an engineered cap rather than a thin layer cap. However, given that natural recovery is documented to be occurring at the Site, the thin layer sediment cap included in Alternative 2 is likely to be as effective as the engineered cap associated with Alternative 3. The estimated cost of Alternative 3 is approximately $3,800,000, which is about 12 percent higher than the estimated cost for Alternative 2, resulting in Alternative 3 having a lower benefit/cost ratio (2.11) than Alternative 2 (2.24), indicating that Alternative 2 is a more cost effective alternative. As a result, the incremental increase in cost ($400,000) is considered disproportionate to the incremental increase in benefit and Alternative 3 is considered impracticable and is eliminated from further consideration.

Alternative 1 has an overall benefit score of 6.9, which is about 9 percent lower than the ranking for Alternative 2 (7.6). Alternative 1 receives a higher ranking than Alternative 2 for implementability and management of short-term risk, but receives lower rankings for overall protectiveness, permanence, net environmental benefit, and long-term effectiveness. Alternative 1 has a benefit/cost ratio of 2.23 compared to 2.24 for Alternative 2, indicating Alternative 1 is more cost effective. The incremental increase in cost for Alternative 2 compared to Alternative 1 is relatively small at approximately $300,000 (10 percent) and is not considered disproportionate to the incremental increase in comparative overall benefit achieved by Alternative 2. As such, Alternative 1 is eliminated from future consideration and Alternative 2 is considered the Marine Site Unit alternative that is permanent to the maximum extent practical.

10.0 SUMMARY AND CONCLUSIONS

The Site RI defined physical characteristics, source areas, the nature and extent of impacted media, and the migration pathways for contaminants. Data from the RI and previous investigations were used in the FS process to develop and evaluate remedial alternatives for the Site.

The FS developed remedial alternatives for each of the Site Units to clean up contaminated media defined in the RI, evaluated the alternatives against criteria defined by MTCA and SMS, provided a comparative analysis of the alternatives to determine the relative benefits of each, and compared the relative benefits of each alternative against their costs to determine the most permanent solution to the maximum extent practicable. This section presents the preferred alternative based on these evaluations, discusses how the preferred alternative will be compatible with the cleanup action selected for the R.G. Haley site, provides a comparison of the preferred alternative to cleanup actions conducted at similar sites, and discusses implementation of Site cleanup.

10.1 PREFERRED ALTERNATIVE

This section presents the preferred cleanup alternative for the Site. The actual cleanup remedy will be selected in the CAP developed by Ecology, and may vary from the preferred cleanup action described herein. Alternative 2 was identified in the DCA [Section 9.7 (Disproportionate Cost Analysis)] as the alternative that is permanent to the maximum extent practicable for the Upland Site Unit and Alternative 2 is identified as the alternative that is permanent to the maximum extent practicable for the for the Marine Site Unit. As a result, the preferred alternative (Containment with Low Permeability Cap and Liner, Shoreline Stabilization with Sand Filter, Thin Layer Sand Cap, and Monitored Natural Recovery) consists of the following elements:

- Upland cap consisting of low permeability soil and a scrim-reinforced liner, pavement, or buildings to reduce stormwater infiltration. Cap will include surface drainage features designed to reduce stormwater infiltration and prevent erosion.
- Upgradient stormwater actions to BNSF property and decommissioning of the existing Site stormwater collection and conveyance system located to the north of the former GP warehouse.
- Passive LFG collection and control system to mitigate the accumulation of LFG.
- Shoreline stabilization system to prevent erosion and limit human and benthic contact
- A sand filter layer to treat groundwater prior to discharge to surface water.
- A thin layer sediment cap installed from the toe of the shoreline stabilization system to the outer limit of Site refuse and wood debris.
- MNR from the outer edge of the containment cap to the limits of sediment IHS above the sediment cleanup levels (i.e., PCBs).

- Compliance monitoring.
- Institutional controls.

The preferred alternative is shown on Figures 10-1 and 10-2. The sand filter layer included in the Upland Site Unit will provide groundwater treatment and will also provide a location for most effectively monitoring groundwater quality at the point of discharge to surface water. It is anticipated that the preferred alternative will achieve groundwater cleanup standards within 1 to 2 years and sediment cleanup standards within 10 to 15 years following implementation of the cleanup action. The total estimated cost for the preferred alternative is $9,100,000.

10.2 COMPATIBILITY WITH R.G. HALEY AND WHATCOM WATERWAY REMEDIAL ACTIVITIES

The R.G. Haley site is located adjacent to the Site. As discussed in the RI, there is some overlap of hazardous substances in soil, groundwater, and sediment between the two sites. Because of this overlap, it is important that the remedial actions implemented at the two sites be coordinated to ensure successful remediation at both sites over the long term. It is the intent of the Port and the City to coordinate remedial activities for the Site with the actions at the R.G. Haley site. Because the City is the owner of portions of both properties, coordination and integration of the two cleanups should be easily accomplished.

Also nearby is the Whatcom Waterway cleanup site. The selected remedy for that cleanup site is MNR, and is now underway. The preferred alternative for cleanup at the Cornwall Site (and each of the alternatives considered) has some overlap with the Whatcom Waterway site in the Marine Site Unit. Because the selected remedy for the Whatcom Waterway cleanup site is MNR, the preferred alternative for cleanup of the Cornwall Site is compatible with that cleanup. Cleanup at the Cornwall Site will include capping and monitored natural recovery in the Marine Site Unit and as such, will not interfere and is likely to result in a quicker cleanup of the area where capping will be conducted. Where MNR overlaps between the sites, monitoring will be coordinated to increase the efficiency of data collection.

Although a preferred cleanup alternative has not yet been selected for the R.G. Haley site, it is anticipated that each site will utilize common remedial technologies, including upland capping and stormwater management, shoreline erosion protection, and other engineering and institutional controls. Cleanup of the R.G. Haley site could also include groundwater extraction, soil excavation, soil treatment, or soil stabilization. Some remedial technologies evaluated in this document are specific to Site issues, but all are considered compatible with the anticipated remedial actions at the R.G. Haley site. The remedial measures to be implemented at each of the sites can be designed and implemented in a coordinated and complementary manner. The spatial relationship between the preferred remedy for the

Site and potential elements of the remedy for the R.G. Haley site is shown on Figure 10-1. As shown on this figure, upland remedial actions in the northern portion of the Site are anticipated for both cleanups. Similarly, sediment remedial areas for both sites may overlap. The administrative issues associated with these areas of overlap (i.e., definition of site boundaries, points of compliance, and PLP roles and responsibilities) can be addressed as part of the CAP and consent decree.

Some sequencing of remedial activities may be required to ensure successful implementation of cleanup actions at the two sites. For example, to prevent potential sediment cap recontamination, the completion of shoreline erosion controls at both of the sites, and the completion of R.G. Haley site source control measures may need to be implemented prior to construction of the engineered containment cap proposed for the Site.

These types of coordination and sequencing issues can be addressed as part of the CAP, consent decree, and engineering design reports for the two sites, following Ecology selection of remedial alternatives for the two sites. At that time, the detailed plans and scheduling issues pertaining to engineering and institutional controls, and integration of these requirements with future land use, will be defined for the remedial alternative selected for each site. Detailed plans for implementing the cleanup in the areas overlapping the two sites will also be clarified.

The Port and the City are committed to working together, and with Ecology, to coordinate remedial actions at the two sites to ensure successful implementation and redevelopment.

11.0 USE OF THIS REPORT

This report was prepared for the exclusive use of the Port of Bellingham, the City of Bellingham, and applicable regulatory agencies, for specific application to the Cornwall Avenue Landfill Site. No other party is entitled to rely on the information, conclusions, and recommendations included in this document without the express written consent of the Port, the City, and Landau Associates. Further, the reuse of information, conclusions, and recommendations provided herein for extensions of the project or for any other project, without review and authorization by Landau Associates, shall be at the user's sole risk. Landau Associates warrants that within the limitations of scope, schedule, and budget, our services have been provided in a manner consistent with that level of care and skill ordinarily exercised by members of the profession currently practicing in the same locality under similar conditions as this project. We make no other warranty, either express or implied. This document was prepared under the supervision and direction of the undersigned.

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