FEASIBILITY STUDY, PULP/TISSUE MILL REMEDIAL ACTION UNIT

Vol. 2a of RI/FS, Georgia-Pacific West Site
Bellingham, Washington

Prepared for: Port of Bellingham

Project No. 070188-001-20 • October 27, 2014 Final

earth + water

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Contents

List of Tables

List of Figures

List of Appendices

Acronyms

ARAR	applicable or relevant and appropriate requirement
ASB	aerated stabilization basin
bgs	below ground surface
BNSF	BNSF Railway Company
CAP	Cleanup Action Plan
cis-DCE	cis, 1-2, dichloroethene
City	City of Bellingham
cPAH	carcinogenic polycyclic aromatic hydrocarbon
CSM	conceptual site model
Ecology	Washington Department of Ecology
EDR	Engineering Design Report
Foc	fraction organic carbon
FS	Feasibility Study
HDPE	high density polyethylene
ISCO	*in situ* chemical oxidation
Koc	octanol-to-water partitioning coefficient
LDR	land disposal requirements
mg/kg	milligrams/kilograms
MNA	monitoring natural attenuation
MTCA	Model Toxics Control Act
NAPL	non-aqueous phase liquid
NPDES	National Pollutant Discharge Elimination System
Order	Agreed Order No. DE 6834
ORP	oxidation-reduction potential
OSHA	Occupational Safety and Health Act
PCE	tetrachloroethene (perchloroethene)
Port	Port of Bellingham
PQL	practical quantitation limit

PRB	permeable reactive barrier
RAO	remedial action objective
RAU	remedial action unit
RCRA	Resource Conservation and Recovery Act
RI	Remedial Investigation
RI/FS	Remedial Investigation/Feasibility Study
Site	GP West Site
SMP	Shoreline Master Program
S/S	solidification/stabilization
TCE	trichloroethylene
TCLP	Toxicity Characteristic Leaching Procedure
TEQ	toxic equivalent quantity/toxic equivalent quotient
TPH	total petroleum hydrocarbons
µg/L	micrograms per liter
USDOT	U.S. Department of Transportation
UTS	Universal Treatment Standard
VC	vinyl chloride
VI	vapor intrusion
VOC	volatile organic compound
WISHA	Washington Industrial Safety and Health Administration
WSDOT	Washington State Department of Transportation

1 Introduction

This document presents the Feasibility Study (FS) for the portion of the Georgia-Pacific (GP) West Site (Site) referred to as the Pulp/Tissue Mill Remedial Action Unit (RAU).

Agreed Order No. DE 6834 (Order), entered into by the State of Washington Department of Ecology (Ecology) and the Port of Bellingham (Port) in August 2009, requires the Port to perform a Remedial Investigation/Feasibility Study (RI/FS) for the Site in accordance with WAC 173-340-350 and pursuant to the Scope of Work and Schedule of the Order as amended.

The First Amendment to the Order, executed in August 2011, required that the Port perform an interim action to remove mercury-contaminated soils and building materials from the Caustic Plume subarea and remove petroleum-contaminated soils from the Bunker C subarea of the Site. The First Amendment also contemplated additional interim actions and set out a process for approval of interim actions proposed by the Port. The Second Amendment to the Order, executed in August 2013, separated the Site into the Pulp/Tissue Mill RAU and the Chlor-Alkali RAU for the purpose of expediting remedial action at the Pulp/Tissue Mill RAU and, thus, putting it back into productive use more quickly. Figure 1-1 shows the Site and boundaries of the two RAUs[1].

Under the Order and its two Amendments, the Port is required to perform a Remedial Investigation (RI) for the entire Site (Volume 1 of the RI/FS), and prepare a separate FS for the Pulp/Tissue Mill RAU and for the Chlor-Alkali RAU (Volumes 2a and 2b, respectively, of the RI/FS). Remediation of contamination in the Chlor-Alkali RAU is expected to be considerably more complex than that in the Pulp/Tissue Mill RAU. Division of the Site into two RAUs allows the Pulp/Tissue Mill RAU FS to be completed prior to the Chlor-Alkali RAU FS. This will allow remedial action and redevelopment at the Pulp/Tissue Mill RAU to proceed more quickly which, in turn, should expedite cleanup of the Site as a whole.

The Site and its history are described in detail in Sections 1 and 2 of the RI (Aspect, 2013), and that information is not reiterated here.

This FS develops and evaluates remedial alternatives for soil and groundwater at the Pulp/Tissue Mill RAU in accordance with WAC 173-340-350(8), to enable Ecology to select a cleanup action for that RAU. The FS process includes identifying applicable or

[1] The boundary between the two RAUs has been modified since the Second Amendment to the Order. The Site includes property owned by BNSF Railway Company (BNSF), which originally occupied both RAUs. As described in Section 7.3 of the RI, the BNSF property encompassing the former Chlorine Plant stormwater swale contains mercury contamination associated with the Chlor-Alkali RAU. To further expedite remedial action at the Pulp/Tissue Mill RAU, the RAU boundary was redrawn such that the entire BNSF property (and BNSF's easement on the Port's property) within the Site now falls within the Chlor-Alkali RAU. This boundary revision does not impact the work elements of the FS and results in minor shifts in the FS schedule of deliverables for the portion of the site that is now in the Chlor-Alkali RAU.

relevant and appropriate requirements (ARARs) for cleanup, establishing cleanup standards that are protective of human health and the environment, identifying extents of contaminated media where remedial action is needed, identifying and evaluating potentially applicable remedial technologies for those media, and assembling remedial technologies into remedial alternatives to address Site contamination. The remedial alternatives are then evaluated against specific Model Toxics Control Act (MTCA) criteria (protectiveness, effectiveness, permanence, implementability, cost, and consideration of public concerns), and application of a disproportionate cost analysis, to inform selection of a preferred remedial alternative. Each step in the FS process involves consideration of site-specific data and planned future land use.

1.1 Recap of Conceptual Site Model (CSM)

The RI identifies four subareas of contamination within the Pulp/Tissue Mill RAU, which are listed below and shown on Figure 2-1 (also shown on Figure 8-2 of the RI):

- Bunker C subarea;
- Dioxin-Contaminated Debris subarea (within Bunker C subarea footprint);
- Acid Plant subarea; and
- LP-MW01 subarea (within the former Lignin Plant).

The RI also identifies soil and groundwater concentrations at locations outside of these subareas that exceed screening levels for unrestricted land use. Section 7 of the RI presents the conceptual site models (CSM) for each of the subareas, and areas outside the defined subareas. The CSM describes, for each area, the contaminants of concern and their historical source(s), nature and extent of contamination, contaminant fate and transport, environmental exposure pathways and receptors, and, based on the collective information, area-specific conclusions regarding contaminants and media to be addressed in the FS.

The following subsections provide a brief recap of the CSM for the Pulp/Tissue Mill RAU. The CSM provides the basis for defining remedial action objectives (RAOs) in this FS.

1.1.1 Bunker C Subarea

The existing conditions for the Bunker C subarea, as described in the RI, have changed following completion of the Bunker C Tank interim action. It is also anticipated that shoreline cleanup activities to be conducted during Phase 1 of the Whatcom Waterway cleanup project will impact conditions within the Bunker C subarea. The interim action and pertinent shoreline improvements are discussed below, followed by a recap of the CSM for these conditions.

Bunker C Tank Interim Action

In November and December 2011, the Port conducted an interim action for the Bunker C subarea in the Pulp/Tissue Mill RAU pursuant to the First Amendment to Agreed Order No. 6834. The goal of the interim action was to achieve permanent control of a substantial total petroleum hydrocarbon (TPH) contaminant source to groundwater and air (via soil vapor) through removal and off-site disposal of TPH-contaminated soil, including the highest TPH soil concentrations detected on Site.

The interim action involved the excavation of contaminated soil and non-aqueous-phase liquid (NAPL) beneath the former 375,000-gallon Bunker C aboveground storage tank located adjacent to the Whatcom Waterway shoreline. In accordance with the Interim Action Work Plan (Aspect, 2011), contaminated soil was excavated beneath the former tank to meet lateral and vertical soil remediation levels defined in the Interim Action Work Plan. The lateral remediation level of 10,000 mg/kg TPH, applied on the excavation sidewalls, was protective of groundwater (both accumulation of NAPL and leaching of dissolved phase) and vapor intrusion (VI). The more restrictive vertical remediation level of 3,100 mg/kg TPH, applied on the excavation bottom, was a risk-based concentration protective of all exposure pathways, including unrestricted (residential) direct contact exposure. The more restrictive vertical remediation level was developed to provide assurance that no further remedial action would be needed within the excavation footprint after it was backfilled.

Contaminated soil beneath the former tank was excavated and, based on visual and olfactory observations, segregated into soils that appeared to be contaminated (TPH concentrations above remediation levels) versus potentially clean overburden (TPH concentrations below remediation levels). Four oil-containing pipes were capped and removed from the excavation, and the oil content was drummed and disposed of at the Thermo Fluids oil recycling facility in Sumner, Washington.

Once field screening indicated a portion of the excavation was not contaminated, verification soil samples were collected at the bottom and sidewalls of the excavation, applying a 15-foot by 15-foot by 3-foot-vertical grid, to verify achievement of soil remediation levels. Based on sample results, additional lateral and vertical excavation was performed as needed to remove soil with TPH concentrations above the remediation levels. Soil remediation levels were ultimately achieved throughout the excavation.

In total, approximately 5,978 tons of soil and debris were removed during the Bunker C Tank interim action. A total of 4,333 tons of petroleum-contaminated soil was transported to the permitted treatment and disposal facility operated by CEMEX USA in Everett, Washington, where the soil was thermally treated and landfilled. An estimated 950 tons of the overburden soil, which were geotechnically suitable for on-site reuse and chemically tested to confirm TPH concentrations below remediation levels, were used as excavation backfill. An additional 377 tons of overburden containing TPH at concentrations below remediation levels but not meeting geotechnical specifications for the backfill were also disposed of at the CEMEX USA facility. Approximately 318 tons of construction and demolition waste were likewise properly disposed of off site.

To facilitate excavation, soil handling, and backfill, approximately 188,000 gallons of water were extracted from the excavation and staging area sumps and pumped through settling tanks and oil-water separators before discharge to the Port’s Aerated Stabilization Basin (ASB) on the north side of Whatcom Waterway. Once remediation levels were achieved, the excavation was backfilled with a combination of imported aggregate and reusable overburden soil. The Bunker C Tank Interim Action Report (Aspect, 2012a) provides additional detail regarding the interim action.

The Bunker C Tank interim action successfully achieved its source control objective through permanent removal of more than 4,300 tons of petroleum-contaminated soil, including removal of the highest TPH soil concentrations detected on the Site.

Shoreline Cutback, Whatcom Waterway Cleanup

The shoreline forming the northern edge of the Bunker C subarea is currently designed to be re-graded and improved as a component of the Whatcom Waterway Phase 1 cleanup. An approximate 275-foot length of shoreline north of the former Bunker C Tank and clarifier will be cut back approximately 70 feet to align with the adjoining shoreline. The clarifier and the vertical bulkhead supporting it will be removed and replaced by a 3H:1V sloping shoreline (area depicted on Figure 2-1). The newly sloped shoreline will be capped by an approximate 6-foot thickness of sand/gravel and armor rock, as outlined in the Ecology-approved Engineering Design Report (EDR) for the Whatcom Waterway Phase 1 cleanup (Anchor QEA, 2013).

Provided that it is geotechnically suitable and does not contain brick or plastic debris, soil generated from the shoreline cutback will be used to fill the former clarifier location to grade. However, soil containing TPH concentrations exceeding 10,000 mg/kg will be disposed of off site. Excess geotechnically suitable cutback soil (estimated volume of approximately 3,000 cubic yards) will be stockpiled, covered, and evaluated for reuse as subgrade fill within the Pulp/Tissue Mill RAU following chemical testing as described in the EDR (Anchor QEA, 2013). Final disposition of the reuse soils will be determined under Ecology oversight and will be consistent with cleanup requirements for the Site. Soil that is not geotechnically suitable for use as subgrade fill or that contains extensive debris will be disposed of off site at a permitted Subtitle D landfill facility.

The Whatcom Waterway Phase 1 cleanup action is currently assumed to occur prior to and/or during Pulp/Tissue Mill RAU remedy construction. Therefore, the cutback shoreline is an assumed condition for purposes of this FS. Likewise, the former GP dock to the west of the shoreline cutback is expected to continue to be used for an interim period, and is assumed to remain intact for purposes of this FS. If the Whatcom Waterway cleanup is not initiated by the time the Pulp/Tissue Mill RAU cleanup is conducted, the upland area within the planned clarifier cutback footprint would be remediated consistent with the surrounding portion of the RAU (all part of Bunker C subarea).

Current (Post-Interim Action) Conditions

Within the interim action excavation footprint, soils meet soil screening levels for unrestricted land use. The interim action also removed mobile NAPL at former monitoring well BC-MW01, where carcinogenic polycyclic aromatic hydrocarbon (cPAH) concentrations in groundwater had exceeded the 0.02 µg/L marine-based screening level prior to the interim action. No further remedial action is required for the interim action area.

Outside of the interim action area, residual soil TPH concentrations exceed both the 3,100 mg/kg soil screening level based on unrestricted (residential) direct contact exposure and, in several locations, the 10,000 mg/kg soil screening level based on groundwater protection[2] (Section 7.6 of RI). Notably, petroleum-contaminated soils (Bunker C concentrations exceeding 30,000 mg/kg) remain at depth adjacent to the former oil pipelines between the former storage tank and the steam plant and pier. The RI data indicate no TPH concentrations above 10,000 mg/kg within the shoreline cutback soil. Concentrations exceeding residual saturation indicate potential NAPL accumulation, and under MTCA, NAPL must be removed to the extent practicable.

Soil naphthalene concentrations in selected subarea locations exceed the unrestricted soil screening level, which is based on leachability to groundwater. However, detected naphthalene concentrations in subarea groundwater were below the most stringent groundwater screening level[3], providing an empirical demonstration of groundwater protection. Concentrations of cPAHs exceeding the unrestricted soil screening level (based on direct contact) are common throughout the subarea, as they are throughout the entire RAU.

Boring BH-SB02 is located within the Bunker C subarea. However, debris fill in the 4- to 8-foot depth interval at that boring[4] contains elevated soil dioxin/furan exceedances and a distinct dioxin/furan congener signature, and represents a distinct subarea for the purposes of this FS (see Section 1.1.2). The TPH concentration detected in that depth interval is below the unrestricted soil screening level, but underlying soils contain concentrations of TPH, naphthalene, and/or total cPAHs above respective soil screening levels for unrestricted land use.

This FS evaluates remedial alternatives within the Bunker C subarea that will prevent direct contact with TPH and cPAHs in soils, and accumulation of Bunker C NAPL for groundwater protection.

1.1.2 Dioxin-Contaminated Debris Fill Subarea

Soil within the 4- to 8-foot depth interval from boring BH-SB02, located on the east side of the former Baghouse, contains debris (e.g., plastic) and total dioxins/furans concentrations above the soil screening level based on direct contact exposure for an unrestricted (residential) land use. The proportions of individual dioxin and furan congener concentrations in the debris fill are distinctly different relative to all other Site soil samples analyzed. The detected total dioxin/furan concentration in the debris fill is below the screening level that is protective of leachability to groundwater; therefore, debris fill does not represent a contaminant source to groundwater (Section 7.9.2 of RI).

The BH-SB02 location is outside of the shoreline cutback, therefore this FS evaluates remedial alternatives that will prevent direct contact exposure with soils within the Dioxin-Contaminated Debris Fill subarea.

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[2] Based on protection of groundwater via leachability (generating dissolved phase hydrocarbons) and NAPL accumulation (residual saturation). As described in the RI, the 10,000 mg/kg concentration is considered a conservative estimate for residual saturation concentration.

[3] Including a very low concentration of groundwater naphthalene detected at well BC-MW04 located immediately adjacent to boring BH-SB02 where the highest soil naphthalene concentration (68 mg/kg) was detected.

[4] Total dioxin/furans concentrations (TCDD [TEQ]) exceed unrestricted but not industrial soil screening level; see Section 7.9.2 of RI.

1.1.3 Acid Plant Subarea

Soil within the former Acid Plant footprint (source area for acidic releases) contains concentrations of arsenic, cadmium, copper, mercury, and lead exceeding soil screening levels based on groundwater protection. The arsenic and lead concentrations in the upper 2 feet of soil also exceed soil screening levels based on unrestricted direct contact exposure. Soil pH within the source area is acidic but meets screening levels for unrestricted use (Section 7.7 of RI).

Groundwater in this subarea contains dissolved arsenic, cadmium, copper, nickel, and zinc concentrations that exceed groundwater screening levels based on marine protection. In addition, the groundwater pH is below the lower limit of the screening level range. The RI data indicate that dissolved metals concentrations and groundwater pH attenuate naturally downgradient of the former Acid Plant source area, with pH and all metals meeting screening levels at the downgradient shoreline well AA-MW01.

The available information indicates the dissolved metals in the Acid Plant subarea are mobile due to the low groundwater pH (between pH 3 and 4 in the source area, and buffering to between pH 4 and 5 further downgradient). Data collected between 2004 and 2009–2010 indicate the acidic groundwater pH is buffering gradually over time. Figure 1-2 illustrates groundwater pH measured between 2004 and 2009–2010 within the Acid Plant source area (the plant footprint within which acidic releases occurred), and at a location approximately 280 feet downgradient of the source area. Because pH is a logarithmic scale, it is represented graphically as the hydrogen ion (H+) concentration directly (= $10^{[-pH]}$) on the figure. The groundwater pH at both locations shows a gradual but definitive increase (reduced acidity) over the 6-year period between measurements. Restoration of groundwater pH should result in remediation of the dissolved metals concentrations as a result of metals precipitation/complexing under less acidic conditions.

This FS evaluates remedial alternatives within the Acid Plant subarea that will prevent direct contact with, and leaching of, metals in soils, and meet cleanup levels for pH- and metals-contaminated groundwater throughout the subarea.

1.1.4 LP-MW01 Subarea

The chlorinated solvent volatile organic compounds (VOCs) vinyl chloride (VC) and tetrachloroethene (aka perchloroethene or PCE) are detected in groundwater from well LP-MW01 at concentrations above groundwater screening levels based on marine protection. The VC concentration also exceeds the VI screening level for unrestricted land use. VOCs were not detected in downgradient groundwater samples, indicating the VOCs are not migrating significantly and do not approach within about 800 feet of the marine environment. The RI data also indicate there is not a significant source of VOCs in soil around well LP-MW01.

Consistent with the lack of a source, substantial reductions in groundwater VOC concentrations were measured over a 6-year monitoring period (2004 to 2009–2010). Figure 1-3 depicts the concentrations of groundwater VOCs (PCE, trichloroethylene [TCE], cis-1,2-dichlorethylene [cis-DCE], and VC) measured over that time period. Cis-DCE remained well below its RI screening level throughout the period of monitoring.

TCE was below its RI screening level in both 2009 and 2010 monitoring events. PCE and VC were above their RI screening levels in one of the 2009–2010 events.

Figure 1-3 includes trend lines through the PCE, TCE, and VC data (logarithmic regressions of concentration versus time) and, from those regressions, provides estimates of the times to meet the cleanup levels proposed in Section 2 of this FS, which are equivalent to the RI screening levels. Based on the trend line estimates, TCE is expected to have met its cleanup level in 2008 (consistent with RI data), PCE is expected to have met its cleanup level in 2010 but at a date after the 2010 RI monitoring event, and VC is expected to have met its cleanup level by the end of 2013. These data, in combination with the reducing groundwater conditions that promote biodegradation of the chlorinated VOCs (via reductive dechlorination), provide a strong weight of evidence that the groundwater VOCs are attenuating naturally to below levels of concern (see also Section 7.8 of the RI).

This FS evaluates remedial alternatives that will meet proposed cleanup levels for VOC-contaminated groundwater and thus prevent VOC VI into future structures at the LP-MW01 subarea.

1.1.5 Screening Level Exceedances Outside of Defined Subareas

1.1.5.1 Scattered Fill Unit Soil Exceedances Throughout RAU

As discussed in Section 7.10 of the RI, Fill Unit soils throughout the Pulp/Tissue Mill RAU contain scattered occurrences of contamination at concentrations above conservative soil screening levels for unrestricted land use. It is assumed for the purposes of this FS that Fill Unit soils[5] at any location within the RAU may contain concentrations of contaminants exceeding soil screening levels for an unrestricted land use. Therefore, this FS evaluates remedial alternatives to prevent direct contact with Fill Unit soils throughout the RAU.

1.1.5.2 Miscellaneous Dissolved Metals Exceedances in Groundwater

Concentrations of miscellaneous dissolved metals exceeding their corresponding RI groundwater screening levels have been detected at monitoring wells LP-MW01 and SC-MW02 (refer to Figure 1-4). As discussed in Section 7.9.1 of the RI, these concentrations are attributable to geochemically reducing groundwater conditions that enhance mobility of naturally occurring metals in the Fill Unit aquifer. These conditions result from the prevalence of organic-rich dredge fill with abundant wood that comprises the Fill Unit; such conditions are typical of man-made (filled) lands throughout the developed shorelines of Puget Sound.

The estimated extent of miscellaneous dissolved metals exceedances is shown on Figure 2-1. The question marks along the exceedance area boundary indicate that this area is not well-defined. However, as discussed in Section 7.9.1.2 of the RI, downgradient data indicate that metals concentrations of concern are not migrating to the Whatcom Waterway. In addition, natural attenuation has effectively reduced dissolved metals concentrations at LP-MW01 and SC-MW02 such that current concentrations are, at

[5] To the depth of underlying native soil (Tidal Flat Aquitard or Glaciomarine Drift, as discussed in Section 4.2 of the RI).

worst, only marginally above levels of concern; Figure 1-4 depicts the time trends for arsenic, chromium, copper, lead, mercury, nickel in the two monitoring wells.

This FS proposes cleanup levels for miscellaneous dissolved metals in RAU groundwater and evaluates remedial alternatives that will meet groundwater cleanup levels throughout the Site.

1.2 Document Organization

This FS, which develops and evaluates remedial alternatives for the Pulp/Tissue Mill RAU, is prepared as Volume 2a of the RI/FS for the Site. It is intended to supplement the findings of the RI (Aspect, 2013), which is Volume 1 of the RI/FS. The RI and FS documents have been prepared in general accordance with the Ecology-approved RI/FS Work Plan for the Site (Aspect, 2009).

Following this introductory Section 1, the remaining sections of this FS document are organized as follows:

- **Section 2, Cleanup Requirements** describes the RAU's land use, potentially complete contaminant exposure pathways, cleanup standards, RAOs, and ARARs for the remedial action;
- **Section 3, Screening of Remedial Technologies** identifies and evaluates a range of potentially applicable remedial technologies for the RAU contaminants and media, evaluates them with respect to applicability to the RAU, and retains the best technologies for possible incorporation into remedial alternatives for the RAU;
- **Section 4, Description of Remedial Alternatives** describes the remedial alternative components developed in consideration of the RAOs;
- **Section 5, Detailed Evaluation of Remedial Alternatives** compares the remedial alternatives relative to MTCA evaluation criteria;
- **Section 6, Summary and Conclusions** presents the preferred remedial alternative for the RAU based on the outcome of the MTCA alternatives evaluation, and provides a general overview of remedy implementation and its compatibility with the Whatcom Waterway cleanup; and
- **Section 7, References** lists the documents cited in this FS.

2 Cleanup Requirements

2.1 Land Use

In accordance with the Port and City of Bellingham's Waterfront District Subarea Plan (Port of Bellingham and City of Bellingham, 2012), the proposed land uses within the Pulp/Tissue Mill RAU include commercial mixed use, institutional mixed use, and industrial mixed use, as depicted on Figure 4-8 in the RI. The Bunker C Tank, Dioxin-Contaminated Debris, and the LP-MW01 subareas are planned for commercial mixed use, and the Acid Plant subarea is planned for institutional mixed use and commercial mixed use.

Under MTCA, sites may be remediated to either unrestricted or industrial cleanup levels. Industrial cleanup levels are developed based on an adult occupational lifetime exposure scenario, which results in higher cleanup levels for the soil direct contact and groundwater VI pathways, relative to unrestricted cleanup levels that are based on a child's lifetime exposure (residential). Assumptions and limitations of industrial properties are defined in WAC 173-340-200 and -745. Industrial properties are often, but not always, covered by buildings, structures, access roads, and parking lots that minimize potential exposure to soil. Access to industrial property by the general public is typically not allowed or, when allowed, is usually highly controlled due to safety or security considerations. Restaurants and other commercial operations are allowed under the MTCA definition of industrial property as long as they are primarily serving the industrial facility employees and not the general public.

Consistent with the intended future land use under the Waterfront District Subarea Plan, the Port intends to remediate the Pulp/Tissue Mill RAU to meet unrestricted cleanup levels.

2.2 Exposure Pathways

Section 5 of the RI (Aspect, 2013) provides a detailed description of environmental exposure pathways that are applicable for establishment of Site soil and groundwater cleanup levels. As described in Section 5.1 of the RI, the following potential exposures to groundwater and soil do not represent complete exposure pathways for the Site:

- **Potable use of Site groundwater**. As described in Section 5.2.1.1 of the RI, Ecology has determined that groundwater at the Site is classified as nonpotable in accordance with WAC 173-340-720(2). Therefore, groundwater cleanup levels are not established specific to this exposure pathway; and
- **Terrestrial ecological receptor contact with soil, and soil erosion to marine sediment**. The Port has committed to Site-wide capping, with associated environmental covenant(s) to maintain the cap in perpetuity (legally binding under Consent Decree), which would prevent terrestrial species exposure to contaminated soil and prevent erosion and transport of contaminated soil, in perpetuity. Therefore, soil cleanup levels are not established specific to these exposure pathways.

As discussed in Section 5.1.1 of the RI, potentially complete groundwater exposure pathways that will be addressed by Site groundwater cleanup levels in this FS include the following:

- Residents, workers, and patrons in buildings inhaling indoor air contaminated (via VI) by the volatilization of contaminants from shallow groundwater;
- Workers contacting contaminated groundwater during excavation or other construction-related activities, if no worker protection controls are in place;
- Direct exposure for benthic and aquatic organisms in Bellingham Bay and Whatcom Waterway, if groundwater contaminants migrate and discharge to marine sediment and surface water; and
- Humans consuming organisms contaminated by discharges of contaminated groundwater to marine sediment and surface water.

As discussed in Section 5.1.2 of the RI, potentially complete soil exposure pathways that will be addressed by Site soil cleanup levels in this FS include:

- Workers contacting contaminated soils (skin contact and incidental ingestion) and/or inhaling contaminated dust or vapors from soil during excavation or other construction-related activities, if no worker protection controls are in place; and
- Residents/visitors contacting contaminated soils and/or inhaling contaminated dust or vapors from soil in the future, if no controls are in place to restrict use of the Site.

In addition, contaminants in soil can leach to groundwater and be released to air through VI of volatile contaminants. Therefore, the soil-to-groundwater and soil-to-groundwater-to-air exposure pathways are also considered in establishing cleanup levels. The soil-to-groundwater pathway provides protection of the most stringent groundwater cleanup levels protective of the multiple exposure pathways described above. Figure 7-11 of the RI provides a graphical illustration of the relevant exposure pathways considered for cleanup level development in this FS.

2.3 Cleanup Standards

A cleanup standard includes both a cleanup level (chemical- and media-specific concentration of a contaminant that is protective of human health and the environment via all exposure pathways) and a point of compliance (the location where the cleanup level must be attained to achieve protectiveness). The proposed cleanup levels and points of compliance for the Pulp/Tissue Mill RAU are described in the following subsections.

2.3.1 Cleanup Levels

The approach for developing screening levels in the RI is consistent with MTCA protocols for cleanup level establishment, and the approach has been consistently applied across cleanup sites throughout Bellingham Bay, in close consultation with Ecology. As such, proposed soil and groundwater cleanup levels addressing potentially complete exposure pathways are consistent with the respective screening levels applied in the RI. There are no soil cleanup levels based on a soil-volatilization-to-air (via soil vapor) pathway, which is limited to vadose zone soil since saturated soil is addressed through the groundwater-to-vapor-intrusion pathway. Ecology (2009) guidance recommends evaluating VI from vadose zone soil using empirical soil vapor data, which was collected from selected areas in the RI.

Tables 2-1 and 2-2 present the proposed cleanup levels for RAU groundwater and soil, respectively, consistent with the potentially complete exposure pathways identified in Section 2.2. Table 2-2 includes the soil screening levels for direct contact and soil-to-groundwater leaching pathways, since remediation levels (less stringent than cleanup levels) can be established to address a specific pathway.

Soil Bunker C Remediation Level

Consistent with the Bunker C Tank interim action, a soil remediation level of 10,000 mg/kg TPH as Bunker C is proposed as protective of the soil-to-groundwater pathway (protective of both dissolved phase leachability and NAPL accumulation). This concentration is not protective of the soil direct contact pathway for unrestricted (residential) use; therefore, this concentration is not a soil cleanup level.

As described in the RI, 10,000 mg/kg TPH is a conservative estimate of residual saturation for weathered Bunker C in this subarea. This is the soil remediation level approved by Ecology for the interim action, and it is retained as a soil remediation level in this FS. If it is deemed impracticable to remove or treat residual Bunker C concentrations above 10,000 mg/kg TPH, more refined subarea-specific analysis (e.g., centrifuge testing for NAPL migration, empirical groundwater monitoring for dissolved-phase migration, etc.) may be conducted to evaluate an alternate soil TPH remediation level as part of remedial design or cleanup action implementation.

2.3.2 Points of Compliance

The proposed points of compliance for the groundwater and soil cleanup levels are described below.

Groundwater

Under MTCA, the standard point of compliance for groundwater cleanup levels is throughout Site groundwater, regardless of whether groundwater is potable or not (WAC 173-340-720(8)(b)).

For volatile groundwater contaminants that can pose a risk via VI, protectiveness is achieved by meeting VI-based groundwater cleanup levels throughout RAU groundwater, or wherever structures would be built on grade in the future. Therefore, the point of compliance for RAU groundwater cleanup levels based on VI protection is throughout the shallowest aquifer (Fill Unit).

Soil

In accordance with MTCA, the point of compliance for direct contact with soil extends to 15 feet below ground surface (bgs), based on a reasonable maximum depth of excavation and assumed placement of excavated soils at the surface where contact occurs.

For soil cleanup levels or remediation levels based on groundwater protection (i.e., leaching to groundwater or NAPL accumulation), the soil point of compliance is all depths, above and below the water table.

2.4 Areas/Volumes Exceeding Cleanup Levels

Based on the CSMs for the Pulp/Tissue Mill RAU as recapped in Section 1.1, this section describes the extent of contamination that exceeds the cleanup levels under current conditions (post-interim action). Figure 2-1 depicts the inferred areas of the RAU exceeding cleanup levels.

2.4.1 Bunker C Subarea

The location of the interim action excavation and the estimated extent of residual Bunker C subarea soils containing TPH concentrations above the 3,100 mg/kg subarea-specific unrestricted soil cleanup level are depicted on Figure 2-1. Figure 2-1 also depicts the inferred extent of TPH soil concentrations exceeding the 10,000 mg/kg TPH remediation level based on groundwater protection, in the area between the former Bunker C storage tank and the former Steam Plant and pier.

Based on the RI data, the estimated areal extent of soil exceeding the 3,100 mg/kg TPH unrestricted soil cleanup level is 12,000 square feet, and the estimated volume is 6,600 cubic yards. Assuming an average soil density of 1.5 tons/cubic yard, this volume equates to 9,900 tons of soil. The estimated quantity of soil exceeding the 10,000 mg/kg TPH soil remediation level is roughly 2,000 cubic yards, or 3,000 tons of soil. However, it should be noted that these quantities are estimates because the investigation of TPH-contaminated soil was limited by access beneath the Steam Plant structure, which was subsequently removed. It is anticipated that soil volumes will be refined in remedial design.

2.4.2 Dioxin-Contaminated Debris Subarea

The dioxin-contaminated soil with plastic debris was encountered in the 4- to 8-foot depth interval at boring BH-SB02, located east of the former baghouse (Figure 2-1). Boring BC-MW04, installed approximately 10 feet east of BH-SB02, did not encounter any plastic debris.

Based on the RI data, the estimated areal extent of dioxin-contaminated debris fill soil in this subarea is approximately 650 square feet. Assuming a thickness of 4 feet, the estimated quantity is approximately 100 cubic yards, or 150 tons of material.

2.4.3 Acid Plant Subarea

Within the Acid Plant subarea, the former Acid Plant was an approximately 80-foot by 140-foot area where sulfuric acid was stored in aboveground storage tanks. Acidic soils and elevated metal concentrations were observed within the former Acid Plant footprint, and an acidic groundwater plume with elevated dissolved metal concentrations extends northward towards Whatcom Waterway (Figure 2-1).

One soil boring/monitoring well, AA-MW04, was completed within the Acid Plant footprint (source area for acidic releases). For the purposes of this FS, it is assumed that the acidic pH and metals contamination observed at AA-MW04 is uniform throughout that footprint. The depth to groundwater ranges from 5 to 8 feet bgs within the Acid Plant footprint.

Based on the RI data, soil containing metals (arsenic, cadmium, copper, and mercury) at concentrations that exceed conservative soil cleanup levels based on groundwater protection[6] extend to a depth of about 10 feet bgs within the former Acid Plant footprint, although the cadmium exceedance extends deeper than 12 feet (that cadmium concentration is well below unrestricted direct contact criteria). Within the Acid Plant footprint, the metals (arsenic and lead) concentrations exceeding soil cleanup levels based on unrestricted direct contact exposure (which are less stringent, and could be established as remediation levels) appear to be limited to the upper 4 feet of soil.

Based on the RI data, the estimated areal extent of soil with acidic pH and metals exceeding the unrestricted soil cleanup level based on groundwater protection is approximately 10,000 square feet (former Acid Plant footprint). Assuming an average thickness of 10 feet of soil exceeding groundwater protection soil concentrations within that footprint, the estimated soil quantity is approximately 3,700 cubic yards or 5,600 tons of soil. Assuming an average thickness of 4 feet of soil exceeding direct contact soil concentrations (potential remediation levels) within that same footprint, the estimated quantity is approximately 1,500 cubic yards or 2,300 tons of soil.

Based on the RI data, the estimated areal extent of the Acid Plant groundwater plume is approximately 2.1 acres.

2.4.4 LP-MW01 Subarea

Based on groundwater concentrations measured in 2009/2010, the areal extent of the LP-MW01 VOC (PCE, VC) groundwater plume was estimated at 2,800 square feet. As discussed in Section 1.1.4, there is strong evidence that groundwater VOCs are naturally attenuating such that cleanup levels may have been achieved by the end of 2013.

2.4.5 Areas/Volumes Outside of Defined Subareas

2.4.5.1 RAU-Wide Fill Unit Soils

For the purposes of the FS, it is assumed that the entire volume of Fill Unit soil within the RAU contains concentrations of one or more contaminants exceeding soil cleanup levels based on unrestricted land use, consistent with Section 7.10 of the RI. Consequently, the Fill Unit across the entire RAU footprint and to the 15-foot point-of-compliance depth for direct contact exposure is assumed to require remedial action to provide protection for the soil direct contact pathway (Figure 2-1). The Fill Unit across the eastern and southern portions of the RAU is less than 15 feet thick; the underlying native soils (Tidal Flat Aquitard or Glaciomarine Drift) are assumed to meet unrestricted soil cleanup levels.

Applying these assumptions, the estimated areal extent of Fill Unit soil exceeding soil cleanup levels is approximately 31 acres, and, for an average depth of 12 feet, the

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[6] Due to conservatism in the cleanup level development methodology, the soil cleanup levels for arsenic, cadmium, copper, nickel, and zinc are based on natural background (not area background), and the soil cleanup levels for selenium and silver are based on the analytical practical quantitation level (PQL) (refer to RI Section 5 including Table 5-2).

estimated volume is roughly 600,000 cubic yards. Applying an average soil density of 1.5 tons/cubic yard, this volume equates to roughly 900,000 tons of contaminated soil.

2.4.5.2 Miscellaneous Dissolved Metals Exceedances

Outside of defined subareas of the Pulp/Tissue Mill RAU, groundwater dissolved metals exceedances were detected at monitoring wells LP-MW01 and SC-MW02. The Fill Unit surrounding these wells comprises the Miscellaneous Dissolved Metals Exceedances area addressed in this FS (Figure 2-1).

The estimated areal extent of the Miscellaneous Dissolved Metals Exceedances area is approximately 2.5 acres.

2.5 Remedial Action Objectives (RAOs)

RAOs are specific goals to be achieved by remedial alternatives that meet cleanup standards and provide adequate protection of human health and the environment under a specified land use. The RAOs for soil and groundwater consider the applicable exposure pathways for those media (Section 2.2) and provide acceptable concentrations for contaminants that are protective of all potential exposure pathways.

Based on the CSM for the Pulp/Tissue Mill RAU (Section 1.1), RAOs to be addressed in this FS are as follows:

- Prevent direct contact with and erosion of Fill Unit soils throughout the RAU, which also includes known contaminated soils within the Bunker C, Dioxin-Contaminated Debris Fill, and Acid Plant subareas;
- Meet groundwater cleanup levels throughout the Site;
- Prevent direct contact with TPH/cPAH-contaminated soils, and prevent the accumulation of NAPL for groundwater protection, within the Bunker C subarea;
- Prevent direct contact with and erosion of dioxin/furan-contaminated soils within the Dioxin-Contaminated Debris Fill subarea; and
- Prevent direct contact with and leaching of metals-contaminated soils within the Acid Plant subarea.

Each RAO will be achieved by terminating the associated exposure pathway. This can be done through contaminant removal or treatment to meet chemical- and media-specific cleanup standards (cleanup levels at points of compliance; Section 2.3) that are based on the specific exposure pathways, and/or otherwise preventing exposure through containment with associated institutional controls.

2.6 Applicable or Relevant and Appropriate Requirements (ARARs)

Cleanup standards represent chemical-specific requirements for a cleanup action under MTCA. As described in Section 2.3, cleanup levels for the Pulp/Tissue Mill RAU were developed in accordance with MTCA protocols, including incorporating chemical criteria from applicable state and federal laws.

In addition to cleanup standards, there may be other location- and action-specific requirements for completing a cleanup action. It is anticipated that the Pulp/Tissue Mill RAU cleanup action will be conducted under a Consent Decree entered into by Ecology and the Port. In performing the cleanup action under a Consent Decree, the Port would be exempt from the procedural requirements of Chapters 70.94, 70.95, 70.105, 77.55, 90.48, and 90.58 RCW, and of any laws requiring or authorizing local government permits or approvals; however, the Port must still comply with the substantive requirements of such permits or approvals (WAC 173-340-520).

The following sections identify the permits or specific federal, state or local requirements deemed applicable, and the applicable substantive requirements of those exempt permits or approvals.

2.6.1 NPDES Construction Stormwater General Permit

If construction-generated dewatering water or stormwater from the cleanup action is treated for discharge to waters of the State of Washington, such discharge would need to comply with requirements of a National Pollutant Discharge Elimination System (NPDES) Construction Stormwater General permit.

2.6.2 State Environmental Policy Act (SEPA)

Compliance with SEPA, Chapter 43.21C RCW, is achieved by conducting SEPA review in accordance with applicable regulatory requirements, including WAC 197-11-268, and Ecology guidance as presented in Ecology Policy 130A (Ecology, 2004). Ecology coordinated SEPA review concurrent with public review of the draft Cleanup Action Plan and Consent Decree for the Pulp/Tissue Mill RAU.

2.6.3 Permit Exemptions and Applicable Substantive Requirements

The following state and local requirements are identified as applicable but procedurally exempt for cleanup actions at the Site:

- Washington State Shoreline Management Act, RCW 90.58; City of Bellingham Shoreline Permit under Shoreline Master Program, Bellingham Municipal Code (BMC) Title 22;
- Major Grading Permit; City of Bellingham Grading Ordinance, BMC 16.70;
- Critical Areas Permit; City of Bellingham Critical Areas Ordinance, BMC 16.55; and
- City of Bellingham Stormwater Requirements, BMC 15.42.

The applicable substantive requirements of these permits or approvals are identified below. Substantive requirements may be further identified during remedial design, and their approval shall reflect Ecology's determination on what substantive requirements apply.

Shoreline Management Act; City of Bellingham Shoreline Permit

The Shoreline Management Act is implemented through the City of Bellingham Shoreline Master Program (SMP). To comply with the SMP, the cleanup action must have no unreasonable adverse effects on the environment or other uses, no interference with public use of public shorelines, compatibility with surroundings, and no contradiction of purpose and intent of SMP designation. It is expected that the Pulp/Tissue Mill RAU cleanup action would meet the conditions of the SMP's Waterfront District Shoreline Mixed Use designation and would be consistent with the SMP.

Major Grading Permit

Pursuant to the City of Bellingham Grading Ordinance (BMC 16.70), a Major Grading Permit is required from the City for grading projects that involve more than 500 cubic yards of grading. The City grading ordinance identifies a number of standards and requirements for obtaining a grading permit. The City standards and requirements will be integrated into the construction plans and specifications for the cleanup action to ensure that the cleanup action complies with the substantive requirements of the City grading ordinance. Those substantive requirements include: staking and flagging property corners and lines when near adjacent property, location and protection of potential underground hazards, proper vehicle access point to prevent transport of soil off-site, erosion control, work hours and methods compatible with weather conditions and surrounding property uses, prevention of damage or nuisance, maintaining a safe and stable work site, compliance with noise ordinances and zoning provisions, development of a traffic plan when utilizing City streets and written permission for grading from legal property owner.

Critical Areas

City of Bellingham critical area substantive requirements will apply to the RAU cleanup action. The cleanup action will occur partially on land designated as geologic hazard areas by BMC 16.55 Critical Areas: seismic hazard throughout the lateral extent of the Fill Unit, potential coal mine hazard in southernmost portion of the RAU, and wave erosion hazard along the RAU's shoreline. The substantive requirements include an assessment or characterization of the hazard areas by a licensed professional, which will be conducted in consultation with City of Bellingham.

Stormwater Requirements

Pursuant to the City of Bellingham Stormwater Management (BMC 15.42), the cleanup action would need to meet the substantive requirements of a City Stormwater Permit. The substantive requirements include preparation of a stormwater site plan, preparation of a construction stormwater pollution prevention plan, source control of pollution, preservation of natural drainage systems and outfalls, on-site stormwater management, runoff treatment, flow control, and system operations and maintenance.

Washington Clean Air Act

Cleanup actions would be regulated under the Washington Clean Air Act (Chapter 70.94 RCW) as implemented through Chapter 173-400 WAC and Chapter 173-460 WAC. The Regulation of the Northwest Clean Air Agency (NWCAA) would also be applicable. The substantive requirements would include not creating conditions that would significantly degrade the ambient air quality or cause exceedance of applicable air quality standards.

Other Requirements

Other local, state, and federal laws and requirements that potentially would apply to the cleanup action include the following:

- Solid Waste Disposal Act (40 CFR 257 and 258), as implemented through the state Solid Waste Handling Standards (Chapter 173-350 WAC) regulating any handling, treatment, or off-site disposal of non-hazardous solid waste;
- Resource Conservation and Recovery Act (RCRA) as implemented through the state Dangerous Waste Regulations (Chapter 173-303 WAC) regulating handling, treatment, or off-site disposal of hazardous/dangerous waste;
- OSHA/WISHA Regulations (29 CFR 1910.120; Chapter 296-62 WAC) governing worker safety during cleanup action execution. Compliance would be achieved through preparation and implementation of Site-specific health and safety plan(s) with appropriate controls, worker training and certifications, and occupational monitoring;
- Washington State Water Well Construction Regulations (Chapter 173-160 WAC) regulating groundwater well installation and decommissioning as part of the cleanup action; and
- USDOT/WSDOT Regulations regarding transport of hazardous materials (49 CFR Parts 171-180) if regulated material is transported off site as part of the cleanup action.

3 Screening of Remedial Technologies

This section identifies and screens remedial technologies that are potentially applicable to cleanup of the Pulp/Tissue Mill RAU. Because the different subareas and RAU-wide soil outside the subareas are impacted by different contaminants, this section is organized by subarea; however, certain technologies are applicable irrespective of contaminant type, and those are discussed first. The retained technology options are summarized at the end of this section, and then used to assemble remedial alternatives for the RAU in Section 4.

The remedial technologies for the Pulp/Tissue Mill RAU are based on RAOs to address direct contact with soil throughout the RAU and to address the additional potentially complete exposure pathways (via contaminant migration) within the four subareas. Remedial technologies are evaluated for their effectiveness for removal, treatment, and/or control of contamination; their implementability at the Site, and their relative cost. The retained remedial technologies may be combined within and among the subareas to provide effective remedial alternatives, which are developed in Section 4.

3.1 Technologies Applicable Throughout RAU

Certain remedial technologies are globally applicable throughout the RAU, irrespective of contaminant type. These technologies include excavation, capping, and natural attenuation of contamination in groundwater. The application of these technologies is considered throughout the RAU in this section, and may be applied on different scales for the individual subareas within the RAU.

3.1.1 Soil Excavation and Off-Site Disposal/Reuse

Excavation and off-site disposal of impacted soil would address all RAOs by removing contaminant sources. Excavation would address the direct-contact soil exposure pathway, the inhalation exposure pathway, and potential impacts to the Bellingham Bay marine environment through soil leaching, groundwater discharge, and erosion.

This technology involves excavation of impacted fill material and backfill with clean fill. Impacted fill material would be excavated to a maximum depth of 15 feet relative to the finished ground surface to be protective of direct contact exposure. The depth of fill is less than 15 feet on the south and east sides of the RAU, but may exceed 15 feet nearer the shoreline. Current redevelopment plans call for raising grade elevations across the entire RAU to protect against future sea level rise and to address grade separations from the downtown Bellingham Central Business District. Thus, excavation depths less than 15 feet below existing grade could be protective of direct contact under the future Site grades; however, for the purposes of this FS, the future grade condition is not considered.

This technology would use standard excavation techniques. However, due to the depth of excavation and the physical setting adjacent to the Whatcom Waterway, groundwater management and temporary shoring would likely be required. Extracted water would require pretreatment before discharge. For the purposes of this FS, it is assumed that discharge of dewatering water would not occur to the Port's ASB since it will be undergoing remediation as part of the Whatcom Waterway cleanup project. The probable discharge options therefore include an off-site wastewater treatment plant via the City of Bellingham sanitary sewer or discharge to the Whatcom Waterway under an NPDES permit. While not assumed for this FS, the ASB could be used if it remains operational under its NPDES permit at the time of remedy implementation for this RAU.

Excavated soil would be characterized for off-site disposal at a licensed and permitted disposal facility. If applicable cleanup standards and geotechnical requirements are met, excavated soil would be considered for potential on-site reuse. Performance monitoring would be conducted by sampling soils on the sidewalls and bottom of the excavation area and comparing against cleanup or remediation levels to determine compliance.

Excavation is retained as a RAU-wide technology for development of remedial alternatives.

3.1.2 Capping to Prevent Soil Direct Contact and Erosion

Capping in the forms of clean soil cover and hard surfaces can be applied as surface barriers to prevent human and terrestrial ecological exposure to, and prevent erosion of, contaminated soil. Hard surfaces can include both existing and future redevelopment pavement, building foundations, etc. Soil covers would be an assumed minimum thickness of 2 feet of soil that meets applicable cleanup levels. Most of the RAU is currently capped with pavement and building foundations which, subject to long-term inspection and maintenance, may provide the required isolation of underlying contaminated soil to achieve environmental protection. When redevelopment modifies these conditions, the existing surfaces likely would not provide sufficient protection.

This engineering control technology category also includes physical stabilization of the nearshore upland as needed to prevent erosion and migration of contaminated soil into the Whatcom Waterway. The planned Whatcom Waterway cleanup includes shoreline capping and stabilization, and the upland capping within the RAU would need to integrate with that work to provide complete coverage and isolation of nearshore contaminated soil.

Placement of new capping to replace current hard surfaces will proceed in accordance with requirements for pervious/impervious covers under the City of Bellingham SMP. Collection and off-site conveyance of stormwater runoff from capped surfaces will also be required in accordance with applicable laws and regulations.

Capping with impervious materials can also be used to restrict surface water infiltration and contaminant leaching from the vadose zone to groundwater. Impervious capping for this purpose is herein termed hydraulic capping to differentiate from capping to prevent direct contact. However, hydraulic capping would only apply to specific subareas, not RAU-wide, and is described in Section 3.4.3.

Capping technologies would require institutional controls to ensure their integrity in perpetuity. Institutional controls are described in Section 3.6.

Capping to prevent soil direct contact and erosion with institutional controls are retained as technologies for development of remedial alternatives.

3.1.3 Natural Attenuation of Contamination in Groundwater

Groundwater contamination is potentially of concern with respect to discharge to the marine environment, and with respect to volatilization from groundwater into indoor air of future occupied buildings within the RAU. Groundwater at the Site is a non-potable water source, and the groundwater ingestion exposure pathway is not complete, as described in Section 2.2.

Contaminants can naturally attenuate in groundwater via dispersion, sorption, and bioattenuation, each of which can occur along the groundwater discharge path to surface water. As groundwater approaches the marine interface, concentrations of contaminants are further attenuated by tidal mixing within the aquifer prior to discharge to marine sediment and then surface water.

Attenuation by sorption is influenced by chemical-specific and environmental parameters. For organic contaminants, sorption is influenced by the chemical-specific octanol-to-water partitioning coefficient (Koc) and the soil's fraction organic carbon (foc). Higher values for either of those parameters result in a greater affinity for that contaminant to sorb to organic matter in the soil (versus remaining in solution). For example, cPAHs are hydrophobic and tightly bound to soil, whereas naphthalene is more mobile in groundwater. The sorption of metal compounds is influenced by pH and by oxidation conditions for some species. Although the low groundwater pH near the Acid Plant has mobilized metals from the soil, metals concentrations attenuate downgradient from the Acid Plant as the groundwater pH recovers toward neutral conditions. Groundwater is generally under reducing conditions throughout the RAU, and oxidation does not contribute to metals mobilization.

Organic contaminants are variably amenable to bioattenuation. The chlorinated solvent VOCs PCE and TCE are primarily bioattenuated by the reductive dechlorination process, where PCE and TCE are used as electron acceptors under anaerobic conditions when the concentrations of competing electron acceptors (e.g., dissolved oxygen, nitrate, sulfate, and ferric iron) are low. The naturally reducing conditions of RAU groundwater are favorable for reductive dechlorination reactions. The cis-DCE and VC daughter products from reductive dechlorination of PCE and TCE bioattenuate by reductive dechlorination under strong reducing conditions, and can also degrade by aerobic pathways even under apparent anaerobic conditions. Hydrocarbons are preferentially bioattenuated under aerobic conditions, which increase via tidal mixing near the waterfront. Naphthalene is generally amenable to natural bioattenuation, whereas the heavier-molecular-weight cPAH compounds have limited potential for natural bioattenuation.

Natural attenuation of contamination in groundwater is retained as a technology for development of remedial alternatives. When using natural attenuation as a cleanup component, it is termed monitored natural attenuation (MNA) to reflect the fact that it must be monitored to ensure its performance.

3.2 Bunker C Subarea Remedial Technologies

The Bunker C subarea includes residual TPH-impacted soils primarily related to the transmission of Bunker C oil from the pier to the storage tank, and from the former storage tank to the Steam Plant. TPH-impacted soil at the former Bunker C oil storage tank was successfully removed to achieve unrestricted soil cleanup levels within the footprint of the interim action excavation (refer to Section 1.1.1).

The technologies screened for addressing contaminants in the Bunker C subarea include excavation and off-site disposal, *in situ* chemical oxidation (ISCO), and *in situ* solidification/stabilization (S/S).

3.2.1 Excavation and Off-Site Disposal

An interim action was performed in November and December 2011, in which petroleum-impacted soil and debris were removed from beneath the former 375,000-gallon Bunker C Tank as described in Section 1.1.1.

Excavation and off-site disposal could likewise be used to address residual TPH contamination outside of the interim action area. The extent of the TPH soil would be further delineated using exploratory soil borings and/or test pits. Soil would be excavated until the concentrations of TPH are below the cleanup levels based on direct contact or remediation levels based on protection of groundwater (NAPL accumulation). As with the RAU-wide excavation and off-site disposal approach, based on the physical setting of the Bunker C subarea, the excavation would require water management and may need temporary shoring. The excavation area could be dewatered by extracting groundwater from dewatering wellpoints outside the excavation and/or from sumps within the excavation. Extracted groundwater would be treated and discharged in accordance with applicable permit requirements. The excavated soil would be characterized for treatment/disposal and/or on-site reuse. The excavated areas would be backfilled with imported gravel borrow or excavated soil confirmed to be geotechnically suitable and meeting cleanup levels, and then compacted to match surrounding conditions.

Excavation and off-site disposal for the Bunker C subarea is retained as a technology for development of remedial alternatives.

3.2.2 In Situ Chemical Oxidation (ISCO)

Bunker C-contaminated soil could also be remediated using ISCO. Peroxide has been shown to be an effective oxidant for the remediation of Bunker C (e.g., Ecology, 2011), but is limited by its distribution potential and short half-life. Fenton’s reagent (ferrous iron catalyst with peroxide; EPA, 2006) creates a strong, exothermic reaction that may be effective for mobilizing and treating residual Bunker C oil in impacted soil. Although the exothermic reaction may be capable of mobilization, peroxide would be spent in the process, thus limiting the treatment effectiveness of ISCO.

Thermal conductive heating would likely be required to increase ISCO effectiveness. This can be accomplished by recirculating hot air through thermal heat exchange wells, which increases the temperature of the groundwater. Groundwater would need to be heated to about 150 ºF to desorb and mobilize residual Bunker C oil contamination.

To apply ISCO within the Bunker C subarea, we assume an estimated 10-foot by 10-foot injection grid would be used in the source areas, and ISCO reagents would be injected through direct-push injection points at multiple depth intervals. ISCO amendments would be injected sequentially, including activated persulfate, iron catalyst, and hydrogen peroxide, and more than one round of injection is expected. The effervescence of peroxide reduces soil porosity, limiting further injection.

A potential downside of using ISCO is that it reduces the pH and increases the oxidation-reduction potential (ORP) of groundwater, which can mobilize and/or transform certain metals. However, this is typically temporary since, as the injected oxidant attenuates, the groundwater pH and ORP recover with a corresponding attenuation in dissolved metals concentrations.

The combination of thermal conductive heating and ISCO has limited precedence for heavy-range petroleum like Bunker C, and it is anticipated that the treatment would be incomplete. Considering its limited application for Bunker C, the likely necessity of concurrent heating to achieve treatment, the anticipated incomplete treatment, and its complexity and consequential high costs, ISCO is not retained as a technology for development of remedial alternatives.

3.2.3 In Situ Solidification/Stabilization

In situ solidification/stabilization (S/S) can be performed to lower the permeability of saturated soil, thus increasing the NAPL residual saturation concentration and rendering the NAPL less mobile. Based on the American Petroleum Institute residual saturation curve (Section 7.5.2.1 of the RI), the residual saturation limit of Bunker C oil ranges from about 5,000 mg/kg at a soil vertical hydraulic conductivity of 1E-1 cm/sec to 100,000 mg/kg at a vertical hydraulic conductivity of 1E-5 cm/sec. *In situ* S/S can be performed to uniformly decrease the permeability of the impacted soil to less than 1E-5 cm/sec, where the corresponding residual saturation limit would be above 100,000 mg/kg. Binding amendments can also be added to the cement to increase the sorption of hydrocarbons, which chemically stabilizes the contamination and further protects the groundwater exposure pathway. *In situ* soil S/S would not generate solid waste that would require off-site disposal; however, it would increase the soil volume due to amendment addition and soil fluffing.

S/S could be performed by several different means, depending on the delineated extent of contamination and other design factors such as area-specific physical conditions. Examples of how *in situ* S/S could be implemented include:

- *In situ* S/S can be performed using large-diameter augers to inject and mix cementitious binding agents into the unsaturated and saturated soil. Rotary mixers can penetrate 5 to 15 feet in the soil, depending on equipment sizing and encountered soils. *In situ* S/S would likely be performed by injecting and mixing amendments into soil on a 10-foot by 10-foot treatment grid; or
- *In situ* S/S could be performed beneath the bottom of an excavation using an excavator to mechanically mix cementitious binding agents into the underlying soil. The treated soil would be compacted and the excavation would be backfilled and compacted to the existing grade.

In situ S/S is retained as a technology for development of remedial alternatives.

3.3 Dioxin-Contaminated Fill Subarea Remedial Technologies

Dioxin-contaminated debris fill was encountered in a discrete depth interval at boring BH-SB02, located near the former Baghouse within the Bunker C subarea. The dioxin-contaminated fill soil poses a risk only via soil direct contact under an unrestricted (residential) land use, consistent with soils throughout the entire RAU. As such, the remedial technologies for this subarea are the same as those described for RAU-wide soils (i.e., excavation and capping) albeit on a much smaller scale (see Sections 3.1.1 and 3.1.2).

3.4 Acid Plant Subarea Remedial Technologies

The Acid Plant subarea contains an assumed 80-foot by 140-foot source area where sulfuric acid was stored in aboveground storage tanks. The depth to groundwater in the source area ranges from 5 to 8 feet bgs. Soil pH values in the range of 3.9 to 5.0 have been measured in soil samples from the source area, while the groundwater pH was measured at 3.3 in 2004 and 4.2 to 4.5 in 2009–2010[7]. The low pH conditions have mobilized metals in soil. Arsenic and lead were detected above unrestricted soil cleanup levels for the direct contact exposure pathway in the 1- to 2-foot bgs interval of boring AA-MW04, but were below the direct-contact soil cleanup levels in the 4- to 5-foot depth interval. Remediation technologies are identified that address metals exceedances of the direct contact cleanup levels in the upper 4 feet of soil and that treat the mobilized metals in groundwater before their discharge to the marine environment.

3.4.1 Capping to Control Direct Contact Exposure Pathway

Capping could be applied to address the direct contact exposure pathway. The cap could consist of hard surfaces (e.g., future development pavement, building foundations) or soil cover. Institutional controls would be required to ensure the long-term integrity of the cap. Capping with institutional controls is retained as a technology for development of remedial alternatives.

3.4.2 Soil Excavation and Off-Site Disposal

Excavation could be performed to remove shallow surface soils within the footprint of the former Acid Plant that contain metals concentrations above the direct-contact cleanup levels. Excavation of acidic, metals-containing soils also removes a source of groundwater contamination. For the purposes of this FS, it is assumed that excavation would occur to a depth of 4 feet across the footprint of the former Acid Plant. Additional sampling would be necessary as part of remedy design to delineate the lateral and vertical extent of the soil exceedances, and to characterize the soil for treatment/disposal purposes (e.g., determine whether metals concentrations would cause the soil to designate as characteristic waste if land disposed, determine options for on-site treatment, etc.).

[7] The 3.3 groundwater pH was detected at well GF-MW02 in 2004, but that well could not be found during the RI. The 4.2 to 4.5 groundwater pH measurements were collected from well AA-MW04 located near former well GF-MW02.

Excavation and off-site disposal is retained as a technology for development of remedial alternatives.

3.4.3 Hydraulic Capping to Prevent Infiltration

This technology is designed to limit infiltration of precipitation through contaminated unsaturated soils within the Acid Plant footprint (source area) as a measure to control a source of groundwater contamination. Hydraulic capping could complement a direct-contact barrier or the excavation of shallow surface soil. The hydraulic cap could be constructed of compacted clay, an impermeable liner (e.g., sealed high density polyethylene [HDPE]), or low-permeability asphalt or concrete. The remedial objective for the hydraulic cap would be to minimize infiltration of surface water through the low-pH, metals-contaminated near-surface soil, and specific performance objectives (including land use compatibility) would be determined as part of remedial design. Stormwater would be conveyed off and around the hydraulic cap, and institutional controls would be needed to maintain cap integrity.

Hydraulic soil capping may also be combined with capping to prevent soil direct contact (direct contact capping is described in Section 3.1.2). This could include a combination of pavements, low-permeability liners, geo-textile separation layers, and soil capping materials.

Hydraulic capping is retained as a technology for development of remedial alternatives.

3.4.4 Infiltration to Buffer Acidic pH

If excavation of metals-impacted near-surface soil in the Acid Plant source area were to occur, the excavation could be backfilled with crushed limestone ($CaCO_3$) or similar alkaline materials to increase the pH of water infiltrating through the underlying unsaturated and saturated soil and groundwater, thus reducing metals mobility from residual underlying soil. Stormwater, irrigation water, or extracted uncontaminated groundwater could be drained through the crushed limestone backfill to increase its alkalinity. When the infiltrating water mixes with the acidic soils/groundwater, carbonate will react with the hydrogen ions to raise the pH and create a bicarbonate buffer. Dissolved-phase metals would attenuate to below groundwater cleanup levels in the bicarbonate-buffered groundwater.

The leachate system could be designed in several ways:

- The crushed limestone could be covered with topsoil and the area vegetated; potentially, a sprinkler system could also be installed to provide a year-round source of infiltrating water; or
- Subsurface drainage layer(s) and leachate piping could be installed above the crushed limestone with the goal of distributing the infiltration water evenly across the crushed limestone. Because of the high permeability of crushed limestone, drainage layers may include an underlying lower-permeability geotextile and an overlying high-permeability geo-mesh or aggregate layer to distribute the water evenly across the geotextile. Leachate piping would be installed within or above the drainage layer(s). Water sources could include extracted uncontaminated groundwater, stormwater, or potable water. The

system could be covered with either an impermeable surface to control infiltration water or a permeable vegetative surface to allow precipitation.

This technology application is not retained for development of remedial alternatives because the requirement to infiltrate water at a specific location may unnecessarily inhibit future development plans for the property, particularly compared to other treatment technologies that are also expected to be more effective for groundwater treatment.

3.4.5 In Situ Buffering of Acidic Groundwater

This technology involves the mixing or placement of chemical amendments into the aquifer to buffer the groundwater's acidic pH, thus precipitating dissolved-phase metals and enhancing/accelerating their natural attenuation. The technology can be applied anywhere within the plume (i.e., in the source area and/or downgradient locations). Treatment could be performed on a sparse grid or in non-continuous trenches that are perpendicular to the groundwater flow direction, or as a continuous PRB through which impacted groundwater passively flows. The amendments would be placed beneath the seasonally low water table, potentially to a depth of 15 feet, and would be allowed to dissolve in migrating groundwater. The amendments can be applied by several methods. For example, they could be mixed into the saturated soil with large-diameter augers or placed in large-diameter borings or excavated pits or trenches. For a PRB application, a funnel-and-gate system could be installed using slurry walls (funnel) to direct groundwater to a PRB (gate) containing alkaline treatment media. The PRB and slurry walls would need to be keyed into the underlying aquitard to control groundwater flow and direct the acidic plume through the PRB.

Potential buffering amendments include crushed limestone, hydrated lime, and calcium carbonate sludge from water softening, as follows:

- Crushed limestone has a relatively low material cost, but is slow to dissolve and can develop an external coating of ferric hydroxide that reduces its buffering efficiency over time. A design consideration for using crushed limestone is that ferric oxide precipitates can coat the calcium carbonate surface, which reduces the reactivity of the limestone and, if used in a PRB application, reduces its permeability. If used in a PRB, organic amendments could be added to the treatment media to stimulate the biologically mediated reduction of the sulfate and iron, and to maintain anoxic conditions that limit iron oxide formation.
- Hydrated lime ($Ca(OH)_2$) is sold as a bulk powder that can be more easily mixed into the soil and provides substantially greater surface area (thus reactivity) than crushed limestone. However, hydrated lime has a substantially higher material cost (approximately six times) than that of crushed limestone. The quick dissolution kinetics of hydrated lime make it well-suited for *in situ* mixing, but poorly suited for PRBs or as backfill in large-diameter borings because its depletion would inhibit long-term groundwater treatment.
- Water softening sludge has the lowest material cost. Lime sludges are produced from the precipitation of calcium carbonate and magnesium hydroxide during water treatment, and they may be essentially pure chemical sludges or they may

include suspended materials from the raw water if turbidity removal is combined with water softening. Sludges with high concentrations of calcium carbonate have higher solids concentrations because calcium carbonate is a fine-grained, dense precipitate, whereas magnesium hydroxide is a more gelatinous material. Lime sludges typically have a high pH (10.5 to 11.5), are odorless, and do not contain significant numbers of viable bacteria. The chemical quality, availability, geotechnical characteristics, and cost of lime sludge, compared to other treatment media options, would need to be further evaluated during remedy design.

In situ buffering of acidic groundwater is retained as a technology for development of remedial alternatives.

3.4.6 Groundwater Pumping and Treatment

Groundwater pumping could be used to provide hydraulic control (containment) of the source area or downgradient acidic plume. Alternatively, groundwater pumping could be used to extract source area water that would then be buffered to reduce pH and precipitate dissolved metals (*ex situ*), and recirculated back into the source area (treatment).

The need for hydraulic control as a remedial component is uncertain, and extended groundwater pumping may interfere with planned development activities. The technology would also be operationally intensive, and thus have high lifecycle costs relative to the passive treatment options outlined above. Therefore, groundwater pumping is not retained as a technology for development of remedial alternatives.

3.5 LP-MW01 Subarea Remedial Technologies

The RI data demonstrate that residual chlorinated VOC concentrations in groundwater are attenuating naturally, with achievement of cleanup levels predicted by the end of 2013 (see Section 1.1.4). Natural attenuation of contamination in groundwater, which applies to groundwater VOCs in this subarea, is discussed in Section 3.1.3. Additional technologies for treatment of chlorinated VOC contamination in groundwater are discussed below.

3.5.1 Biostimulation

Chemical amendments designed to stimulate biological degradation of residual chlorinated VOCs can be injected into the groundwater to create anaerobic reducing conditions that are conducive for reductive dechlorination. Biostimulant amendments (e.g., HRC®) provide a carbon source for indigenous microbes, which use electron acceptors for respiration. Reductive dechlorination bioattenuation reactions are optimized under iron- and sulfate-reducing conditions, where the more oxidized chlorinated VOCs (PCE and TCE), are used as electron acceptors in reductive dechlorination reactions.

While there is a strong weight of evidence that natural attenuation is effectively remediating the chlorinated VOCs in this subarea, biostimulation is retained as a technology for a potential contingency action if MNA is demonstrated to not be effective.

3.5.2 *In Situ Chemical Oxidation*

Chlorinated VOC contamination is amenable to treatment using ISCO. Oxidants, including peroxide, permanganate, persulfate, percarbonate, and/or ozone, can be injected or mixed into impacted soil and groundwater to oxidize the chlorinated VOCs into short-lived end-products. These oxidants differ in the strength, selectivity, surfactant effect, buoyancy, and resiliency. Permanganate is often selected for chlorinated VOCs because of its effectiveness, selectivity, and resilience in groundwater, which allows less direct mixing during application and leaves residual oxidant to treat desorbing contamination. Permanganate is stable and remains in groundwater until reduced by the natural oxidative demand of the aquifer. Relatively high doses of permanganate may be needed to overcome the naturally anaerobic conditions in groundwater. ISCO can mobilize naturally occurring metals due to decreased pH and increased oxidation conditions. Groundwater pH typically recovers within several months and the oxidative conditions typically last longer depending on the selected oxidant.

Biostimulation is judged to be a better contingency measure than ISCO, if needed, for application at the LP-MW01 subarea based on future groundwater monitoring; therefore, ISCO is not retained as a technology for development of remedial alternatives.

3.6 Institutional Controls

Institutional controls are mechanisms for ensuring the long-term performance of cleanup actions. While not considered a stand-alone remedial technology, institutional controls would be an integral component of remedies where contaminants exceeding cleanup levels remain at the Site. Institutional controls involve administrative/legal tools to provide notification regarding the presence of contaminated materials, regulate the disturbance/management of these materials and the cleanup action components including prohibiting creation of preferential pathways for contaminant migration, and provide for long-term care of cleanup actions including long-term monitoring. Under MTCA, the legal instruments for applying institutional controls are termed environmental covenants, equivalent to restrictive covenants for a specific property or portion of a property.

The specifics of the institutional controls required as a component of the selected cleanup action for the Pulp/Tissue Mill RAU will be developed by Ecology and the Port, in consultation with stakeholders including the City of Bellingham, during preparation of Ecology’s Cleanup Action Plan (CAP) and Consent Decree for the cleanup action.

The details of the required institutional controls and their implementation will be further defined in an Institutional Controls Plan specific to the Pulp/Tissue Mill RAU cleanup action. It is anticipated that the Institutional Controls Plan will be prepared as a component of the cleanup Consent Decree for the RAU. The Institutional Controls Plan will integrate with engineering controls (e.g., soil caps) required by the CAP, and will define use limitations and/or specific worker protection standards applicable to specific areas of the RAU. The Institutional Controls Plan will also identify responsibilities for institutional controls implementation (including those of the Port, City, and future land owner), provisions for inspection and maintenance of engineering controls, and protocols for notification regarding the presence of the institutional controls (e.g., including notification triggered by utilities on-call requests).

The cleanup-required institutional controls will be recorded on property deeds for land owned by the Port, City, or private land owners. To assist in information transfer, the Institutional Controls Plan will also be filed with Port property files and with the City building department. The Institutional Control Plan will be reviewed as part of property sales, leases, or proposed development projects within the RAU. The cleanup-required institutional controls for the RAU will remain in place indefinitely unless and until removal is approved by Ecology.

3.7 Summary of Retained Technologies

The following technologies are retained for development of remedial alternatives for the Pulp/Tissue Mill RAU:

- Capping to prevent soil direct contact and erosion (engineering controls), applied across the entire RAU and in specific subareas;
- Soil excavation and off-site disposal/reuse, applied across the entire RAU and/or in specific subareas;
- Natural attenuation of contamination in groundwater;
- *In situ* S/S of Bunker C-contaminated soil;
- Hydraulic capping of Acid Plant source area to prevent infiltration;
- Crushed limestone amendments to backfill the Acid Plant source area excavation;
- *In situ* buffering of acidic groundwater in the Acid Plant subarea, which can be applied several ways;
- Biostimulation of chlorinated VOCs in groundwater; and
- Institutional controls.

4 Description of Remedial Alternatives

In this section, the retained remedial technologies are assembled into remedial alternatives developed to meet the RAOs for the RAU (refer to Section 2.5). Although the remedial alternatives are independent of specific redevelopment actions, they may include components that are performed in conjunction with redevelopment actions as they occur.

Four remedial alternatives are described in this section, which are presented in order of increasing permanence and cost. Each of the four alternatives include the previously completed interim action for the Bunker C subarea (described in Section 1.1.1), and removal of remaining soils that contain Bunker C oil concentrations greater than the residual saturation remediation level (potential NAPL source) in the Bunker C subarea. The latter is required to meet the MTCA requirement to remove free product (NAPL) to the maximum extent practicable.

Beyond the Bunker C oil source control common to each alternative, the increasing remedy permanence for the alternatives is summarized below:

- Alternative 1: Primarily relies on capping and institutional controls and natural attenuation of contamination in groundwater.
- Alternative 2: Includes *in situ* groundwater treatment and source area hydraulic capping in the Acid Plant subarea.
- Alternative 3: Includes *in situ* groundwater treatment and source removal in the Acid Plant subarea.
- Alternative 4: Removes the fill material and associated contamination throughout the RAU to a depth of 15 feet.

The following sections describe each of the four alternatives in detail. Figures 4-1 through 4-4 present FS remedy design concepts for the four alternatives.

4.1 Alternative 1

Alternative 1 provides removal and contingent treatment options for Bunker C oil-contaminated soil and provides RAU-wide engineering and institutional controls with groundwater monitored natural attenuation. The components of Alternative 1 are described below.

4.1.1 Engineering Controls (Capping), RAU-Wide

RAU-wide capping would be performed to control the soil direct contact exposure and soil erosion pathways for known contaminated soils within the Bunker C, Dioxin-Contaminated Debris Fill, and Acid Plant subareas, and for RAU soils outside of those subareas that may contain concentrations of contaminants exceeding soil screening levels for an unrestricted land use.

Capping would consist of a combination of existing pavement and building foundations, new buildings and pavement, and/or new soil covers. Anywhere that existing pavement/building foundations would be disturbed for the purposes of redevelopment would need to be capped with new materials. The RAU-wide cap would integrate with the shoreline capping to be conducted for the Whatcom Waterway cleanup, such that no contaminated soils are left exposed (uncapped) along the upland-shoreline transition.

For the purposes of this FS, it is assumed that the caps would be designed consistent with Type 2 caps described in Ecology's Model Remedies Guidance for the Tacoma Smelter Plume (Ecology, 2012). Specifically, hard caps would be composed of a minimum of 3 inches of concrete, asphalt, paving blocks, or building foundations. Soil caps would be composed of a minimum of 24 inches of uncontaminated soil cover with a geotextile separation layer to distinguish the capping material from the underlying soil. Uncontaminated soil could include imported uncontaminated soil and/or site soil confirmed to meet applicable soil cleanup levels (soil reuse).

The redevelopment plans for the property include increasing the Site elevation to mitigate the impact of potential sea level rise and to reduce the grade separation with the downtown Bellingham Central Business District. The future Site grading would be designed to maintain the required remediation performance standards, integrated with redevelopment aesthetics and drainage. Potential sources of imported borrow soil would be evaluated for geotechnical and chemical criteria, and clean fill material would be imported and graded per the Site redevelopment plans. Stormwater generated on the capped areas would be managed in accordance with applicable local development regulations and ordinances. Further details on cap design would be determined during remedy design.

4.1.2 Removal Action for Bunker C Subarea Soil

Alternative 1 includes the completed interim action removal of soil beneath the former Bunker C Tank, and removal of additional soils containing Bunker C oil concentrations exceeding the residual saturation remediation level (10,000 mg/kg). The RI data indicate soils exceeding residual saturation exist between the former Bunker C tank and the pier, including areas under the former Steam Plant. For the purpose of this FS, the extent of soil exceeding the residual saturation remediation level is estimated to be 13 feet deep in the area depicted on Figure 4-1. The extent of oil-contaminated soil would be further delineated during remedy design.

Targeted excavation would be performed to remove Bunker C oil-contaminated soil exceeding the residual saturation remediation level of 10,000 mg/kg, consistent with procedures described in Section 3.1.1.

In situ S/S is retained as a contingent treatment option if it is determined during remedy design or implementation that is impracticable to remove soil containing Bunker C oil concentrations above the soil remediation level based on residual saturation. The extent of such soil may be greater than estimated at this time. In that case, S/S could be performed, as described in Section 3.2.3, to increase the residual saturation concentration for the residual Bunker C oil and thus prevent NAPL accumulation, and to encapsulate impacted soil which is protective of the direct-contact exposure pathway.

4.1.3 Monitored Natural Attenuation of Groundwater Contamination

MNA would be applied to address residual contamination in groundwater that exceeds applicable groundwater cleanup standards. Contaminants will continue to naturally attenuate in groundwater through a combination of sorption, bioattenuation, volatilization, dispersion, and tidal mixing. Based on the RI data, the contaminants that exceed cleanup levels in upland groundwater include pH and selected metals in the Acid Plant subarea, PCE and VC in the LP-MW01 subarea, and selected metals in the Miscellaneous Dissolved Metals Exceedances area. Different natural attenuation mechanisms operate for the different contaminants, and RI data indicate that natural attenuation is effectively reducing concentrations of groundwater contaminants in each area (refer to subarea-specific CSM recaps in Section 1.1).

It is anticipated that the Consent Decree and CAP for the RAU will require the development of a groundwater monitoring plan to evaluate the performance of the groundwater contaminant natural attenuation. The groundwater monitoring plan would present the locations of upland monitoring wells, location-specific monitoring analytes and analytical methods including quality control, monitoring frequency, and a decision process for evaluating and adaptively managing the MNA remedy.

Several contingent actions may be considered for implementation if MNA fails to achieve the expected continued groundwater restoration and is determined to be not protective of human health and the environment (remedy failure). The contingent actions could include enhanced source attenuation or downgradient groundwater treatment and/or control. For the Acid Plant subarea pH/metals plume, enhanced attenuation is assumed to be performed by implementing *in situ* treatment methods to buffer the groundwater pH, and thus enhance the precipitation of metals, applying methods described in Section 3.4.5. These same technologies could be applicable as a contingent action for addressing the Miscellaneous Dissolved Metals Exceedances area. While the need for a contingent action seems unlikely for MNA of groundwater VOCs in the LP-MW01 subarea, biostimulation (Section 3.5.1) is a viable treatment technology that could be applied.

The design of a contingent action would be conducted if potential failure of MNA was indicated through monitoring, at which time substantial additional information would be available to determine the causes of failure and therefore the most effective and practicable means to remedy it. The cost of contingent remedial actions is not included in the estimated cost for Alternative 1.

4.1.4 Institutional Controls

Alternative 1 includes application of institutional controls to provide notification regarding the presence of contaminated materials, regulate the disturbance/management of these materials and the cleanup action components, and provide for long-term monitoring and stewardship of the RAU's selected cleanup action. In addition, if groundwater monitoring indicates that VOC concentrations have not naturally attenuated to below cleanup levels in the LP-MW01 subarea, an institutional control would be needed requiring that VI potential be evaluated and/or VI controls constructed beneath future buildings in that subarea.

As described in Section 3.6, the Port and Ecology, in consultation with the City of Bellingham, would develop an Institutional Controls Plan for the RAU, which will identify the inspection and maintenance requirements for engineering controls (capping), use limitations (e.g., prohibit groundwater usage), specific worker protection standards, VI evaluation/control requirements (if necessary), and notification requirements.

4.1.5 Restoration Time Frame

It is estimated that design and construction of Alternative 1 would take 1 to 2 years. Some cleanup may be integrated with redevelopment, which could control schedule. As described in the Preliminary Geochemical Modeling, Acid Plant Subarea Groundwater Remediation Alternatives (Appendix A), the anticipated time to meet groundwater cleanup levels in the Acid Plant subarea is on the order of 20-40 years. That subarea is expected to have the longest groundwater restoration timeframe and, as such, defines the estimated restoration timeframe for the Site.

4.1.6 Estimated Cost

Net present value costs in 2014 dollars were estimated for each of the remedial alternatives using a discount factor of 1.9 percent. The estimates (Appendix B) include costs for remedy design, construction, and long-term operation and maintenance (O&M) which includes long-term inspection, monitoring, and maintenance. The net present value cost represents the dollar amount which, if invested in the initial year of the remedy and disbursed as needed, would be sufficient to cover all costs associated with the remedial action. O&M costs were evaluated over a 30-year period, consistent with EPA guidance. The estimates are order-of-magnitude, with an intended accuracy in the range of -30 to +50 percent. They include the sunk costs for design and construction of the completed Bunker C Tank interim action (approximately $770,000).

The cost for Alternative 1 is estimated at approximately $5.6 million. This cost estimate assumes that 20 percent of the RAU area would be capped by soil cover (e.g., landscaping), 30 percent would be capped by pavement (asphalt assumed for costing), and 50 percent would be capped by future building foundations. The building foundations were considered as future redevelopment costs, and were thus not included in the FS cost estimate. Applying these assumptions, the estimated RAU-wide soil capping cost is estimated at approximately $3.1 million, or over half of the total alternative cost. Table B-2 in Appendix B includes the detailed cost estimate assumptions for Alternative 1.

4.2 Alternative 2

Alternative 2 includes the components described in Alternative 1 (including completed interim action), and adds to them a hydraulic cap within the Acid Plant footprint to control acidic leaching and *in situ* buffering of groundwater to enhance the attenuation of the acidic plume and thereby provide greater confidence for eliminating contaminant discharge to the Whatcom Waterway. The components of Alternative 2 are described below.

4.2.1 Removal Action for Bunker C Subarea Soil

Alternative 2 includes the completed interim action and additional Bunker C soil removal, as described for Alternative 1.

4.2.2 Treatment Actions

Alternative 2 includes enhanced attenuation of the Acid Plant groundwater plume via pH buffering achieved by placement of crushed limestone into the aquifer. The treatment action is intended to accelerate buffering of the acidic groundwater pH and thus precipitation of metals from the groundwater. The treatment action would therefore enhance attenuation of the acidic plume, increase the reliability of natural attenuation in this subarea, and decrease the groundwater restoration time frame relative to Alternative 1's MNA in this subarea. In this alternative, the crushed limestone would be placed beneath the static water table in large-diameter borings or excavated pits/trenches at depths up to 15 feet deep. For the purposes of this FS, it is assumed that the limestone would be placed in non-continuous transects perpendicular to the groundwater flow direction. Transects could be constructed both within the Acid Plant source area and in the acidic groundwater plume downgradient of the source area. For cost estimating purposes, the following configuration is assumed:

- All transects consist of 3-foot-wide, 10-foot-long, 15- foot-deep trenches that are spaced at 20 feet on-center;
- Four transects are constructed within the source area at 30-foot spacing on-center; and
- Two transects are constructed downgradient of the source area at 150-foot spacing on-center.

This transect configuration is depicted schematically on Figure 4-2. At each location, unsaturated soil would be removed to accommodate the volume of treatment media added below the water table. For the purposes of cost estimating in this FS, we assume, based on detected metals concentrations (e.g., 750 mg/kg lead), that the metals-contaminated unsaturated soil from the source area would have a hazardous characteristic based on metals leaching, and thus would be mixed with phosphate binder prior to excavation to remove the hazardous waste characteristic and then be disposed off site at a permitted non-hazardous landfill. Unsaturated soil downgradient from the source area would contain much lower metals concentrations; therefore, unsaturated soil would be excavated and, following testing to confirm chemical concentrations for waste designation, reused as on-site fill or disposed of off site at a permitted facility. In both areas, the underlying saturated soil would then be mixed with crushed limestone within the excavation and placed beneath the water table as treatment media.

The crushed limestone treatment media would slowly dissolve in groundwater and provide a long-term source of bicarbonate ions to buffer the groundwater pH. Because crushed limestone is soluble, the limestone treatment locations would be prone to settlement over time, which would be a consideration for future redevelopment. Groundwater near the limestone would disperse and mix with surrounding groundwater. The treatment system would be designed to dissolve and disperse sufficient bicarbonate buffer to increase the groundwater pH above 6.3, which is sufficient to precipitate dissolved metals from groundwater so as to achieve groundwater cleanup levels.

Remedy design would evaluate alternative treatment media and construction methods to deliver it, including *in situ* mixing with large-diameter augers (see Section 3.4.5). The

EDR would specify the treatment media and placement method (e.g., trenches or borings or auger mixing, specific composition and gradation of carbonate media, etc.).

4.2.3 Engineering Controls

Alternative 2 includes the RAU-wide capping described for Alternative 1. Additionally, it includes hydraulic capping over the Acid Plant source area to prevent infiltration of surface water through the unsaturated, low pH, metals-contaminated soil in that area. It is assumed that the hydraulic cap in that area would include a sealed 60-mil HDPE membrane underlying the Type 2 direct contact cap described in Alternative 1. Because the HDPE membrane prevents the infiltration of surface water, the surface of the direct contact cap would be graded to prevent stormwater accumulation on the hydraulic cap area. The cap would be constructed by grading the existing surface of the Acid Plant as needed to form a flat surface for the placement of the HDPE membrane without excavation of impacted soil. The HDPE membrane would also be placed over the limestone treatment trenches within the source area.

4.2.4 Groundwater Treatment and Natural Attenuation

Alternative 2 would include the same implementation of MNA for the Miscellaneous Dissolved Metals Exceedances Area and LP-MW01 subarea as Alternative 1, including MNA performance monitoring. By controlling the infiltration of surface water through acidic source area soils and by passively buffering groundwater, Alternative 2 enhances attenuation of the Acid Plant plume—thus providing a more aggressive remedy than MNA for that subarea —and includes rigorous monitoring of remedy performance.

The EDR would include a plan for monitoring performance of the Acid Plant groundwater treatment program, and performance of MNA in the Miscellaneous Dissolved Metals Exceedances area and LP-MW01 subarea.

In situ S/S of Bunker C contaminated soil, as described for Alternative 1, is a contingent action in Alternative 2 as well. In addition, Alternative 2 may include extending the areal coverage of treatment and/or replenishing the crushed limestone, which may have a diminished reactivity or permeability because of iron precipitation. These contingent actions would be implemented after remedial construction if performance monitoring indicates that remedial objectives are not being achieved. This FS does not evaluate the probability or cost of implementing the contingent actions.

4.2.5 Institutional Controls

An Institutional Controls Plan would be implemented as described for Alternative 1. Under Alternative 2, the Institutional Controls Plan would include additional provisions to prevent disruption of the groundwater treatment media and prevent accumulation of stormwater on top of the Acid Plant footprint hydraulic cap or otherwise compromise its integrity.

4.2.6 Restoration Time Frame

Design and construction of the Acid Plant treatment actions included in this alternative would likely be concurrently completed with the remedial components common to Alternative 1, and would not increase the remedy implementation time frame. Therefore, the time frame for implementing Alternative 2 is expected to be the same as for Alternative 1 (1 to 2 years). As with Alternative 1, some cleanup may be integrated with redevelopment, which could control schedule. As described in the Preliminary Geochemical Modeling, Acid Plant Subarea Groundwater Remediation Alternatives (Appendix A), the anticipated time to meet cleanup levels throughout the Acid Plant subarea is on the order of ten years. That subarea is expected to have the longest groundwater restoration timeframe and, as such, defines the estimated restoration timeframe for the Site.

4.2.7 Estimated Cost

The cost for Alternative 2, applying the same RAU-wide capping assumptions as noted in Section 4.1.6 for Alternative 1, is estimated at approximately $6.5 million. Compared to Alternative 1, this alternative includes an additional approximately $500,000 for pH-buffering treatment of acidic/metals-contaminated groundwater in the Acid Plant subarea. Table B-3 in Appendix B includes the detailed cost estimate assumptions for Alternative 2.

4.3 Alternative 3

Alternative 3 includes the components of Alternative 1 and the enhanced attenuation of Acid Plant groundwater from Alternative 2. Whereas Alternative 2 controls Acid Plant source contamination with a hydraulic cap, Alternative 3 provides permanent removal of shallow, unsaturated soils from that source area that contain residual acidity and high metals concentrations. The components of Alternative 3 are described below.

4.3.1 Removal Actions

In addition to the completed Bunker C interim action and Bunker C soil removal action described for Alternative 1, Alternative 3 includes removal of metals-contaminated shallow soil in the Acid Plant source area (Figure 4-3). The shallow soils would be excavated to a depth of 4 feet bgs to remove contaminated soil assumed to exceed the direct contact soil cleanup levels for metals, and which represent a source of acidity and dissolved metals in infiltrating water. The lateral and vertical extent of this soil would be delineated in greater detail during remedy design. The design effort would also characterize the soil for disposal purposes.

The excavation would be backfilled with gravel borrow, which could also be amended with crushed limestone depending on information gathered during remedy design as well as Site development plans. The addition of crushed limestone amendment could provide additional pH buffering for infiltrating water. Because crushed limestone is soluble, a limestone-amended backfill would be prone to settlement over time, which would be a consideration for future redevelopment in that location.

4.3.2 Treatment Actions

Alternative 3 includes the enhanced attenuation of the acidic plume described for Alternative 2.

4.3.3 Engineering Controls

Alternative 3 includes the RAU-wide capping described in Alternative 1. The Acid Plant source excavation bottom would be covered with a geotextile fabric that is rated for soil separation prior to excavation backfill. Unless precluded by development plans (i.e., construction of building foundation or hard cover), the cap could be designed to allow infiltration through the carbonate-amended backfill, which would increase groundwater alkalinity and further enhance restoration of the Acid Plant subarea plume.

4.3.4 Groundwater Treatment and Natural Attenuation

Alternative 3 would include the same implementation of MNA for the Miscellaneous Dissolved Metals Exceedances area and LP-MW01 subarea as Alternatives 1 and 2. By combining permanent source removal with passive buffering of groundwater in the Acid Plant subarea, Alternative 3 would further enhance and accelerate attenuation of the acidic plume relative to Alternative 2. Infiltration of surface water through limestone amended backfill, if used, would also enhance the buffering of groundwater pH and the precipitation of metals.

The EDR would include a plan for monitoring performance of the Acid Plant subarea groundwater treatment, and performance of MNA for the Miscellaneous Dissolved Metals Exceedances area and LP-MW01 subarea.

A contingent action would probably involve extending the areal coverage of treatment and/or to replenish the crushed limestone, which may have a diminished reactivity or permeability because of iron precipitation. Additional contingent actions are described in Alternative 1. This FS does not evaluate the probability or cost of implementing the contingent actions.

4.3.5 Institutional Controls

An Institutional Controls Plan would be implemented generally as described for Alternative 1, and including provisions to prevent disruption of the groundwater treatment media.

4.3.6 Restoration Time Frame

Similar to Alternative 2, design and construction of the Acid Plant treatment actions included in this alternative would likely be concurrently completed with the remedial components common to Alternative 1, and would not increase the remedy implementation time frame. Therefore, the time frame for implementing Alternative 3 is expected to be the same as for Alternatives 1 and 2 (1 to 2 years). As with those alternatives, some cleanup may be integrated with redevelopment, which could control schedule. As described in the Preliminary Geochemical Modeling, Acid Plant Subarea Groundwater Remediation Alternatives (Appendix A), the anticipated time to meet cleanup levels throughout the Acid Plant subarea is on the order of ten years. That subarea is expected to have the longest groundwater restoration timeframe and, as such, defines the estimated restoration timeframe for the Site.

4.3.7 Estimated Cost

The cost for Alternative 3, applying the same RAU-wide capping assumptions as noted in Section 4.1.6 for Alternative 1, is estimated at approximately $7.6 million. This alternative includes approximately $730,000 for removal of acidic/metals-contaminated shallow soil within the Acid Plant source area. Table B-4 in Appendix B includes the detailed cost estimate assumptions for Alternative 3.

4.4 Alternative 4

Alternative 4 provides RAU-wide permanent removal of contaminated soil in the Fill Unit to a maximum depth of 15 feet bgs, unless soil concentrations posing a groundwater risk extend deeper (Figure 4-4). Groundwater MNA would be included in this alternative if residual groundwater contamination persisted following source removal. The components of Alternative 4 are described below.

4.4.1 Removal Actions

Alternative 4 includes the completed Bunker C interim action and complete RAU-wide removal of contaminated fill material to address NAPL accumulation in the Bunker C subarea and the direct contact point of exposure throughout the RAU. The Fill Unit is thinnest on the southern and eastern edges of the RAU (typically 10 feet or less), thickening to 15 feet or more on the north and west sides. The direct contact point of exposure is the top 15 feet of soil. It is anticipated that the final elevation of the RAU will be increased during redevelopment; therefore, the existing fill material may be excavated to less than 15 feet. For the purpose of this FS, an average excavation depth is estimated to be 12 feet bgs across the RAU. The excavated fill material (estimated 600,000 cubic yards) would be characterized and transported off site for reuse and disposal. The excavation would be backfilled with uncontaminated fill material from a local borrow area that is evaluated for contamination and geotechnical acceptance criteria.

For the purposes of this FS, it is assumed that a bentonite-cement slurry wall, keyed into the Tidal Flat Aquitard or Glaciomarine Drift, would be constructed around the full periphery of the RAU to control groundwater inflows throughout the extended excavation program. The slurry walls are assumed to be constructed adjacent to the waterfront, and soils would be excavated from about 5 feet inset from the slurry wall and sloped at a 1.5H:1V (horizontal:vertical) grade to the bottom of excavation.

Excavation would likely be performed in a grid pattern or trench and fill pattern such that excavation, dewatering, and fill operations are performed concurrently. Because of the exterior groundwater cutoff wall keyed into low-permeability material, it is assumed that dewatering would be performed from trenches and sumps within the excavation area during excavation operations. It is further assumed that extracted groundwater would be treated with duplex (or more) sand filtration and granular activated carbon vessels, and continuously discharged to the Whatcom Waterway under an NPDES permit.

4.4.2 Natural Attenuation

Alternative 4 includes natural attenuation to address residual groundwater contamination that may exceed applicable cleanup levels following removal of the Fill Unit; however, Alternative 4 does not formally implement an MNA remedy.

4.4.3 Institutional Controls

Depending on the extent of fill existing at depth following RAU-wide soil removal, an Institutional Controls Plan would be implemented if needed to identify use limitations, specific worker protection standards for excavating into residual fill, and notification requirements.

4.4.4 Restoration Time Frame

It is estimated that design and construction of Alternative 4 would take 3 to 6 years. The restoration time frame is considered to be the time needed to implement the removal alternative (3 to 6 years). As with Alternatives 1 through 3, some cleanup may be integrated with redevelopment, which could control schedule.

4.4.5 Estimated Cost

The probable cost for Alternative 4 is estimated at approximately $90 million. Table B-5 in Appendix B includes the detailed cost estimate assumptions for Alternative 4.

5 Detailed Evaluation of Remedial Alternatives

The four remedial alternatives described in Section 4 are evaluated with respect to MTCA criteria in this section. Elements of each alternative are listed in Table 5-1.

5.1 Feasibility Study Evaluation Criteria

This section discusses the minimum requirements and procedures for selecting cleanup actions under MTCA (WAC 173-340-360).

5.1.1 MTCA Threshold Requirements

Cleanup actions selected under MTCA must meet four "threshold" requirements identified in WAC 173-340-360(2)(a) to be accepted by Ecology. All cleanup actions must:

- Protect human health and the environment;
- Comply with cleanup standards;
- Comply with applicable state and federal laws; and
- Provide for compliance monitoring.

5.1.2 MTCA Selection Criteria

When selecting from remedial alternatives that meet the threshold requirements, the following three criteria, identified in WAC 173-340-360(2)(b), must be evaluated:

- **Use permanent solutions to the maximum extent practicable.** A disproportionate cost analysis (DCA) is conducted to assess the extent to which the remedial alternatives address this criterion. The general procedure for conducting a DCA is described in Section 5.1.3.
- **Provide a reasonable restoration time frame.** MTCA places a preference on remedial alternatives that can achieve the required cleanup levels at the points of compliance in a shorter period of time. Factors to be considered in evaluating whether an alternative provides for a reasonable restoration time frame (per WAC 173-340-360(4)(b)) are listed in Table 5-2.
- **Consider public concerns.** Consideration of public concerns is an inherent part of the Site cleanup process under MTCA. The Draft FS report is issued for public review and comment, and Ecology determines whether changes to the report are needed in response to public comments.

5.1.3 MTCA Disproportionate Cost Analysis

A DCA is conducted to determine whether a cleanup action uses permanent solutions to the maximum extent practicable. This is done by evaluating the relative benefits and costs of remedial alternatives. Seven criteria are considered in the evaluation as specified in WAC173-340-360(3)(f):

- **Protectiveness** – overall protectiveness of human health and the environment, including the degree to which existing site risks are reduced, time required to reduce the risks and attain cleanup standards, on-site and off-site risks during implementation, and improvement in overall environmental quality.

- **Permanence** – degree to which the alternative permanently reduces the toxicity, mobility, or volume of hazardous substances, including the adequacy of destroying hazardous substances, the reduction or elimination of hazardous substance releases and sources of releases, the degree of irreversibility of treatment, and the characteristics and quantity of the treatment residuals.
- **Cost** – Remedy design, construction, and long-term O&M costs to implement the alternative.
- **Long-term effectiveness** – degree of certainty that the alternative will successfully and reliably address contamination that exceeds applicable cleanup levels until cleanup levels are attained, the magnitude of the residual risk with the alternative in place, and the effectiveness of controls to manage treatment residue and remaining wastes.
- **Short-term risk management** – the risks to human health and the environment during construction and implementation of the alternative, and the effectiveness of measures that will be taken to manage such risks.
- **Implementability** – includes 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 the alternative; monitoring requirements; access for construction, operations, and monitoring; and integration with existing facility operations and other current or potential remedial actions. This FS also considers the impact to and integration with future redevelopment planned under the Waterfront District Subarea Plan (Port of Bellingham and City of Bellingham, 2012).
- **Consideration of public concerns** – concerns from individuals, community groups, local governments, tribes, federal and state agencies, and other interested organizations are addressed by Ecology responding to public comments on the Draft FS report and the Draft CAP.

The DCA is based on a comparative evaluation of an alternative's cost against the other six criteria (environmental benefits). Per WAC 173-340-360(3)(e)(i), cost is disproportionate to benefits if the incremental cost of an alternative over that of a lower-cost alternative exceeds the incremental degree of benefits achieved by the alternative over that of the lower-cost alternative.

5.2 Evaluation with Respect to MTCA Threshold Requirements

The four remedial alternatives are evaluated for compliance with the MTCA threshold criteria in this section. Evaluation results are summarized in Table 5-1.

5.2.1 Protection of Human Health and the Environment

Alternatives 1, 2, and 3 would provide protection of human health and the environment through a combination of: 1) removal of TPH-contaminated soils from the Bunker C subarea; 2) RAU-wide capping of contaminated Fill Unit soils; 3) MNA of groundwater contamination, with groundwater compliance monitoring and contingency actions included in case the MNA remedy is determined to be not protective; and 4) institutional controls (described in Sections 3.6 and 4.1.4). Alternative 3 would marginally increase protectiveness through removal of acidic/metals-contaminated soils from the Acid Plant source area.

Alternative 4 would provide protection of human health and the environment through RAU-wide removal of contaminated Fill Unit soils. While unlikely, MNA of residual groundwater contamination and associated institutional controls would be included as necessary following source removal.

5.2.2 Compliance with Cleanup Standards

Alternatives 1, 2, and 3 would comply with soil cleanup standards primarily through containment of soils exceeding cleanup levels, and would comply with groundwater cleanup standards through natural attenuation and/or treatment throughout the site. Alternative 4 would achieve cleanup standards through contaminated soil removal and offsite disposal. Additional descriptions of how containment (for soils) and point of compliance (for groundwater) are considered in remedy selection are presented below.

5.2.2.1 Containment of Soils Exceeding Cleanup Levels

RAU-wide capping of contaminated soils in Alternatives 1, 2, and 3 would provide a barrier against human direct contact and terrestrial ecological exposures as well as preventing release to the environment via soil erosion, thereby satisfying the MTCA definition of “containment.” Per WAC 173-340-355(2), a cleanup action involving containment of soils exceeding cleanup levels at the point of compliance may be determined to comply with cleanup standards, provided the requirements specified in WAC 173-340-740(6)(f) are met. Those requirements are[8]:

- the selected remedy is permanent to the maximum extent practicable;
- the cleanup action is protective of human health and terrestrial ecological receptors;
- institutional controls are put in place that prohibit or limit activities that could interfere with the long-term integrity of the containment system;
- compliance monitoring and periodic reviews are designed to ensure the long-term integrity of the containment system; and
- the types, levels, and amount of hazardous substances remaining on-site and the measures that will be used to prevent migration and contact with those substances are specified in the draft cleanup action plan.

Alternatives 1, 2, and 3 would be designed and implemented such that the above requirements would be met. Therefore, these three alternatives would comply with soil cleanup standards upon completion of remedy construction. Alternative 4 would also

[8] The requirements of WAC 173-340-740(6)(f) are paraphrased here; refer to the MTCA regulation for the complete language.

comply with soil cleanup standards upon completion of construction, since all soils exceeding cleanup levels would be excavated and disposed of offsite.

5.2.3 Compliance with Applicable State and Federal Laws

Through identification of ARARs (Section 2.6) and compliance with the MTCA regulation, Alternatives 1 through 4 would all comply with applicable state and federal laws.

5.2.4 Provisions for Compliance Monitoring

All four alternatives would provide for compliance monitoring. Health and safety protocols outlined in a Site-specific health and safety plan (required in all alternatives) would provide protection monitoring. All four alternatives would also include soil quality monitoring to guide excavations and confirm that performance objectives associated with the soil removal actions were met. Periodic groundwater sampling and analysis would provide both performance and confirmation monitoring in Alternatives 1 through 3, and in Alternative 4 if groundwater cleanup levels are not achieved upon completion of remedy construction.

5.2.5 Conclusion Regarding Compliance with Threshold Requirements

Based on the above evaluation, Alternatives 1 through 4 are all expected to comply with the MTCA threshold criteria. Therefore, all four alternatives are carried forward to the next stage of evaluation.

5.3 Evaluation with Respect to Reasonable Restoration Time Frame

A cleanup action is considered to have achieved restoration once cleanup standards have been met. As discussed in Section 5.2.2, all four alternatives are expected to comply with cleanup standards. The restoration time frame for Alternatives 1 through 3 is the time to meet groundwater cleanup levels in the Acid Plant subarea, which is estimated to be up to 36 years in Alternative 1 and approximately 10 years in Alternatives 2 and 3. Under Alternative 4, the restoration time frame is assumed to be equal to the implementation time frame, which is estimated at up to 6 years.

WAC173-340-360(4)(b) provides a list of factors to be considered to determine whether a cleanup action provides for a reasonable restoration time frame. Table 5-2 presents an evaluation of the remedial alternatives with respect to these factors. Based on that evaluation, all four alternatives are expected to provide for a reasonable restoration time frame.

5.4 Disproportionate Cost Analysis

As described in Section 5.1.3, a DCA is performed to evaluate whether a cleanup action uses permanent solutions to the maximum extent practicable. The DCA quantifies the environmental benefits of each remedial alternative, and then compares alternative benefits versus costs. Costs are disproportionate to benefits if the incremental cost of a more permanent alternative over that of a lower-cost alternative exceeds the incremental benefits achieved by the alternative over that of the lower-cost alternative. Alternatives that exhibit disproportionate costs are considered "impracticable" under MTCA.

The DCA is performed in the following sections and summarized in Table 5-3. Environmental benefit is quantified by first rating the alternatives with respect to each of the six criteria discussed in Section 5.1.3. Rating values are assigned on a scale of 1 to 10, where 1 indicates the criterion is satisfied to a very low degree, and 10 indicates the criterion is satisfied to a very high degree. Since Ecology does not consider the criteria to be of equal importance, each criterion is assigned a "weighting factor." Consistent with feasibility studies and cleanup action plans conducted on other Bellingham Bay cleanup sites, weighting factors are assigned as follows:

- Overall protectiveness: 30 percent;
- Permanence: 20 percent;
- Long-term effectiveness: 20 percent;
- Short-term effectiveness: 10 percent;
- Implementability: 10 percent; and
- Consideration of public concerns: 10 percent.

A MTCA benefits ranking is then obtained for each alternative by multiplying the six rating values by their corresponding weighting factors, and summing the weighted values. Finally, the benefits ranking of each alternative is divided by the alternative's estimated cost to obtain a benefit/cost ratio, which is a relative measure of the cost effectiveness of the alternative.

5.4.1 Overall Protectiveness

The remedial alternatives would all be protective of human health and the environment, but vary in the technologies used to achieve that protectiveness. Alternative 4 would address the human direct contact and terrestrial ecological exposure pathways, as well as the potential for soil erosion, through RAU-wide removal and offsite disposal of contaminated soils. Alternatives 1 through 3, on the other hand, would rely primarily on *in situ* containment of contaminated soils via capping, combined with institutional controls. Although removal is not inherently more protective than technologies such as containment that leave contamination in place, it does provide a higher level of certainty that protectiveness will be maintained in the long term.

There is no evidence that groundwater contamination extends beyond the property boundaries, or that contaminant plumes are advancing. Furthermore, VOCs in LP-MW01 groundwater appear to be naturally attenuating, and maximum concentrations may currently be at or below cleanup levels for protection of the vapor intrusion pathway. Alternatives 1 through 3 would protect against potential contaminated groundwater discharge to Whatcom Waterway in the future, as well as potential vapor intrusion into future Site buildings, through a combination of targeted treatment/removal, compliance monitoring (with contingency actions if necessary), and institutional controls. It is assumed that RAU-wide removal of contaminated soils in Alternative 4 would largely remediate onsite contamination in groundwater and soil vapor as well as soil, such that compliance monitoring and institutional controls would not be needed. Therefore, Alternative 4 is considered to be more protective than Alternatives 1 through 3 with respect to these potential exposure pathways.

Based on the above considerations, Alternatives 1 and 4 were given ratings of 5 and 9, respectively, for overall protectiveness. Hydraulic capping and passive buffering of groundwater in the Acid Plant source area as proposed in Alternative 2 would marginally improve protectiveness over Alternative 1, so Alternative 2 was assigned a rating of 6. Alternative 3 was assigned a rating of 7 since removal of contaminated vadose zone soils from the Acid Plant source area would marginally improve protectiveness relative to Alternative 2.

5.4.2 Permanence

Alternative 4 is considered the most permanent alternative because all contaminated soils would be removed from the RAU and contained in an engineered landfill. Landfill disposal addresses contaminant mobility, but does not directly reduce toxicity or volume (although contaminants may continue to naturally attenuate in the landfill). Alternatives 1 through 3 would include targeted removal and landfill disposal of contaminated soils (and NAPL, if any) from the Bunker C subarea, and contaminated vadose zone soils would also be removed from the Acid Plant source area in Alternative 3. Mobility via erosion is also effectively addressed in Alternatives 1 through 3 via RAU-wide capping, and institutional controls would be implemented to protect the cap and provide for periodic inspection and maintenance.

Natural attenuation is effectively reducing groundwater concentrations in the Acid Plant and LP-MW01 subareas, and would continue to do so in Alternatives 1 through 3. Contaminant mobility in the Acid Plant would be further reduced in Alternatives 2 and 3 by hydraulic capping (Alternative 2 only) and passive buffering of groundwater.

Based on the above considerations, Alternatives 1 and 4 were given ratings of 3 and 9, respectively, for the permanence criterion. Hydraulic capping and passive buffering of groundwater in the Acid Plant source area as proposed in Alternative 2 would marginally reduce contaminant mobility over Alternative 1, so Alternative 2 was assigned a rating of 4. Alternative 3 was assigned a rating of 5 since it would have the benefits of Alternative 2 plus additional removal of contaminated soils (from the Acid Plant source area).

5.4.3 Long-Term Effectiveness

Alternative 4 has the highest certainty for long-term effectiveness because all contaminated soils would be removed from the RAU. Alternatives 1 through 3 would achieve targeted removal of contaminated soils (and NAPL, if any) from the Bunker C subarea. Contaminated vadose zone soils would also be removed from the Acid Plant source area in Alternative 3. Alternatives 1 through 3 would rely on the long-term integrity of the RAU-wide cap (and associated institutional controls) to address the potential for erosion, direct contact exposures, and terrestrial ecological exposures associated with remaining soil contamination.

The potential for migration of groundwater contaminants (e.g., to Whatcom Waterway and to indoor air) is currently limited and, due to ongoing natural attenuation, is expected to be even less of a concern in the long-term.

Based on the above considerations, Alternatives 1 and 4 were given ratings of 5 and 10, respectively, for long-term effectiveness. Hydraulic capping and passive buffering of groundwater in the Acid Plant source area as proposed in Alternative 2 would improve long-term effectiveness over Alternative 1, so Alternative 2 was assigned a rating of 6. Alternative 3 was assigned a rating of 7 since removal of contaminated vadose zone soils from the Acid Plant source area would marginally improve the long-term effectiveness compared to Alternatives 1 and 2.

5.4.4 Short-Term Risk Management

Alternative 1 was rated relatively high (8) for short-term risk management because there are minimal short-term risks (e.g., worker safety concerns, dust and erosion control) associated with RAU-wide capping and excavation of Bunker C soils. Alternative 2 was also given a rating of 8 because installation of the hydraulic cap and crushed limestone in the Acid Plant source area would not significantly increase short-term risks. Alternative 3 was given a rating of 7, slightly lower than Alternatives 1 and 2 because it also includes excavation of contaminated vadose zone soils from the Acid Plant source area. Alternative 4 was rated relatively low (2) because the magnitude of short-term risks tends to correlate with the scale of a construction project. Alternative 4 would involve excavation and off-site transport of an exceptionally large quantity of contaminated soils over multiple construction seasons.

5.4.5 Implementability

Alternatives 1 and 3 were both given a rating of 7 for implementability. These alternatives are relatively modest in scope and would use readily available services/equipment and common earthwork construction techniques. However, there may be implementability challenges associated with (for example) extensive capping along the waterfront, excavating TPH-saturated soil at depth, and implementing effective institutional controls with multiple property owners. Alternative 2 was rated slightly lower (6) because of the specialized construction (hydraulic capping) required in the Acid Plant source area. Alternative 4 was rated very low (1) for implementability because an excavation project involving such a large quantity of contaminated fill soils would be technically, logistically, and administratively complex.

5.4.6 Consideration of Public Concerns

Alternative 4 (removal) was given the highest rating of 10 based on input received during the public comment period. Alternatives 1 through 3 were adjusted lower in consideration of public concerns. Beyond the Bunker C oil source control common to each alternative, Alternative 1 was given a rating of 4 because it primarily relies on capping, natural attenuation, and institutional controls. Alternative 2 was rated slightly higher (5) because it adds *in situ* groundwater treatment and a hydraulic cap. Alternative 3 includes *in situ* groundwater treatment and replaces the hydraulic cap with source removal in the Acid Plant subarea and was given a ranking of 6.

5.4.7 Benefits Rankings, Estimated Costs, and Benefit/Cost Ratios

The MTCA benefits rankings, estimated costs, and benefit/cost ratios for the four remedial alternatives are presented at the bottom of Table 5-3 and graphically on Figure 5-1. As previously noted, the MTCA benefits ranking is obtained for each alternative by multiplying the rating values assigned for the six evaluation criteria by their corresponding weighting factors, and summing the weighted values. The benefit rankings range from a low of 5.0 for Alternative 1 to a high of 7.8 for Alternative 4.

RAU-wide soil capping is the most prominent cost in the net present value estimates for the first three alternatives, which range from $5.7 million (Alternative 1) to $7.6 million (Alternative 3). Changes in assumptions for RAU-wide capping could greatly change the remedial alternative costs estimated in the FS, but, because the changes would equally apply to Alternatives 1 through 3, would not change the incremental cost differences between those alternatives. RAU-wide removal of contaminated soils in Alternative 4 results in a much higher estimated cost ($91 million).

The benefit/cost ratio, which is a relative measure of cost effectiveness, is obtained by dividing each alternative's benefits ranking by its estimated cost. Because the cost of Alternative 4 is so high, its benefit/cost ratio (0.09) is much lower than that of the other three alternatives. Alternative 1 has the highest benefit/cost ratio (0.88), followed by Alternatives 2 and 3 which each had a benefit/cost ratio of 0.86 (Table 5-3).

5.4.8 Disproportionate Cost Analysis Conclusion

Based on the results of the DCA presented above, Alternative 1 is the most cost effective of the four remedial alternatives evaluated in this FS. Therefore, under MTCA, Alternative 1 is identified as the alternative that is permanent to the maximum extent practicable.

6 Summary and Conclusions

The Site RI (Aspect, 2013) defined physical characteristics, source areas, the nature and extent of impacted media, and potential contaminant migration pathways. Information from the RI and previous investigations was used in this FS to develop and evaluate four remedial alternatives for the Site. The alternatives were evaluated with respect to criteria defined by MTCA, including a comparative analysis to determine the relative benefits of each and an evaluation of benefits versus estimated costs to determine the most permanent solution to the maximum extent practicable. This section presents the preferred alternative based on these evaluations and discusses how the preferred alternative will be compatible with Whatcom Waterway remedial activities.

6.1 Preferred Alternative

This section presents the preferred cleanup alternative for the Pulp/Tissue Mill RAU. The actual cleanup remedy will be selected in the CAP developed by Ecology, and may vary from the preferred cleanup alternative described herein.

Alternative 1 was identified in the DCA (Section 5.4) as the alternative that is permanent to the maximum extent practicable for the Pulp/Tissue Mill RAU and is therefore the preferred alternative. The preferred alternative consists of the following elements:

- The completed interim action removal of soil beneath the former Bunker C Tank;
- Removal of additional soils from the Bunker C subarea that contain oil concentrations exceeding the residual saturation remediation level (10,000 mg/kg);
- RAU-wide capping to control the soil direct contact exposure and soil erosion pathways for known contaminated soils within the Bunker C, Dioxin-Contaminated Debris Fill, and Acid Plant subareas, and for RAU soils outside of those subareas that may contain concentrations of contaminants exceeding soil cleanup levels for an unrestricted land use;
- Monitored natural attenuation to address residual contamination in groundwater that exceeds applicable groundwater cleanup standards. Based on the RI data, the contaminants that exceed cleanup levels in upland groundwater include pH and selected metals in the Acid Plant subarea, PCE and VC in the LP-MW01 subarea, and selected metals in the Miscellaneous Dissolved Metals Exceedances area;
- Establishment of institutional controls to provide notification regarding the presence of residual contaminated materials, regulate the disturbance/management of these materials and the cleanup action components, and provide for long-term monitoring and stewardship of the cleanup action. In addition, an institutional control would require capping of soils along the BNSF rail alignment within the RAU, consistent with capping requirements elsewhere in the RAU, at such time that active use of the rail line is terminated. And, if groundwater monitoring indicates that VOC concentrations have not naturally attenuated to below cleanup levels in the LP-MW01 subarea, an institutional

control would require that VI potential be evaluated and/or VI controls constructed beneath future buildings in that subarea; and

- Contingency actions, as described in Section 4.1, would be employed if it is determined during remedy implementation that they are necessary to achieve protection of human health and the environment. We expect that *in situ* pH buffering of groundwater (as in Alternative 2) would be a reasonable contingency action if MNA of Acid Plant subarea groundwater is demonstrated to not be protective.

The preferred alternative remedy design concept is presented on Figure 4-1. It is anticipated that the preferred alternative will comply with soil cleanup standards upon completion of remedy design and construction (estimated at 1 to 2 years) and will comply with groundwater cleanup standards throughout the Site in up to about 36 years. The total estimated cost for the preferred alternative is $5.7 million.

6.2 Compatibility with Whatcom Waterway Remedial Activities

The Pulp/Tissue Mill RAU is adjacent to the Whatcom Waterway cleanup site, which has a cleanup remedy and schedule defined under a Consent Decree with Ecology. The preferred alternative for the Pulp/Tissue Mill RAU has overlap with the Whatcom Waterway site, in terms of integrating the RAU-wide soil cap with capping of the south bank of the Whatcom Waterway. The preferred alternative for the Pulp/Tissue Mill RAU is compatible with the Whatcom Waterway cleanup.

As stated in Section 1.1.1, if the Whatcom Waterway cleanup is not initiated by the time the Pulp/Tissue Mill RAU cleanup is conducted, the upland area within the planned clarifier cutback footprint (planned for removal/regrading under the Whatcom Waterway cleanup) will be remediated consistent with the surrounding portion of the RAU (all part of the Bunker C subarea). The clarifier cutback area is a small fraction of the RAU, and including it would not change the remedy selection for this RAU.

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Limitations

Work for this project was performed and this report prepared in accordance with generally accepted professional practices for the nature and conditions of work completed in the same or similar localities, at the time the work was performed. This report does not represent a legal opinion. No other warranty, expressed or implied, is made.

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TABLES

Table 2-1 - Groundwater Cleanup Levels for Pulp/Tissue Mill RAU

Feasibility Study, GP West Site

ANALYTE (BY GROUP)	Groundwater Screening Level for Marine Water and Sediment Protection	Vapor Intrusion Groundwater Screening Levels for Unrestricted Land Use	Practical Quantitation Level (PQL)	Groundwater Cleanup Level for Unrestricted Land Use
Metals				
Arsenic in µg/L	5		0.5	**5**
Cadmium in µg/L	8.8		0.02	**8.8**
Chromium (Total) in µg/L	260		0.2	**260**
Copper in µg/L	3.1		0.1	**3.1**
Lead in µg/L	8.1		0.02	**8.1**
Mercury in µg/L	0.059	0.89	0.001	**0.059**
Nickel in µg/L	8.2		0.2	**8.2**
Selenium in µg/L	71		1	**71**
Silver in µg/L	1.9		0.02	**1.9**
Zinc in µg/L	81		0.5	**81**
Volatile Organic Compounds				
cis-1,2-Dichloroethene (DCE) in µg/L			0.5	
Tetrachloroethene (PCE) in µg/L	3	24	0.5	**3.3**
Trichloroethene (TCE) in µg/L	30	1.5	0.5	**1.5**
Vinyl chloride in µg/L	2	0.35	0.5	**0.5**
Polycyclic Aromatic Hydrocarbons (PAHs)				
Acenaphthene in µg/L			0.02	**3.3**
Acenaphthylene in µg/L			0.02	
Anthracene in µg/L			0.02	**9.6**
Benzo(g,h,i)perylene in µg/L			0.02	
Fluoranthene in µg/L			0.02	**3.3**
Fluorene in µg/L			0.02	**3**
Phenanthrene in µg/L			0.02	
Pyrene in µg/L			0.02	**15**
1-Methylnaphthalene in µg/L			0.02	
2-Methylnaphthalene in µg/L			0.02	
Naphthalene in µg/L	83	170	0.02	**83**
Benz(a)anthracene in µg/L	0.018		0.02	**0.02**
Benzo(a)pyrene in µg/L	0.018		0.02	**0.02**
Benzo(b)fluoranthene in µg/L	0.018		0.02	**0.02**
Benzo(k)fluoranthene in µg/L	0.018		0.02	**0.02**
Chrysene in µg/L	0.018		0.02	**0.02**
Dibenzo(a,h)anthracene in µg/L	0.007		0.02	**0.02**
Indeno(1,2,3-cd)pyrene in µg/L	0.010		0.02	**0.02**
Total cPAHs TEQ in µg/L	0.018		0.02	**0.02**
Field Parameters				
pH in pH units				**>6.2 and <8.5**

Note:

Refer to Section 5 and Table 5-1 of the RI for derivation of groundwater screening levels that are adopted as groundwater cleanup levels. Cleanup levels are the most stringent value protective of all exposure pathways.

Table 2-2 - Soil Cleanup Levels for Pulp/Tissue Mill RAU

Feasibility Study, GP West Site

	Groundwater Protection for Unrestricted Land Use		Unrestricted Direct Contact (mg/kg)	Natural Background Concentrations (mg/kg)	Practical Quantitation Level (PQL) (mg/kg)	Unrestricted Soil Cleanup Levels	
ANALYTE (BY GROUP)	Unsaturated Soil (mg/kg)	Saturated Soil (mg/kg)				Unsaturated Soil (mg/kg)	Saturated Soil (mg/kg)
Total Petroleum Hydrocarbons							
Diesel Range Hydrocarbons			2,000		25	**2,000**	**2,000**
Oil Range Hydrocarbons			2,000		100	**2,000**	**2,000**
Bunker C in Bunker C subarea	10,000	10,000	3,100			**3,100**	**3,100**
Heavy Metals							
Arsenic	2.9	0.15	20	20	0.5	**20**	**20**
Cadmium	1.2	0.061	80	1	0.02	**1.2**	**1**
Chromium (Total)	5,200	260			0.2	**5,200**	**260**
Copper	1.4	0.069	3,200	36	0.1	**36**	**36**
Lead	1,600	81	250	17	0.05	**250**	**81**
Mercury	2	0.1	24	0.07	0.001	**2**	**0.1**
Nickel	11	0.54	1,600	48	0.2	**48**	**48**
Selenium	7.4	0.38	400		1	**7.4**	**1**
Silver	0.32	0.016	400		0.02	**0.32**	**0.02**
Zinc	100	5	24,000	85	0.5	**100**	**85**
Conventionals							
pH			>2.5 and <11.0			**>2.5 and <11.0**	**>2.5 and <11.0**
Volatile Organic Compounds							
cis-1,2-Dichloroethene (DCE)	2.5	0.14	160		0.005	**2.5**	**0.14**
Tetrachloroethene (PCE)	0.3	0.015	480		0.005	**0.3**	**0.015**
Trichloroethene (TCE)	0.056	0.0029	120		0.005	**0.056**	**0.005**
Vinyl chloride	0.006	0.0003	0.67		0.005	**0.006**	**0.005**
Polycyclic Aromatic Hydrocarbons (PAHs)							
Acenaphthene	5.2	0.26	4,800		0.0005	**5.2**	**0.26**
Acenaphthylene					0.0005		
Anthracene	71	3.5	24,000		0.0005	**71**	**3.5**
Benzo(g,h,i)perylene					0.0005		
Fluoranthene	52	2.6	3,200		0.0005	**52**	**2.6**
Fluorene	7.4	0.37	3,200		0.0005	**7.4**	**0.37**
Phenanthrene					0.0005		
Pyrene	330	16	2,400		0.0005	**330**	**16**
1-Methylnaphthalene			35		0.001	**35**	**35**
2-Methylnaphthalene			320		0.001	**320**	**320**
Naphthalene	32	1.6	1,600		0.001	**32**	**1.6**
Benz(a)anthracene	2.3	0.12	1.4		0.0005	**1.4**	**0.12**
Benzo(a)pyrene	6.2	0.31	0.14		0.0005	**0.14**	**0.14**
Benzo(b)fluoranthene	7.7	0.38	1.4		0.0005	**1.4**	**0.38**
Benzo(k)fluoranthene	7.7	0.38	14		0.0005	**7.7**	**0.38**
Chrysene	2.6	0.13	140		0.0005	**2.6**	**0.13**
Dibenzo(a,h)anthracene	12	0.58	0.14		0.0005	**0.14**	**0.14**
Indeno(1,2,3-cd)pyrene	22	1.1	1.4		0.0005	**1.4**	**1.1**
Total cPAHs TEQ	6.2	0.31	0.14		0.00076	**0.14**	**0.14**
Dioxins/Furans							
Total 2,3,7,8 TCDD (TEQ)	7.8E-02	3.9E-03	1.3E-05		6.3E-06	**1.3E-05**	**1.3E-05**

Note:

Refer to Section 5 and Table 5-2 of the RI for derivation of soil screening levels that are adopted as soil cleanup levels. Cleanup levels are the most stringent value protective of all exposure pathways. Arsenic is based on natural background concentrations for Washington state (WAC 173-340-900 Table 720-1).

Table 5-1 Summary of Remedial Alternatives and Evaluation with Respect to Threshold Criteria

Pulp/Tissue Mill RAU Feasibility Study, GP West Site

Design Concept	Alternative 1 Figure 4-1	Alternative 2 Figure 4-2	Alternative 3 Figure 4-3	Alternative 4 Figure 4-4
Elements of Remedial Alternative[1]	• Completed Bunker C soil removal action • Remove add'l Bunker C soils exceeding TPH residual saturation[2] • RAU-wide cap (bldgs., pavement, soil cover) • Groundwater MNA in Misc. Dissolved Metals, Acid Plant, and LP-MW01 areas [3] • Institutional controls addressing: - inspection/maintenance of soil cap - use limitations[4] - worker protection standards - VI potential in LP-MW01 subarea[5] - notification requirements	• Completed Bunker C soil removal action • Remove add'l Bunker C soils exceeding TPH residual saturation[2] • RAU-wide cap (bldgs., pavement, soil cover) • Hydraulic cap over Acid Plant source area • *In situ* treatment of acidic groundwater plume in Acid Plant subarea • Groundwater MNA in Misc. Dissolved Metals and LP-MW01 areas [3] • Institutional controls addressing: - inspection/maintenance of soil cap - use limitations[4] - worker protection standards - VI potential in LP-MW01 subarea[5] - notification requirements - additional ICs for Acid Plant area[6]	• Completed Bunker C soil removal action • Remove add'l Bunker C soils exceeding TPH residual saturation[2] • RAU-wide cap (bldgs., pavement, soil cover) • Remove acidic/metals-contaminated vadose zone soils from Acid Plant source area • *In situ* treatment of acidic groundwater plume in Acid Plant subarea • Groundwater MNA in Misc. Dissolved Metals and LP-MW01 areas [3] • Institutional controls addressing: - inspection/maintenance of soil cap - use limitations[4] - worker protection standards - VI potential in LP-MW01 subarea[5] - notification requirements - additional ICs for Acid Plant area(6)	• Completed Bunker C soil removal action • RAU-wide removal of Fill Unit soils

Remedial Alternative Evaluation with Respect to MTCA Threshold Criteria[7]

MTCA Threshold Criteria *(WAC 173-340-360(2)(a))*	**Does Alternative Comply with Threshold Criterion?**			
Protect human health and the environment	Yes	Yes	Yes	Yes
Comply with cleanup standards	Yes	Yes	Yes	Yes
Comply with applicable state & federal laws	Yes	Yes	Yes	Yes
Provide for compliance monitoring	Yes	Yes	Yes	Yes
Evaluation Results	**Carried Forward to Detailed Evaluation**	**Carried Forward to Detailed Evaluation**	**Carried Forward to Detailed Evaluation**	**Carried Forward to Detailed Evaluation**

IC institutional control
MNA monitored natural attenuation
TPH total petroleum hydrocarbon
VI vapor intrusion
RAU Remedial Action Unit
MTCA Model Toxics Control Act
WAC Washington Administrative Code

Notes:

1) Refer to Section 4 for a detailed description of each remedial alternative.
2) *In situ* solidification/stabilization would be included as a contingency action in the event that soil removal is impracticable.
3) Compliance monitoring would be conducted to evaluate the effectiveness of groundwater MNA, and contingency actions would be included in case the MNA remedy is insufficient.
4) Use limitations would include a prohibition against groundwater usage and restrictions to protect/maintain the soil cap.
5) In the LP-MW01 subarea, VI potential would be evaluated and/or VI controls would be constructed beneath future buildings located above areas containing VOCs in groundwater. This IC would only be necessary if groundwater monitoring indicates that VOC concentrations have not naturally attenuated to below cleanup levels (refer to Section 1.1.4 discussion).
6) Additional ICs would protect the Acid Plant area groundwater treatment media in Alternatives 2 and 3. In Alternative 2, maintenance of storm water drainage features and protection of the hydraulic cap would also be addressed.
7) Refer to Section 5.3 for detailed evaluation with respect to the MTCA threshold criteria.

Table 5-2 Evaluation of Reasonable Restoration Time Frame

Pulp/Tissue Mill RAU Feasibility Study, GP West Site

	Design Concept	Alternative 1 Figure 4-1	Alternative 2 Figure 4-2	Alternative 3 Figure 4-3	Alternative 4 Figure 4-4
	Estimated Restoration Time Frame	16 to 36 years	10 years	10 years	3 to 6 years
Factors Used to Determine Whether the Restoration Time Frame is Reasonable (WAC 173-340-360(4)(b))	*Potential risks posed by the Site to human health and the environment*	Risk is low because: groundwater is not potable; capping addresses direct contact; and plume does not currently reach surface water and is not expected to.	Risk is low because: groundwater is not potable; capping addresses direct contact; and plume does not currently reach surface water and is not expected to.	Risk is low because: groundwater is not potable; capping addresses direct contact; and plume does not currently reach surface water and is not expected to.	Interim risks (until Site is restored) are relatively low.
	Practicability of achieving shorter restoration time frame	Alternatives 2, 3, and 4 would likely achieve a shorter restoration time frame.	Alternatives 2 and 3 are expected to restore Site in similar time frame.	Alternatives 2 and 3 are expected to restore Site in similar time frame.	Alternative 4 would likely achieve a shorter restoration time frame than Alternatives 1, 2, and 3.
	Current and potential future use of Site, surrounding areas, and associated resources that are, or may be, affected by releases from the Site	Current use of Site is limited by presence of contamination. There are no ongoing releases from Site. Estimated restoration time frame is reasonable for planned Site redevelopment.	Current use of Site is limited by presence of contamination. There are no ongoing releases from Site. Estimated restoration time frame is reasonable for planned Site redevelopment.	Current use of Site is limited by presence of contamination. There are no ongoing releases from Site. Estimated restoration time frame is reasonable for planned Site redevelopment.	Current use of Site is limited by presence of contamination. There are no ongoing releases from Site. Estimated restoration time frame is reasonable for planned Site redevelopment.
	Availability of alternate water supplies	City of Bellingham municipal water supply is readily available and would not be affected by Site cleanup.	City of Bellingham municipal water supply is readily available and would not be affected by Site cleanup.	City of Bellingham municipal water supply is readily available and would not be affected by Site cleanup.	City of Bellingham municipal water supply is readily available and would not be affected by Site cleanup.
	Likely effectiveness and reliability of institutional controls	ICs are expected to be effective and reliable at maintaining protectiveness of soil cap *in perpetuity*.	ICs are expected to be effective and reliable at maintaining protectiveness of soil cap *in perpetuity*.	ICs are expected to be effective and reliable at maintaining protectiveness of soil cap *in perpetuity*.	Not applicable, since there should not be a need for ICs.
	Ability to control and monitor migration of hazardous substances from the Site	RI results indicate that there is no migration of hazardous substances from the Site	RI results indicate that there is no migration of hazardous substances from the Site	RI results indicate that there is no migration of hazardous substances from the Site	RI results indicate that there is no migration of hazardous substances from the Site
	Toxicity of the hazardous substances at the Site	The hazardous substances at the Site have a relatively low toxicity.	The hazardous substances at the Site have a relatively low toxicity.	The hazardous substances at the Site have a relatively low toxicity.	The hazardous substances at the Site have a relatively low toxicity.
	Natural processes which reduce concentrations of hazardous substances and have been documented to occur at the Site or under similar Site conditions	Natural processes which reduce concentrations of hazardous substances have been documented to occur at the Site.	Natural processes which reduce concentrations of hazardous substances have been documented to occur at the Site.	Natural processes which reduce concentrations of hazardous substances have been documented to occur at the Site.	The restoration time frame estimated for this alternative does not rely on natural attenuation of hazardous substances.
Conclusion Regarding Reasonableness of Restoration Time Frame		The restoration time frame estimated for this alternative is reasonable.	The restoration time frame estimated for this alternative is reasonable.	The restoration time frame estimated for this alternative is reasonable.	The restoration time frame estimated for this alternative is reasonable.

IC institutional control RAU remedial action unit RI remedial investigation

Table 5-3 Disproportionate Cost Analysis

Pulp/Tissue Mill RAU Feasibility Study, GP West Site

Criteria to Evaluate Use of Permanent Solutions to the Maximum Extent Practicable

Design Concept	Weighting Factor (2)	Alternative 1 Figure 4-1	Alternative 2 Figure 4-2	Alternative 3 Figure 4-3	Alternative 4 Figure 4-4
Overall Protectiveness	30%	5 • Human and terrestrial ecological soil direct contact and soil erosion exposure pathways addressed by capping with ICs; • Confirmation that groundwater vapor intrusion and discharge-to-marine pathways are addressed; • Relies on long-term effectiveness of compliance monitoring and ICs.	6 Hydraulic capping and neutralizing the Acid Plant source area in this alternative may marginally improve protectiveness. ICs protect integrity of treatment locations.	7 Benefits of Alt. 1 plus additional protectiveness by removing Acid Plant source material and replacing with neutralizing media, thus achieving greater source control for acidity and dissolved metals to groundwater (facilitate MNA). ICs protect integrity of source treatment.	9 • RAU-wide removal of contaminated soils; • Should not require long-term groundwater monitoring or rely on ICs for protectiveness.
Permanence	20%	3 Natural attenuation is effectively reducing groundwater contaminant mass. Contaminated soil removal reduces mobility in Bunker C subarea. RAU-wide cap reduces direct contact risk and potential mobility via erosion.	4 Benefits of Alt. 1 plus reduced contaminant mobility in Acid Plant subarea due to buffering of groundwater pH.	5 Benefits of Alt. 2 plus additional benefit of permanent soil removal in Acid Plant source area.	9 Most permanent reduction in contaminant mobility through RAU-wide removal of contaminated soils. However, no reduction in contaminant toxicity or volume (beyond potential natural attenuation in off-site landfill).
Long-Term Effectiveness	20%	5 Removes NAPL and contaminated soil from Bunker C subarea. Long-term effectiveness in addressing erosion and direct contact/terrestrial ecological exposure potential of remaining contaminated soil would be dependent on the long-term integrity of the RAU-wide cap.	6 Hydraulic capping and neutralizing the Acid Plant source area in this alternative would marginally increase the long-term effectiveness of the remedy as a whole.	7 Benefits of Alt. 1 plus additional long-term effectiveness due to vadose zone soil removal in Acid Plant source area.	10 RAU-wide removal of contaminated soils provides the greatest long-term benefit, effectively eliminating residual risk via all exposure pathways and need for ICs.
Short-Term Risk Management	10%	8 Minimal short-term risks associated with RAU-wide soil capping and excavation of Bunker C soils (worker safety, dust and erosion control, etc.). Maintains redevelopment flexibility with minimal impact to adjacent properties.	8 Same rating as Alt. 1; installation of hydraulic cap and crushed limestone in the Acid Plant source area in this alternative would not significantly increase short-term risks.	7 Marginally greater short-term risks compared to Alts. 1 and 2 due to excavation of contaminated vadose zone soils in large Acid Plant source area.	2 Major earthwork construction project would create significant issues with respect to worker safety, dust and erosion control, etc.
Implementability	10%	7 Moderate challenges associated with extensive capping along waterfront, excavating TPH-saturated soil at depth, and implementing effective ICs after parcels are sold.	6 Marginally lower implementability compared to Alt. 1 due to installation of hydraulic cap and crushed limestone in the Acid Plant source area. Settlement or ICs at treatment locations may encumber reuse.	7 Marginally lower implementability compared to Alt. 1 due to excavation of contaminated vadose zone soils in Acid Plant source area. Settlement or ICs at treatment locations may encumber reuse.	1 Lowest implementability. Major earthwork project creates substantial challenges in terms of excavation, dewatering, debris management, and utilities.
Consideration of Public Concerns	10%	4 (Note 3)	5 (Note 3)	6 (Note 3)	10 (Note 3)
MTCA Benefits Ranking(4)		**5.0**	**5.7**	**6.5**	**7.8**
Estimated Cost(5)		**$5,700,000**	**$6,600,000**	**$7,600,000**	**$91,000,000**
Benefit/Cost Ratio(6)		**0.88**	**0.86**	**0.86**	**0.09**

DCA disproportionate cost analysis; IC institutional control; M&M monitoring and maintenance; MNA monitored natural attenuation; MTCA Model Toxics Control Act; RAU Remedial Action Unit; TPH total petroleum hydrocarbon; WAC Washington Administrative Code

Notes:

1) A scale of 1 to 10 is used to rate the alternatives with respect to the criteria, where "1" indicates the criterion is satisfied to a very low degree, and "10" indicates the criterion is satisfied to a very high degree. Rating values are shown in RED.

2) The weighting factors are based on Ecology input provided for feasibility studies conducted on other Port of Bellingham sites.

3) Ecology considers and responds to all public comments received on the Draft FS and Draft CAP documents as part of the cleanup process under MTCA.

4) The MTCA benefits ranking is obtained by multiplying the rating for each criterion by its weighting factor, and summing the results for the five criteria.

5) Net present value costs are estimated in 2014 dollars, and were calculated using a discount factor of 1.9 percent. The costs shown are rounded to two significant figures. Itemized estimates are provided in Appendix B.

6) The benefit/cost ratio is obtained by dividing the alternative's MTCA benefits ranking by its estimated cost (in $million).

FIGURES

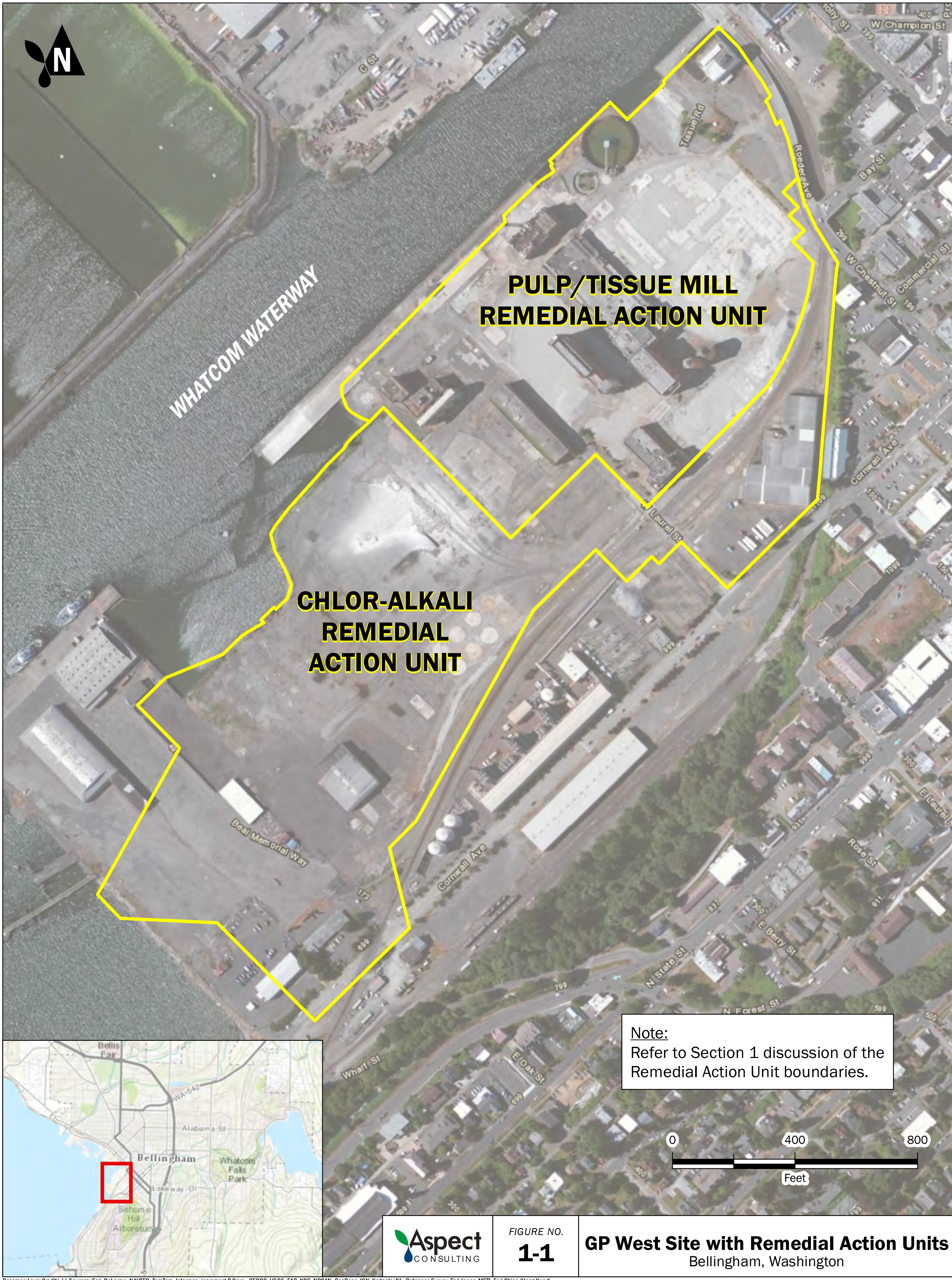
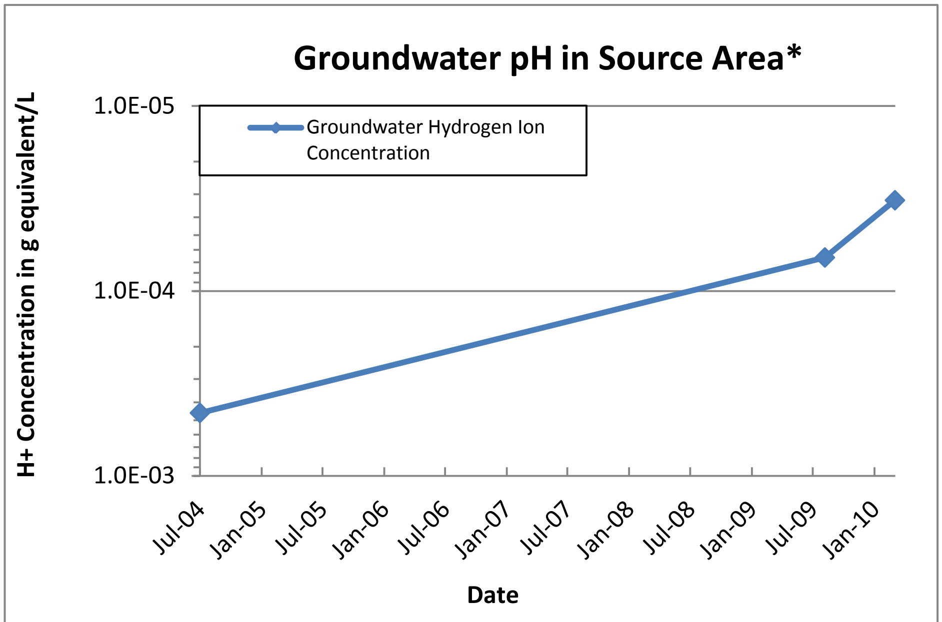


FIGURE NO. **1-1**

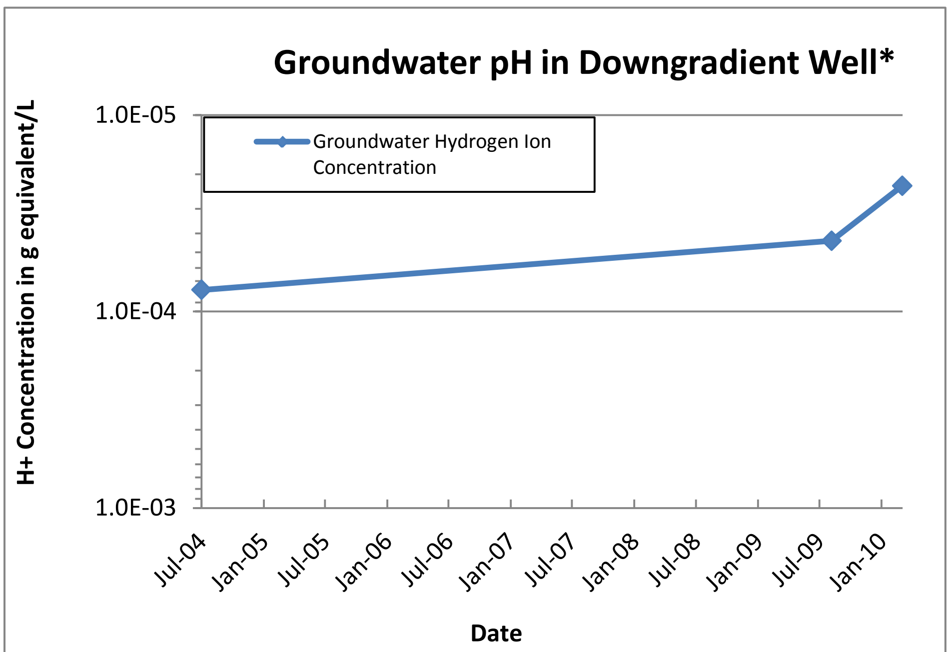
GP West Site with Remedial Action Units
Bellingham, Washington

Basemap Layer Credits || Sources: Esri, DeLorme, NAVTEQ, TomTom, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, and the GIS User Community

GIS Path: T:\projects_8\Port_of_Bellingham\Working\RAU Feas Study\PulpTissue Mill April 2014\1-1 Remedial Action Units.mxd || Coordinate System: NAD 1983 StatePlane Washington North FIPS 4601 Feet || Date Saved: 4/17/2014 || User: hlovelace || Print Date: 4/18/2014



* Combines data from wells GF-MW02 (2004) and AA-MW04 (2009-10)



* Well FH-MW01

Notes:

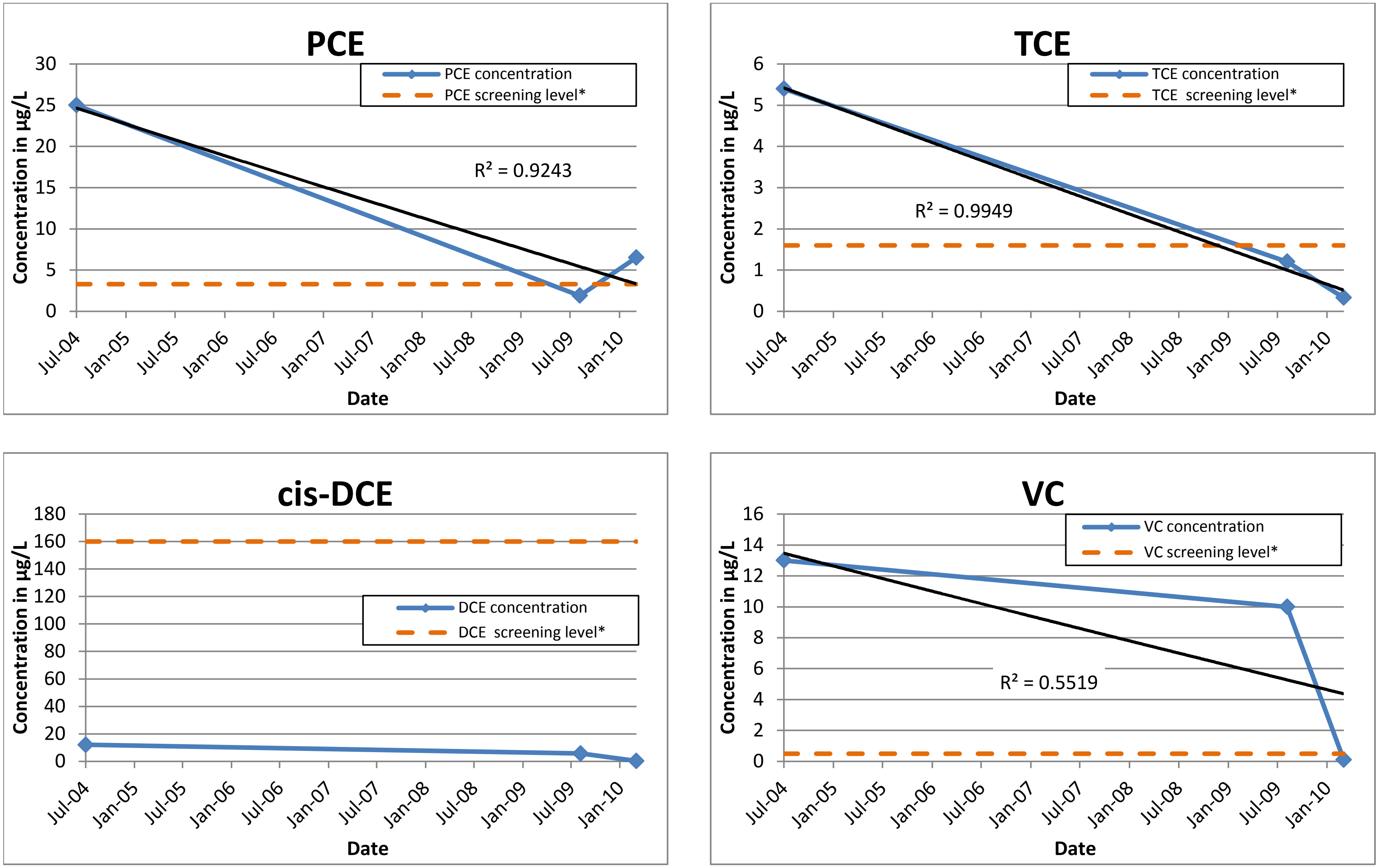
(a): pH (-log [H+ concentration]) is plotted as the H+ concentration for better illustration, since pH is a logarithmic scale. The y-axis (H+ concentration) is plotted in reverse so that a higher pH is up (lower H+).

Acid Plant Subarea
Groundwater pH Over Time

Pulp/Tissue Mill RAU Feasibility Study
GP West Site, Bellingham, WA

Aspect CONSULTING

OCT-2014	BY: DAH / HRL	FIGURE NO.
PROJECT NO. 070188	REVISED BY: RAA	1-2



* These RI screening levels are equivalent to the cleanup levels proposed in Section 2 of this FS.

Estimated restoration timeframes

PCE	TCE	VC
y = -404ln(x) + 4286.6	y = -92.93ln(x) + 985.85	y = -172.2ln(x) + 1830.2
t = exp[(3.3-4287)/-404)]	t = exp[(1.6-986)/-93)]	t = exp[(0.5-1830)/-172)]
t = Mar-10	**t = Mar-08**	**t = Dec-13**

LP-MW01 Subarea Groundwater VOC Concentrations Over Time

Pulp/Tissue Mill RAU Feasibility Study
GP West Site, Bellingham, WA

Aspect CONSULTING | OCT-2014 | BY: DAH / HRL | FIGURE NO. **1-3**
PROJECT NO. 070188 | REVISED BY: RAA

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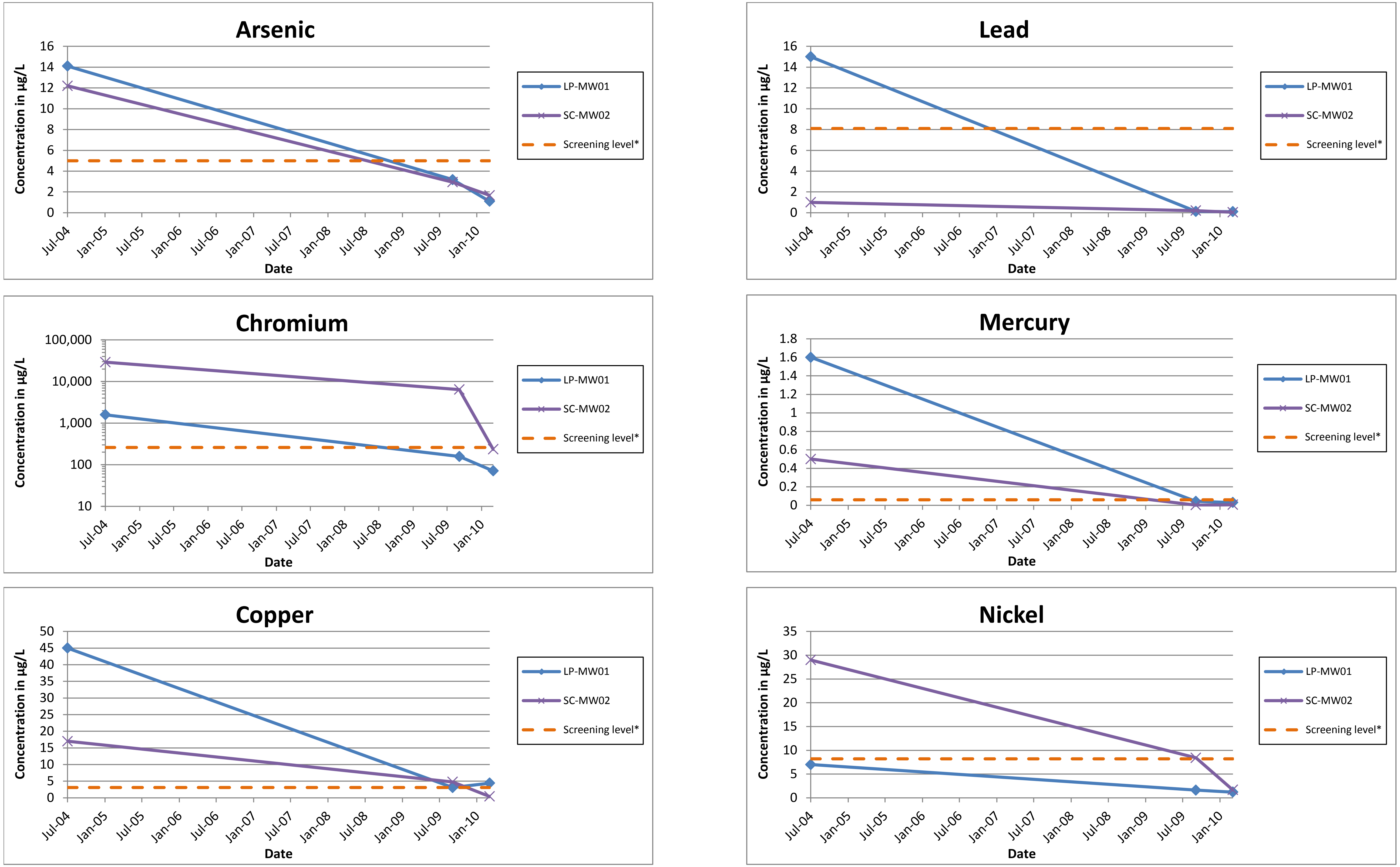
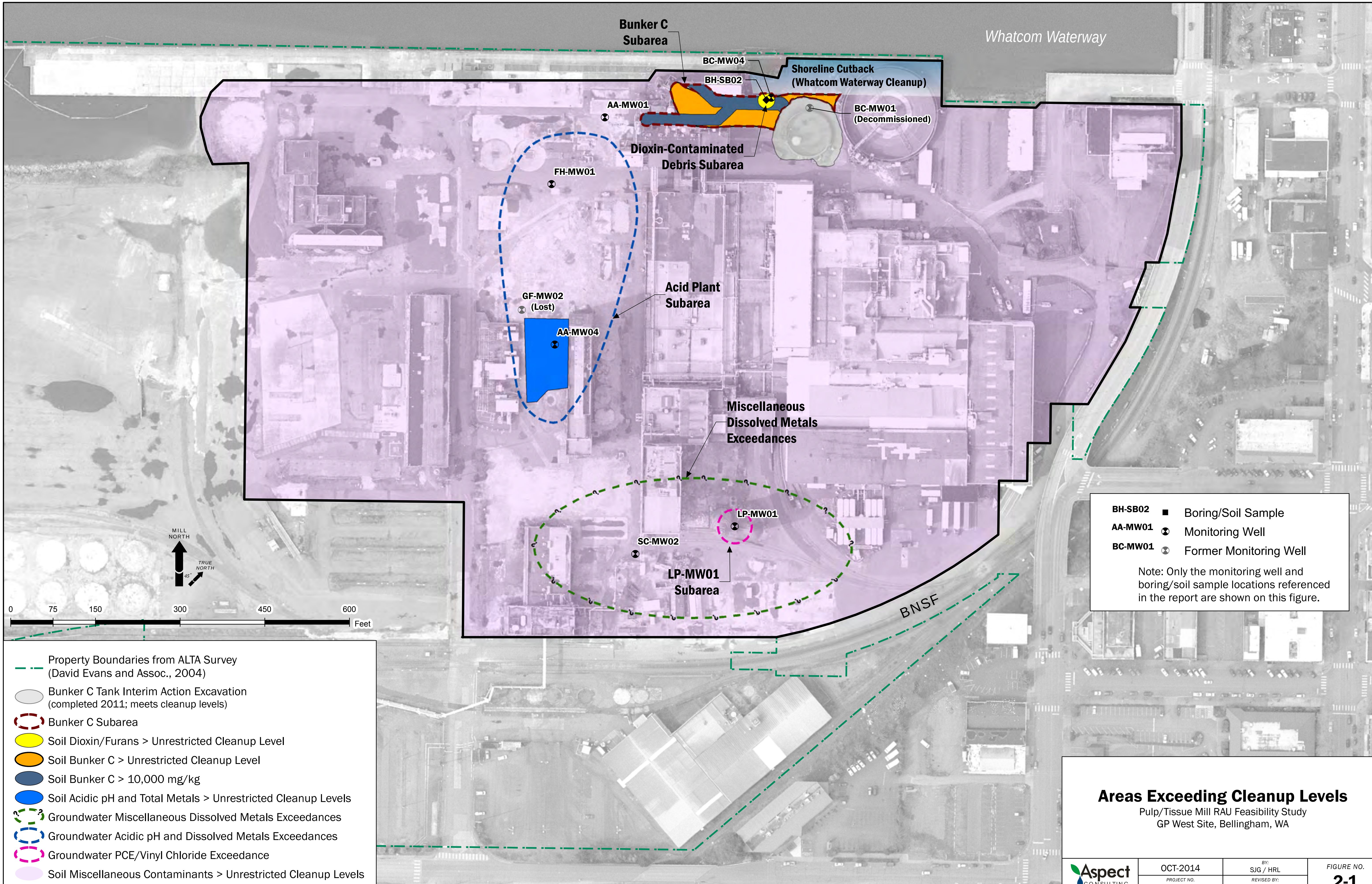


* These RI screening levels are equivalent to the cleanup levels proposed in Section 2 of this FS.

Miscellaneous Dissolved Metals Concentrations Over Time

Pulp/Tissue Mill RAU Feasibility Study
GP West Site, Bellingham, WA

Aspect CONSULTING	OCT-2014	BY: DAH / HRL	FIGURE NO.
	PROJECT NO. 070188	REVISED BY: RAA	1-4



Whatcom Waterway
Bunker C Subarea
BC-MW04
BH-SB02
Shoreline Cutback (Whatcom Waterway Cleanup)
AA-MW01
BC-MW01 (Decommissioned)
Dioxin-Contaminated Debris Subarea
FH-MW01
Acid Plant Subarea
GF-MW02 (Lost)
AA-MW04
Miscellaneous Dissolved Metals Exceedances
LP-MW01
SC-MW02
LP-MW01 Subarea
BNSF
MILL NORTH
TRUE NORTH
45°
0 75 150 300 450 600 Feet
BH-SB02 Boring/Soil Sample
AA-MW01 Monitoring Well
BC-MW01 Former Monitoring Well
Note: Only the monitoring well and boring/soil sample locations referenced in the report are shown on this figure.
Property Boundaries from ALTA Survey (David Evans and Assoc., 2004)
Bunker C Tank Interim Action Excavation (completed 2011; meets cleanup levels)
Bunker C Subarea
Soil Dioxin/Furans > Unrestricted Cleanup Level
Soil Bunker C > Unrestricted Cleanup Level
Soil Bunker C > 10,000 mg/kg
Soil Acidic pH and Total Metals > Unrestricted Cleanup Levels
Groundwater Miscellaneous Dissolved Metals Exceedances
Groundwater Acidic pH and Dissolved Metals Exceedances
Groundwater PCE/Vinyl Chloride Exceedance
Soil Miscellaneous Contaminants > Unrestricted Cleanup Levels
Areas Exceeding Cleanup Levels
Pulp/Tissue Mill RAU Feasibility Study
GP West Site, Bellingham, WA
Aspect CONSULTING
OCT-2014
PROJECT NO. 070188
BY: SJG / HRL
REVISED BY: DAH / HRL / RAA
FIGURE NO. 2-1
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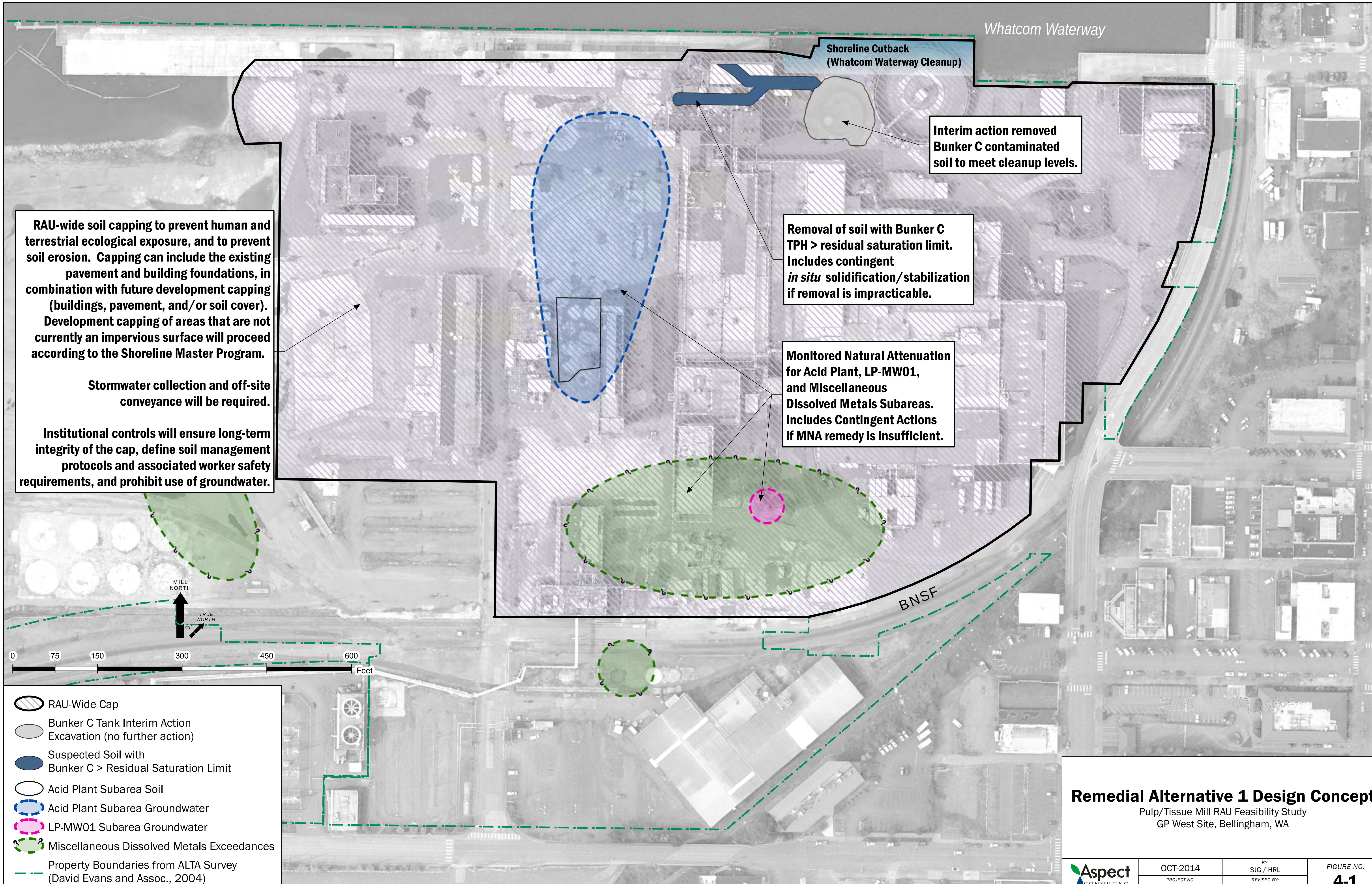
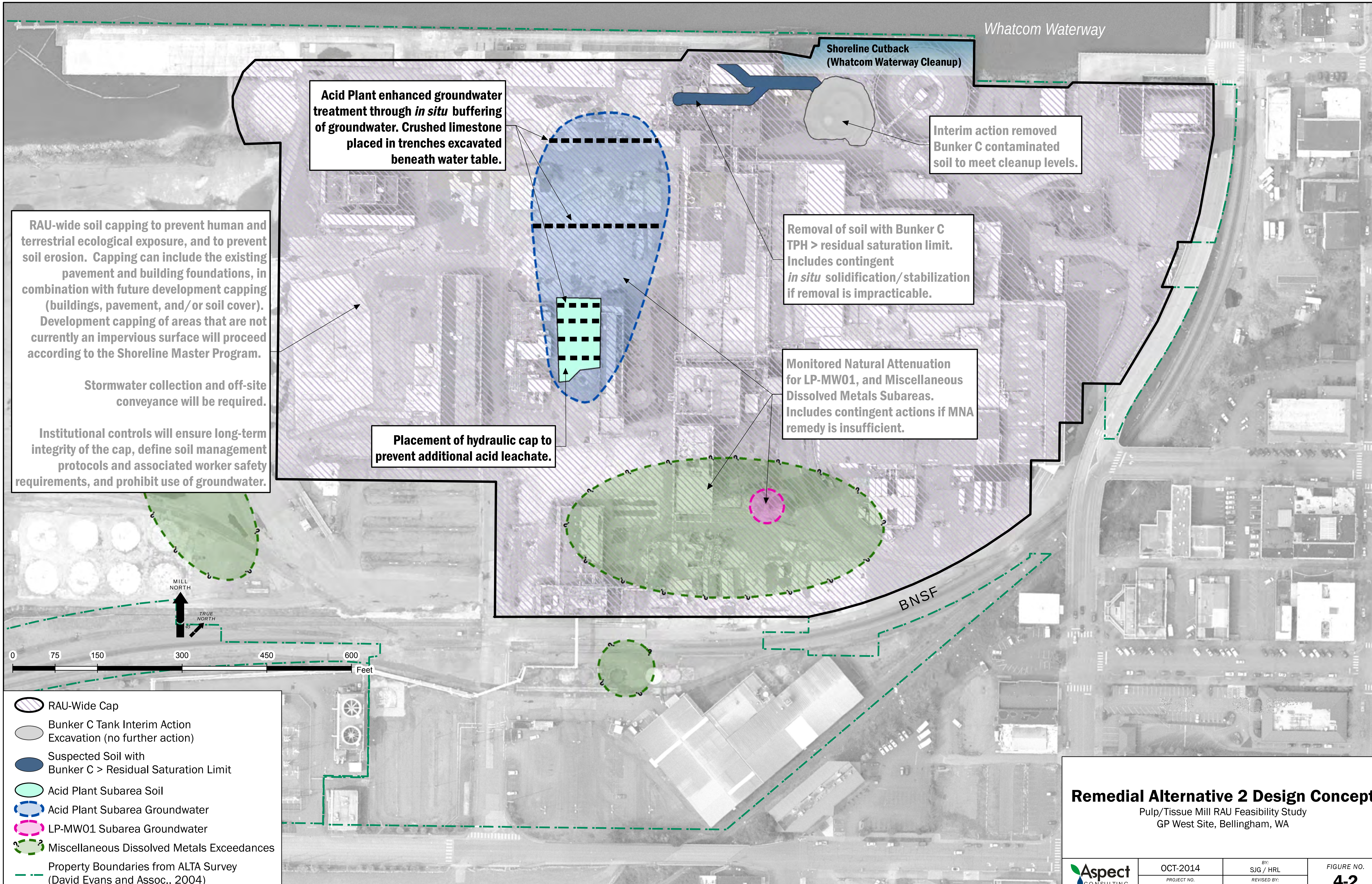


Remedial Alternative 1 Design Concept

Pulp/Tissue Mill RAU Feasibility Study

GP West Site, Bellingham, WA



Remedial Alternative 2 Design Concept

Pulp/Tissue Mill RAU Feasibility Study
GP West Site, Bellingham, WA

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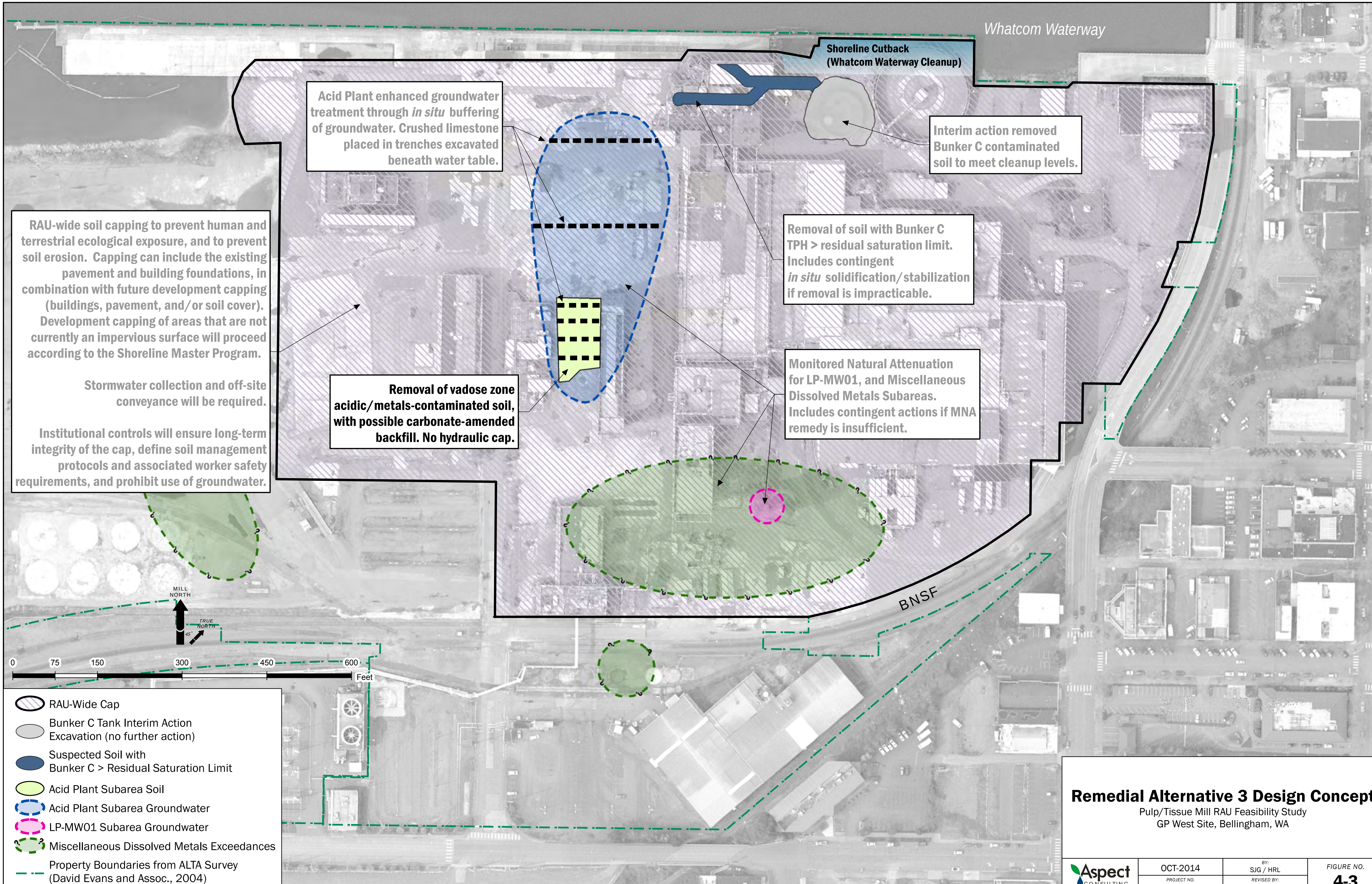
Whatcom Waterway
Shoreline Cutback (Whatcom Waterway Cleanup)
Acid Plant enhanced groundwater treatment through *in situ* buffering of groundwater. Crushed limestone placed in trenches excavated beneath water table.
Interim action removed Bunker C contaminated soil to meet cleanup levels.
RAU-wide soil capping to prevent human and terrestrial ecological exposure, and to prevent soil erosion. Capping can include the existing pavement and building foundations, in combination with future development capping (buildings, pavement, and/or soil cover). Development capping of areas that are not currently an impervious surface will proceed according to the Shoreline Master Program.
Stormwater collection and off-site conveyance will be required.
Institutional controls will ensure long-term integrity of the cap, define soil management protocols and associated worker safety requirements, and prohibit use of groundwater.
Removal of soil with Bunker C TPH > residual saturation limit. Includes contingent *in situ* solidification/stabilization if removal is impracticable.
Removal of vadose zone acidic/metals-contaminated soil, with possible carbonate-amended backfill. No hydraulic cap.
Monitored Natural Attenuation for LP-MW01, and Miscellaneous Dissolved Metals Subareas. Includes contingent actions if MNA remedy is insufficient.
BNSF
MILL NORTH
TRUE NORTH
45°
0
75
150
300
450
600
Feet
RAU-Wide Cap
Bunker C Tank Interim Action Excavation (no further action)
Suspected Soil with Bunker C > Residual Saturation Limit
Acid Plant Subarea Soil
Acid Plant Subarea Groundwater
LP-MW01 Subarea Groundwater
Miscellaneous Dissolved Metals Exceedances
Property Boundaries from ALTA Survey (David Evans and Assoc., 2004)
Remedial Alternative 3 Design Concept
Pulp/Tissue Mill RAU Feasibility Study
GP West Site, Bellingham, WA
Aspect CONSULTING
OCT-2014
PROJECT NO. 070188
BY: SJG / HRL
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FIGURE NO. 4-3
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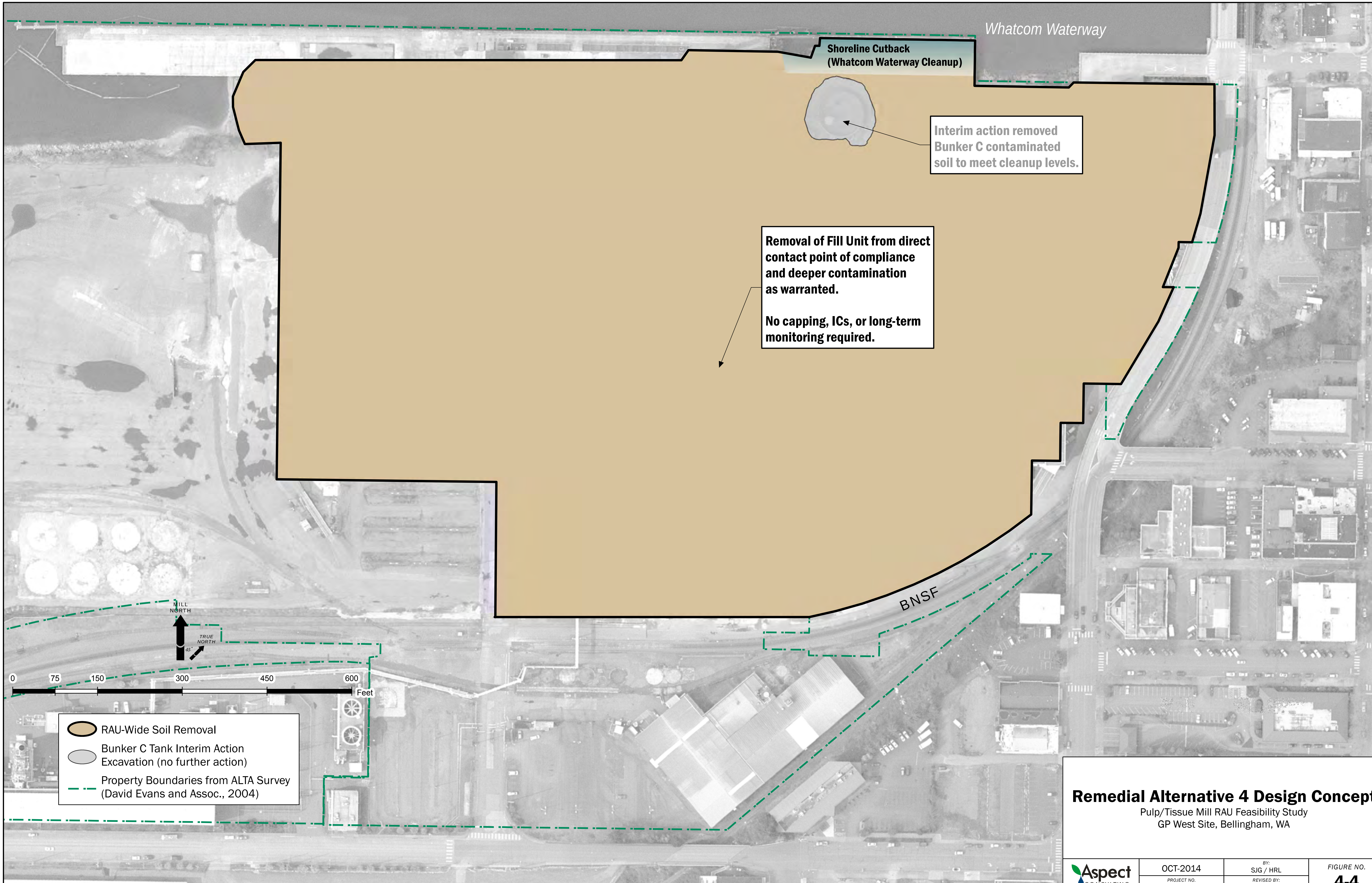


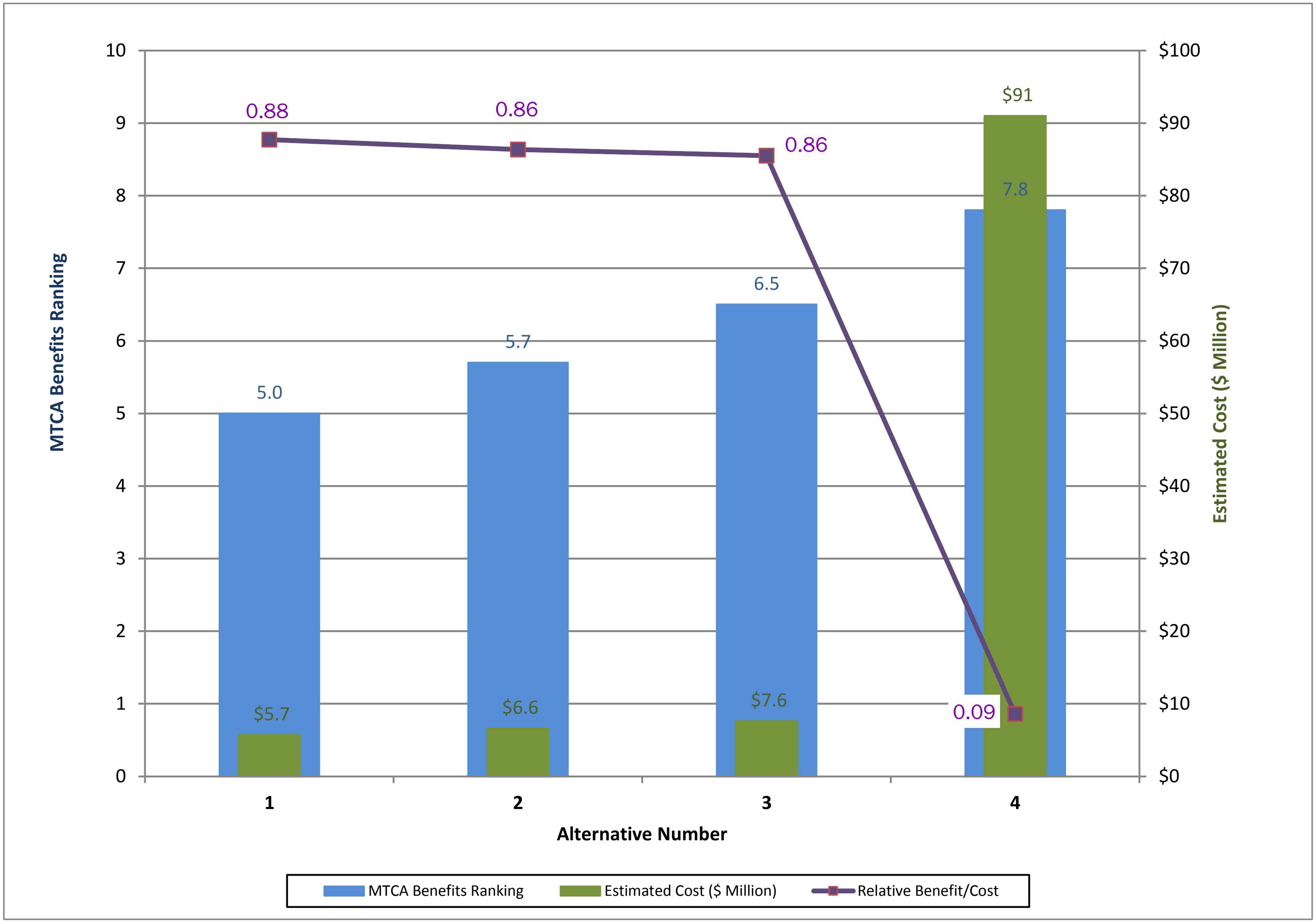
Remedial Alternative 4 Design Concept

Pulp/Tissue Mill RAU Feasibility Study
GP West Site, Bellingham, WA

Aspect CONSULTING

OCT-2014	BY: SJG / HRL	FIGURE NO.	
PROJECT NO. 070188	REVISED BY: DAH	4-4	

Path: T:\projects_8\Port_of_Bellingham\Working\RAU Feas Study\Oct2014\4-4 Remedial Alternative 4 Design Concept.mxd



Notes:
1) Present worth costs in 2014 dollars, calculated using a discount factor of 1.9%.
2) The benefit/cost ratio values in Table 5-3 have been multiplied by 10 to scale them appropriately to the left axis, for display purposes only.

Disproportionate Cost Analysis Summary

Pulp/Tissue Mill RAU Feasibility Study
GP West Site, Bellingham, WA

Aspect CONSULTING	OCT-2014	BY: DAH / HRL	FIGURE NO.
	PROJECT NO. 070188	REVISED BY: RAA	5-1

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APPENDIX A

Preliminary Geochemical Modeling, Acid Plant Subarea Groundwater Remediation Alternatives

Introduction

This appendix presents the methods and results from preliminary geochemical transport modeling conducted to estimate Acid Plant subarea groundwater restoration time frame under a range of prospective remediation alternatives. The information is incorporated into development and evaluation of remedial alternatives for the Pulp/Tissue Mill Remedial Action Unit (RAU). The geochemical transport model was constructed using data presented in the RI (Aspect, 2013).

The following section provides background information and definitions useful for understanding the modeled geochemical processes. Later sections provide detailed discussions of modeling methods and results.

Water Quality Parameter Definitions

The following water quality parameters are important to understanding the concepts behind geochemical equilibrium modeling and geochemical controls on mobility of metals.

pH

pH is a measurement of the hydrogen ion (H^+) in solution, as measured in negative log units (e.g., a pH of 6 is equivalent to a hydrogen ion concentration of 10^{-6} moles). A pH of 7 is neutral, below 7 indicates acidic conditions, and above 7 indicates basic conditions. The pH strongly influences metal speciation and mobility, as (H+) and/or the counter-ion (OH-) are commonly products and/or reactants in many aqueous/mineral reactions. The pH controls aqueous phase speciation of most dissolved ions, as well as the sorption potential of mineral surfaces. In general, increasing pH (going toward neutrality from acidic conditions) immobilizes metals by decreasing cationic metal species solubilities and increasing sorption to solid phase by lowering solid-phase surface charge. However, some metals, including mercury, can become more mobile in high pH environments.

Alkalinity

Alkalinity is a measurement of water's ability to resist changes in pH. Alkalinity in groundwater, principally as the ions HCO_3^- and CO_3^{2-}, allows water to buffer or resist changes in pH by neutralizing acids or bases. Alkalinity can result from equilibration with carbonate minerals, atmospheric carbon dioxide, and to some extent silicate minerals, lime, phosphates, and other salts. Alkalinity is formally defined as the sum of all titratable bases, and is usually expressed as equivalent mg/L of $CaCO_3$ (calcite), a convention that considers the amount of calcite that would need to be dissolved to produce the given alkalinity.

Mineral Saturation

Saturation indices (SIs) describe the thermodynamic equilibrium relationship between an aqueous phase and a mineral phase. SIs are calculated using chemical data in the aqueous phase and mineral phase. SI calculations consider numerous factors related to specific water quality sample results, and predefined thermodynamic constants for species involved in the reaction. In general, a positive SI indicated likely mineral phase precipitation from the water; a negative SI indicates dissolution is favorable.

Mineral dissolution and precipitation reactions, governed by SIs, can buffer changes to pH by neutralizing acids or bases. For a general example, take an acidic water sample containing dissolved iron. Slow addition of a base to this sample would cause an initial precipitation of iron oxides at a relatively constant pH; the base would be used in the precipitation reaction. The pH would then increase after the dissolved iron is "used-up". The SI is key to understanding if pH-controlling mineral dissolution and precipitation reactions can occur given a particular aqueous and mineral phase assemblage.

Geochemical Modeling Methods

This section identified the geochemical model software, and summarizes model input assumptions and definitions.

Model Software

Groundwater transport and geochemical reactions were modeled using PHAST for Windows 1.0.3-7462 (Parkhurst et al., 2004). PHAST simulates groundwater flow and transport based on HST3D (Kipp, 1997), a 3D flow and transport finite difference code for steady state and transient conditions. PHAST geochemical thermodynamic equilibrium simulations use PHREEQC (Parkhurst and Appelo, 1999) modeling program. Water quality data from the RI were analyzed in PHREEQC using the *minteq.dat* comprehensive thermodynamic dataset, which is provided with PHREEQC.

Model Flow and Transport Definitions

The model was developed using the following simplified grid parameters and hydrogeologic definitions, applied to the acidic groundwater plume of the Acid Plant subarea:

- A 2D flow model space is defined with a 600 feet (ft) by 300 ft by 10 ft grid, with approximately 20 ft grid cell spacing in the x and y direction;
- The advective flow components of the model assume a linear hydraulic gradient of 0.01 ft/ft and aquifer hydraulic conductivity of 0.003 centimeters per second (cm/sec), as specified in the RI (Aspect, 2013); and
- Model time begins in 1961 and continues until 2070, with time steps of 0.5 years.

Model Geochemical Conditions

This section describes modeled conditions for the Acid Plant subarea acidity source, background groundwater quality, downgradient boundary conditions, mineral phase assemblages, and restoration criteria.

The model uses two basic groundwater chemistries defined as the acidic-release water, and uncontaminated background water. Water chemistry parameters were derived from water quality data collected in the RI. The acid source was modeled using groundwater data collected from wells GF-MW02 in 2004 (pH of 3.34) and AA-MW04 in 2009 (pH of 4.18), located within the footprint of the former Acid Plant ("source area wells"). For purposes of the model, the source release was defined to begin in 1961 and terminate in 2001 (Pulp Mill closed). The modeled acid plume reaches steady state conditions prior to 2001, indicating the assumed termination date is of limited significance.

Background water was modeled using data collected from shoreline well AA-MW01 in 2010. The pH in AA-MW01 is consistent with other nearby wells outside the acidic impact: wells AA-MW02, LB-MW01, BC-MW01, BC-MW02, GF-MW01 all have pHs between 6.6 and 7.2. The average pH of upgradient well LB-MW01 was 6.82 in 2009/10 sampling, which is also in close agreement with the modeled pH from AA-MW01 of 6.92. In the absence of detailed geochemical data from LB-MW01, AA-MW01 (2010) is a reasonable best approximation of general "background" pH and alkalinity conditions for the limited purposes of this modeling.

Modeling Approach

Mineral reactions were handled using two separate modeling approaches. The conservative models assume that mineral precipitation reactions are not buffering pH. The reactive models allow for mineral buffering.

The conservative models generally show faster restoration times. They allow for a best-case conservative result based strictly on aqueous mixing effects, physical hydrogeology assumptions, and alkalinity buffering of pH.

In addition to these components, the reactive models allow precipitation of generalized mineral complexes to buffer pH. We used iron-oxide (goethite) and aluminum-oxide (gibbsite) minerals to buffer changes in pH as neutralizing background water mixes with more acidic water. Goethite and gibbsite are reasonable mineral controls in the pH ranges modeled. Gibbsite is soluble at very low pH but becomes very insoluble under mildly acidic and neutral conditions. Gibbsite and goethite reactions provide generalized estimates for mechanisms controlling mineral buffering of pH.

For the purpose of the model, restoration is defined as achieving a pH of 6.2 (groundwater cleanup level) at a location near the downgradient acidic plume boundary, approximately 500 feet north of the source area. Based on site-specific data, this is a conservative estimate, as the monitoring well AA-MW03 had a pH of 4.87 to 5.06 in 2009/10 and no metal screening level exceedances. It can be shown that significant decreases in dissolved cadmium, copper, iron, nickel, manganese, and to a lesser extent zinc concentrations generally correlate with pH increases within this range.

Geochemical Modeling Results

The models were each run assuming three prospective remediation scenarios for the Acid Plant subarea: monitored natural attenuation (MNA), source area treatment, and downgradient plume treatment.

Predicted restoration time frames for each of the remediation alternatives are as follows:

- MNA achieves a pH of 6.2 in the time frame of 2030 to 2050;
- Source removal and replacement with calcite-equilibrated groundwater achieves a pH of 6.2 also in the time frame of 2030 to 2050. While there is no benefit in terms of accelerated restoration indicated by the modeling under this scenario, the final pH is about 0.5 pH units higher than under the MNA scenario due to equilibration with calcite (pH 7.45 compared to 6.92); and
- Downgradient groundwater plume treatment, via construction of limestone-filled trenches in three transverse locations, could result in a pH of 6.2 as soon as 2024.

Model Calibration under Natural Attenuation Conditions

A general calibration of the geochemical model was performed by comparing model results under natural attenuation against measured pH data collected from source area monitoring wells during the RI. As discussed in the RI, the acidic groundwater pH in this subarea is attenuating naturally, so the measured data, albeit limited, provide a representation of a potential MNA remedy. The comparisons are illustrated on Figure A-1, where three model iterations are presented. The iterations are MNA scenarios that differ from one another in initial composition of acidic source water, and in reactivity of aquifer minerals. The measured data are from source area monitoring wells GF-MW02 in 2004 and AA-MW04 in 2009.

The MNA-conservative model uses GF-MW02 water as the acidic source solution and does not allow for mineral-phase equilibration. This model is the most accelerated of the three because no mineral interactions are buffering pH changes that occur during mixing. In comparison to the observed source area pH data, the MNA-conservative model attenuates too quickly, which suggests that mineral interaction is buffering changes in pH.

The MNA-reactive (pH 3.34) model also uses GF-MW02 water as the acidic source solution, but simulates aluminum and iron-oxide mineral buffering of pH. This scenario is characterized by an initial buffering period where pH increases gradually followed by a pronounced attenuation period. Observed pH buffering is a result of mineral precipitation reactions. While this model provides a mechanistic framework for describing the observed source area behavior, the model does not allow pH to attenuate as quickly as measured pH data indicate.

The MNA-reactive (pH 4.18) model uses the same reactive framework as the previously described model (MNA reactive pH 3.34), but uses the AA-MW04 2009 water as the acidic source solution. Using this slightly less acidic source term provides further insight into restoration time frame relative to observed groundwater data. This pH may be more characteristic of general plume conditions following termination of acid release than the lower pH (3.34) used for the treatment scenario models.

These results demonstrate the effects of geochemical assumptions on time frame estimations in this preliminary modeling. Using an alternate empirical method, a line of best fit through the source area pH data points suggests a source area MNA restoration by about 2020 (Figure A-1). However, actual groundwater buffering and neutralization reactions are dependent on numerous factors including acidic source water compositions and distribution, groundwater flow dynamics, upgradient water composition, possible tidal mixing near the downgradient plume edge, aquifer composition, and reaction rates.

While none of the three model results exactly predict the observed pH attenuation in the source area, the data do suggest a reasonable range of results that can be used to estimate groundwater pH restoration time frame adequately for the purposes of an FS. Additional evaluation can be conducted as part of remedial design, as appropriate to the selected remedial alternative.

Simulation of Source Area Control Alternative

Figure A-2 compares the MNA scenario to source area control and groundwater treatment model scenarios. Source removal is not predicted to significantly decrease the restoration time frame, although it may have a secondary benefit of removing acidic minerals (and metals) from the unsaturated zone in the source area, and may result in a higher pH, more alkaline post-restoration groundwater condition. The higher restoration pH and alkalinity would likely result in greater stability of attenuated metals. Although there may be a potential for residual acidity in both the unsaturated zone and the saturated zone, background water is likely sufficiently alkaline to neutralize residual acidity in the source area saturated zone.

Simulation of Downgradient Plume Treatment Alternative

Downgradient plume treatment was modeled as the introduction of a curtain of calcite-equilibrated water in three equidistant transverse locations across the groundwater plume width. Assuming optimal treatment efficiency conditions, this generally results in a restoration time frame equivalent to one-third of the natural attenuation time frame. Restoration is modeled to occur by 2024 (Figure A-2); however, other design considerations may affect the groundwater treatment time frame. Like source area treatment, downgradient treatment would likely result in a higher pH, higher alkalinity post-restoration groundwater conditions.

References for Appendix A

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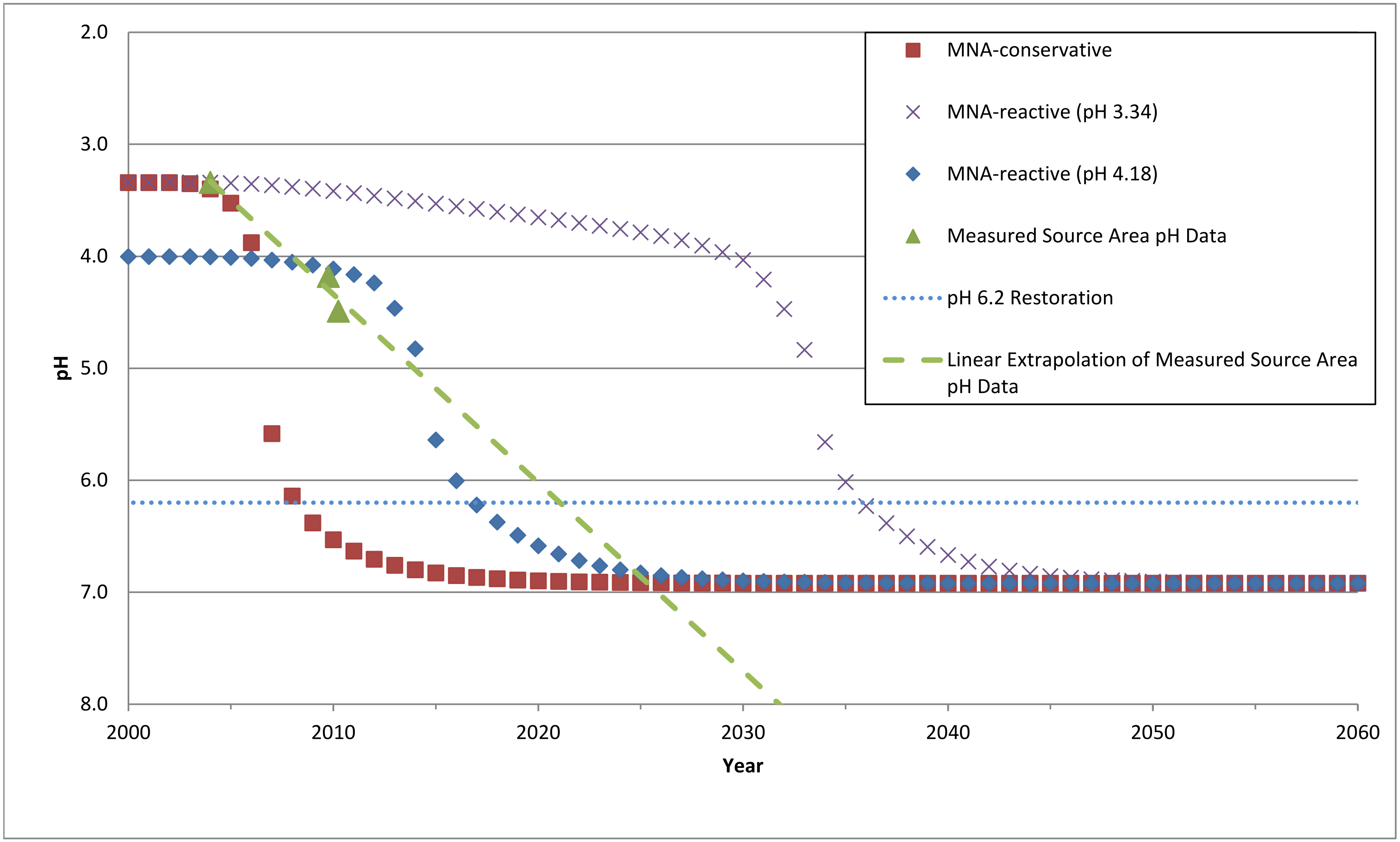

Aspect Consulting
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Figure A-1
Comparison of Modeled and Measured pH in Acid Plant Source Area

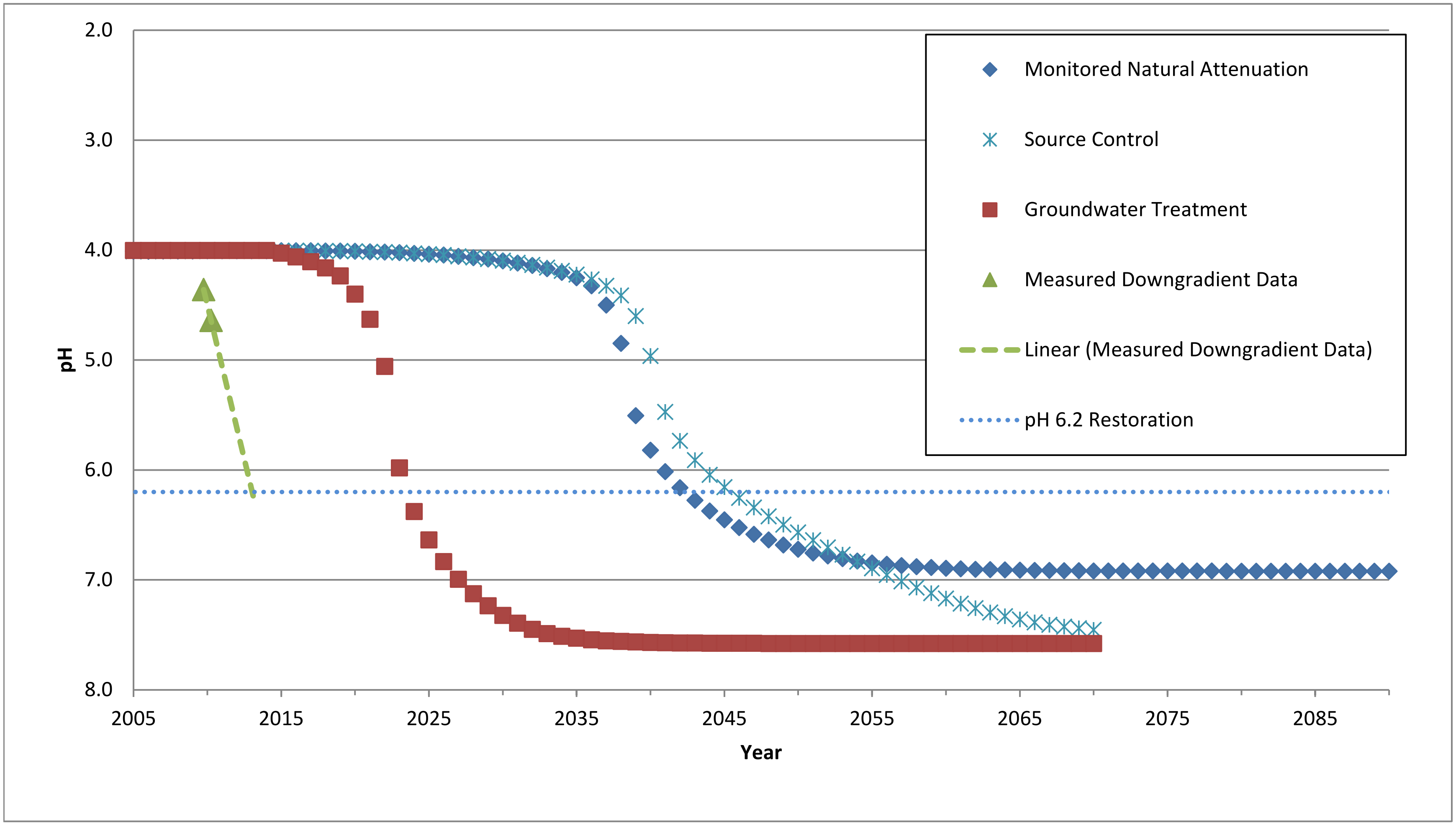

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Figure A-2
Modeled Restoration Timeframes under Remediation Alternatives

APPENDIX B

Detailed Cost Estimates for Remedial Alternatives

Table B-1 - Summary of Cost Estimates for Remedial Alternatives

Feasibility Study, Pulp/Tissue Mill RAU, GP West Site

Remedial Alternatives for Pulp/Tissue Mill RAU	Total Estimated Cost
1) Bunker C Soil Removal, RAU-Wide Soil Capping, MNA, and ICs	$ 5,700,000
2) Bunker C Soil Removal, RAU-Wide Soil Capping, Acid Plant Groundwater Treatment, MNA, and ICs	$ 6,600,000
3) Bunker C Soil Removal, RAU-Wide Soil Capping, Acid Plant Groundwater Treatment and Source Removal, MNA, and ICs	$ 7,600,000
4) Full Removal of Fill Unit	$ 91,000,000

Notes:

1) Cost are in 2014 dollars. Costs were estimated using Net Present Value (NPV) analysis, assuming a discount rate of 1.9 percent. Long-term inspection, monitoring, and maintenance ("O&M") costs were evaluated over a 30-year period, consistent with EPA guidance. The estimates are order-of-magnitude, with an intended accuracy in the range of -30 to +50 percent.

2) Costs are displayed to two significant digits.

Table B-2 - Alternative 1 Cost Estimate

Feasibility Study, Pulp/Tissue Mill RAU, GP West Site

Site:	Former Georgia-Pacific West Site - Pulp/Tissue Mill Remedial Action Unit		
Remedial Action Description:	**Alternative:**	**1**	**Bunker C Soil Removal, RAU-Wide Soil Capping, MNA, and ICs**
Cost Estimate Accuracy:	FS Screening Level (+50/-30 percent)		

Key Assumptions and Quantities:

31	acre	total RAU area
150,300	SY	total RAU area
5,700	ft	cap perimeter
2,000	BCY	Bunker C excavation volume
790	BCY	Bunker C overburden
7	each	monitoring wells for MNA
1.5	tons/BCY	soil density

CONSTRUCTION COSTS

Item	Quantity	Unit	Unit Cost	Total Cost	Notes
Bunker C Interim Action					
Sunk cost	1	LS	$ 772,000	$ 772,000	including remedial design, construction, and oversight
Subtotal Bunker C Interim Action				*$ 772,000*	
RAU-Wide Soil Capping					
Mobilization/Demobilization	1	LS	$ 100,000	$ 100,000	
Existing Cap	**0%**				
-No Cost	-	acre	$0	$ -	
New Cap	**100%**				
Soil Cover as Cap	*20%*				
-Site Preparation	6	acre	$ 4,500	$ 27,932	clearing and leveling
-Geotextile marker layer	30,043	SY	$ 2	$ 60,085	Specification 9 33.2(1) Table 3 (WSDOT, 2012)
-Import, place, and compact fill	20,028	CY	$ 18	$ 360,512	
Asphalt Pavement as Cap	*30%*				
-Site Preparation	9	acre	$ 4,500	$ 41,898	clearing and leveling
-Pre-grading	9	acre	$ 5,200	$ 48,416	light grading for asphalt
-Asphalt	9	acre	$ 115,400	$ 1,074,461	6" stone base, 2" binder layer, 1" topping layer
Buildings as Cap	*50%*				
-No Cost	16	acre	$0	$ -	Assume buildings cost are redevelopment, not cleanup
Stormwater collection and conveyance system	5,654	LF	$0	$ -	Assumed redevelopment cost
Institutional Controls Plan	1	LS	$ 50,000	$ 50,000	includes I&M manual for cover systems, legal support
Remedial design	25%			$ 440,826	
Construction management and reporting	20%			$ 352,661	
Subtotal				*$ 2,556,792*	
Tax	8.7%		$ 1,713,305	$ 149,058	
Contingency	15%		$ 2,705,849	$ 405,877	
Subtotal Soil Cap Cost				*$ 3,111,727*	
Bunker C Subarea Soil Removal - TPH > Residual Concentration					
Mobilization/Demobilization	1	LS	$ 100,000	$ 100,000	
Dewatering	10	day	$ 800	$ 8,000	based on 200 yd/day removal rate, includes daily sampling
Excavation	2,000	BCY	$ 5	$ 10,000	assumes excavation limited to 10' below pipes (Figure 4-1)
Confirmation Sampling	40	each	$ 270	$ 10,800	
Waste Profiling	10	each	$ 270	$ 2,700	10 + 1 sample per 500 yd3 over 2000 yd3
Transport and disposal - Non-Hazardous Waste	1,815	ton	$ 60	$ 108,910	Thermal treatment and disposal at CEMEX USA
Potentially clean overburden handling and stockpiling	790	BCY	$ 5	$ 3,949	top 3' assumed to be clean
Analytical sampling of potentially clean stockpiles	24	each	$ 270	$ 6,480	3 samples per 100 yd3
Place and compact overburden	790	BCY	$ 10	$ 7,899	
Import, place, and compact fill	1,815	BCY	$ 18	$ 32,673	
In Situ Solidification/Stabilization	-	BCY	$ 80	$ -	contingency - auger application
Remedial design	25%			$ 72,853	
Construction management and reporting	20%			$ 58,282	
Subtotal				*$ 422,546*	
Tax	8.7%		$ 291,411	$ 25,353	
Contingency	100%		$ 447,899	$ 447,899	
Subtotal Soil Removal - Bunker C > Residual Saturation				*$ 895,798*	
Monitored Natural Attenuation					
Groundwater monitoring plan	1	LS	$ 15,000	$ 15,000	
Monitoring wells	7	each	$ 4,000	$ 28,000	
Remedial design	15%			$ 6,450	
Construction management and reporting	20%			$ 8,600	
Subtotal				*$ 43,000*	
Tax	8.7%		$ 28,000	$ 2,436	
Contingency	20%		$ 45,436	$ 9,087	
Subtotal Monitored Natural Attenuation Cost				*$ 54,523*	
Professional Services (as percent of capital costs)					
Project administration	3.0%		$ 4,834,049	$ 145,021	
Total Estimated Capital Costs				**$ 4,980,000**	

O&M COSTS - Net Present Value

Item	Frequency	Unit Cost	Annual Cost	NPV Cost	Notes
Periodic O&M					
Periodic inspection and maintenance of cover systems	1	$ 5,000	$ 5,000	$ 113,537	annual inspection/reporting; maintenance as needed
Periodic GW quality monitoring and MNA					
-Years 1&2 monitoring	4	$ 4,000	$ 16,000	$ 15,702	quarterly monitoring
-Years 3-30 monitoring	2	$ 3,500	$ 7,000	$ 145,342	semi-annual monitoring
Replace GW treatment media	20yr	$ -		$ -	assumed 20-year lifespan of PRB
Subtotal Periodic O&M Cost				*$ 274,581*	
Tax		8.7%		$ 23,889	Sales Tax
Contingency		20.0%		$ 59,694	
				$ 358,163	
Professional Services (as percent of Periodic O&M costs)					
Project administration		5%		$ 17,908	
Project management/reporting		6%		$ 21,490	
Total, Periodic O&M Net Present Value:				**$ 672,142**	
TOTAL ESTIMATED COST				**$ 5,652,142**	

Notes:
Costs are in 2014 dollars.
1.9% discount rate for NPV analysis based on 2013 real treasury rates
Mobilization/Demobilization costs are assumed to include equipment transport and setup, temporary erosion and sedimentation control (TESC) measures, bonds, and insurance.
Contingency costs include miscellaneous costs not currently itemized due to the current (preliminary) stage of design development, as well as costs to address unanticipated conditions encountered during construction.
Taxes are not applied to project administration, design, and reporting costs.

Table B-3 - Alternative 2 Cost Estimate

Feasibility Study, Pulp/Tissue Mill RAU, GP West Site

Remedial Action Description: **Alternative: 2** **Bunker C Soil Removal, RAU-Wide Soil Capping, Acid Plant Groundwater Treatment, MNA, and ICs**

Cost Estimate Accuracy: FS Screening Level (+50/-30 percent)

Key Assumptions and Quantities:

31	acre	total RAU area
150,300	SY	total RAU area
5,700	ft	cap perimeter
2,000	BCY	Bunker C excavation volume
790	BCY	Bunker C overburden
10,200	SF	acid plant impermeable cap area
1,125	BCY	acid plant trench volumes
208	BCY	acid plant downgradient overburden
167	BCY	acid plant source area excavation
200	ton	phosphate binder amendment per ton treated
900	ton	crushed limestone
7	each	monitoring wells for MNA
1.5	tons/BCY	soil density

CONSTRUCTION COSTS

Item	Quantity	Unit	Unit Cost	Total Cost	Notes
Bunker C Interim Action					
Sunk cost	1	LS	$ 772,000	$ 772,000	including remedial design, construction, and oversight
Subtotal Bunker C Interim Action				*$ 772,000*	
RAU-Wide Soil Capping					
Mobilization/Demobilization	1	LS	$ 100,000	$ 100,000	
Existing Cap	**0%**				
-No Cost	-	acre	$0	$ -	
New Cap	**100%**				
Soil Cover as Cap	*20%*				
-Site Preparation	6	acre	$ 4,500	$ 27,932	clearing and leveling
-Geotextile marker layer	30,043	SY	$ 2	$ 60,085	Specification 9 33.2(1) Table 3 (WSDOT, 2012)
-Import, place, and compact fill	20,028	CY	$ 18	$ 360,512	
Asphalt Pavement as Cap	*30%*				
-Site Preparation	9	acre	$ 4,500	$ 41,898	clearing and leveling
-Pre-grading	9	acre	$ 5,200	$ 48,416	light grading for asphalt
-Asphalt	9	acre	$ 115,400	$ 1,074,461	6" stone base, 2" binder layer, 1" topping layer
Buildings as Cap	*50%*				
-No Cost	16	acre	$0	$ -	Assume buildings cost are redevelopment, not cleanup
Stormwater collection and conveyance system	5,654	LF	$0	$ -	Assumed redevelopment cost
Institutional Controls Plan	1	LS	$ 50,000	$ 50,000	includes I&M manual for cover systems, legal support
Remedial design	25%			$ 440,826	
Construction management and reporting	20%			$ 352,661	
Subtotal				*$ 2,556,792*	
Tax	8.7%		$ 1,713,305	$ 149,058	
Contingency	15%		$ 2,705,849	$ 405,877	
Subtotal Soil Cap Cost				*$ 3,111,727*	
Bunker C Subarea Soil Removal - TPH > Residual Concentration					
Mobilization/Demobilization	1	LS	$ 100,000	$ 100,000	
Dewatering	10	day	$ 800	$ 8,000	based on 200 yd/day removal rate, includes daily sampling
Excavation	2,000	BCY	$ 5	$ 10,000	assumes excavation limited to 10' below pipes (Figure 4-1)
Confirmation Sampling	40	each	$ 270	$ 10,800	
Waste Profiling	10	each	$ 270	$ 2,700	10 + 1 sample per 500 yd3 over 2000 yd3
Transport and disposal - Non-Hazardous Waste	1,815	ton	$ 60	$ 108,910	Thermal treatment and disposal at CEMEX USA
Potentially clean overburden handling and stockpiling	790	BCY	$ 5	$ 3,949	top 3' assumed to be clean
Analytical sampling of potentially clean stockpiles	24	each	$ 270	$ 6,480	3 samples per 100 yd3
Place and compact overburden	790	BCY	$ 10	$ 7,899	
Import, place, and compact fill	1,815	BCY	$ 18	$ 32,673	
In Situ Solidification/Stabilization	-	BCY	$ 80	$ -	contingency - auger application
Remedial design	25%			$ 72,853	
Construction management and reporting	20%			$ 58,282	
Subtotal				*$ 422,546*	
Tax	8.7%		$ 291,411	$ 25,353	
Contingency	100%		$ 447,899	$ 447,899	
Subtotal Soil Removal - Bunker C > Residual Saturation				*$ 895,798*	
In Situ Treatment of Acid Plant Subarea Groundwater					
Mobilization/Demobilization	1	LS	$ 75,000	$ 75,000	
Source area trench excavation	1,125	BCY	$ 25	$ 28,125	multiple excavations, includes trench box
Potentially clean trench overburden handling and stockpiling	208	BCY	$ 5	$ 1,042	
Transport and disposal - Non-Hazardous Waste	1,375	ton	$ 80	$ 110,000	Tansport and disposal to Roosevelt
Import, place, and compact fill	208	BCY	$ 18	$ 3,750	
Analytical sampling of potentially clean stockpiles	7	each	$ 270	$ 1,890	3 samples per 100 yd3
Place and compact overburden	208	BCY	$ 10	$ 2,083	
Phosphate binder treatment	200	ton	$ 40	$ 8,000	per ton of material treated, 5% phosphate
Crushed limestone	900	ton	$ 20	$ 18,000	imported and placed
Amendment mixing for disposal	167	BCY	$ 5	$ 833	
Impermeable membrane	10,200	ft2	$ 2	$ 20,400	60-mil HDPE
Remedial design	20%		$ 269,123	$ 53,825	
Construction management and reporting	20%		$ 269,123	$ 53,825	
Subtotal				*$ 376,773*	
Tax	8.7%		$ 269,123	$ 23,414	
Contingency	25%		$ 400,186	$ 100,047	
Subtotal In Situ Treatment of Acid Plant Subarea Groundwater				*$ 500,233*	
Monitored Natural Attenuation					
Groundwater monitoring plan	1	LS	$ 15,000	$ 15,000	
Monitoring wells	7	each	$ 4,000	$ 28,000	
Remedial design	15%			$ 6,450	
Construction management and reporting	20%			$ 8,600	
Subtotal				*$ 43,000*	
Tax	8.7%		$ 28,000	$ 2,436	
Contingency	20%		$ 45,436	$ 9,087	
Subtotal Monitored Natural Attenuation Cost				*$ 54,523*	
Professional Services (as percent of capital costs)					
Project administration	3.0%		$ 5,334,282	$ 160,028	
Total Estimated Capital Costs				**$ 5,490,000**	

O&M COSTS - Net Present Value

Item	Frequency	Unit Cost	Annual Cost	NPV Cost	Notes
Periodic O&M					
Periodic inspection and maintenance of cover systems	1	$ 5,000	$ 5,000	$ 113,537	annual inspection/reporting; maintenance as needed
Periodic GW quality monitoring and MNA					
-Years 1&2 monitoring	4	$ 4,000	$ 16,000	$ 15,702	quarterly monitoring
-Years 3-30 monitoring	2	$ 3,500	$ 7,000	$ 145,342	semi-annual monitoring
Replace GW treatment media	20yr	$ 232,167		$ 159,337	assumed 20-year lifespan of PRB
Subtotal Periodic O&M Cost				*$ 433,918*	
Tax		8.7%		$ 37,751	Sales Tax
Contingency		20%		$ 94,334	
				$ 566,002	
Professional Services (as percent of Periodic O&M costs)					
Project administration		5%		$ 28,300	
Project management/reporting		6%		$ 33,960	
Total, Periodic O&M Net Present Value:				**$ 1,062,180**	
TOTAL ESTIMATED COST				**$ 6,552,180**	

Notes:

Costs are in 2014 dollars.

1.9% discount rate for NPV analysis based on 2013 real treasury rates

Mobilization/Demobilization costs are assumed to include equipment transport and setup, temporary erosion and sedimentation control (TESC) measures, bonds, and insurance.

Contingency costs include miscellaneous costs not currently itemized due to the current (preliminary) stage of design development, as well as costs to address unanticipated conditions encountered during construction

Taxes are not applied to project administration, design, and reporting costs.

Table B-4 - Alternative 3 Cost Estimate

Feasibility Study, Pulp/Tissue Mill RAU, GP West Site

Site:	Former Georgia-Pacific West Site - Pulp/Tissue Mill Remedial Action Unit	
Remedial Action Description:	**Alternative: 3**	**Bunker C Soil Removal, RAU-Wide Soil Capping, Acid Plant Groundwater Treatment and Source Removal, MNA, and ICs**
Cost Estimate Accuracy:	FS Screening Level (+50/-30 percent)	

Key Assumptions and Quantities:

Quantity	Unit	Description	Note
31	acre	total RAU area	
150,300	SY	total RAU area	
5,700	ft	cap perimeter	
2,000	BCY	Bunker C excavation volume	
790	BCY	Bunker C overburden	
625	BCY	acid plant trench volumes	(some volume included in source area excavation)
208	BCY	acid plant downgradient overburden	
1,500	BCY	acid plant source area excavation	
2,250	ton	phosphate binder amendment per ton treated	
500	ton	crushed limestone	
7	each	monitoring wells for MNA	
1.5	tons/BCY	soil density	

CONSTRUCTION COSTS

Item	Quantity	Unit	Unit Cost	Total Cost	Notes
Bunker C Interim Action					
Sunk cost	1	LS	$ 772,000	$ 772,000	including remedial design, construction, and oversight
Subtotal Bunker C Interim Action				*$ 772,000*	
RAU-Wide Soil Capping					
Mobilization/Demobilization	1	LS	$ 100,000	$ 100,000	
Existing Cap	**0%**				
-No Cost	-	acre	$0	$ -	
New Cap	**100%**				
Soil Cover as Cap	*20%*				
-Site Preparation	6	acre	$ 4,500	$ 27,932	clearing and leveling
-Geotextile marker layer	30,043	SY	$ 2	$ 60,085	Specification 9 33.2(1) Table 3 (WSDOT, 2012)
-Import, place, and compact fill	20,028	CY	$ 18	$ 360,512	
Asphalt Pavement as Cap	*30%*				
-Site Preparation	9	acre	$ 4,500	$ 41,898	clearing and leveling
-Pre-grading	9	acre	$ 5,200	$ 48,416	light grading for asphalt
-Asphalt	9	acre	$ 115,400	$ 1,074,461	6" stone base, 2" binder layer, 1" topping layer
Buildings as Cap	*50%*				
-No Cost	16	acre	$0	$ -	Assume buildings cost are redevelopment, not cleanup
Stormwater collection and conveyance system	5,654	LF	$0	$ -	Assumed redevelopment cost
Institutional Controls Plan	1	LS	$ 50,000	$ 50,000	includes I&M manual for cover systems, legal support
Remedial design	25%			$ 440,826	
Construction management and reporting	20%			$ 352,661	
Subtotal				*$ 2,556,792*	
Tax	8.7%		$ 1,713,305	$ 149,058	
Contingency	15%		$ 2,705,849	$ 405,877	
Subtotal Soil Cap Cost				*$ 3,111,727*	
Bunker C Subarea Soil Removal - TPH > Residual Concentration					
Mobilization/Demobilization	1	LS	$ 100,000	$ 100,000	
Dewatering	10	day	$ 800	$ 8,000	based on 200 yd/day removal rate, includes daily sampling
Excavation	2,000	BCY	$ 5	$ 10,000	assumes excavation limited to 10' below pipes (Figure 4-1)
Confirmation Sampling	40	each	$ 270	$ 10,800	
Waste Profiling	10	each	$ 270	$ 2,700	10 + 1 sample per 500 yd3 over 2000 yd3
Transport and disposal - Non-Hazardous Waste	1,815	ton	$ 60	$ 108,910	Thermal treatment and disposal at CEMEX USA
Potentially clean overburden handling and stockpiling	790	BCY	$ 5	$ 3,949	top 3' assumed to be clean
Analytical sampling of potentially clean stockpiles	24	each	$ 270	$ 6,480	3 samples per 100 yd3
Place and compact overburden	790	BCY	$ 10	$ 7,899	
Import, place, and compact fill	1,815	BCY	$ 18	$ 32,673	
In Situ Solidification/Stabilization	-	BCY	$ 80	$ -	contingency - auger application
Remedial design	25%			$ 72,853	
Construction management and reporting	20%			$ 58,282	
Subtotal				*$ 422,546*	
Tax	8.7%		$ 291,411	$ 25,353	
Contingency	100%		$ 447,899	$ 447,899	
Subtotal Soil Removal - Bunker C > Residual Saturation				*$ 895,798*	
In Situ Treatment of Acid Plant Subarea Groundwater					
Mobilization/Demobilization	1	LS	$ 75,000	$ 75,000	
Source area trench excavation	625	BCY	$ 25	$ 15,625	multiple excavations, includes trench box
Potentially clean trench overburden handling and stockpiling	208	BCY	$ 5	$ 1,042	
Transport and disposal - Non-Hazardous Waste	625	ton	$ 80	$ 50,000	Tansport and disposal to Roosevelt
Import, place, and compact fill	208	BCY	$ 18	$ 3,750	
Analytical sampling of potentially clean stockpiles	7	each	$ 270	$ 1,890	3 samples per 100 yd3
Place and compact overburden	208	BCY	$ 10	$ 2,083	
Phosphate binder treatment	2,250	ton	$ 40	$ 89,982	per ton of material treated, 5% phosphate
Crushed limestone	500	ton	$ 20	$ 10,000	imported and placed
Amendment mixing for disposal	1,500	BCY	$ 5	$ 7,500	
Impermeable membrane	-	ft2	$ 2	$ -	60-mil HDPE
Remedial design	20%		$ 256,872	$ 51,374	
Construction management and reporting	20%		$ 256,872	$ 51,374	
Subtotal				*$ 359,621*	
Tax	8.7%		$ 359,621	$ 31,287	
Contingency	25%		$ 390,908	$ 97,727	
Subtotal In Situ Treatment of Acid Plant Subarea Groundwater				*$ 488,635*	
Soil Removal - Acid Plant Source Area					
Mobilization/Demobilization	1	LS	$ 100,000	$ 100,000	
Excavation	2,125	BCY	$ 5	$ 10,625	
Transport and disposal - Non-Hazardouse Waste	2,875	ton	$ 80	$ 230,000	Transport and disposal to Roosevelt
Import, place, and compact fill	1,500	BCY	$ 18	$ 27,000	
Potentially clean trench overburden handling and stockpiling	208	BCY	$ 5	$ 1,042	
Analytical sampling of potentially clean stockpiles	7	each	$ 270	$ 1,890	3 samples per 100 yd3
Place and compact overburden	208	BCY	$ 10	$ 2,083	
Phosphate binder treatment	2,250	ton	$ 40	$ 89,982	per ton of material treated, 5% phosphate
Crushed limestone	500	ton	$ 20	$ 10,000	imported and placed
Amendment mixing for disposal	1,500	BCY	$ 5	$ 7,500	
Remedial design	20%			$ 96,024	
Construction management and reporting	20%			$ 96,024	
Subtotal				*$ 672,171*	
Tax	8.7%		$ 480,122	$ 41,771	
Contingency	20%		$ 713,942	$ 142,788	
Subtotal Soil Removal - Acid Plant Source Area Cost				*$ 856,730*	
Monitored Natural Attenuation					
Groundwater monitoring plan	1	LS	$ 15,000	$ 15,000	
Monitoring wells	7	each	$ 4,000	$ 28,000	
Remedial design	15%			$ 6,450	
Construction management and reporting	20%			$ 8,600	
Subtotal				*$ 43,000*	
Tax	8.7%		$ 28,000	$ 2,436	
Contingency	20%		$ 45,436	$ 9,087	
Subtotal Monitored Natural Attenuation Cost				*$ 54,523*	
Professional Services (as percent of capital costs)					
Project administration	3.0%		$ 6,179,414	$ 185,382	
Total Estimated Capital Costs				**$ 6,360,000**	

O&M COSTS - Net Present Value

Item	Frequency	Unit Cost	Annual Cost	NPV Cost	Notes
Periodic O&M					
Periodic inspection and maintenance of cover systems	1	$ 5,000	$ 5,000	$ 113,537	annual inspection/reporting; maintenance as needed
Periodic GW quality monitoring and MNA					
-Years 1&2 monitoring	4	$ 4,000	$ 16,000	$ 15,702	quarterly monitoring
-Years 3-30 monitoring	2	$ 3,500	$ 7,000	$ 145,342	semi-annual monitoring
Replace GW treatment media	20yr	$ 350,625		$ 240,635	assumed 20-year lifespan of PRB
Subtotal Periodic O&M Cost				*$ 515,216*	
Tax		8.7%		$ 44,824	Sales Tax
Contingency		20.0%		$ 112,008	
				$ 672,048	
Professional Services (as percent of Periodic O&M costs)					
Project administration		5%		$ 33,602	
Project management/reporting		6%		$ 40,323	
Total, Periodic O&M Net Present Value:				**$ 1,261,189**	
TOTAL ESTIMATED COST				**$ 7,621,189**	

Notes:
Costs are in 2014 dollars.
1.9% discount rate for NPV analysis based on 2013 real treasury rates
Mobilization/Demobilization costs are assumed to include equipment transport and setup, temporary erosion and sedimentation control (TESC) measures, bonds, and insurance.
Contingency costs include miscellaneous costs not currently itemized due to the current (preliminary) stage of design development, as well as costs to address unanticipated conditions encountered during construction.
Taxes are not applied to project administration, design, and reporting costs.

Table B-5 - Alternative 4 Cost Estimate

Feasibility Study, Pulp/Tissue Mill RAU, GP West Site

Site: Former Georgia-Pacific West Site - Pulp/Tissue Mill Remedial Action Unit

Remedial Action Description: **Alternative: 4 Full Removal of Fill Unit**

Cost Estimate Accuracy: FS Screening Level (+50/-30 percent)

Key Assumptions and Quantities:

31	acre	total RAU area
150,300	SY	total RAU area
600,900	BCY	fill excavation volume
1.5	tons/BCY	soil density

CONSTRUCTION COSTS

Item	Quantity	Unit	Unit Cost	Total Cost	Notes
Bunker C Interim Action					
Sunk cost	1	LS	$ 772,000	$ 772,000	including remedial design, construction, and oversight
Subtotal Bunker C Interim Action				*$ 772,000*	
Soil Removal - Fill Unit					
Mobilization/Demobilization	1	LS	$ 500,000	$ 500,000	
Bentonite-cement slurry wall	25,500	SF	$ 13	$ 321,300	1700' length along shoreline, 15 foot depth
Dewatering	1,502	day	$ 800	$ 1,201,800	based on 400 yd/day removal rate, includes daily sampling
Waste profiling	1,208	each	$ 270	$ 326,160	10 + 1 sample per 500 yd3 over 2000 yd3
Excavation	600,900	BCY	$ 2.5	$ 1,502,250	discounted unit cost for large volume
Transport and disposal - Non-Hazardous Waste	901,350	ton	$ 70	$ 63,094,500	Transport and disposal to Roosevelt (w/ volume discount)
Confirmation sampling	541	each	$ 270	$ 146,092	1 sample per 2500 ft2
Import, place, and compact fill	600,900	BCY	$ 15	$ 9,013,500	discounted unit cost for large volume
Institutional Controls Plan	100.00%	LS	$ 15,000	$ 15,000	
Remedial design	0.50%			$ 380,603	
Construction management and reporting	3%			$ 2,283,618	
Subtotal				*$ 78,784,823*	
Tax	8.7%		$ 76,105,602	$ 6,621,187	
Contingency	5%		$ 85,406,010	$ 4,270,300	
Subtotal Soil Removal - Fill Unit Cost				*$ 89,676,310*	
Professional Services (as percent of capital costs)					
Project administration	0.5%		$ 90,448,310	$ 452,242	
TOTAL ESTIMATED COST				**$ 90,900,000**	

Notes:

Costs are in 2014 dollars.

1.9% discount rate for NPV analysis based on 2013 real treasury rates

Mobilization/Demobilization costs are assumed to include equipment transport and setup, temporary erosion and sedimentation control (TESC) measures, bonds, and insurance.

Contingency costs include miscellaneous costs not currently itemized due to the current (preliminary) stage of design development, as well as costs to address unanticipated conditions encountered during construction.

Taxes are not applied to project administration, design, and reporting costs.