Feasibility Study

Parcel 15 (Portac) Investigation

Ecology Facility Site No. 1215 / Cleanup Site No. 3642

February 2018

Prepared for

Port of Tacoma and

Portac, Inc.

Prepared by

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Abbreviations and Acronyms

µg/L	microgram per liter
ARAR	applicable or relevant and appropriate requirement
bgs	below ground surface
CAP	Cleanup Action Plan
CMMP	contaminated media management plan
cm	centimeter
cm/sec	centimeter per second
CSL	cleanup screening level
CUL	MTCA's Cleanup Levels
CWA	Clean Water Act
DCA	disproportionate cost analysis
Ecology	Washington State Department of Ecology
EPA	U.S. Environmental Protection Agency
FRTR	Federal Remediation Technologies Roundtable
FS	feasibility study
GCL	geosynthetic clay liner
GSI	GSI Water Solutions, Inc.
HDPE	high-density polyethylene
HMA	hot mix asphalt
IC	institutional control
LEL	lower explosive limit
LLC	limited liability company
Log Yard	former log yard area at the Site
mg/kg	milligram per kilogram
MLLW	mean lower low water
MNA	monitored natural attenuation
MTCA	Model Toxics Control Act
NPDES	National Pollutant Discharge Elimination System
NPV	net present value
O&M	operation and maintenance
OF	outfall
Order	Agreed Order
PCP	pentachlorophenol
pH	negative log of the hydrogen ion concentration in solution
POC	point of compliance
Port	Port of Tacoma
Portac	Portac, LLC
PPE	personal protective equipment
PQL	practical quantification limits
PRB	permeable reactive barrier
PSL	Preliminary Screening Levels
RCC	roller-compacted concrete
RCW	Revised Code of Washington
REL	remediation levels
RI	remedial investigation
RI/FS	Remedial Investigation/Feasibility Study
Sawmill	former sawmill area at the Site

SCO	sediment cleanup objective
Site	Parcel 15 – Former Portac sawmill and log yard
SMS	sediment management standards
SR	State Route
SSPA	S.S. Papadopulos & Associates
SVOC	semivolatile organic compound
SWAC	surface weighted average concentration
VCP	Ecology's Voluntary Cleanup Program
VOC	volatile organic compound
WAC	Washington Administrative Code
ZVI	zero valent iron

1 Introduction

This Feasibility Study (FS) was prepared by GSI Water Solutions, Inc. (GSI), on behalf of the Port of Tacoma (Port) and Portac, Inc. (Portac), in accordance with the requirements of the Agreed Order (Order) No. DE11237 between the State of Washington Department of Ecology (Ecology), the Port, and Portac, pursuant to the Washington State Model Toxics Control Act ([MTCA]; Revised Code of Washington [RCW] 70.105D), MTCA regulations (Washington Administrative Code [WAC] Chapter 173-340), and Washington's Sediment Management Standards (SMS; WAC 173-204).

The objective of this FS is to address concerns raised during the Remedial Investigation (RI), screen remedial alternatives compiled in the FS Technical Memorandum (GSI, 2017), and select a preferred remedial alternative. This FS Report is being submitted concurrently with the Final RI Report (RI Report) that identifies current site environmental conditions (GSI and SSPA, 2017).

2 Site Description

2.1 Site Location

Parcel 15 (the Site[1]) consists of an approximately triangular parcel of about 52 acres of land owned by the Port. The Site is located at 4215 State Route (SR) 509 – North Frontage Road in an industrial area between Interstate 5 and Commencement Bay, in Tacoma, Washington, as shown in Figure 1. The Site is bounded by East 4th Street (northern boundary), Alexander Avenue East (western boundary), and North Frontage Road (SR 509) (southeastern boundary). Wapato Creek is situated between Alexander Avenue East and the western edge of the property, and empties into the Blair Waterway through a culvert under East 4th Street. The Blair Waterway is in the southern portion of Commencement Bay, one of multiple industrial waterways developed in the 1900s to support international commerce.

2.2 Site History

Portac and its predecessors leased the Site from the Port beginning in 1974 and vacated the Site in 2009. The Site consists of two functionally distinct historical use areas: the former sawmill area (Sawmill) in the southwestern part of the property, and the former log yard area (Log Yard) occupying the remainder of the Site.

Historical industrial activities conducted on the Site adversely impacted upland soil, groundwater, and surface water in the adjacent Wapato Creek. Environmental investigations and cleanup under Ecology oversight have been ongoing since the late 1980s; they are described in Section 2 of the RI Report and are summarized below.

Similar to other milling and log storage operations in the region, slag from the former ASARCO smelter was used as ballast (e.g., road base) to stabilize surface soils in the Log Yard. An investigation conducted by Ecology, under authority of RCW 90.48 in the 1980s, showed that metals (e.g., arsenic, copper, lead, and zinc) were leaching from the slag and being discharged into surface water. Historical analysis of upland soil and fill containing slag indicated that metals (e.g., arsenic)

1 For the purpose of this FS Report, the Site encompasses the Log Yard and Sawmill, and is based on the Site Boundary shown in Exhibit A of the Order. The final Site definition will be updated in the Draft CAP to include any migration of Site-related contamination outside of that Site Boundary.

were present at concentrations that would exceed current MTCA soil cleanup levels (CULs). In addition, historical groundwater monitoring did not confirm that current MTCA CULs were met at a conditional point of compliance (POC), as would be required under current MTCA rules. Current MTCA rules require confirmational monitoring and institutional controls (ICs).

Pursuant to a 1988 Order on Consent (under RCW 90.48), Portac and the Port agreed to cap the Log Yard to abate metals contamination of surface water runoff discharging to adjacent Wapato Creek. Although the primary purpose for capping the Log Yard was to mitigate surface water metals contamination, the action also was expected to mitigate groundwater contamination by preventing stormwater infiltration through the slag and associated leaching of metals. The Site was capped between late 1988 and early 1989, and inspection and maintenance of the cap have been ongoing under the 1988 Order on Consent (Section VI (4)).

In 2009, Portac entered into Ecology's Voluntary Cleanup Program (VCP) to address the presence of contaminants (e.g., pentachlorophenol [PCP]) in soil and groundwater in the Sawmill. As described in Section 2.2.3 of the RI Report, Portac implemented soil removals to address areas of identified contaminants. Approximately 4,950 tons of soil were removed as part of the combined VCP soil cleanup activities.

2.3 Conceptual Site Model

This section provides a brief summary of the Site's conceptual site model as presented in Section 8 and Appendix G of the RI Report.

The Site encompasses the Log Yard and Sawmill. Currently, the Log Yard is capped with roller-compacted concrete (RCC), installed as part of a remedial action, with two subsurface stormwater conveyance lines serving as Log Yard drainage (Figure 2). Currently, the Sawmill is partially paved; however, the particular area of interest (the former dip tank) remains unpaved.

The Site-associated contaminants identified for cleanup are arsenic and PCP, with arsenic being the primary driver in the Log Yard, and PCP being the primary driver in the Sawmill. In addition, methane gas is identified as a Site-associated contaminant in the Log Yard and portions of the Sawmill.

2.3.1 Log Yard

Before installation of the cap, infiltration or precipitation through the fill containing slag and subsequent discharge of stormwater to Wapato Creek (via the former central drainage ditch, subsurface drains, and direct overland flow) served as a direct pathway for metals migration to surface water and potentially groundwater. The cap in the Log Yard was installed between late 1988 and early 1989 with the intention of cutting off surficial and shallow subsurface stormwater drainage through the fill containing slag. Although perched groundwater was observed in shallow monitoring wells HC-1 and HC-2 soon after the cap was installed, it was anticipated that those wells would run dry as the source of the perched water (i.e., surficial infiltration) was cut off and the perched groundwater zones drained. However, observations of ongoing perched water in HC-2, and some of the new monitoring wells advanced as part of the RI confirmed that there are portions of the Site where fill containing slag is still saturated, and thus leaching of metals from the slag still serves as an ongoing source of arsenic to groundwater (Figure 3). Although the cap significantly reduced infiltration and groundwater flux to the creek, seepage of ponded stormwater through the cap appears to be the source of the ongoing perched water (see Section 4 of the RI Report). Because the Log Yard has been capped, surface soil migration through wind erosion is not a significant release mechanism in the Log Yard portion of the Site.

The highest arsenic concentrations in Log Yard groundwater were observed in areas where perched groundwater is in contact with the fill containing slag underlying the Log Yard. Arsenic in groundwater has the potential to be transported toward Wapato Creek via either the groundwater--to-surface-water pathway, or through infiltration into the storm drain system:

- **Groundwater-to-surface-water pathway:** The zone located just below the sediment/ surface water interface is called the transition zone. This zone is where groundwater and surface water may mix prior to groundwater discharge (Ecology 2017). Given the fine-grained nature of the alluvial deposits underlying the site (i.e., interbedded silty sand, silts, and clays), groundwater flow toward the creek is slow, and further restrained by semidiurnal high tides in Wapato Creek. In addition, the geochemical conditions at the Site favor the precipitation, co-precipitation, and adsorption of arsenic along the groundwater-to-surface-water pathway (see Section 8 and Appendices H and I of the RI Report). The long-term fate of arsenic will continue to be shaped by natural attenuation processes and potential actions implemented to reduce infiltration through the cap.
- **Storm drain infiltration:** Some groundwater seepage into the stormwater conveyance system was confirmed to be occurring and is likely the source of the elevated arsenic observed in discharges from outfall (OF) #2 and OF#3.

Methane, a naturally occurring gas, is present below the Log Yard cap as a result of decomposition of the wood waste associated with the fill containing slag.

The quality of surface sediments was investigated during the RI. The surface weighted average concentration of arsenic in Wapato Creek surface sediment is less than the natural background-based screening level, and there were no exceedances at any location of the sediment cleanup objective for protection of the benthic community (57 mg/kg). Therefore no further evaluations or remedial actions are warranted for sediment.

2.3.2 Sawmill

PCP was used at the Sawmill as an anti-sap stain in a water-based solution applied historically using spray booths and later a dip tank. In previous remedial actions, PCP sources and contaminated soil underneath were removed. However, some PCP contamination persists in groundwater in the immediate vicinity of the former dip tank (Figure 4); this PCP has not migrated above screening levels to porewater or surface water. In soil and groundwater, the major degradation pathway for PCP occurs by microbial degradation. Decreases in PCP concentration have been observed over time (Appendix A). However, elevated pH values in groundwater have been observed at the same well as the highest PCP detections (well MW-2R). Alkaline groundwater conditions can inhibit biological activity and reduce the adsorptive capacity of PCP, resulting in a localized increase in PCP mobility.

In addition to PCP, there are two wells north of the former dip tank area (MW-1 and MW-3) where arsenic concentrations are elevated above natural background concentrations. Groundwater arsenic concentrations in this range likely are caused by arsenic desorption from naturally occurring iron oxyhydroxides (a process that is promoted under the reducing geochemical conditions [and the nearby alkaline conditions in the former dip tank area]) (Appendix H in the RI Report). Methane gas also is present in those wells.

3 Cleanup Standards

As discussed in Section 8.1 of the RI Report, the Site-associated contaminants driving the RI and the need for added cleanup at the Site are arsenic and PCP, with arsenic being the primary driver in the Log Yard (Section 8.3.1 of the RI Report), and PCP being the primary driver in the Sawmill, although arsenic and pH also are elevated in some locations in the Sawmill (Section 8.3.2 of the RI Report). In addition, methane gas is identified as a Site-associated contaminant and is present as a result of decomposition of the wood waste associated with the fill containing slag or decomposition of naturally occurring organics (e.g., tide flat deposits). Soil and groundwater cleanup standards must be set for these Site-associated contaminants to ensure that the quality of the cleanup and protection of human health and the environment are not compromised.

A cleanup standard is defined by establishing the following two components of the standard (1) cleanup level (CUL) (s); and (2) POC(s). The CUL is the concentration of a hazardous substance that must be met to avoid risks to human health and the environment through a specified exposure pathway. POCs designate the location on the site where the CULs must be met. Ecology will select final CULs and associated POCs in the Cleanup Action Plan (CAP). This section presents proposed CULs and POCs for purposes of evaluating cleanup actions (i.e., alternatives) and the potential need for conditional POCs and/or contingent remediation levels (RELs) in this FS Report.

3.1 Cleanup Level Selection

MTCA's CULs are risk-based concentrations that are protective of generic exposure scenarios for a given site use. Tables 6-1 through 6-4 of the RI Report summarize potentially relevant human health and ecological screening criteria by medium. These screening criteria were derived from the following sources, consistent with MTCA cleanup regulations:

- Concentrations listed in WAC Tables 173-740-1, and -745-1 (for soil)
- SMS concentrations for marine sediment listed in Table 8-1 of the Sediment Cleanup User's Manual II, Department of Ecology, March 2015 (SCUM II; for sediment)
- Acute and chronic water quality standards for surface waters of the state of Washington, including the new Clean Water Act (CWA) effective criteria (WAC 173-201A)
- MTCA Method B cancer and non-cancer criteria for surface water (WAC 173-340)
- National Toxic Rule human health criteria for consumption of marine organisms (40CFR 131.36)
- Concentrations established under applicable or relevant and appropriate requirements (ARARs)
- Concentrations protective of the environment and surface water beneficial uses
- Natural background concentrations
- Practical quantification limits (PQLs; to be used in lieu of natural background, when background values have not been established)

The CUL for each medium is selected as the most stringent of the MTCA or ARAR concentration, unless the natural background concentration is higher than that criterion. Because MTCA states that CULs should not be lower than natural background concentrations, CULs default up to the natural background concentration (or PQL where background concentrations are not available). CULs and the associated protection basis are provided in Table 1 for soil and groundwater.

The POCs also are included in Table 1and further discussed by media in the following sections.

3.2 Soil Cleanup Standards

Table 6-1 of the RI Report shows screening levels that are applicable to soil data. As discussed in Section 6.1 of the RI Report, the upland Site conditions meet the criteria in WAC 173-340-7491(1)(b) for an exclusion from a Terrestrial Ecological Evaluation because the Site is zoned for industrial uses characterized by surface paving, buildings, and hard-scape that provide physical barriers preventing plant and wildlife exposure to soils containing elevated concentrations of hazardous substances. Therefore, terrestrial habitat in the upland portion of the Site is extremely limited and the adult worker exposure scenario is the primary cleanup driver at the Site. MTCA Method A and MTCA Method C (WAC 173-340) levels for industrial use are appropriate thresholds to screen soil for direct contact exposure scenarios.

As summarized in Table 1, the lowest screening level for soil has been selected as the CUL for the two Site-associated contaminants at the Site as follows:

- **Arsenic CUL = 20 milligrams per kilogram (mg/kg)** based on the MTCA Method A industrial screening value. Note that the MTCA Method A criterion of 20 mg/kg was developed to be protective of groundwater at a concentration of 5 micrograms per liter (µg/L) which is the most stringent surface water or groundwater screening level evaluated in the RI.
- **PCP CUL = 328 mg/kg** based on the MTCA Method C cancer screening value.

While containment or removal of the arsenic in the Log Yard is a focus of this FS and future remedial action, PCP in soil is not considered to be a cleanup driver because approximately 4,950 tons of impacted soil were removed as part of the combined VCP soil cleanup activities in the Sawmill and no RI soil samples exceeded the CULs listed above.

In addition to the direct contact soil exposure scenario, methane gas in soil at the Site poses a potential risk for indoor air quality for potential future use scenarios at the Site. As such, the MTCA Air Quality Guidance (WAC 173-340) sets a standard of 10 percent of the lower explosive limit (LEL) for all volatile organic compounds (VOCs). Therefore, the CUL for methane is:

- **Methane CUL = 0.5 percent by volume** based on an LEL of 5 percent.

Standard MTCA POCs will be used for soil. Given that the CULs for arsenic and PCP were established on the basis of the direct contact scenario, the POC for those chemicals is defined as throughout the site from the ground surface to 15 feet below ground surface (bgs). For methane, the POC is defined as throughout the site from the ground surface to the uppermost groundwater-saturated zone (e.g., water table), which at the Site varies from about 7 to 18 feet bgs. ICs for methane are included under all cleanup alternatives evaluated as part of this FS.

3.3 Groundwater Cleanup Standards

As discussed in the RI Report, groundwater at the Site is nonpotable, and current and future Site use will be industrial. The highest beneficial use of groundwater at the Site is discharge to marine waters. Therefore, groundwater cleanup levels were established to be protective of surface water resources.

- **Arsenic CUL = 5 µg/L** based on MTCA Method A, adjusted for background[2]. **PCP CUL = 1 µg/L** based on the PQL.

PCP is consistently elevated only in a single well in the Sawmill (MW-2R) that sits within the former dip tank excavation. Two other wells (MW-5R and MW-6R) in the Sawmill area have intermittent exceedances of PCP, but are located approximately 550 feet from Wapato Creek. Treatment of PCP in the immediate vicinity of the former dip tank excavation is the focus of the remedial action comparisons in the Sawmill presented in Section 6.2. A standard POC for groundwater will be applied to PCP in the Sawmill. Thus the POC extends from the uppermost level of the saturated zone (which was measured to be between approximately 5 and 11 feet bgs in well MW-2R during the four RI sampling events) to the lowest depth that potentially could be affected by Site releases.

Arsenic concentrations throughout the Log Yard exceed the CUL with the highest concentrations observed within and below the perched water zone located approximately 250 feet upgradient of Wapato Creek. As described in Section 8 and Appendices H and I of the RI Report, arsenic transport is limited by the fine-grained nature of the native alluvial deposits, and the groundwater and soil conditions that promote arsenic precipitation and adsorption. The average concentration observed in wells located along the top of the bank in the Log Yard (about 50 feet upgradient of Wapato Creek) was 37 µg/L, with average concentrations in shallow porewater decreasing to about 11 µg/L. Although the Site naturally limits arsenic mobility toward the creek, it is not practicable to meet groundwater CULs throughout the Site within a reasonable time frame given the slow rate of groundwater flow and the high level of natural attenuation occurring at the Site.

According to WAC 173-340-720(8)(c):

> "Where it can be demonstrated under WAC 173-340-350 through 173-340-390 that it is not practicable to meet the cleanup level throughout the site within a reasonable restoration time frame, Ecology may approve a conditional point of compliance that shall be as close as practicable to the source of hazardous substances, and except as provided under (d) of this subsection, not to exceed the property boundary. Where a conditional POC is proposed, the person responsible for undertaking the cleanup action shall demonstrate that all practicable methods of treatment be used in the site cleanup."

As demonstrated in subsequent sections, none of the FS alternatives being evaluated potentially could achieve groundwater CULs at the standard POC within a relatively short time frame. As such, a conditional POC is proposed at nearshore groundwater monitoring wells located at the top of the bank. This conditional POC is located as close as practicable downgradient from the source areas and before discharge to surface water, in accordance with WAC 173-340-720(8)(c).

Each of the FS alternatives considered for the Log Yard include source control measures (i.e., capping or removal of the fill containing slag), groundwater treatment by natural attenuation, and contingent groundwater treatment using a permeable reactive barrier (PRB).

Arsenic concentrations in groundwater in the Sawmill are much lower than in the Log Yard. However, there are two wells (MW-1 and MW-3) where concentrations exceed the marine

[2] Under MTCA, cleanup levels are not established below natural background levels. Although arsenic occurs naturally in the environment, a background number has been evaluated but not finalized by Ecology (Ecology, 1989 and 2016). Therefore, the MTCA Method A value for groundwater is used as surrogate for the natural background concentration of arsenic.

background surface water CUL of 5 µg/L. These areas also are anticipated to be addressed by MNA and as with the Log Yard wells, the wells located along the top of the bank would be monitored to evaluate if arsenic trends are stable or decreasing in nature. Sawmill remedial alternatives developed below focus on PCP specifically and arsenic is considered to be addressed as part of the Log Yard remedial approach. Naturally occurring arsenic will be considered during remedy implementation.

3.4 Remediation Levels

Remediation levels (RELs) are concentrations of contaminants or other metrics that define when additional remedial action should be undertaken. RELs are often quantitative, but may also be qualitative and consider multiple lines of evidence.

Given the extended restoration time frames for Site groundwater, all FS cleanup alternatives include contingent remedial actions for arsenic in groundwater. RELs will be used to determine whether or not contingent groundwater remedial actions should be undertaken at the Site.

The final details of the long-term monitoring program and the RELs will be defined in the CAP so that they can be specific to the selected remedial action. The following expectations will be considered in REL development for the selected remedial action:

- The abundance of perched water is expected to reduce over time under remedial alternatives involving cap repairs and enhancements. Monitoring will be performed to confirm this.
- Arsenic concentrations in CPOC wells are expected to remain stable or decrease throughout the restoration timeframe. Monitoring will be performed to confirm this.
- Arsenic concentrations in porewater are expected to remain below levels protective of the benthic community. Contingency monitoring may be performed to confirm this based on the outcome of Site groundwater monitoring and trend analysis.

The CAP will define additional evaluations and potential contingent remedial actions (e.g., installation of a PRB) based on the long-term monitoring.

3.5 Applicable or Relevant and Appropriate Requirements

In accordance with WAC 173-340-710, applicable federal and state laws or statutes were considered during development of corrective actions and proposed CULs. Though a cleanup action performed under formal MTCA authorities (e.g., a Consent Decree) would be exempt from the procedural requirements of certain state and local environmental laws, the action nevertheless must comply with the substantive requirements of such laws (RCW 70.105D.090; WAC 173-340-710).

Potentially applicable federal laws and regulations that may impact the implementation of remedial actions at the Site include:

- Clean Water Act (CWA; 33 USC Section 1251 et seq.), including the National Toxics Rule and National Pollutant Discharge Elimination System (NPDES) requirements
- Resource Conservation and Recovery Act
- Toxic Substances Control Act (15 USC s/s 2601 et seq. [1976])
- Clean Air Act (42 USC §7401 et seq.)

- Stormwater Permit Program, Water Pollution Control Act

Potentially applicable state laws and regulations include:

- MTCA
- SMS; Chapters 90.48 and 70.105D RCW; Chapter 173-204 WAC
- Water Resources Act
- Washington Water Pollution Control Act (Chapter 90.48 RCW; Chapter 173-201A
- WAC)
- Hazardous Waste Management Act (including Dangerous Waste Regulations; Chapter 70.105 RCW)

4 Remedial Technology Screening

This section describes remedial technologies for addressing arsenic-impacted groundwater in the Log Yard and residual PCP in the Sawmill.

4.1 Screening Approach

Potentially applicable remedial technologies were identified and screened on the basis of available published resources and industry common practice. Two primary contaminants of interest are considered throughout this evaluation, PCP and arsenic; the treatment of both focuses on contamination in soil and water. The following sources of information were used to screen these constituents relative to the pertinent media:

- The Federal Remediation Technologies Roundtable (FRTR) screening matrix (http://www.frtr.gov)

- Federal (U.S. Environmental Protection Agency [EPA], U.S. Navy, U.S. Air Force, and U.S. Army Corps of Engineers) documents available online (https://cluin.org/databases/#67; http://www.epa.gov/remedytech/publicationsremediation-technologies-cleaning-contaminated-sites)

- Regional industry common practices for soil and water treatment

The FRTR screening matrix contains a wide array of potentially applicable technologies that are either fully developed, field tested, or under development. The FRTR screening matrix was used and adapted into Tables 2 and 3 to provide a base collection of technologies to which further evaluation through additional literature and industry experience was applied.

4.2 Preliminary Identification of Technologies

The FRTR screening matrix provides an overall rating of a technology group or process (e.g., In Situ Biological Treatment) with respect to broad chemical types such as "Inorganics." "Inorganics" is understood to include metals, such as arsenic, and "Halogenated SVOCs" (semivolatile organic compounds) is understood to include PCP. The FRTR rating system is structured as "Above Average," "Average," or "Below Average." As a result, the preliminary identification was performed in the following steps:

- All technologies rated “Above Average” for “Inorganics” or “Halogenated SVOCs” were determined to be applicable.
- Technologies that were rated “Average,” “Below Average,” or “Site Dependent” for “Inorganics” and “Halogenated SVOCs,” but were known to be applicable, were added to the list of identified technologies.

The results of the preliminary technology identification screening for PCP and arsenic in soil are provided in Table 2; screening results for the contaminants in water are provided in Table 3.

4.3 Technology Evaluation

Available information in literature was reviewed to determine Site-specific applicability of each technology identified in the preliminary screening. Each technology was screened for effectiveness and implementability. Technologies determined to be effective and implementable were retained for further consideration (see Section 5). Those technologies deemed ineffective or not implementable at the Site were eliminated from further consideration.

In general, effectiveness addresses the ability of a technology to remove, treat, or contain contaminants to reduce risk of exposure. More specifically, a technology’s effectiveness describes:

- The degree of certainty that the technology can successfully meet cleanup standards
- The reliability of a technology to perform within design expectations and with minimal disruption during the anticipated term of operations
- The magnitude of residual risk with the cleanup complete or in place
- The magnitude of short-term risk during cleanup implementation
- The effectiveness of controls required to manage treatment residues or remaining wastes

Implementability addresses technical feasibility, availability of equipment and expertise, and administrative acceptance of a technology. In general, implementability addresses the practical ability to use the technology, regardless of its effectiveness. Specifically, the screening criteria include:

- Whether the technology is technically feasible for site cleanup with respect to physical site conditions, including hydrogeology and contaminant characteristics
- The extent to which the technology is developed (i.e., research, development, commercially available)
- Administrative and regulatory requirements
- Availability of requisite materials and services to implement the remedial technology
- Compatibility of remedial technology with current and future land uses

5 Remedial Technologies

General discussion of each remedial technology and Site-specific application details are provided in this section. Remedial technologies determined to be effective and implementable through the preliminary screening were advanced for Site-specific consideration (see Table 4). Given that the two primary Site contaminants can be divided regionally on the property, subsequent discussion evaluates technologies applicable to each contaminant by region (i.e., PCP in the Sawmill and arsenic in the Log Yard).

ICs were not evaluated in the preliminary screening, but are included in this discussion as applicable technologies to all media types and remedial strategies. Methane gas, not considered during preliminary screening, is considered in subsequent discussions for the application of ICs.

5.1 In Situ Biological Treatment

5.1.1 Monitored Natural Attenuation (MNA)

MNA is a technology reliant on natural processes, such as a variety of physical, chemical, or biological processes that act without human intervention to reduce contaminant mass, toxicity, or mobility. As a remedial alternative, MNA typically follows a source removal or containment action where an appropriate monitoring schedule is developed to assess and document the stability of residual contamination and rate of attenuation. MNA also can be an appropriate technology for managing contaminants where conventional treatment is otherwise impracticable.

Log Yard: MNA could be an appropriate technology for the attenuation of arsenic in groundwater in the Log Yard. A detailed discussion of Site conditions and ongoing attenuation in the Log Yard is provided in the RI Report. MNA of arsenic and other metals can be an effective approach when natural conditions are conducive for precipitation, sorption, or a change in the valence state of the metal that results in its immobilization. Immobilization of arsenic would reduce the flux of arsenic from the Site, but arsenic would remain in the soil matrix leaving a potential for arsenic mobilization if Site conditions change. Consequently, MNA approaches would require IC measures to limit stormwater infiltration and thereby the potential for re-mobilization.

Sawmill: MNA of organic contaminants, such as PCP, is a commonly accepted remedy for low concentrations of residual contamination that can include in situ processes, such as biodegradation, dispersion, diffusion, recharge, tidal mixing, sorption, volatilization, and chemical or biological stabilization, transformation, or destruction of contaminants.

5.1.2 Enhanced Bioremediation

Enhanced bioremediation is a process in which native or inoculated microorganisms degrade organic contaminants found in soil and/or groundwater, converting them to benign end products. In situ applications typically include the delivery of air or oxygen and/or nutrients, as needed, to contaminated areas in saturated or unsaturated zones to enhance microbial degradation. For source area applications, the energy source (i.e., the contaminants) is present and microbial activity is limited by the lack of key nutrients (e.g., nitrogen and phosphorus) to accelerate the degradation of the source. For lower contaminant concentrations, additional energy sources (e.g., emulsified vegetable oil) may be needed to sustain microbial communities.

Sawmill: As discussed in the RI Report, existing alkaline conditions (identified by elevated pH in groundwater) in the Sawmill may be inhibiting local biological communities that otherwise may degrade residual PCP. Neutralizing these alkaline conditions with an appropriate amendment could foster improved biological growth and increase the rate of natural PCP degradation. Amendments could be introduced through a series of injections, in situ soil mixing, or ex situ soil mixing. Bench scale studies would be necessary to determine the most effective amendment or combination of amendments for Site conditions.

5.2 In Situ Physical/Chemical Treatment

5.2.1 In Situ Chemical Oxidation

Chemical oxidants have been able to cause the rapid and complete chemical destruction of many toxic organic chemicals. For other organics, partial degradation via chemical oxidation can act as an aid to subsequent bioremediation. Reduction/oxidation chemically converts hazardous contaminants to nonhazardous or less toxic compounds that are more stable, less mobile, and/or inert. Redox reactions involve the transfer of electrons from one compound to another. Specifically, one reactant is oxidized (loses electrons) and one is reduced (gains electrons). The oxidizing agents most commonly used are ozone, hydrogen peroxide, permanganate, hypochlorite, chlorine, and chlorine dioxide, and the most common application is in situ versus ex situ.

Sawmill: Application of chemical oxidants to degrade residual PCP could be an appropriate technology to treat residual contamination in soil and groundwater. Chemical oxidants would be introduced similarly to enhanced bioremediation amendments via injections, in situ soil mixing, or ex situ soil mixing. Bench scale testing would be required to determine the appropriate oxidant for Site conditions and the necessary dosing for treatment.

5.2.2 Permeable Reactive Barrier (PRB)

PRBs are an in situ groundwater treatment technology that uses directed or natural groundwater flow to force contaminants through an in situ treatment media. Depending on site conditions and reactive media type, PRBs are applicable to the treatment of both organic and inorganic contaminants. The most common application of PRBs is the in situ treatment of groundwater contaminated with chlorinated solvents; however, more diverse applications have exhibited success, such as with dissolved metals.

Log Yard: A variety of treatment media is commercially available for arsenic treatment, including zero valent iron (ZVI), limestone, basic oxygen furnace slag, iron oxides, zeolite, and ion exchange resin. To reduce arsenic flux beyond the extent of the Log Yard and cap (see Section 5.5.2), a PRB could be installed along the western and northwestern perimeters of the Log Yard. The PRB would be installed deep enough to intercept arsenic flux to Wapato Creek. The PRB design would consider expected design life and would provide for media replenishment as necessary.

5.3 Ex Situ Physical/Chemical Treatment (assuming pumping)

5.3.1 Extraction and Ex Situ Treatment

A commonly implemented remedy, groundwater extraction and ex situ treatment or “pump and treat” systems can remove contaminant mass and hydraulically control migration of contaminated groundwater. Extraction wells or trenches are required to intercept the groundwater plume, which then can be treated and either reinjected or discharged to an appropriate location (e.g., municipal sewers, surface water, etc.). Ex situ treatment can vary depending on the characteristics of the contaminant using physical removal/entrainment or destruction/degradation of the contaminant to an innocuous state. Dissolved metals treatment generally takes the form of precipitation, sorption, and physical separation using an appropriate media or substrate with a subsequent offsite disposal or reuse. Organic contaminant treatment similarly can use sorption for physical removal or destructive means through chemical, biological, or thermal reactions.

Log Yard: Elevated concentrations of dissolved arsenic have been identified in groundwater and perched water zones beneath the Log Yard cap. Perched water from these areas could be extracted using sumps or French drains and pumped to a surface treatment unit. The treatment vessel could use a number of commercially available treatment media and/or chemicals to precipitate and separate out arsenic. The treatment vessel would require periodic maintenance and media replacement. Treated water would be discharged either to surface water (Wapato Creek) under an NPDES permit or infiltration back into groundwater.

Sawmill: Groundwater extraction and ex situ treatment of organic contaminants, such as PCP, is a common industry practice. Ex situ treatment of PCP typically involves either media absorption and offsite disposal or a chemically destructive treatment. The performance of various commercially available treatment media and chemicals is well documented and treatment trains can be tailored to water composition. Groundwater extraction as an independent remedial strategy or in conjunction with other remedial actions in the Sawmill (e.g., excavation) could reduce PCP contaminant mass and mobility within the range of extraction influence.

5.3.2 In-Line Stormwater Treatment on Existing System

Log Yard: Similar to groundwater extraction and ex situ treatment, in-line stormwater treatment refers to the passive or active treatment of water flowing through the Site's existing stormwater conveyance system. Under current Site conditions, groundwater infiltration is suspected of contributing the arsenic observed in stormwater system's discharge. An in-line treatment system would incorporate the placement of a passive or active treatment vessel within the conveyance system before discharge. The treatment vessel could use a number of commercially available treatment media and/or chemicals to reduce arsenic concentrations before discharge into Wapato Creek.

5.4 Ex Situ Physical/Chemical Treatment (assuming excavation)

5.4.1 Enhanced Bioremediation

Enhanced bioremediation is a process in which native or inoculated microorganisms degrade organic contaminants found in soil and/or groundwater, converting them to benign end products. Similar to in situ bioremediation technologies, ex situ bioremediation technologies diverge with the initial excavation of contaminated media. Extracted soils or slurry can be manipulated more easily ex situ to optimize biological activity with metered application of amendments (e.g., nutrients, heat, oxygen, moisture, etc.). Ex situ bioremediation techniques can include the construction of a biopile.

Sawmill: Similar to the in situ bioremediation approach discussed in Section 5.1, existing alkaline conditions (identified by elevated pH in groundwater) in the Sawmill may be inhibiting local biological communities that otherwise may degrade residual PCP. Excavation and construction of a biopile would allow for better distribution of a neutralizing amendment and create a more aerobic environment for biodegradation.

5.5 Containment

5.5.1 Conveyance System Replacement or Improvement (Stormwater)

Containment involves the construction of physical barriers—such as soil/bentonite slurry walls, asphalt concrete caps, and sealed pipes and vaults—to control the movement of water through or out of a contaminated medium.

Log Yard: In the site-specific instance of suspected groundwater flow into and out of the stormwater conveyance system, reducing seepage into the system functions as a physical barrier. Reducing seepage into the existing system could be accomplished by slip lining, which is a trenchless technology where a smaller-diameter high-density polyethylene (HDPE) or similar sealed pipe is installed within the existing concrete pipe. Alternatively, the entire conveyance system could be replaced with sealed pipes, joints, and vaults (e.g., HDPE, etc.). The replacement system could be constructed at the existing grade or a higher grade to raise the system above the natural groundwater elevation. Under both alternatives periodic monitoring, maintenance, and repair of the improved conveyance system would be needed to prevent groundwater infiltration and tidal influence.

5.5.2 Cap Enhancement and Maintenance

An existing cap is present in the Log Yard. Capping remedies involve physical barriers, natural or engineered, that limit exposure of human and terrestrial ecologic receptors to contaminated media and limit migration of soil contaminants via erosion or surface water infiltration and leaching. Maintenance of the existing cap is required to mitigate ponding and increased permeability caused by cracking and raveling of pavement as it wears over time. Periodic inspection, repair (as needed), and resurfacing (as needed) are necessary to sustain the effectiveness of a surface cap as a barrier to stormwater infiltration and contaminant isolation.

The Log Yard cap consists of two layers of RCC overlying a layer of clean gravel. Portions of the cap also contain localized areas of asphalt concrete surfacing. The existing cap undergoes periodic inspection and repair; the most recent repair effort was conducted in 2013. Further repairs to the cap were recommended in the 2014 and 2017 inspection reports, but have not been implemented yet.

- **Cap Maintenance:** To reduce cap permeability, frequent crack repair is necessary. Based on cap inspection reports, repairs would be warranted biannually under its current condition. Over time, the cap would require periodic resurfacing.

- **Cap Enhancement:** Cap enhancement would include upgrading the existing cap to reduce cracking and achieve a lower effective permeability to precipitation while supporting expected land uses. Ongoing monitoring and maintenance of an enhanced cap would be necessary, including regular inspections, periodic crack repair, and resurfacing.

5.6 Other Treatment

5.6.1 Source Removal (Excavation and Offsite Disposal)

Excavation and offsite disposal is a remedial technology that removes contaminant mass in soil and reduces contaminant loading potential to groundwater. Generally, excavated soils are temporarily stockpiled onsite, characterized per applicable waste disposal requirements, and transported to an appropriate offsite disposal facility. Clean fill is placed in the excavated area and compacted to meet desired land use requirements. Extensive removal of contaminated soil beneath the groundwater table would require dewatering of the excavation area and potentially some form of ex situ treatment if groundwater were contaminated.

Log Yard: A source removal action in the Log Yard would target the fill containing slag, and underlying soils exceeding the CUL. Existing RCC and subgrade gravel coarse would be stockpiled as clean material for reuse. Fill containing slag at the Site historically has been characterized as nonhazardous material, but may require some stabilization with cement (or a similar binder) for offsite landfill disposal if saturated. Imported clean fill may be backfilled as necessary to meet the property's grading needs.

It is expected that residual arsenic contamination would remain in groundwater in the Log Yard. Additional actions may need to be taken (including, but not limited to, MNA) to address that residual groundwater contamination. This material likely would be impracticable to remove and would remain in place. An appropriate impermeable surface would be needed to maintain Site conditions and reduce precipitation and hydraulic loading to arsenic-laden saturated soils beneath the Log Yard.

Sawmill: Low concentrations of PCP and localized area of high-pH remain in groundwater around the former dip tank. Excavation would target the saturated zone around the perimeter of historical removal areas to remove additional soil and associated PCP-impacted groundwater. Excavation below the groundwater table would require addressing dewatering and geotechnical considerations.

5.7 Institutional Controls (ICs)

Potentially applicable ICs include:

- Deed restrictions addressing land use and soil excavation
- Use of restrictions and monitoring requirements to prevent disturbance of caps or other engineered controls
- Site worker awareness and communication

ICs have the potential to address potential onsite worker exposure-related corrective action objectives at the Site. A contaminated media management plan (CMMP) requiring the use of personal protective equipment (PPE) during any subsurface soil excavation work and ventilation controls to mitigate potentially hazardous atmospheres can reliably prevent worker exposure to contaminants in subsurface soil and shallow groundwater. Properly trained and qualified personnel are needed for any work involving the handling of media impacted by Site-related contaminants. A deed restriction also can be applied to the property to prevent future residential uses of the property, prohibit onsite groundwater from being used for drinking, and require a CMMP with PPE during soil excavations. ICs to protect against exposure to affected downgradient groundwater could be implemented through Site worker or public (as applicable) awareness and communication.

Log Yard: Wellhead space measurements collected during RI field activities indicate elevated methane concentrations in the Log Yard; consideration for trench work and new Site structures is necessary to mitigate vapor intrusion and explosion hazards. A CMMP is necessary for future construction work in areas of known or suspected arsenic contamination. The CMMP would outline procedures for the management of contaminated soils onsite. As long as fill containing slag remains at the Site, deed restrictions to maintain low permeability coverage of that fill are necessary to prevent terrestrial exposure or adverse changes to Site conditions.

Sawmill: Well headspace measurements collected during RI field activities indicate elevated methane concentrations in localized portions of the Sawmill; consideration for trench work and future Site structures is necessary to mitigate vapor intrusion and explosion hazards. A CMMP is necessary for future construction work in areas exceeding PCP CULs.

6 Remedial Alternatives

Drawing from the retained technologies evaluated in Section 5 (summarized in Table 4) and considering Site-specific conditions, five remedial alternatives were developed for the Log Yard and three remedial alternatives for the Sawmill area. The subsequent sections provide details on the conceptual implementation of each alternative.

6.1 Log Yard Remedial Alternatives

The following five remedial alternatives for the Log Yard are constructed from a selection of remedial technologies presented in Section 5. A matrix of the alternatives and associated remedial technology is provided in Table 5.

6.1.1 Remedies Applicable to All Alternatives

- **MNA**: Conduct a monitoring program to evaluate arsenic attenuation and cap performance within the groundwater flow path between capped areas and POCs.
- **ICs:** Attach the CMMP, contamination notifications, and land use restrictions to the property deed. Deed restrictions would describe how to maintain the cap coverage and Site conditions.
- **Contingency PRB**: Based on performance monitoring results, a PRB may be installed parallel to Wapato Creek along the full westernmost boundary of the cap and along the northwestern boundary near the identified perched water areas (see Figures 5 through 9). The PRB would extend to below the streambed of Wapato Creek and be backfilled with reactive media (such as iron filing or ZVI) to treat dissolved arsenic in the groundwater passing through the PRB. Before installation, a design study (including bench scale testing) would be completed to determine the appropriate dimensions and composition of the PRB to optimize treatment and long-term effectiveness. Based on preliminary analysis, it is expected that the PRB would extend to a depth of approximately 25 feet bgs with reactive media emplaced between the interval of 25 and 10 feet bgs to intercept impacted groundwater (Figure 5a). A low-permeability material to inhibit surface water infiltration and provide structural strength, such as a low-strength concrete, would be placed atop the reactive media and restore the grade. PRB performance and the MNA program would be monitored to determine effectiveness and the reactive media replenishment schedule.

6.1.2 Alternative 1 (Figure 5)

- **Existing Cap Maintenance and Monitoring:** This alternative calls for continuing to maintain the existing RCC surface cap. Continued maintenance of the RCC cap would include an asphaltic concrete overlay of the existing surface using standard hot mix asphalt (HMA). Long-term maintenance of the cap would incorporate regular inspections, crack repair (as needed), and periodic resurfacing with standard HMA. The objectives of the cap maintenance regime are to minimize infiltration through the cap and maintain surface drainage. Preliminary evaluation of expected performance of a maintained HMA overlay on the existing RCC cap is included in Appendix B. The performance expectation of this capping alternative is to maintain the permeability of a standard HMA surface, modeled at an effective permeability of approximately $5x10^{-7}$ centimeters per second (cm/sec) (Appendix B).

- **Conveyance System Repair:** Conveyance system repair begins with an investigation of groundwater seepage into the system followed by repairs that could include sealing vaults, joints, and cracks. The investigation would include, but not be limited to, removing solids and debris, and conducting dry weather flow sampling at incremental stations. Repair efforts initially would include sealing joints and cracks with grout or other appropriate sealant at locations identified in the investigation effort. Repair would be followed by performance monitoring to confirm that impacted groundwater infiltration has been reduced. If repair is determined to be insufficient based on performance monitoring, more robust slip lining or other trenchless pipe installations would be used at select locations. Based on preliminary analysis in the RI Report and comparison of groundwater to existing conveyance piping, it is assumed that the primary target repair areas would extend from the outfalls to the oil-water separators (i.e., the lowest elevations in the system), including the oil-water separator vaults.

6.1.3 Alternative 2 (Figure 6)

- **Enhanced Cap (RCC Left in Place):** In this alternative, the existing RCC cap would remain in place, similar to Alternative 1; however, to mitigate the propagation of RCC cracking into the HMA overlay and lengthen the expected performance of the HMA cap, this enhanced cap would include: a geogrid atop the RCC, a layer of gravel atop the geogrid, and an HMA overlay atop the gravel. This enhanced cap alternative is expected to reduce the frequency and extent of cracking and settlement, consequently reducing the effective permeability of the cap through time. The standard HMA surface would expect a permeability similar to Alternative 1 (approximately $1x10^{-7}$ cm/sec) at the time of installation, but improved subgrade integrity would provide enhanced long-term performance (Appendix B). A long-term maintenance program, similar to Alternative 1, would incorporate periodic HMA resurfacing and crack repair as needed to maintain the permeability of the cap.
- **Conveyance System Repair (Same as Alternative 1):** Conveyance system repair incorporates an investigation of groundwater seepage into the system followed by repairs that could include sealing vaults, joints, and cracks.

6.1.4 Alternative 3 (Figure 7)

- **Low-Permeability Cap (Rubblize RCC and Install Clay Liner):** In this alternative, the existing RCC cap would be rubblized and the underlying gravel course removed to install a low-permeability geosynthetic clay liner (GCL) atop the fill containing slag and sloped to drain. The GCL could have an effective permeability of approximately $3x10^{-9}$ cm/sec and generally good long-term performance against settlement because of the cohesive nature of associated clay material (Appendix B). A working surface would be constructed atop the GCL and the Site would be restored to a similar existing grade. It is assumed rubblized RCC and existing gravel are adequate materials for constructing the subgrade for the working surface and would be stockpiled for reuse. The working surface generally would be composed sequentially of a geogrid, gravel, and standard HMA surface (typical cross section and evaluation provided in Appendix B). While the HMA surface would reduce stormwater infiltration, it would not be maintained as an environmental cap and would undergo regular Port operational maintenance. GCL maintenance would incorporate repairs to the GCL as needed and could be accomplished through spot excavation and GCL patch installation.

- **Interim Conveyance System Repair:** Similar to Alternatives 1 and 2, this interim system repair approach would incorporate an investigation of groundwater seepage into the system followed by repairs that would include sealing vaults, joints, and cracks. This interim repair is assumed to be a first action to address obvious leaks within the stormwater conveyance system in anticipation of conveyance system abandonment and replacement. This interim action would not include robust remedies, such as slip lining or other trenchless pipe lining technologies.
- **Conveyance System Replacement:** As part of the RCC cap rubblization and removal included in this alternative, the existing stormwater conveyance system would be abandoned and a replacement system installed at the same or higher grade with watertight seals and joints. The existing system would be abandoned by either complete removal or plugging with low-permeability material (e.g., low-strength concrete) at multiple stations throughout the system. To prevent preferential groundwater flux through the bedding material for the former and replacement system, spot trenching could be performed and backfilled with low-permeability material (e.g., low-strength concrete) to similarly plug the pathway.

6.1.5 Alternative 4 (Figure 8)

- **Existing Cap Maintenance and Monitoring (Same as Alternative 1):** This alternative would provide continued maintenance of the existing RCC surface cap, which would include an asphaltic concrete overlay of the existing surface using standard HMA.
- **Ex Situ Perched Groundwater Treatment:** This alternative would approach the control of stormwater infiltration and interaction with the fill containing slag by capturing perched water with multiple French drain type collection systems. Each French drain or similar groundwater collection system would be designed to remove accumulated water in perched groundwater zones and likely would require the use of several laterals spanning the north/south extent of the Log Yard. Conceptually, the system could be a perforated drain pipe within a layer of angular drain rock, sloped to drain to a central collector well. Extracted accumulating perched water then would be pumped to a media treatment vault or other treatment vessel for induced arsenic precipitation and separation. Treated water subsequently would be discharged to Wapato Creek directly or via the existing stormwater conveyance system. The alternative would require an NPDES permit with regular compliance monitoring, treatment media replacement, and system maintenance.
- **Conveyance System Repair (Same as Alternative 1 and Alternative 2):** Conveyance system repair would begin with an investigation of groundwater seepage into the system followed by repairs that could include sealing vaults, joints, and cracks. The investigation would include, but not be limited to, removing solids and debris from the conveyance system, then conducting dry weather flow sampling at incremental stations. Repair efforts initially would include sealing joints and cracks with grout or other appropriate sealant at locations

identified in the investigation effort. Repair would be followed by performance monitoring to confirm impacted groundwater infiltration has been reduced. If repair is determined to be insufficient based on performance monitoring, more robust slip lining or other trenchless pipe installations would be used at select locations. Based on preliminary analysis in the RI Report and comparison of groundwater to existing conveyance piping elevation, it is assumed that the primary target repair areas would extend from the outfalls to the oil-water separators (i.e., the lowest elevations in the system) including the oil-water separator vaults.

6.1.6 Alternative 5 (Figure 9)

- **Source Removal (Excavation and Disposal):** Fill containing slag and underlying soils exceeding the CUL would be removed and disposed of offsite. Based on soil cores and analytical data collected during the RI and prior investigations, the thickness of the removal section (i.e., fill containing slag and underlying soils exceeding CULs) is estimated to be approximately 5 feet across the Log Yard. Systematic sampling and profiling of excavated material would be ongoing during the removal effort to ensure material is taken to the appropriate disposal facility. Based on prior investigations, the fill containing slag is expected to be nonhazardous and suitable for disposal at a Subtitle D facility (Anchor QEA, 2014). Following removal, the excavation area would be backfilled with clean imported fill suitable to continue with current Site uses. It is assumed that the Site would be restored to a similar grade and capped with a standard HMA working surface.
- **Interim Conveyance System Repair:** Similar to Alternatives 1 and 2, this interim system repair approach would incorporate an investigation of groundwater seepage into the system followed by repairs that include sealing vaults, joints, and cracks. This interim repair is assumed to be a first action to address obvious leaks within the stormwater conveyance system in anticipation of conveyance system abandonment and replacement. This interim action would not include robust remedies, such as slip lining or other trenchless pipe lining technologies.
- **Conveyance System Replacement:** As part of the removal effort conducted in this alternative, the existing stormwater conveyance system would be abandoned and a replacement system would be installed at the same or higher grade with watertight seals and joints. The existing system would be abandoned by either complete removal or plugging with low-permeability material (e.g., low-strength concrete) at multiple stations throughout the system. To prevent preferential groundwater flux through the bedding material for the former and replacement system, spot trenching could be performed and backfilled with low-permeability material (e.g., low-strength concrete) to similarly plug the pathway.

6.2 Sawmill Remedial Alternatives

The following three remedial alternatives for the Sawmill are constructed from a selection of remedial technologies presented in Section 5. A matrix of the alternatives and associated remedial technology is provided in Table 6.

6.2.1 Alternative 1 (Figure 10)

- **MNA:** Conduct a monitoring program to evaluate PCP attenuation within the groundwater flow path between the former dip tank area and POCs.

- **ICs:** Attach the CMMP, contamination notifications, and land use restrictions to the property deed. Deed restrictions would describe how to maintain Site conditions.

6.2.2 Alternative 2 (Figure 11)

- **Enhanced Bioremediation:** Given that groundwater conditions in the former dip tank area indicate a high-pH environment that does not provide an optimal environment for biological activity, this alternative would implement enhanced bioremediation. Enhanced biodegradation of residual PCP in the groundwater could include the injection of amendments to create a more neutral pH for improved biological activity. Neutralizing alkaline conditions is not expected to mobilize naturally occurring arsenic in the Sawmill.
- **MNA:** Conduct a monitoring program to evaluate PCP attenuation within the groundwater flow path between the former dip tank area and POCs.
- **ICs:** Attach the CMMP, contamination notifications, and land use restrictions to the property deed. Deed restrictions would describe how to maintain Site conditions.

6.2.3 Alternative 3 (Figure 12)

- **Expanded Soil Removal with Groundwater Extraction and Ex Situ Treatment (during Soil Removal):** This alternative would remove vadose zone and upper saturated zone soils targeting areas outside the limits of the historical excavation. Excavated soils exceeding site CULs would be disposed of offsite and replaced with clean fill. Groundwater would be extracted, as needed, to dewater the soil excavation, and would be treated ex situ using chemically or biologically destructive means, or through physical media filtration.
- **MNA:** Conduct a monitoring program to evaluate PCP attenuation within the groundwater flow path between the former dip tank area and POCs.
- **ICs:** Attach the CMMP, contamination notifications, and land use restrictions to the property deed. Deed restrictions would describe how to maintain Site conditions.

7 Remedial Alternative Evaluation Criteria

This section provides descriptions of the MTCA requirements and evaluation criteria used to determine the efficacy of the assembled alternatives.

7.1 Threshold Requirements

Remedial actions performed under MTCA must meet a set of minimum requirements or threshold requirements. Per WAC 173-340-360(2)(a), alternatives that do not meet the threshold requirements are not considered viable remedial alternatives under MTCA. Threshold requirements are as follows:

- **Protect human health and environment –** Consider the degree to which an alternative meets MTCA cleanup standards, the degree to which the remedy is permanent, and the short-term risk associated with implementing the remedy.

- **Comply with cleanup standards –** For an alternative to be considered viable, the alternative must comply with cleanup standards, including the CULs, POCs, and ARARs discussed in Section 3.

- **Comply with applicable state and federal laws –** Remedial actions under MTCA must comply with applicable state and federal laws deemed relevant as discussed in Section 3.
- **Provide for compliance monitoring –** Per WAC 173-340-410, compliance monitoring can include protection, performance, or confirmational monitoring. For remedies that propose onsite disposal, isolation, or containment as the selected cleanup action for all or a portion of a site, a long-term monitoring plan is required.

7.2 Other MTCA Requirements

- **Use permanent solutions to the maximum extent possible –** Per WAC 173-340-200, a permanent solution means a cleanup action that meets cleanup standards without further action being required at the site or any other site involved with the cleanup action, other than the approved disposal of any residue from the treatment of hazardous substances.
- **Provide for a reasonable restoration time frame –** Per WAC 173-340-360(4), cleanup actions should provide for a reasonable restoration timeline considering factors such as:
    - Potential risks posed by the site to human health and the environment
    - Practicability of achieving a shorter restoration time frame
    - Current use of the site, surrounding areas, and associated resources that are, or may be, affected by releases from the site
    - Potential future use of the site, surrounding areas, and associated resources that are, or may be, affected by releases from the site
    - Availability of alternative water supplies
    - Likely effectiveness and reliability of ICs
    - Ability to control and monitor migration of hazardous substances from the site
    - Toxicity of the hazardous substances at the site
    - Natural processes that reduce concentrations of hazardous substances and have been documented to occur at the site or under similar site conditions
- **Consider public concerns –** As outlined in WAC 173-340-600, MTCA provides for public participation through various avenues including public notices, a site register, public meetings, etc. Specific notice requirements must be followed for, among others, off-property conditional POCs and CULs for groundwater flowing into nearby surface water.

7.3 Disproportionate Cost Analysis (DCA)

The MTCA DCA calls for comparing the costs and benefits of alternatives and selecting the alternative with incremental costs that are not disproportionate to the incremental benefits. The evaluation criteria for the DCA are specified in WAC 173-340-360(2) and (3), and include protectiveness, permanence, cost, long-term effectiveness, management of short-term risks, implementability, and consideration of public concerns. As outlined in WAC 173-340-360(3), MTCA provides a methodology that uses the criteria listed below.

- **Protectiveness –** The overall protectiveness of a cleanup action alternative is evaluated on the basis of several factors: overall protectiveness of human health and the environment, including the degree to which existing risks are reduced; time required to reduce the risk at the Site and attain cleanup standards; onsite and offsite risks resulting from implementing the alternative; and improvement of the overall environmental quality.

- **Permanence –** MTCA specifies that when selecting a remedial alternative, preference will be given to actions that are “permanent solutions to the maximum extent practicable.” Evaluation criteria include the degree to which the alternative permanently reduces the toxicity, mobility, or volume of hazardous substances, including the adequacy of the alternative in destroying the hazardous substances, the reduction or elimination of hazardous substance releases and sources of releases, the degree of irreversibility of waste treatment process, and the characteristics and quantity of treatment residuals generated.
- **Cost –** Costs associated with implementing an alternative include design, construction, long-term monitoring, agency oversight, ICs, the net present value (NPV) of any long-term costs, and agency oversight. Long-term costs include operation and maintenance costs, monitoring costs, equipment replacement costs, and the cost of maintaining ICs. Unit costs were developed using construction cost estimates provided by relevant vendors and contractors, review of actual costs incurred from past remediation projects, EPA and Interstate Technology and Regulatory Council guidance documents, and professional judgment (Appendix C).
- **Long-Term Effectiveness –** Long-term effectiveness is the degree of certainty that the alternative will be successful in maintaining compliance with cleanup standards during the long-term performance of the cleanup action, the magnitude of residual risk with the alternative in place, and the effectiveness of controls required to manage treatment residues or remaining wastes. MTCA provides a guide for ranking the long-term effectiveness of different types of technologies. MTCA ranks technologies in descending order as follows:
    - Reuse or recycling
    - Detoxification
    - Immobilization or solidification
    - Disposal in an engineered, lined, and monitored facility
    - Onsite isolation/containment with attendant engineered controls
    - ICs and monitoring
- **Management of Short-Term Risks –** The risk to human health and the environment associated with the alternative during construction and implementation, and the effectiveness of measures that will be taken to manage such risks.
- **Implementability –** The ability of the alternative to be implemented, including consideration of whether the alternative is technically possible; availability of necessary offsite facilities, services and materials; administrative and regulatory requirements; scheduling; size; complexity; monitoring requirement; access for construction operations and monitoring; and integration with existing facility operations and other current or potential remedial actions. It also includes administrative factors associated with permitting and completing the cleanup.

- **Consideration of Public Concerns –** Consideration about whether the community has concerns regarding the alternative and, if so, the extent to which the alternative addresses those concerns. This process includes concerns from individuals, community groups, local governments, tribes, federal and state agencies, or any other organization that may have an interest in or knowledge of the site.

8 Alternative Evaluation

This section provides an evaluation and comparative analysis of each remedial alternative using the MTCA criteria outlined in the Section 7.1. For the Log Yard, the contingent PRB was not evaluated in the subsequent sections because it is a part of all remedies. Remedial alternative evaluation details are provided with DCA scoring parameters in Table 7 for the Log Yard and Table 8 for the Sawmill. Figure 13 (Log Yard) and Figure 14 (Sawmill) depict the relative cost/benefit rankings from the DCA.

8.1 Threshold Requirements

All alternatives considered in this FS meet the four threshold MTCA criteria:

- **Protection of human health and the environment:** All alternatives considered control of identified risks to human health and the environment.
- **Compliance with cleanup standards:** All alternatives are expected to meet site cleanup standards. Remediation levels for arsenic are applied in each alternative during the restoration time frame.
- **Compliance with applicable state and federal regulations:** All alternatives are expected to comply with ARARs.
- **Provision for compliance monitoring:** All alternatives include compliance monitoring to verify compliance with cleanup standards.

8.2 Restoration Time-Frame

Log Yard: All five proposed remedial alternatives in the Log Yard are expected to achieve cleanup objectives within a similar time frame. That time varies as described below:

- Groundwater restoration time-frame: Residual groundwater contamination is expected to remain within the Site under all alternatives. Following remedial actions (capping or soil removal), residual groundwater contamination is expected to attenuate as a result of ongoing geochemical processes that sequester arsenic. However, this is expected to require many decades under all alternatives. No practicable alternatives were defined that could result in a more rapid groundwater restoration time frame. Given the extended restoration time frames for Site groundwater, all FS cleanup alternatives include contingent remedial actions for arsenic in groundwater. As described in Section 3.4, RELs will be used to determine whether or not contingent remedial actions should be undertaken at the Site.
- Restoration time-frame for benthic receptors, sediments and surface water: Despite the extended groundwater restoration time frame, RI monitoring documented that concentrations of arsenic in Wapato Creek surface water were below levels protective of aquatic organisms and groundwater background levels, the levels in sediments were below natural background, and arsenic concentrations in porewater were below those protective

of benthic organisms. Therefore, aquatic and benthic receptors are expected to remain protected throughout the groundwater restoration time frame.

- Termination of stormwater migration pathway: Groundwater infiltration to the stormwater system currently serves as a preferential pathway for arsenic migration to Wapato Creek. Stormwater conveyance system repairs or replacement is proposed in all Log Yard remedial alternatives and is considered to be a priority action. Implementation of stormwater system repair is expected to occur in year one following regulatory approval. Reduction of seepage in the stormwater conveyance system is expected to occur immediately following these system repairs.

Sawmill: All three remedial alternatives in the Sawmill are expected to achieve cleanup objectives within a reasonable time frame (Appendix A). Ongoing natural attenuation of the primary contaminant, PCP, is an element of all three alternatives and is the primary treatment in Alternative 1. Based on existing data, residual PCP in the Sawmill is expected to achieve cleanup standards through natural attenuation within approximately 12 to 16 years (Appendix A). The baseline alternative, Alternative 3, which proposes excavation, offsite disposal, temporary groundwater treatment, and MNA, anticipates a shorter restoration time frame of 4 to 6 years with performance monitoring. Alternative 2, an enhanced MNA or biodegradation alternative, anticipates an enhanced restoration time frame of 6 to 8 years with performance monitoring. Groundwater monitoring conducted during the RI demonstrate that the PCP CUL has already met at the proposed conditional POC for groundwater (i.e. currently monitoring well MW-4).

8.3 Climate Change Evaluation

Climate change vulnerabilities were not identified at the Site during the RI; however, a review of current climate change predictions for the Puget Sound and a cursory evaluation of remedial alternatives resiliency to climate change was conducted. Two main factors were considered:

- Potential effects from a rise in static sea level
- Potential effects from increased frequency and intensity of weather events

Estimated sea level rise in the Puget Sound is projected to be +24 inches in the year 2100 (with a range of +4 to +54 inches) compared to the year 2000 (University of Washington, 2015). Although the Site is not expected to be inundated under even the extreme scenario, sea level rise would likely increase the standing water height of Wapato Creek. Amongst other factors, this could flatten the groundwater gradient through the Site. This would not be expected to reduce the long-term effectiveness or stability of any of the proposed alternatives as it is highly unlikely fill containing slag would become in contact with the groundwater table. In fact, it is more likely that the transport of Site contaminants to Wapato Creek would decrease as the gradient along groundwater to surface water pathway flattens.

The location of Site is, and will continue to be, isolated from wave activity that occurs in Commencement Bay; therefore, shoreline integrity is not a concern. Increases in precipitation events would occur at the site and the potential for this future scenario was considered in the model used to develop and evaluate the performance of the various caps included in the alternatives (refer to Appendix B for details). As such, increased frequency and intensity of weather events is not a concern as they would be appropriately considered during remedy design.

8.4 Disproportionate Cost Analysis

The DCA is used to define the remedial alternatives that are considered permanent to the maximum extent practicable.

8.4.1 Benefit Scoring and Weighting Criteria

For each remedial alternative, the overall relative benefit was determined on the basis of the sum of weighted scores for each DCA criterion. As outlined in Section 7.3, these criteria include protectiveness, permanence, long-term effectiveness, management of short-term risks, technical and administrative implementability, and consideration of public concerns. For each criterion, the alternative was scored on a scale of 1 to 10 based on the degree to which the alternative meets that criterion. A score of 1 indicates that the alternative poorly meets the criterion and a score of 10 indicates that the alternative provides the highest benefit for that criterion. For each alternative, the individual criterion scores were weighted to lend preference to protectiveness, permanence, and long-term effectiveness. The same weighting factors were used in the evaluation of Sawmill and Log Yard alternatives. The respective weighting factors are:

- Protectiveness: 25 percent
- Permanence: 20 percent
- Long-term effectiveness: 20 percent
- Management of short-term risks: 15 percent
- Technical and administrative implementability: 10 percent
- Consideration of public concerns: 10 percent

8.4.2 Log Yard (Table 7 and Figure 13)

Comparative analysis used to determine the benefit scoring and overall ranking of proposed remedial alternatives in the Log Yard are described below. The individual benefit scores and rankings are provided in Table 7.

- **Protectiveness:** All proposed remedial alternatives meet the protectiveness threshold criteria and would be protective of human health and environment. However, significant differences in protectiveness were identified among the alternatives. Alternative 3 was the highest-ranked capping alternative because it uses a low-permeability cap expected to protectively address the source of perched water and reduce groundwater flux to Wapato Creek. The cap also separates the infiltration control layer from the working surface, providing better protection of cap performance over the long term in comparison to other alternatives. Alternative 3 also addresses the stormwater pathway through raising and replacement of the stormwater system rather than attempting repair-in-place as with Alternatives 1, 2, and 4. The protectiveness scores for Alternatives 1, 2, and 4 were lower because of the lower level of infiltration control achieved by the capping methods, and the use of repairs rather than replacements to address the stormwater pathway. Alternative 5 received the highest score for protectiveness because it conducts a high degree of source control (through soil removal) and uses stormwater system raising and replacement.
- **Permanence:** Scores for remedy permanence generally follow those for protectiveness. Among the capping alternatives, Alternative 3 received the highest score for permanence because of its use of the low-permeability cap, separation of the cap working surface from

the infiltration control layer, and stormwater system replacement. Scores for Alternatives 1, 2, and 4 were lower. Alternative 5 received the highest score for permanence because it conducts a high degree of source control (through soil removal) and uses stormwater system raising and replacement.

- **Long-Term Effectiveness:** Scores for long-term effectiveness were highest for those alternatives expected to require the least active maintenance to protect remedy performance for the long term. Among the capping alternatives, long-term effectiveness scores were highest for Alternative 3. Initial investments in a low -permeability cap under Alternative 3 are expected to control the high-arsenic concentrations in perched groundwater and reduce groundwater flux toward Wapato Creek, enhancing the performance of natural attenuation processes. The separation of the cap working surface from the infiltration control layer enhances the long-term performance of the cap and makes the remedy less dependent on active cap inspections and maintenance in comparison to Alternatives 1, 2, and 4. The remedy for Alternative 3 does not require long-term active groundwater extraction, treatment, and monitoring, as required under Alternative 4. Alternative 3 also replaces the existing stormwater system rather than attempting a repair in place of the existing system. The replacement approach is considered more robust for the long term. Alternative 3 is considered the least likely of the capping alternatives to require use of contingent groundwater treatment measures. Alternative 5 received a high score for long-term effectiveness because of its use of offsite disposal in a commercial landfill for management of contaminated soils, rather than onsite containment beneath a cap.
- **Management of Short-Term Risks:** Scores for short-term risk-management varied significantly among the alternatives. Those alternatives that require the greatest exposure of contaminated materials during remedy implementation (i.e., Alternatives 4 and 5) received the lowest scores. Alternatives 1, 2, and 3 received higher scores because those alternatives require little or no exposure of contaminated soils or groundwater during remedy implementation.
- **Implementability:** All Log Yard alternatives are considered to be sufficiently implementable to be evaluated in the FS. However, the complexity of implementation requirements varies significantly among the alternatives. Alternatives 1 and 2 are considered the most implementable because these alternatives use relatively simple construction methods not requiring exposure of contaminated soils or groundwater, and do not require additional permitting as do Alternatives 3, 4, or 5. Alternative 3 requires more regrading of the Site during construction, and will require issuance of a construction stormwater permit not required under Alternatives 1 and 2 because of the rubblization of the RCC cap. Implementation requirements for Alternatives 4 and 5 are much greater, resulting in lower scores for implementability. To be protective, Alternative 4 requires the use of short-term and long-term management methods for extracted groundwater. This would include development and maintenance of an individual NPDES permit, and performance of active groundwater treatment, monitoring, and reporting throughout the life-cycle of the remedy. Alternative 5 requires implementation of the largest construction effort, use of management practices to prevent contaminant releases via stormwater, and implementation of measures to ensure safety during offsite transportation and disposal of contaminated soils removed from the Site.

- **Consideration of Public Concerns:** Public concerns will be evaluated after the public comment period and alternative scoring altered as appropriate.

- **Cost:** Cost estimates for each alternative are provided in Appendix C and were evaluated on a 100-year timescale to fully capture the expected long-term care costs of the proposed remedies. Because of the areal extent of the Site and quantity of contaminated media present, remedies are material sensitive. Alternative 5, which proposes Site-wide excavation and offsite disposal, was estimated to have the highest cost (approximately $31 million). Alternatives 1 through 4 vary in initial construction cost, driven primarily by cap material quantities and significance of existing cap alteration. In terms of NPV, Alternatives 1 through 4 fall into a similar overall cost, ranging from $9.5 to $12.2 million.

8.4.3 Sawmill (Table 8 and Figure 14)

Comparative analysis used to determine the benefit scoring and overall ranking of proposed remedial alternatives in the Sawmill are detailed below. The individual benefit scores and rankings are provided in Table 8.

- **Protectiveness:** The three Sawmill alternatives were evaluated for protectiveness relative to the expected timeline to reach CULs in all Site wells. Scores for Alternatives 3 and 2 were higher than for Alternative 1, given the longer restoration time frame for that alternative. However, all alternatives are expected to achieve compliance with Site CULs and protect human health and the environment.
- **Permanence:** All alternatives propose permanent remedies that would result in permanent reduction of contaminant mass and toxicity. PCP degrades naturally in aerobic and anaerobic groundwater conditions, ultimately to innocuous by-products. Differences among the alternatives were associated with the expected time to reach CULs in all Site wells. Alternative 3 had the highest score and Alternative 1 had the lowest score.
- **Long-Term Effectiveness:** All alternatives propose permanent remedies that would result in permanent reduction of contaminant mass and toxicity. PCP degrades naturally in aerobic and anaerobic groundwater conditions, ultimately to innocuous by-products. Alternative 1 scored lower than Alternatives 2 and 3 because of the longer time frame required to reach CULs in all wells, and the longer time frame required for implementation of interim environmental covenants at the Site.
- **Management of Short-Term Risks:** Each alternative was ranked relative to the significance of expected interaction and handling of contaminated media during implementation of the respective remedy. Alternative 3, which proposes excavation and temporary groundwater treatment, received the lowest relative ranking because it poses the greatest short-term exposure risks to workers during material removal and offsite transportation and disposal.
- **Implementability:** All Sawmill alternatives use commercially available construction methods. Alternative 3 received the lowest score because of its greater relative complexity in handling excavated materials and coordinating offsite disposal. Alternative 1 received the highest implementability score because the treatment mechanism is ongoing and requires minimal infrastructure changes for long-term monitoring.
- **Consideration of Public Concerns:** Public concerns will be evaluated after the conclusion of the public comment period and alternative scoring will be altered as appropriate.

- **Cost:** Cost estimates for each alternative are provided in Appendix C. Each alternative includes provisions for compliance and confirmation monitoring, and cost estimates for the monitoring program are included in each alternative. Alternative 3, which proposes excavation and offsite disposal with temporary groundwater treatment, poses the greatest cost at an NPV of approximately $740,000; landfill disposal fees represent the greatest unit cost. Alternatives 1 and 2 had a similar NPV cost of approximately $500,000 to $540,000 despite initial capital expenditures in Alternative 2 because of expected savings in long-term monitoring costs.

8.4.4 Disproportionate Cost Analysis

Consistent with MTCA evaluation requirements, DCA is used to identify a preferred alternative that is considered permanent to the maximum extent practicable. An alternative is not considered permanent to the maximum extent practicable if the costs of the alternative are disproportionate to the incremental benefits of the alternative over those of other lower-cost alternatives (WAC 173-340-360(3)(i)). DCA results are presented in Table 7 and Figure 13 for the Log Yard, and Table 8 and in Figure 14 for the Sawmill. The evaluations are based on the information summarized in Sections 8.3.2 and 8.3.3.

Log Yard: Benefits of remediation alternatives for the Log Yard are presented along with costs in Figure 13. Environmental benefits increase in the following order: Alternative 1 (lowest), 4, 2, 3, and 5 (highest). The incremental benefit increases in rough proportion with cost from Alternatives 1 through 3. However, a large (more than two-fold) cost increase occurs between Alternatives 3 and 5 without a corresponding increase in environmental benefits. Environmental benefits increase only 6 percent in contrast to a 150 percent increase in costs. Based on the disproportionate increase in costs for Alternative 5, Alternative 3 is identified as the preferred remedial alternative. Alternative 3 is permanent to the maximum extent practicable.

Sawmill: Benefits of remediation alternatives for the Sawmill are presented along with costs in Figure 14. Environmental benefits scores increase from Alternatives 1 to 2, but decrease between Alternatives 2 and 3. Remedy costs increase slightly between Alternatives 1 and 2. However, they increase substantially between Alternatives 2 and 3, without a corresponding increase in environmental benefit. Based on the disproportionate increase in costs for Alternative 3, Alternative 2 is identified as the preferred remedial alternative. Alternative 2 is permanent to the maximum extent practicable.

9 Preferred Remedial Alternatives

Based on the investigation results presented in the RI Report and remedial evaluation in this FS Report, **Alternative 3 was selected as the preferred remedial alternative for the Log Yard** and **Alternative 2 was selected as the preferred remedial alternative for the Sawmill.** These alternatives meet all of the threshold requirements under MTCA and provide for optimal benefit as determined in the DCA. Summary considerations for selecting these alternatives are as follows:

- **<u>Log Yard Alternative 3 (compared to Alternatives 1, 2, and 4):</u>**
  - **Permanence**
    - Reduces perched water quantity to the highest degree.
    - Prevents arsenic discharges to the stormwater system.

- **Protectiveness**
  - Minimizes risks of arsenic transport to Wapato Creek.
- **Long-Term Effectiveness**
  - Separates the infiltration control layer from the working surface, protecting it from damage.
  - Isolation layer material (GCL) has lower permeability and a longer design life compared to asphalt or RCC.
- **Implementability**
  - Integrates best with facility operations, and cap performance is less dependent on frequent maintenance.
  - Not reliant on long-term active operations and maintenance or ongoing permitting.

- **<u>Log Yard Alternative 3 (compared to Alternative 5):</u>**
  - The cost of Alternative 5 is disproportionate to the benefit compared to Alternative 3.
- **<u>Sawmill Alternative 2 (compared to Alternatives 1 and 3):</u>**
  - **Protectiveness**
    - Reduces the time to reach CULs compared to Alternative 1.
  - **Permanence and Long-Term Effectiveness**
    - Biodegradation permanently destroys the contaminants.
  - **Implementability**
    - Can be implemented quickly and with less disturbance to facility operations compared to Alternative 3.
  - **Management of Short-Term Risks**
    - Uses in situ technologies, minimizing direct contact with contaminants compared to Alternative 3.

10 References

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University of Washington. 2015. State of Knowledge: Climate Change in Puget Sound. Climate Impacts Group, University of Washington. November. Washington State Department of Ecology (Ecology). 2013a. Model Toxics Control Act (MTCA) Regulation and Statute, Publication No. 94-06.

Washington State Department of Ecology (Ecology). 2013b. Sediment Cleanup User's Manual II. March.

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Tables

Site-Associated Contaminant	Cleanup Level (CUL)	CUL Units	Protection Basis	Point of Compliance or Measuring Point	Nature and Extent and Remedial Action Summary	Remedy to Include Remediation Levels (REL)?	REL Description
Soil							
Arsenic	20	mg/kg	MTCA Method A (Industrial)	Site-Wide Soil (to 15 ft bgs)	Soils in and below the fill containing slag exceed the MTCA A CUL throughout much of the capped Log Yard area. One exceedance in a shallow fill sample from the former dip tank excavation (Sawmill) was observed but no active remediation is anticipated in that area.	No	N/A
Pentachlorophenol	328	mg/kg	MTCA Method C (Cancer)	Site-Wide Soil (to 15 ft bgs)	No exceedances of CULs (see RI Table 7-1). No active remediation or monitoring anticipated.	No	N/A
Methane (as Vapor)	1	% by Volume	MTCA Air Quality Guidance	Site-Wide Soil (to the water table)	Present at concentrations above CULs throughout the capped Log Yard and in the area around the former dip tank on the Sawmill.	No	N/A
Groundwater							
Pentachlorophenol	1.0	µg/L	PQL	Site-wide groundwater	All groundwater from top of bank monitoring wells had PCP concentrations that were below CULs. Consistent exceedances of CULs were observed only at MW-2R, within the former dip tank excavation area. Concentrations are decreasing over time.	No	N/A
Arsenic	5.0	µg/L	MTCA Method A, Adjusted for Background	Conditional POC in nearshore groundwater	Groundwater throughout most of the Log Yard and a portion of the Sawmill exceeds the CUL for arsenic. Because none of the FS alternatives could achieve groundwater CULS at the standard POC within a relatively short time frame, a conditional POC is proposed at nearshore groundwater monitoring wells located at the top of the bank. This conditional POC is located as close as practicable downgradient from the source areas and before discharge to surface water, in accordance with WAC 173-340-720(8)(c).	Yes	As described in Section 3.4, RELs will be incorporated into the groundwater monitoring program (details to be defined in the CAP) to determine whether/when contingency response measures (i.e., implementation of PRB treatment of groundwater) are required. Monitoring will include tracking of perched water abundance and trends in groundwater arsenic concentrations.

Notes:

bgs = below ground surface
PQL = Practical Quantitation Level
N/A = not applicable
µg/L = micrograms per liter
PCP = pentachlorophenol
POC = point of compliance
CAP = corrective action plan
PRB = permeable reactive barrier
WAC = Washington Administrative Code

	General Technology Screening										
	Development Status	Treatment Train	O&M	Capital	System Reliability and Maintainability	Relative Costs	Time	Availability	Pentachlorophenol (Halogenated SVOCs)	Arsenic (Inorganics)	Comments
In Situ Biological Treatment											
Enhanced Bioremediation	3	3	1	2	2	3	2	3	*	*	Retained for Evaluation
Phytoremediation	3	3	3	3	1	3	1	2	*	2	
In Situ Physical/Chemical Treatment											
Electrokinetic Separation	3	1	1	2	2	1	2	2	2	3	
Fracturing	3	2	2	1	2	2	2	3	2	3	
Soil Flushing	3	3	1	2	2	2	2	3	2	3	
Solidification/Stabilization	3	3	2	1	3	3	3	3	2	3	
In Situ Thermal Treatment											
Thermal Treatment	3	1	1	1	3	2	3	3	3	1	
Ex Situ Physical/Chemical Treatment (assuming excavation)											
Chemical Extraction	3	1	1	1	2	2	2	3	3	3	
Chemical Reduction/Oxidation	3	2	2	1	3	2	3	3	2	3	Retained for Evaluation
Dehalogenation	3	2	1	1	1	1	2	2	3	1	
Separation	3	2	1	2	3	2	3	3	2	2	Retained for Evaluation
Soil Washing	3	1	1	1	3	2	3	3	2	2	
Solidification/Stabilization	3	3	2	1	3	3	3	3	2	3	Retained for Evaluation
Ex Situ Thermal Treatment (assuming excavation)											
Incineration	3	3	1	1	2	1	3	3	3	1	
Pyrolysis	3	3	1	1	1	1	3	3	3	1	
Thermal Desorption	3	3	1	1	2	2	3	3	3	1	
Containment											
Landfill Cap	3	3	2	1	3	3	1	3	2	2	
Landfill Cap Enhancements/Alternatives	3	3	2	1	3	3	1	3	2	2	Retained for Evaluation
Other Treatment											
Excavation, Retrieval, Off-Site Disposal	3	3	3	3	3	*	3	3	2	2	Retained for Evaluation

Notes:

[1] From the Federal Remediation Technologies Roundtable, further detail on individual rankings and ranking development can be found at https://frtr.gov/matrix2/section3/table3_2.pdf

* = Highly dependent upon site conditions
1 = Below average ranking
2 = Average ranking
3 = Above average ranking

	General Technology Screening								Contaminant Screening		
	Development Status	Treatment Train	O&M	Capital	System Reliability and Maintainability	Relative Costs	Time	Availability	Pentachlorophenol	Arsenic	Comments
In Situ Biological Treatment											
Enhanced Bioremediation	3	3	1	2	2	3	3	3	*	*	Retained for Evaluation
Monitored Natural Attenuation	3	3	1	2	2	3	*	3	2	1	Retained for Evaluation
Phytoremediation	3	3	3	3	1	3	1	2	2	*	
In Situ Physical/Chemical Treatment											
Air Sparging	3	3	3	3	3	3	3	3	2	1	
Bioslurping	3	2	3	3	2	3	2	3	3	2	
Chemical Oxidation	3	3	1	2	2	2	3	3	2	*	Retained for Evaluation
Directional Wells (enhancement)	3	3	2	1	2	2	2	3	2	2	
Dual Phase Extraction	3	1	1	1	2	2	2	3	3	1	
Thermal Treatment	3	1	1	1	2	2	3	3	3	1	
Passive/Reactive Treatment Walls	3	3	2	1	3	2	1	3	3	3	Retained for Evaluation
Ex Situ Biological Treatment											
Bioreactors	3	3	2	1	2	3	2	3	*	1	
Constructed Wetlands	3	3	2	1	3	2	3	1	3	3	
Ex Situ Physical/Chemical Treatment (assuming pumping)											
Adsorption/Absorption	3	3	1	2	2	1	1	3	2	3	Retained for Evaluation
Advanced Oxidation Processes	3	2	1	1	2	2	1	3	3	3	Retained for Evaluation
Granulated Activated Carbon/Liquid Phase Carbon Adsorption	3	2	1	2	3	2	1	3	3	3	
Groundwater Pumping/Pump and Treat	3	2	1	1	3	1	1	3	*	2	Retained for Evaluation
Ion Exchange	3	2	1	1	3	2	1	3	1	3	
Precipitation/Coagulation/Flocculation	3	2	2	1	3	2	1	3	1	3	Retained for Evaluation
Separation	3	2	1	1	3	1	3	3	3	3	Retained for Evaluation
Containment											
Physical Barriers	3	3	2	1	3	3	1	3	3	3	Retained for Evaluation
Deep Well Injection	3	3	3	3	2	3	1	3	2	2	
Air Emissions/Off-Gas Treatment											
High Energy Destruction	1	NA	ID	ID	1	2	ID	2	3	2	
Membrane Separation	1	NA	ID	ID	1	2	ID	2	2	1	
Oxidation	3	NA	3	3	3	3	ID	3	3	1	
Scrubbers	3	NA	2	1	3	3	ID	3	1	3	
Vapor Phase Carbon Adsorption	3	NA	3	3	3	3	ID	3	3	2	

Notes:

[1] From the Federal Remediation Technologies Roundtable, further detail on individual rankings and ranking development can be found at https://frtr.gov/matrix2/section3/table3_2.pdf

NA = not applicable
ID = insufficient data
* = Highly dependent upon site conditions
1 = Below average ranking
2 = Average ranking
3 = Above average ranking

FRTR Technology	Site-Specific Technology	Treatment Application: Saw Mill (Pentachlorophenol)	Treatment Application: Log Yard (Arsenic)	Comments
In Situ Biological Treatment				
Monitored Natural Attenuation	Monitored Natural Attenuation	x	x	
Enhanced Bioremediation	Enhanced Bioremedation	x		pH neutralization and/or other soil amendments could be added through injections or soil mixing to generate more favorable conditions for biological degradation.
In Situ Physical/Chemical Treatment				
Chemical Oxidation	In Situ Chemical Oxidation	x		Injection or soil mixing for application of oxidant
Passive/Reactive Treatment Walls	Permeable Reactive Barrier		x	Iron mediated arsenic precipitation
Ex Situ Physical/Chemical Treatment (assuming pumping)				
Adsorption/Absorption	Extraction and Ex Situ Treatment (Groundwater), In-Line Stormwater Treatment		x	Various commercially available media and chemical amendments potentially applicable to the ex situ treatment of contaminants in site groundwater and surface water.
Advanced Oxidation Processes		x	x	
Groundwater Pumping/Pump and Treat		x	x	
Precipitation/Coagulation/Flocculation			x	
Separation			x	
Ex Situ Physical/Chemical Treatment (assuming excavation)				
Chemical Reduction/Oxidation	Enhanced Bioremediation	x		Ex situ treatment via chemical amendment for enhanced biological degradation or chemical oxidation. Soil backfilled into original location
Separation	Source Removal (Excavation and Off-Site Disposal)		x	Stablization with cement or other amendments may be necessary for offsite disposal depending upon excavated material characterization and moisture content
Solidification/Stabilization			x	
Containment				
Physical Barriers	Conveyance System Replacement/Enhancement (Stormwater)		x	Improvement to stormwater line to reduce groundwater intrusion via cracking and joints.
Landfill Cap Enhancements/Alternatives	Cap Enhancement and Maintenance		x	
Other Treatment				
Excavation, Retrieval, Off-Site Disposal	Source Removal (Excavation and Off-Site Disposal)	x	x	

Remedial Technology	Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5	Remedy Detail
Log Yard Cap/Soil						
Existing Cap Maintenance and Monitoring	x			x		Maintenance activities includes regular inspections and periodic crack repair and resurfacing using a suitable overlay.
Cap Enhancement (geogrid and gravel)		x				Cap enhancement would include cap upgrades to reduce the effects of cracking and reduce effective cap permeability to precipitation. In this alternative the infiltration control layer is considered to be the asphalt concrete working surface. On-going monitoring and maintenance of the cap will also be required and include regular inspections and periodic repair and maintenance of of infiltration control layer.
Cap Enhancement (low permeability)			x			This alternative includes the rubbilization of the existing roller compacted concrete (RCC) cap and installation of a low permeability infiltration conctrol layer separate from the working surface. For costing purposes, the preliminary design used in this FS includes a geosynthetic clay liner (GCL) that would be installed atop the rubbilized RCC, with subsequent layers of recycled gravel base coarse, geogrid, new gravel base coarse, and a asphalt concrete working surface. For the purposes of this FS, the asphalt concrete working surface is considered separate from maintenance and monitoring following installation as the infiltration control layer would subsequently be separate. On-going monitoring and maintenance of the GCL would be required and include regular inspections and periodic repair and maintenance.
Source Removal (Excavation and Disposal)					x	Fill containing slag would be removed and disposed offsite. RCC and cap subgrade materials overlaying the source material are assumed to be clean and would be stockpiled on site during removal for subsequent use as fill material. Existing stormwater conveyance system reconstruction and usable surface restoration would be required.
Institutional Controls	x	x	x	x		Periodic inspection and/or repair of engineered system or barrier while contamination remains. A notification of potential exposure for workers handling impacted soils would be attached to the property deed.
Stormwater						
Conveyance System Repair	x	x		x		Conveyance system repair incorporates lining the existing system (pipes, manholes, and spill containment vessels) to significantly reduce leakage where joints and cracks are observed, as well as slip-lining sections at the lowest elevations. It is assumed in this remedy that an investigation and incremental repair approach will be adopted. The repair approach may include cleaning the existing lines,video surveying the system, collecting dry weather flow samples at intermediate stations, followed by sealing identified cracks and joints. Slip lining is assumed for this report to extend from OF 2 and OF 3 to the respective oil/water separators, approximately 300 feet up line. Periodic maintenance, monitoring, and repair of the improved conveyance system would be conducted to prevent groundwater seepage.
Conveyance System Interim Repair			x		x	This remedy is the same approach as conveyance system repair detailed above, however, this remedy does not include slip lining. This remedy is considered to be an interim action to reduce groundwater seepage prior to a full conveyance system replacement.
Conveyance System Replacement			x		x	A replacement system would incorporate the abandonment of the existing system and construction of a shallower, watertight system. This alternative would require periodic monitoring, maintenance, and repair of the improved conveyance system would be needed to prevent groundwater infiltration.
Institutional Controls				x		Periodic inspection and/or repair of engineered system or barrier while contamination remains. A notification of potential exposure for workers handling stormwater containing site related contaminants would be attached to the property deed.

Remedial Technology	Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5	Remedy Detail
Groundwater						
Monitored Natural Attenuation	x	x	x	x	x	Periodic monitoring would be conducted to ensure cleanup goals are met.
Permeable Reactive Barrier (PRB)	x	x	x	x	x	A permeable reactive barrier would be installed parallel to Wapato Creek inside the fenceline and running along the full extent of the westernmost boundary of the cap and along the northwestern boundary near identifed perched water areas. The barrier would extend to below the stream bed of Wapato Creek and be backfilled with reactive media (such as iron filings or zero valent iron) to treat dissolved arsenic in the groundwater flux.
Extraction and Ex Situ Treatment				x		Areas of perched groundwater will be extracted via sumps, shallow wells, or french drains to minimized areas of perched groundwater in contact with the fill containing slag. Ex-situ treatment may include precipitation and separation media (e.g., filters, iron reactive media, etc.). Separated arsenic would be disposed offsite and the treated groundwater would be discharged to surface water.
Institutional Controls	x	x	x	x	x	Periodic inspection and/or repair of engineered system or barrier while contamination remains. A notification of potential exposure for workers handling impacted groundwater would be attached to the property deed.
Soil Gas						
Institutional Controls	x	x	x	x	x	Methane gas does not present an imminent hazard under existing site conditions. A notification of potential hazardous conditions for trenchworkers or vapor intrusion to enclosed structures would be attached to the property deed.

Remedial Technology	Alternative 1	Alternative 2	Alternative 3	Remedy Detail
Groundwater				
Monitored Natural Attenuation	x	x	x	Periodic monitoring would be conducted to ensure cleanup goals are met.
Enhanced Bioremediation		x		Groundwater conditions in the dip tank area indicate a high-pH environment that does not provide an optimal environment for biological activity. Enhanced biodegradation of residual PCP in groundwater could include the injection of amendments to create a more neutral pH for improved biological activity. Amendment selection could incorporate a bench scale analysis to determine the optimal application to degrade residual PCP.
Extraction and Ex-Situ Treatment (During Soil Removal)			x	Removal of vadose zone and upper saturated zone soils would target areas outside the limits of the historical excavation. Excavated soil would be disposed off-site and replaced with clean fill. Groundwater extracted, as needed, to dewater the soil excavation, would be treated ex-situ using chemically or biologically destructive means, or through physical media filtration. Treatment could be conducted on or off site.
Institutional Controls	x	x		A notification of potential exposure for excavation workers would be attached to the property deed until cleanup levels have been met.
Soil Gas				
Institutional Controls	x	x	x	Methane gas does not present an imminent hazard under existing site conditions. A notification of potential hazardous conditions for trenchworkers or vapor intrusion to enclosed structures would be attached to the property deed.

Remedial Alternative[1]	Protectiveness (25%)[2]	Permanence (20%)	Long-Term Effectiveness (20%)	Short-Term Risk Management (15%)	Technical and Administrative Implementability (10%)	Public Concerns (10%)	Environmental Benefit Score	Probable Cost[3]	Benefit Score / Probable Cost[4]
	Relative Ranking - Scored from 1 (lowest) to 10 (highest)								
Alternative 1 - Cap Overlay - Conveyance System Repair - PRB - MNA - Institutional Controls	Achieves a lower score for protectiveness than other alternatives. However, the capping approach is less protective than those under Alternatives 2 and 3. Frequent inspections and sealing of cracks will be required to maintain cap performance. The stormwater repairs are less robust than the system replacement conducted under Alternatives 3 and 5. Protectiveness is enhanced with the use of a contingent PRB.	Achieves a low-medium score for permanence. Permanence under this alternative is lower than under Alternatives 2 and 3, because the capping approach does less to reduce the production of arsenic-contaminated perched groundwater as much as other alternatives, and no treatment of this water is provided as under Alternative 4. The alternative also uses stormwater line repairs rather than replacing the system. Together these factors result in a greater risk of arsenic migration toward Wapato Creek, and a greater likelihood that contingent groundwater treatment will be required.	Alternative 1 achieves a low-medium score for long-term effectiveness. Unlike Alternative 3, the permeability of the cap is not reduced, and arsenic-contaminated perched water will continue to be generated at significant rates. The cap performance will also require frequent inspections and sealing of cracks that are expected to occur at higher rates than under Alternative 2. The repair-in place of the stormwater system has a higher likelihood of failure over the long-term in comparison to the system raising and replacement as performed under Alternative 3. Groundwater flux rates will be higher than under Alternatives 2 or 3, placing higher demands on natural attenuation processes, and increasing the likelihood that a contingent PRB will be required.	This Alternative has a medium-high score for short-term risk management. It involves less extensive construction activities than under any other alternatives, and requires no exposure of arsenic-contaminated soils. The alternative uses routine construction methods (asphalt overlay placement) for capping. Stormwater management risks are minimized by keeping the existing RCC cap in place.	Alternative 1 has a medium-high score for implementability. Initial design and construction requirements are less than under any other alternatives. It uses standard construction methods for capping. It will not require a construction stormwater permit and will not expose contaminated soils. However, this alternative will require more frequent inspections and cap maintenance activities over the long-term.	Evaluation pending public comment.	4.2	$9.5M	0.44
	3	**3**	**4**	**8**	**8**	**--**			
Alternative 2 - Enhanced Cap - Conveyance System Repair - PRB - MNA - Institutional Controls	Achieves a medium score for protectiveness. Protectiveness of Alternative 2 is higher than for Alternative 1, because measures are taken to reduce ongoing crack formation within the cap surface layer. However, the capping approach is less protective than Alternative 3. Frequent inspections and sealing of cracks will be required to maintain cap performance. The stormwater repairs are less robust than the system replacement conducted under Alternatives 3 and 5. Protectiveness is enhanced with the use of a contingent PRB.	Achieves a medium score for permanence. Permanence under this alternative is better than under Alternative 1 but less than Alternative 3. The capping approach reduces anticipated infiltration in comparison to Alternative 1. However, the capping approach does less to address the generation of perched groundwater in comparison to Alternative 3. The alternative also uses stormwater line repairs rather than replacing the system. Together these factors result in a an intermediate risk of arsenic migration toward Wapato Creek, and an intermediate risk that contingent groundwater treatment will be required.	Alternative 2 achieves a medium score for long-term effectiveness. The long-term cap performance is expected to be better than under Alternative 1, with reduced surface cracking. However, the permeability of the cap is not reduced as much as under Alternative 3. The cap performance will also require frequent inspections and maintenance in comparison to Alternative 3. The repair-in place of the stormwater system has a higher likelihood of failure over the long-term in comparison to the system raising and replacement as performed under Alternative 3. Groundwater flux rates will be higher than under Alternative 3, placing higher demands on natural attenuation processes, and increasing the likelihood that a contingent PRB will be required.	This Alternative has a medium-high score for short-term risk management. It involves less extensive construction activities than under alternatives 3, 4 or 5. It does not requires exposure of arsenic-contaminated soils. The alternative uses routine construction methods (gravel placement and asphalt paving) for capping. Stormwater management risks are minimized by keeping the existing RCC cap in place.	Alternative 2 has a medium-high score for implementability. Initial design and construction requirements are less than under alternatives 3, 4 or 5. It uses standard construction methods for capping. It will not require a construction stormwater permit and will not expose contaminated soils. However, this alternative will require more frequent inspections and cap maintenance activities over the long-term in comparison to alternative 3.	Evaluation pending public comment.	5.5	$10.5M	0.52
	5	**5**	**6**	**8**	**8**	**--**			

Remedial Alternative[1]	Protectiveness (25%)[2]	Permanence (20%)	Long-Term Effectiveness (20%)	Short-Term Risk Management (15%)	Technical and Administrative Implementability (10%)	Public Concerns (10%)	Environmental Benefit Score	Probable Cost[3]	Benefit Score / Probable Cost[4]
	Relative Ranking - Scored from 1 (lowest) to 10 (highest)								
Alternative 3 - Low Permeability Cap - Conveyance System Replacement - PRB - MNA - Institutional Controls	Achieves a high level of overall protectiveness through the use of a low-permeability composite cap to reduce infiltration through source material and prevent accumulation of perched water. The infiltration control layer is separated from the cap working surface to minimize the risks of cap damage during long-term maintenance. The stormwater conveyance system will be replaced and raised to prevent groundwater infiltration. Protectiveness is enhanced with the use of a contingent PRB. Given anticipated reduction in infiltration and groundwater flux, the need for the PRB is less likely than under Alternatives 1, 2 or 4.	Achieves a medium-high score for permanence. Permanence under this alternative is enhanced over Alternatives 1, 2 and 4 by including both a more robust cap and a new stormwater system. The cap design is expected to reduce the generation of high-arsenic perched water in comparison to Alternatives 1, 2 and 4. The stormwater system replacement will also prevent future seepage of arsenic-containing groundwater into the storm drainage system.	Achieves a high level of long-term effectiveness through the use of a low-permeability composite cap to reduce infiltration through source material and prevent accumulation of arsenic-contaminated perched water. The infiltration control layer is separated from the cap working surface to maximize long-term cap performance and minimize dependence on ongoing cap inspections and maintenance. The stormwater conveyance system will be replaced and raised rather than being repaired in place, eliminating risks that leaks would recur over the long-term. The reduction in infiltration and groundwater flux under this alternative optimizes conditions for ongoing natural attenuation of arsenic, reducing the likelihood that the contingent PRB will be required. If the PRB is required, the lifespan of the treatment media will be improved relative to other alternatives with higher groundwater flux rates.	This Alternative has a medium-high score for short-term risk management. It involves more extensive construction activities during initial cap installation than under Alternatives 1, 2 or 4. However, this initial work is offset over the long-term by fewer requirements for on-site inspections and cap maintenance actions. Construction-related risks are lower than under Alternative 5, because the arsenic-contaminated soils will not be exposed to workers or to stormwater during cap installation. The alternative includes significant on-site construction activities, but does not involve extensive off-site transportation of contaminated soils as under Alternative 5.	Alternative 3 has a lower score for implementability than Alternatives 1 or 2, because initial design and construction requirements are greater. Though the alternative doesn't require exposure of contaminated soils, it will involve removal of the RCC cap and re-grading of cap materials. A construction stormwater permit will be required. However, this alternative will require less frequent inspections and cap maintenance activities over the long-term in comparison to alternatives 1, 2 and 4.	Evaluation pending public comment.	6.8	$12.2M	0.55
	8	**7**	**8**	**7**	**7**	**--**			
Alternative 4 - Cap Overlay - Conveyance System Repair - Perched Water Ex Situ Treatment - PRB - MNA - Institutional Controls	Achieves a medium score for overall protectiveness through the continued use and maintenance of a surface cap to reduce infiltration through source material, stormwater conveyance system repairs, natural attenuation and institutional controls. Perched water is actively addressed through extraction, ex situ treatment and discharge to Wapato Creek. Protectiveness is enhanced with the use of a contingent PRB. However, the capping approach is less protective than those under Alternatives 2 and 3 because more cracking and infiltration will likely occur under Alternative 1.	Achieves a medium score for permanence. Like Alternative 1 the capping approach used does less to address the production of arsenic-contaminated perched groundwater in comparison to alternatives 2 or 3. The active extraction and treatment of this water will require extensive ongoing operation and maintenance in order to remain effective. The repair-in place of the stormwater system has a higher likelihood of failure over the long-term in comparison to the system raising and replacement as performed under Alternative 3.	Alternative 4 achieves a medium level of long-term effectiveness. Unlike Alternative 3, the permeability of the cap is not reduced, and arsenic-contaminated perched water will continue to be generated at significant rates. Though the perched water is managed through extraction and treatment, these measures will require extensive ongoing operation, monitoring and maintenance to prevent inadvertent discharge of contaminated groundwater. The cap performance will also require frequent inspections and sealing of cracks that are expected to occur at higher rates than under Alternative 2. The repair-in place of the stormwater system has a higher likelihood of failure over the long-term in comparison to the system raising and replacement as performed under Alternative 3.	This Alternative has a medium score for short-term risk management. It involves more extensive construction activities during initial cap installation than under Alternatives 1 or 2, including installation of drains and sumps for extraction of groundwater. Appropriate methods will be required to prevent discharge of contaminated groundwater during treatment system start-up and initial operation. Construction-related risks are lower than under Alternative 5, because the arsenic-contaminated soils will not be exposed to workers or to stormwater during cap installation. The alternative includes significant on-site construction activities, but does not involve extensive off-site transportation of contaminated soils as under Alternative 5.	Alternative 4 has a lower score for implementability than alternatives 1, 2 or 3. This reduction in score reflects the increased complexity of construction associated with installation of the perched water extraction and treatment system. Alternative 4 uses standard construction methods for capping, will not require a construction stormwater permit and will not expose contaminated soils. However, this alternative will require more frequent inspections and cap maintenance activities over the long-term in comparison to alternative 3. This alternative also require long-term operation, maintenance of the water treatment system, including procurement and periodic renewal of a NPDES permit.	Evaluation pending public comment.	5.1	$12.1M	0.42
	6	**5**	**6**	**6**	**5**	**--**			

Remedial Alternative[1]	Protectiveness (25%)[2]	Permanence (20%)	Long-Term Effectiveness (20%)	Short-Term Risk Management (15%)	Technical and Administrative Implementability (10%)	Public Concerns (10%)	Environmental Benefit Score	Probable Cost[3]	Benefit Score / Probable Cost[4]
	Relative Ranking - Scored from 1 (lowest) to 10 (highest)								
Alternative 5 - Conveyance System Repair - Excavation and Disposal -Conveyance System Replacement - PRB - MNA - Institutional Controls	Achieves a high level of overall protectiveness through excavation and off-site disposal of arsenic contaminated soils. Residual groundwater contamination will remain and will be managed by stormwater system replacement, natural attenuation and institutional controls. Given the presence of residual groundwater contamination and potential increases in groundwater infiltration and flux after cap removal, this alternative includes a content PRB to ensure protectiveness.	Achieves a higher score for permanence than other alternatives by removing slag and contaminated soils that are a potential ongoing source of groundwater contamination. Residual groundwater contamination will remain. That contamination is managed through institutional controls, stormwater system replacement and a contingent groundwater PRB.	Achieves a high score for long-term effectiveness through excavation and offsite disposal of arsenic contaminated soils. These soils will be transferred to an off-site commercial landfill, rather than be contained on-site beneath an environmental cap. Residual groundwater contamination will remain and will be managed by stormwater system replacement, natural attenuation and institutional controls. Given the presence of residual groundwater contamination and potential increases in groundwater infiltration and flux after cap removal, this alternative includes a content PRB to ensure long-term effectiveness of groundwater controls.	Alternative 5 has a low-medium score for short-term risk management. Short-term risks associated with this alternative would be moderately high. . The work includes extensive construction activities to remove, transport and safely manage contaminated soils without exposing workers to contaminate-related risks. Stormwater and dust will need to be appropriately managed during construction activities. This alternative also involves significant modifications to existing site conditions with the removal of the existing cap and changes to groundwater control measures. These changes could affect existing groundwater attenuation processes (this risk is managed with the contingent PRB).	This alternative has a medium score for implementability. The project will require a construction general stormwater permit and additional control measures to manage construction-related stormwater containing arsenic. The project will require extensive off-site transportation of contaminated soils. The duration of the construction project is longer than under the other Alternatives, impacting ongoing site uses to a greater degree.	Evaluation pending public comment.	7.2	$31.0M	0.23
	9	**10**	**9**	**4**	**5**	**--**			

Notes:

1. Consideration of public concerns is not addressed in this table because the public has not yet had an opportunity to provide comments.
2. Each of the DCA criteria listed were weighted, so the overall DCA score would be influenced by criteria directly relating to protectiveness and effectiveness. A score of 10 represents an alternative that satisfies the criteria to the highest degree.
3. Probable cost reflects the total estimated cost including applicable contingencies (see cost detail in Appendix C).
4. Probable costs were evaluated in increments of $1 million for comparison to benefit scoring.

PRB = permeable reactive barrier
MNA = monitored natural attenuation

Remedial Alternative[1]	Protectiveness (25%)[2]	Permanence (20%)	Long-Term Effectiveness (20%)	Short-Term Risk Management (15%)	Technical and Administrative Implementability (10%)	Public Concerns (10%)	Environmental Benefit Score	Probable Cost[3]	Benefit Score / Probable Cost[4]
	Relative Ranking - Scored from 1 (lowest) to 10 (highest)								
Alternative 1 - MNA - Institutional Controls	Achieves a medium score for overall protectiveness through ongoing monitored natural attenuation.	Residual contamination can be permanently detoxified through natural processes. This alternative receives a medium-high score for permanent reduction of mass and toxicity of hazardous substances at the Site.	This alternative receives a medium score for effectiveness as the time to complete the cleanup is longer than under the other alternatives. Long term effectiveness of this alternative depends upon maintaining institutional controls until contaminants attenuate and degrade.	This alternative was scored high for short term risk management. This alternative does not require any ex situ handling of residual contamination as treatment would occur in situ. There are no additional construction-related risks requiring management.	This alternative is scored high for implementability. This alternative requires only routine site monitoring.	Evaluation pending public comment.	6.2	$495K	1.24
	6	**6**	**6**	**9**	**9**	**--**			
Alternative 2 - Enhanced Bioremediation - MNA - Institutional Controls	Achieves a medium-high score for overall protectiveness through accelerated in situ biodegradation and natural attenuation, reducing the expected timeline until residual contamination is below cleanup levels in all wells.	This alternative receives a high score for permanent reduction of mass and toxicity of hazardous substances at the Site, and at a faster rate than under Alternative 1. Residual contamination can be permanently detoxified through natural processes.	This alternative receives a medium-high score for effectiveness because the time required to complete the cleanup is shorter than under Alternative 1. Long term effectiveness of this alternative depends upon maintaining institutional controls until contaminants attenuate and degrade.	This alternative was scored medium-high for short term risk management. This alternative does not require any ex situ handling of residual contamination as treatment would occur in situ. However, some handling of corrosive chemicals would be required during amendment injection.	This alternative is scored high for implementability. Neutralization agents and injection mechanisms are well-developed technologies that could be rapidly procured and implemented.	Evaluation pending public comment.	7.2	$539K	1.34
	8	**8**	**8**	**8**	**8**	**--**			
Alternative 3 - Expanded Excavation and Off-Site Disposal - Temporary Groundwater Extraction and Treatment - MNA - Institutional Controls	Achieves a high score for overall protectiveness by reducing residual contaminant mass through excavation and temporary groundwater treatment, reducing the expected timeline until residual contamination is below cleanup levels in all wells.	This alternative receives a high score for rapid removal of remaining groundwater contamination at the Site, relative to Alternatives 1 or 2.	This alternative receives a high score for long-term effectiveness because it has shortest restoration time-frame and interim institutional controls are not likely required for groundwater.	This alternative was score medium for short term risk management. Excavation and ex situ treatment are included as remedial elements in this alternative. Ex situ handling of contaminated media creates short term exposure potential for site workers or fugitive emissions.	This alternative is scored medium for implementability. The alternative will require management of stormwater and extracted groundwater during construction, and off-site management of excavated soils.	Evaluation pending public comment.	7.1	$742K	0.96
	9	**9**	**9**	**5**	**5**	**--**			

Notes:
1. Consideration of public concerns is not addressed in this table because the public has not yet had an opportunity to provide comments
2. Each of the DCA criteria listed were weighted, so the overall DCA score would be influenced by criteria directly relating to protectiveness and effectiveness. A score of 10 represents an alternative that satisfies the criteria to the highest degree
3. Probable cost reflects the total estimated cost including applicable contingencies (see cost detail in Appendix C)
4. Probable costs were evaluated in $100,000 increments for comparison to benefit scoring.
MNA = monitored natural attenuation

Figures

FIGURE 1

Vicinity Map

Feasibility Study
Parcel 15
Tacoma, WA

LEGEND

- Site Boundary
- Watercourse
- Waterbody

N

0 1,000 2,000 3,000
Feet

Date: October 19, 2017
Data Sources: PORTAC, Aerial photo taken September 2016 by Metro

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Document Path: P:\Portland\603-Port of Tacoma\GIS\Project_mxds\FS\Figure1_Vicinity_Map.mxd

FIGURE 2

Current Site Conditions Map

Feasibility Study
Parcel 15
Tacoma, WA

LEGEND

Site Features[1]
- Monitoring Well
- Perched Monitoring Well
- Stormwater Outfall

Site Storm Features
- Outfall
- Vault
- Storm Line

All Other Features
- Site Boundary[2]
- Cap[3]
- Former Dip Tank Excavation/Fill Extent (Approximate)
- Groundwater Contour, Dashed Where Inferred (Event 1-May 2016)
- Perched Water (Event 1-May 2016)

NOTES:
1. Locations have been surveyed, May 2016.
2. Site Boundary defined in Exhibit A of the Draft Agreed Order No. DE 11237 (Ecology, 2015).
3. Cap extent defined on Figure 2 of the Former Portac Inc. Site (AQEA, 2014).

N

0 115 230 345
Feet

Date: October 19, 2017
Data Sources: PORTAC, Aerial photo taken September 2016 by Metro

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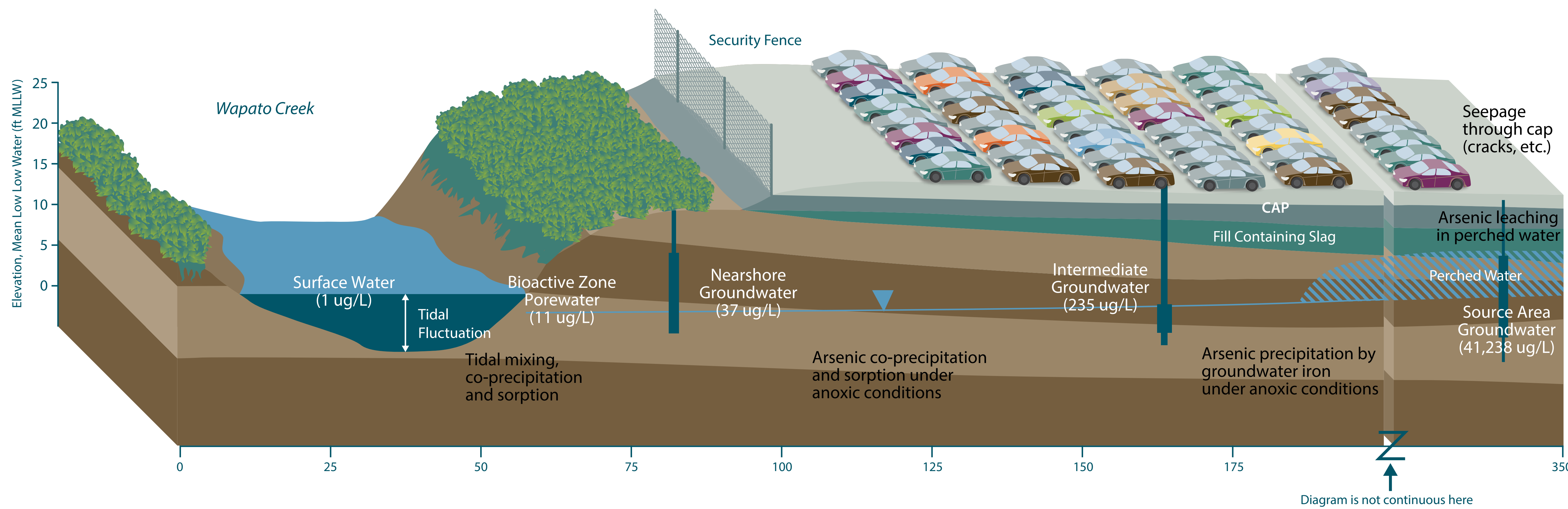

LEGEND

- Soil Boring/Well
- Screened Interval May 2016
- May 2016 Water Level
- Perched Groundwater

Geology

- Roller Compacted Concrete
- Gravel Base Course
- Fill Containing Slag
- Silty Sand
- Fine Grained Deposits (Silt and Clay)

FIGURE 3

Conceptual Site Model - Log Yard

Feasibility Study
Parcel 15
Tacoma, WA

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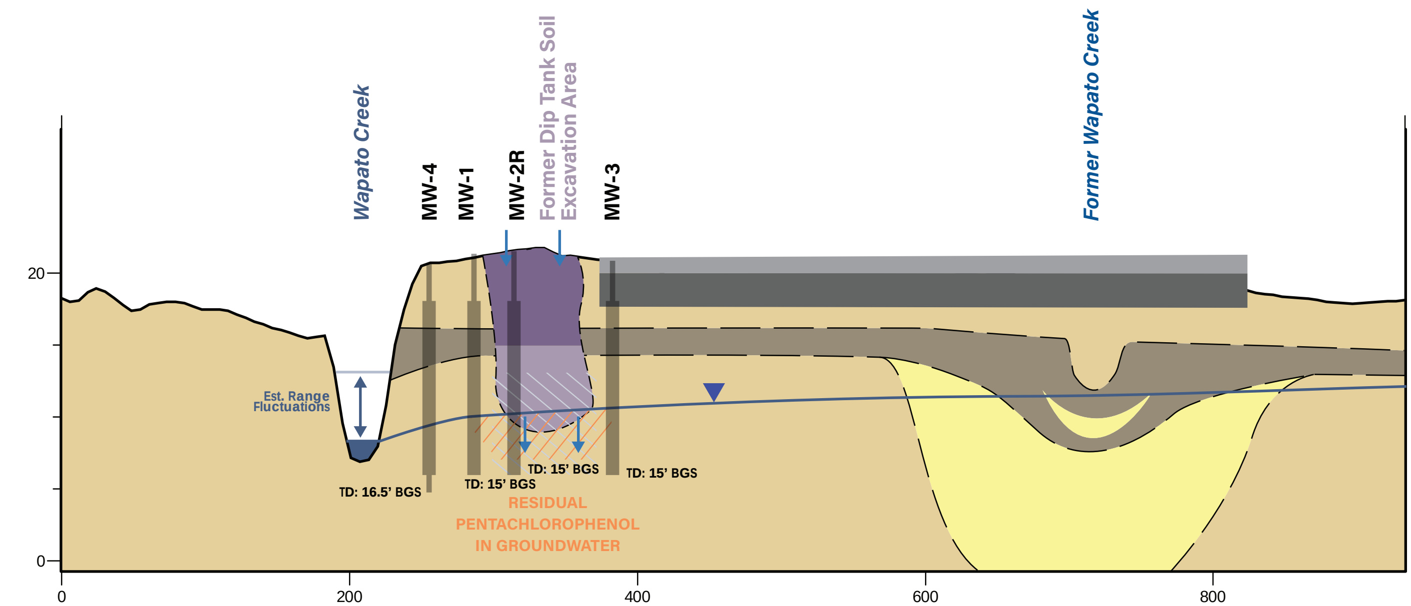


FIGURE 4

Conceptual Site Model - Sawmill

Feasibility Study
Parcel 15
Tacoma, WA

LEGEND

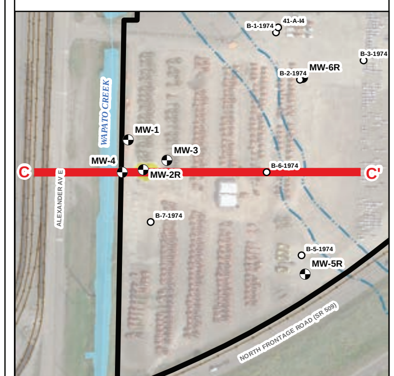
- May 2016 Estimated Water Level
- Precipitation Infiltration
- Residual Pentachlorophenol
- Groundwater with Elevated pH

Geology

- Asphalt Concrete
- Gravel Base Coarse
- Crushed Concrete Fill
- Sand FIll (Soil Excavation Area)
- Silty Sand
- Fine Grained Deposits (Silt and Clay)
- Sand

NOTES:

Vertical Exaggeration = 10X
Lidar data is from 2010 from Puget Sound Lidar Consortium's website (http://pugetsoundlidar.ess.washington.edu/lidardata/). Data converted from NAVD88 to MLLW by adding 2.67', made by GSI.



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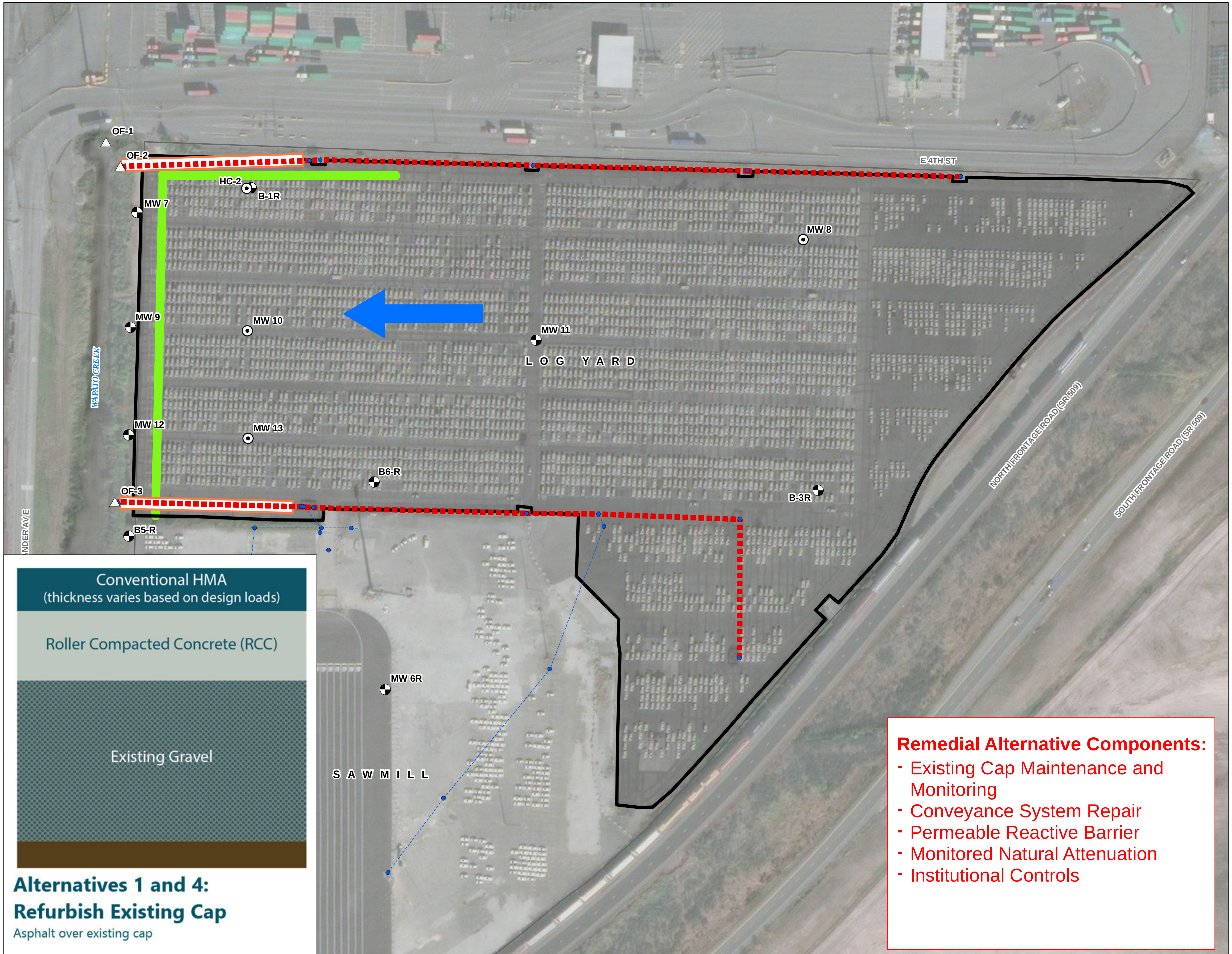

FIGURE 5

Log Yard Remedial Alternative 1

Feasibility Study
Parcel 15
Tacoma, WA

LEGEND

Site Features[1]
- Monitoring Well
- Perched Monitoring Well
- Stormwater Outfall

Site Storm Features
- Outfall
- Vault
- Storm Line

Remedial Alternative Features
- Stormwater System Repair
- Slip Line Stormwater Line
- Permeable Reactive Barrier[4]
- Current Cap Boundary[3]

All Other Features
- Site Boundary[2]
- Groundwater Flow Direction

NOTES:
1. Locations have been surveyed, May 2016.
2. Site Boundary defined in Exhibit A of the Draft Agreed Order No. DE 11237 (Ecology, 2015).
3. Cap extent defined on Figure 2 of the Former Portac Inc. Site (AQEA, 2014).
4. Permeable reactive barrier dimensions and extent are subject to change to during remedial design.

HMA: Hot Mix Asphalt

N

0 90 180 270
Feet

Date: November 7, 2017
Data Sources: PORTAC, Aerial photo taken September 2016 by Metro

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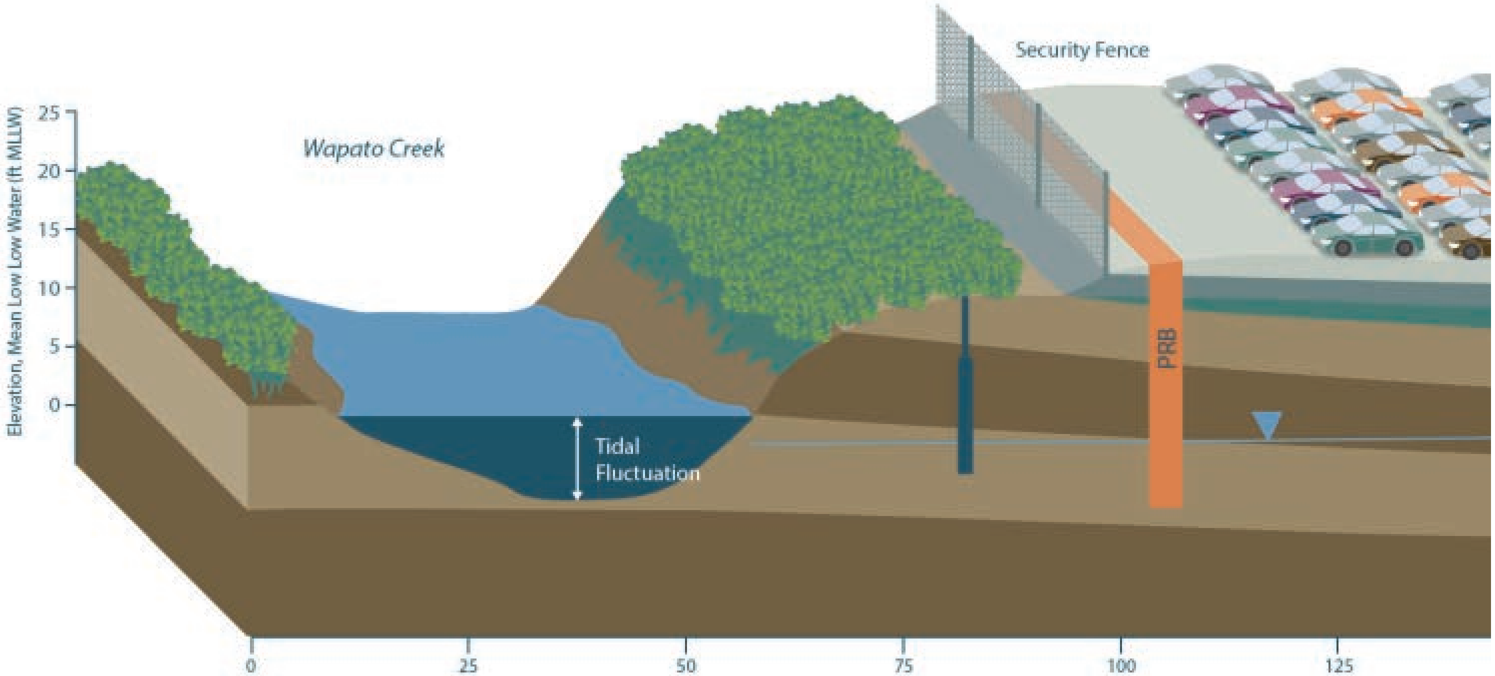

FIGURE 5a

Contingency Permeable Reactive Barrier

Feasibility Study
Parcel 15
Tacoma, WA

NOTES:
1. PRB conceptual and dimensions, locations, etc. will be subject to design considerations.

PRB: Permeable Reactive Barrier.

SOURCE: AQEA

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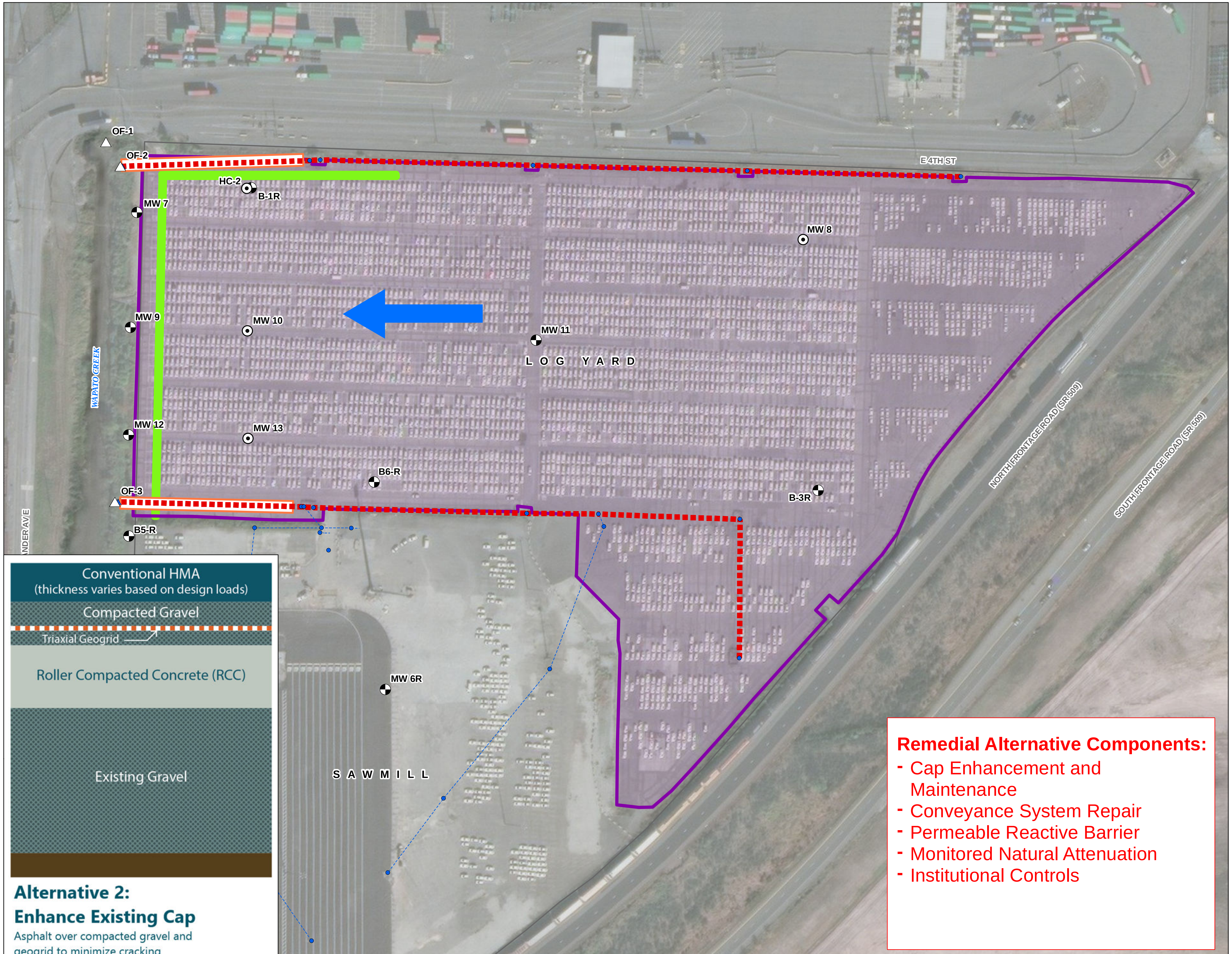
FIGURE 6

Log Yard Remedial Alternative 2

Feasibility Study
Parcel 15
Tacoma, WA



LEGEND

Site Features[1]

- Monitoring Well
- Perched Monitoring Well
- Stormwater Outfall

Storm Features

- Outfall
- Vault
- Storm Line

Remedial Alternative Features

- Stormwater System Repair
- Slip Line Stormwater Line
- Permeable Reactive Barrier[4]
- Enhanced Cap

All Other Features

- Site Boundary[2]
- Groundwater Flow Direction

NOTES:

1. Locations have been surveyed, May 2016.
2. Site Boundary defined in Exhibit A of the Draft Agreed Order No. DE 11237 (Ecology, 2015).
3. Cap extent defined on Figure 2 of the Former Portac Inc. Site (AQEA, 2014).
4. Permeable reactive barrier dimensions and extent are subject to change to during remedial design.

HMA: Hot Mix Asphalt

N

0 90 180 270
Feet

Date: November 7, 2017
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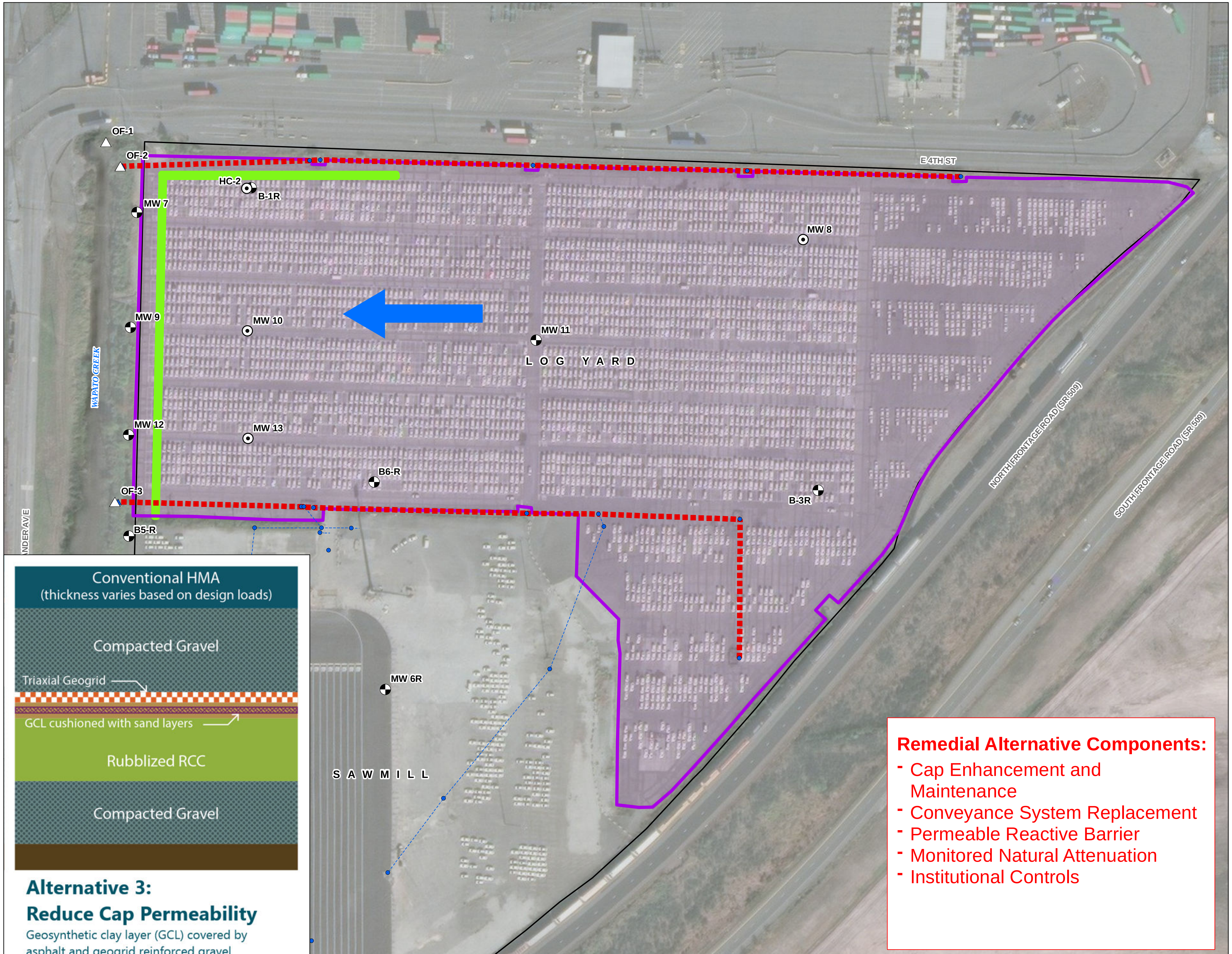
FIGURE 7

Log Yard Remedial Alternative 3

Feasibility Study
Parcel 15
Tacoma, WA



LEGEND

Site Features[1]
- Monitoring Well
- Perched Monitoring Well
- Stormwater Outfall

Site Storm Features
- Outfall
- Vault
- Storm Line

Remedial Alternative Features
- Replaced Stormwater Line
- Permeable Reactive Barrier[4]
- Enhanced Cap

All Other Features
- Site Boundary[2]
- Groundwater Flow Direction

NOTES:

1. Locations have been surveyed, May 2016.
2. Site Boundary defined in Exhibit A of the Draft Agreed Order No. DE 11237 (Ecology, 2015).
3. Cap extent defined on Figure 2 of the Former Portac Inc. Site (AQEA, 2014).
4. Permeable reactive barrier dimensions and extent are subject to change to during remedial design.

HMA: Hot Mix Asphalt
RCC: Roller Compacted Concrete
GCL: Geosynthetic Clay Liner

N

0 90 180 270
Feet

Date: November 7, 2017
Data Sources: PORTAC, Aerial photo taken September 2016 by Metro

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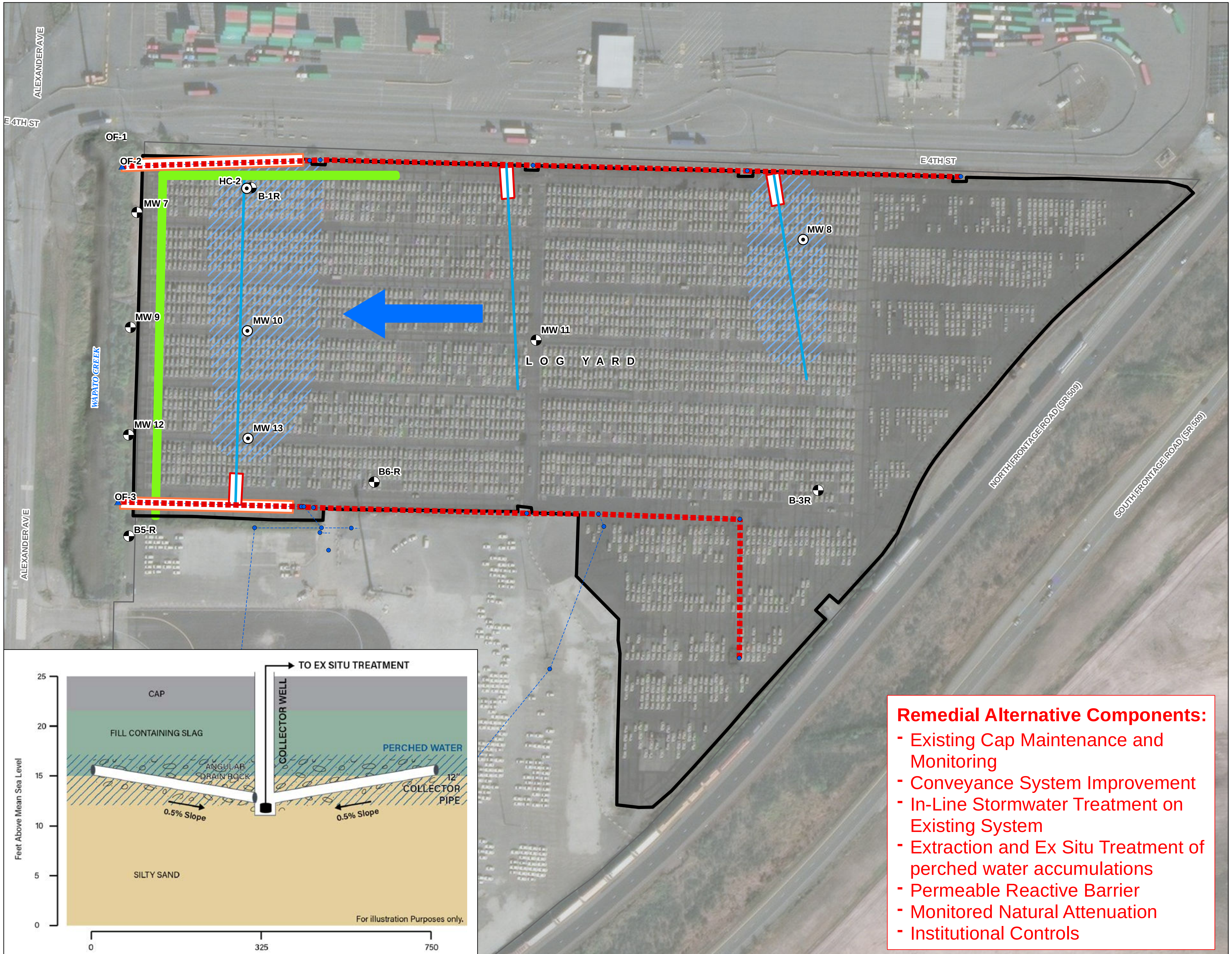
FIGURE 8

Log Yard Remedial Alternative 4

Feasibility Study
Parcel 15
Tacoma, WA



Remedial Alternative Components:

- Existing Cap Maintenance and Monitoring
- Conveyance System Improvement
- In-Line Stormwater Treatment on Existing System
- Extraction and Ex Situ Treatment of perched water accumulations
- Permeable Reactive Barrier
- Monitored Natural Attenuation
- Institutional Controls

LEGEND

Site Features[1]
- Monitoring Well
- Perched Monitoring Well
- Dry Monitoring Well

Site Storm Features
- Outfall
- Vault
- Storm Line

Stormwater System Repair
- Replaced Stormwater Line
- Permeable Reactive Barrier[4]
- French Drain to Ex Situ Treatment
- Perched Water Ex Situ Treatment
- Slip Line Stormwater Line
- Current Cap Boundary[3]

All Other Features
- Site Boundary[2]
- Perched Water (Event 1-May 2016)
- Groundwater Flow Direction

NOTES:
1. Locations have been surveyed, May 2016.
2. Site Boundary defined in Exhibit A of the Draft Agreed Order No. DE 11237 (Ecology, 2015).
3. Cap extent defined on Figure 2 of the Former Portac Inc. Site (AQEA, 2014).
4. Permeable reactive barrier dimensions and extent are subject to change to during remedial design.

N

0 90 180 270
Feet

Date: October 19, 2017
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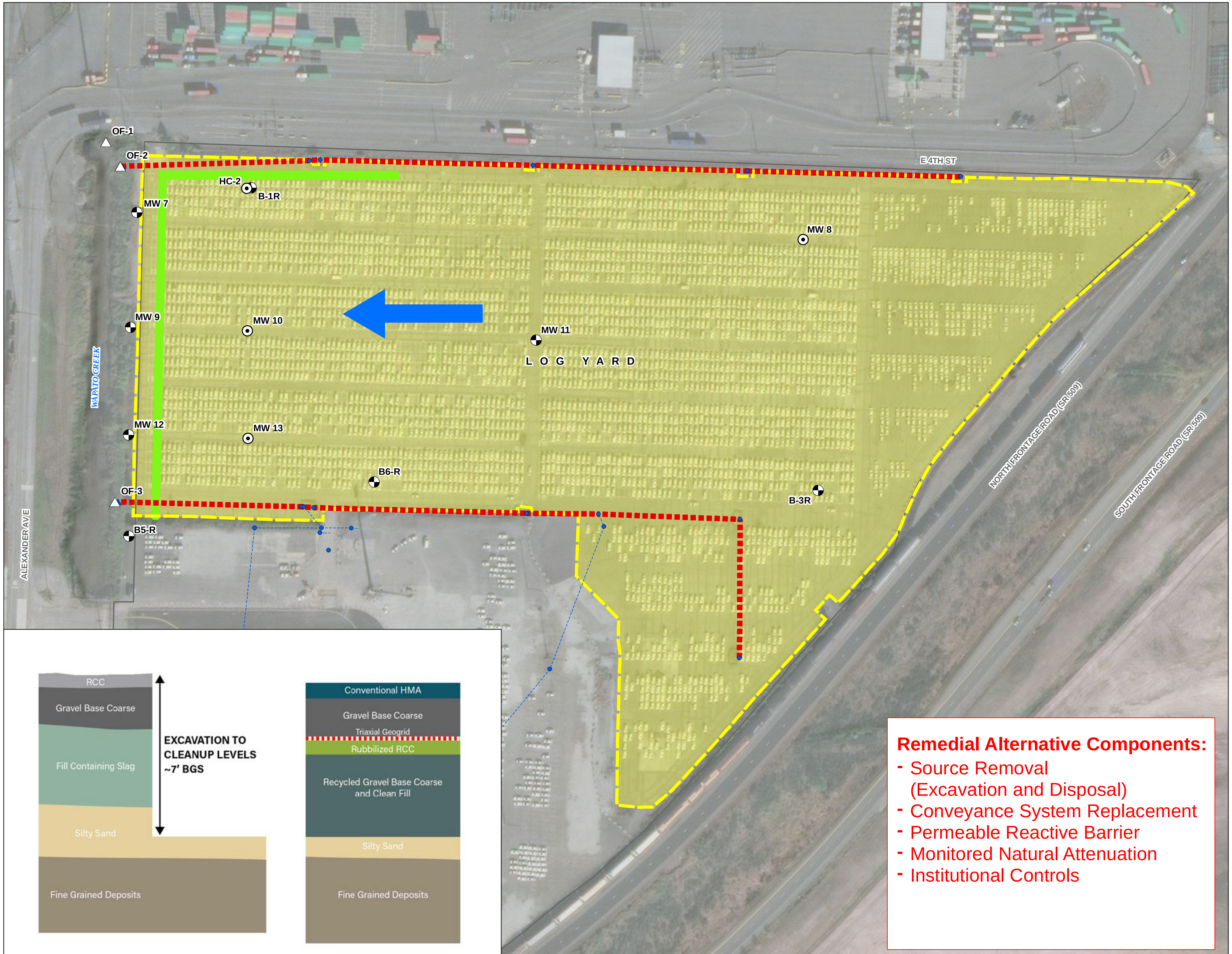
FIGURE 9

Log Yard Remedial Alternative 5

Feasibility Study
Parcel 15
Tacoma, WA



LEGEND

Site Features[1]
- Monitoring Well
- Perched Monitoring Well
- Stormwater Outfall

Site Storm Features
- Outfall
- Vault
- Storm Line

Remedial Alternative Features
- Replaced Stormwater Line
- Permeable Reactive Barrier[3]
- Extent of Source Removal (Excavation)

All Other Features
- Site Boundary[2]

NOTES:
1. Locations have been surveyed, May 2016.
2. Site Boundary defined in Exhibit A of the Draft Agreed Order No. DE 11237 (Ecology, 2015).
3. Permeable reactive barrier dimensions and extent are subject to change to during remedial design.
4. Excavation depth is based upon attached Ancher QEA 2014 soil sampling data.
5. Excavation is planned to extend to all soils exceeding cleanup levels.

HMA: Hot Mix Asphalt
RCC: Roller Compacted Concrete
GCL: Geosynthetic Clay Liner

N

0 90 180 270
Feet

Date: November 7, 2017
Data Sources: PORTAC, Aerial photo taken September 2016 by Metro

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FIGURE 10

Sawmill Remedial Alternative 1

Feasibility Study
Parcel 15
Tacoma, WA

LEGEND

Site Features[1]
- Monitoring Well
- Stormwater Outfall

Storm Features
- Outfall
- Vault
- Storm Line

Remedial Alternative Features
- Former Dip Tank Excavation/Fill Extent (Approximate)

All Other Features
- Site Boundary[2]
- Groundwater Flow Direction

NOTES:
1. Locations have been surveyed, May 2016.
2. Site Boundary defined in Exhibit A of the Draft Agreed Order No. DE 11237 (Ecology, 2015).

N

0 65 130 195
Feet

Date: October 19, 2017
Data Sources: PORTAC, Aerial photo taken September 2016 by Metro

GSI Water Solutions, Inc.

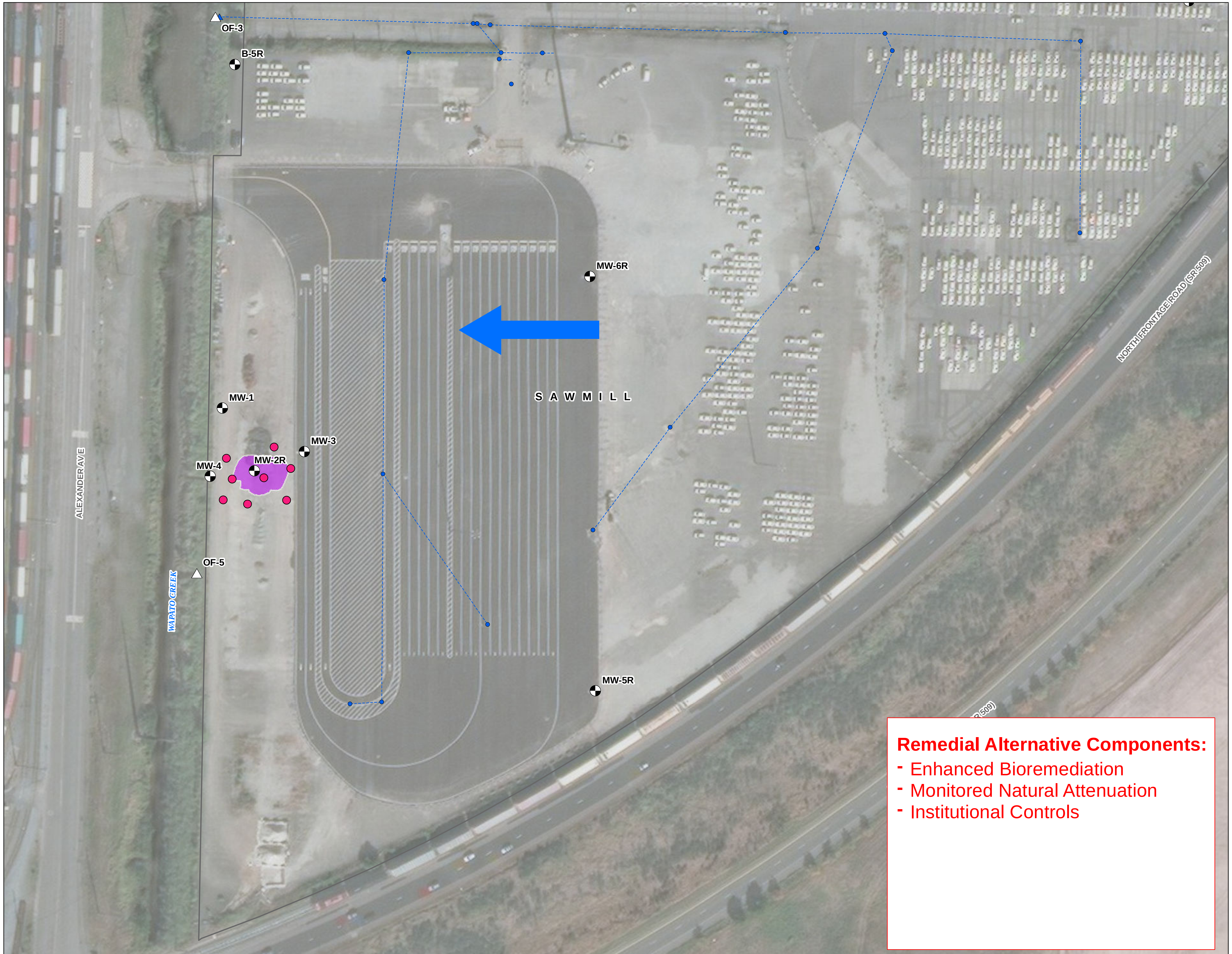

FIGURE 11

Sawmill Remedial Alternative 2

Feasibility Study
Parcel 15
Tacoma, WA

LEGEND

Site Features[1]
- Monitoring Well
- Stormwater Outfall

Storm Features
- Outfall
- Vault
- Storm Line

Remedial Alternative Features
- Former Dip Tank Excavation/Fill Extent (Approximate)
- Enhanced Bioremedation Amendment Injection Point (Conceptual)

All Other Features
- Site Boundary[2]
- Groundwater Flow Direction

NOTES:

1. Locations have been surveyed, May 2016.
2. Site Boundary defined in Exhibit A of the Draft Agreed Order No. DE 11237 (Ecology, 2015).

Enhanced biodegradation amendment introduced via injection. Amendment to target neutralization of alkaline conditions or as needed to optimize biological activity and degradation of residual PCP.

N

0 65 130 195
Feet

GSI Water Solutions, Inc.

Date: October 19, 2017
Data Sources: PORTAC, Aerial photo taken September 2016 by Metro

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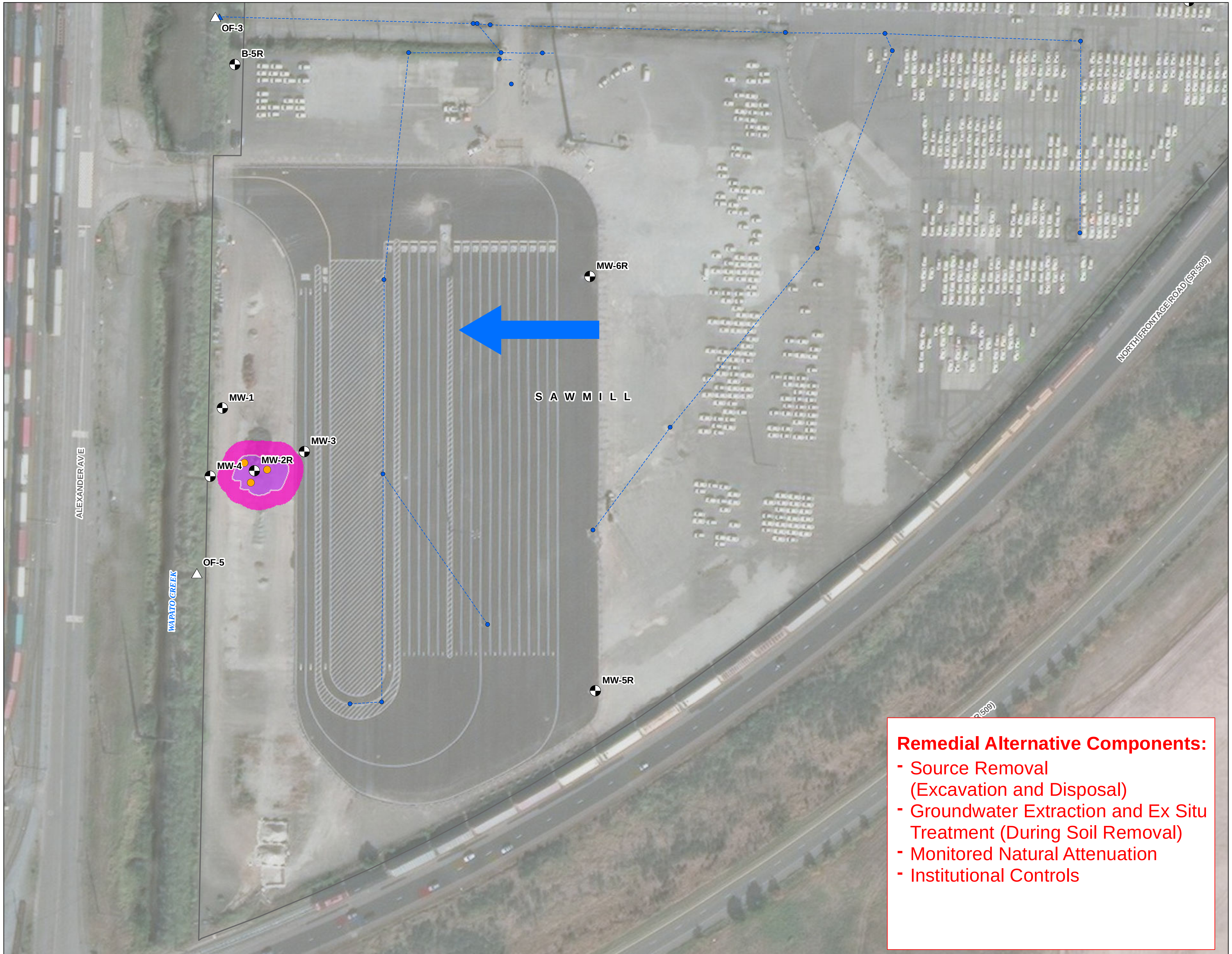

FIGURE 12

Sawmill Remedial Alternative 3

Feasibility Study
Parcel 15
Tacoma, WA

LEGEND

Site Features[1]
- Monitoring Well
- Stormwater Outfall

Storm Features
- Outfall
- Vault
- Storm Line

Remedial Alternative Features
- Former Dip Tank Excavation/Fill Extent (Approximate)
- Expanded Removal (Excavation with temporary dewatering)
- Temporary Extraction Well

All Other Features
- Site Boundary[2]
- Groundwater Flow Direction

NOTES:
1. Locations have been surveyed, May 2016.
2. Site Boundary defined in Exhibit A of the Draft Agreed Order No. DE 11237 (Ecology, 2015).

N

0 65 130 195
Feet

Date: November 7, 2017
Data Sources: PORTAC, Aerial photo taken September 2016 by Metro

GSI Water Solutions, Inc.

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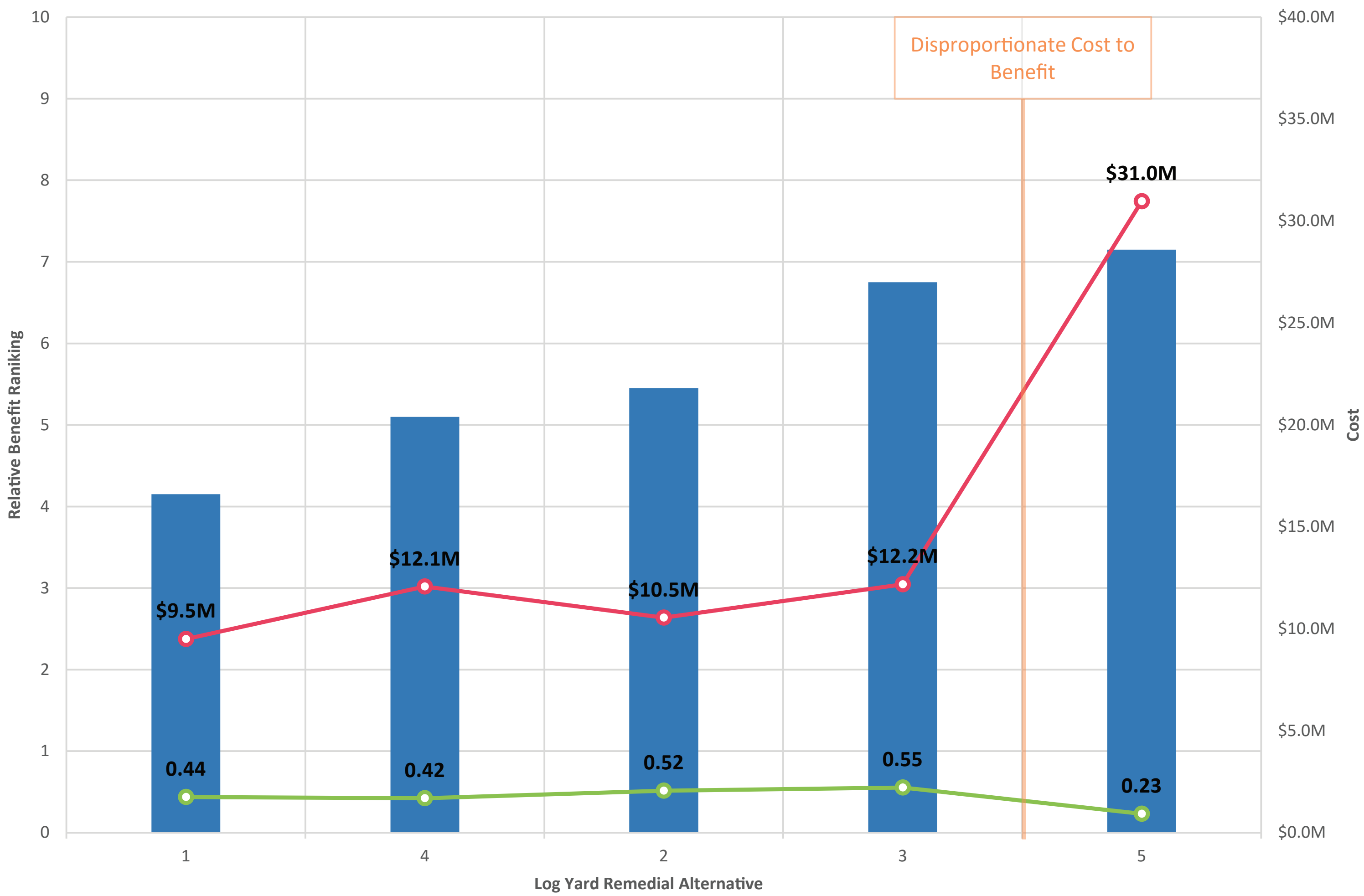

FIGURE 13

Log Yard Disproportionate Cost Analysis

Feasibility Study
Parcel 15
Tacoma, WA

LEGEND

- Relative Benefit Ranking
- Relative Benefit / Cost ($M)
- Estimated Cost

GSI Water Solutions, Inc.

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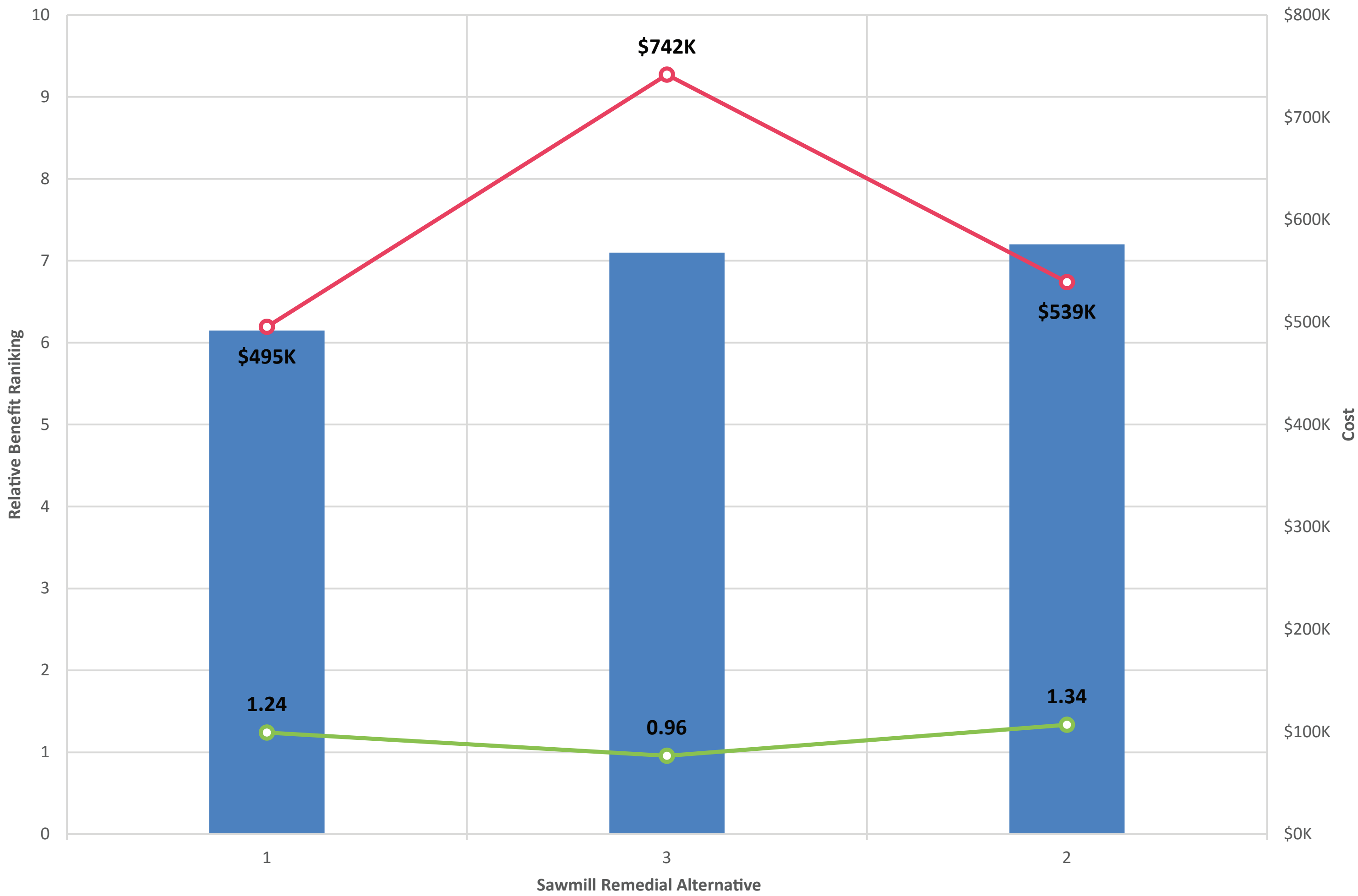

FIGURE 14

Sawmill Disproportionate Cost Analysis

Feasibility Study
Parcel 15
Tacoma, WA

LEGEND

- Relative Benefit Ranking
- Relative Benefit / Cost ($100K)
- Estimated Cost

GSI Water Solutions, Inc.

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APPENDIX A

Sawmill Natural Attenuation Modeling

This appendix describes additional evaluation performed to determine the estimated time to reach proposed cleanup levels via ongoing natural attenuation for pentachlorophenol (PCP) in the Sawmill area of Parcel 15 (the Site) in Tacoma, WA (Ecology Facility Site No. 1215/Cleanup Site No. 3642). The extent of contamination in the Sawmill, as identified in the Remedial Investigation Report (RI Report) is defined by the occurrences of constituents exceeding the proposed cleanup levels and is limited to well MW-2R because of its proximity to the eastern bank of Wapato Creek riverbank and the consistent detections that exceed cleanup levels (GSI and SSPA, 2017). Two other wells (MW-5R and MW-6R) also have periodic exceedances of PCP cleanup levels; however, the wells are located approximately 550 feet from Wapato Creek. Note that the nearshore wells (MW-1, MW-3, and B-5R) are downgradient of all former sources and have PCP concentrations of less than the 1 microgram per liter (µg/L) PCP cleanup level.

Although PCP-contaminated soil was removed from the former dip tank area at the Site in 2008, elevated PCP levels continue to be observed in the well, MW-2R, which is situated within the former excavation. PCP is subject to microbial degradation in groundwater, which can occur during either aerobic or anaerobic conditions. The fate and transport of PCP in groundwater is primarily influenced by the pH of the media. MW-2R also had elevated pH values ranging from 11.21 to 12.01, which are much greater than the more neutral pH values (of approximately 5.5 to 7.0) observed throughout the rest of the Site. Alkaline conditions in this range can inhibit biological activity and reduce PCP's adsorptive capacity, likely contributing to the localized PCP persistence. (GSI and SSP, 2017)

Using all recent and historical data, PCP concentrations in well MW-2R were modeled with a natural logarithmic decay function and using the Washington Department of Ecology's (Ecology) Toxic Cleanup Program's Natural Attenuation Analysis Tool Package for Petroleum-Contaminated Ground Water Washington Department of Ecology (Ecology, 2005). The complete dataset for MW-2R is provided in the RI Report, but is summarized for PCP in Table A-1.

Table A-1. Historical Pentachlorophenol Results in Groundwater

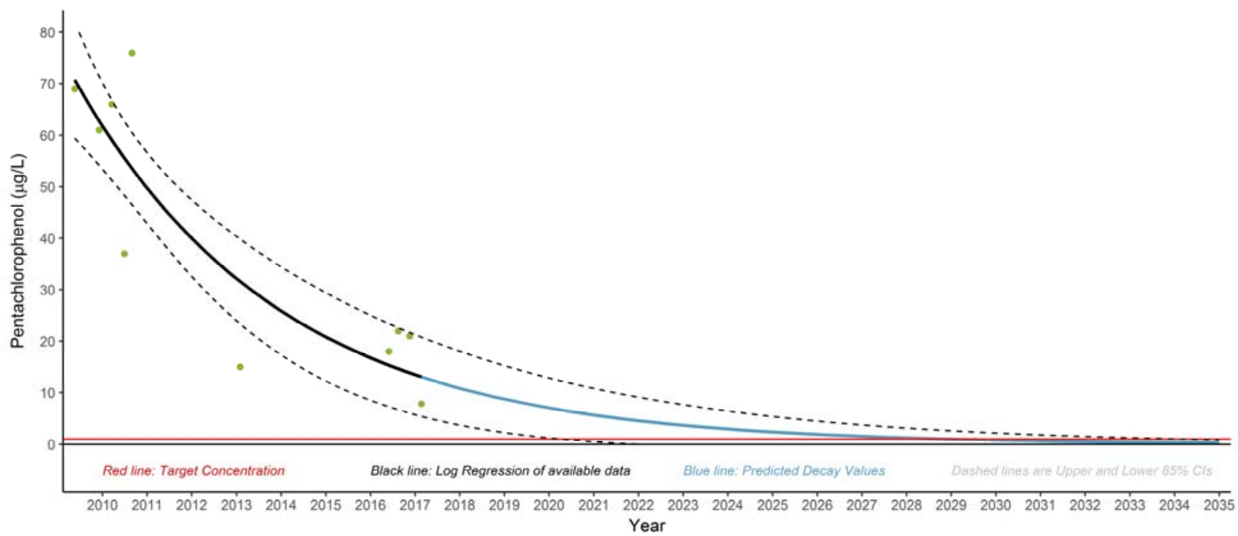
Location	Date	Pentachlorophenol (µg/L)
Groundwater		
MW-2R	5/19/2009	69
	12/4/2009	61
	3/17/2010	66
	6/30/2010	37
	8/30/2010	76
	1/31/2013	15
	5/31/2016	18
	8/15/2016	22
	11/17/2016	21
	2/20/2017	8

Notes:

µg/L= micrograms per liter

As indicated in Section 3 of the Feasibility Study (FS) Report, the proposed cleanup level for PCP is the practical quantitation limit or 1 µg/L (GSI, 2017). Using the decision criteria bounds or confidence limit of 85 percent (as suggested in Ecology's analysis tool) and the target cleanup level of 1 µg/L, the natural decay model indicates a range of 12 years (modeled) to 16 years (upper range) to reach proposed cleanup levels in well MW-2R (see Figure A-1). The model further indicates a half-life of approximately 3 years.

Figure A-1. Natural Decay Plot for PCP in MW-2R



PCP Concentrations at Site MW-2R

Note: Half-life is 3.19 years, calculated based on modeled decay constant

Using existing conditions as a point of comparison, the reduced time in Alternatives 1 and 2 (FS Report) to achieve cleanup levels was approximated using professional judgment. Alternative 1 proposes excavation and groundwater treatment; it is assumed through mass removal that the remaining residual contamination would be reduced to cleanup levels. Given that this alternative includes confirmation monitoring and contingency post-remediation attenuation of remaining PCP, Alternative 1 is estimated to reach cleanup levels in 4 to 6 years. Alternative 2 proposes to enhance natural attenuation through the use of in situ amendments to neutralize pH and generate more favorable conditions for biodegradation of PCP. Assuming these conditions are achieved, the time to reach cleanup levels would be reduced by half or approximately 6 to 8 years with a corresponding half-life of approximately 1.5 years. Within a neutral pH range, under aerobic or anaerobic conditions, PCP has been observed to degrade with a half-life of less than 1 year (EPA, 2008).

References

Ecology. 2005. Package A: Natural Attenuation Analysis Tool Package for Petroleum-Contaminated Ground Water. Version 1.0. Washington Department of Ecology (Ecology). July.

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APPENDIX B

Log Yard Cap Alternative Evaluation

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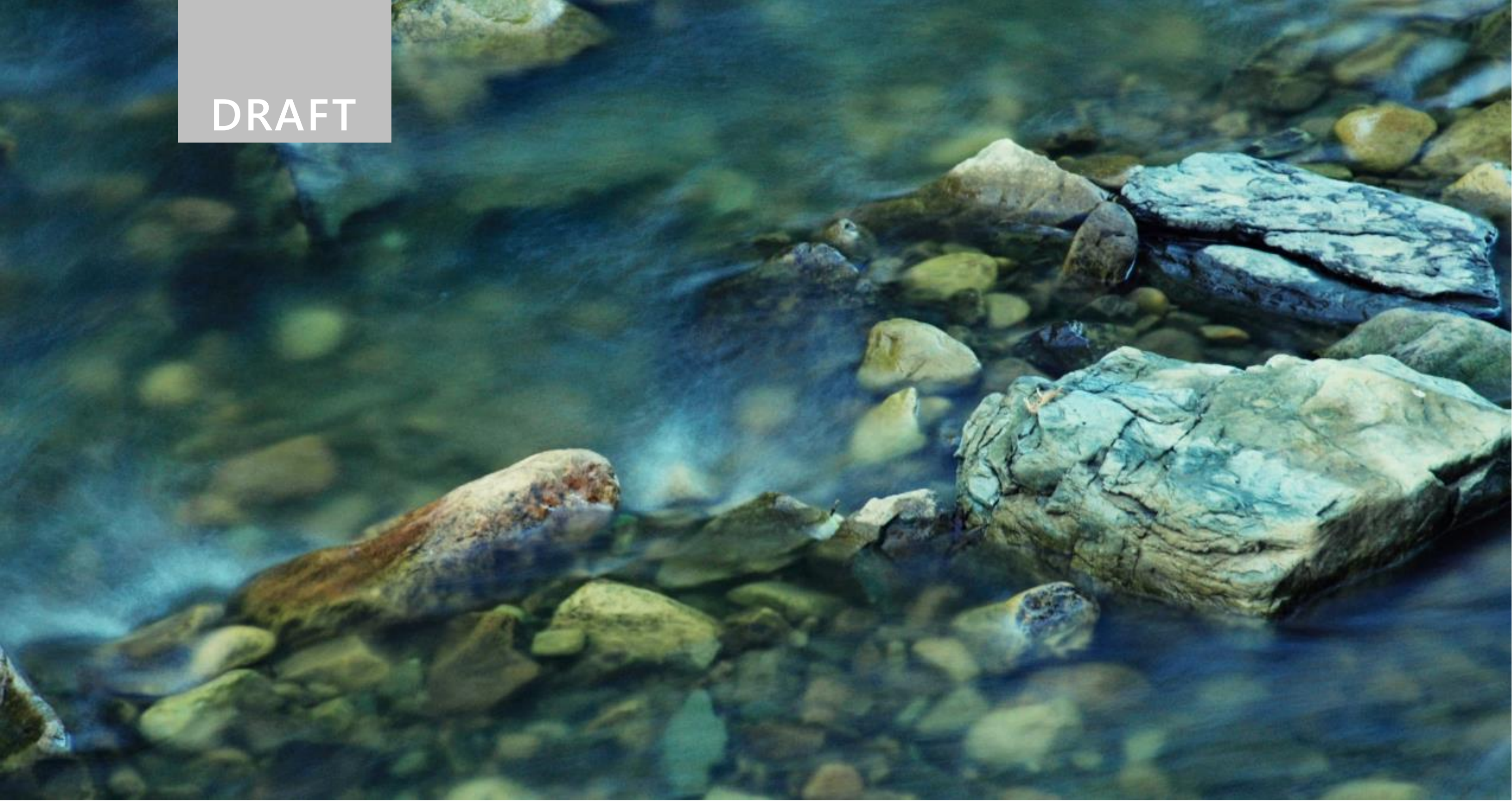

November 2017
Portac Log Yard Site

Groundwater Evaluation of Capping Alternatives

Prepared for
Portac, Inc.
Port of Tacoma

DRAFT

November 2017
Portac Log Yard Site

Groundwater Evaluation of Capping Alternatives

Prepared for
Portac, Inc.
Port of Tacoma

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ABBREVIATIONS

cm/s	centimeters per second
ft/day	feet per day
ft^2	square foot
gal/day	gallons per day
gal/yr	gallons per year
$gal/yr/ft^3$	gallons per year per cubic foot
GCL	geosynthetic clay layer
HELP	Hydrologic Evaluation of Landfill Performance
HMA	hot-mixed asphalt
in/yr	inches per year
MLLW	mean lower low water
PRB	permeable reactive barrier
RCC	roller-compacted concrete

1 Introduction

This report evaluates three capping alternatives for the Log Yard at the Parcel 15 (Former Portac, Inc.) site based on their impact on groundwater hydraulics. The groundwater impact of the three capping alternatives are compared with current condition.

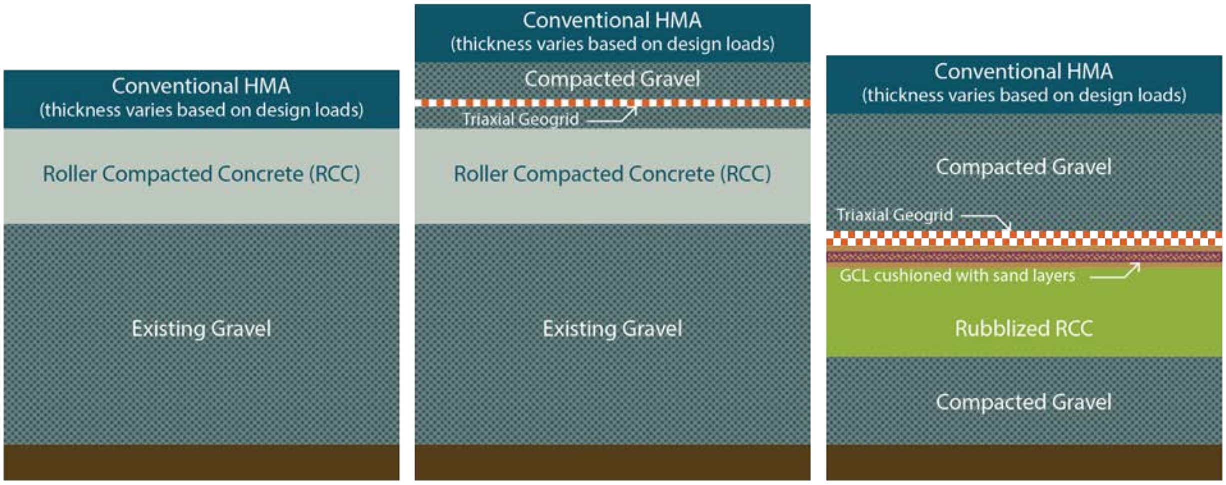
Previous investigation work indicated that perched groundwater is present beneath portions of the Log Yard cap, presumably as a result of rainwater percolating through the existing cap and being restricted by low-permeability material above the groundwater table.

The continued presence of the perched water zone is significant, because it contains the highest concentrations of arsenic noted in site groundwaters. As perched groundwater infiltrates through the low-permeability unit, it transports arsenic to the underlying groundwater. That groundwater ultimately discharges to the Wapato Creek. Though attenuation processes have been shown to be controlling lateral migration of groundwater arsenic, the reduction of perched water generation within the arsenic-contaminated areas is desirable to optimize groundwater source control and reduce the potential for contaminant migration to occur in the future.

The current cap in the Log Yard consists of roller-compacted concrete (RCC) installed in 1989. Thermal and settlement cracking of the RCC has occurred over time, and these cracks have been addressed with cap inspections, crack sealing, and in some areas thin asphalt overlays.

As part of the Feasibility Study, three different capping alternatives are being evaluated for their ability to reduce the rainwater infiltration rate through the cap. The goals of this reduction are to reduce or eliminate the presence of perched water with elevated arsenic concentrations, and also reduce the flux of groundwater toward Wapato Creek. Capping alternatives under evaluation in the Feasibility Study are shown on Figure 1.

Figure 1
Overview of Cap Alternatives



Alternatives 1 and 4:
Refurbish Existing Cap
Asphalt over existing cap

Alternative 2:
Enhance Existing Cap
Asphalt over compacted gravel and geogrid to minimize cracking

Alternative 3:
Reduce Cap Permeability
Geosynthetic clay layer (GCL) covered by asphalt and geogrid reinforced gravel

The work described in this report uses groundwater modeling and a cap simulation model to quantitatively evaluate potential performance of the cap alternatives against existing conditions. Goals of the work included the following:

- Estimate capping performance using a hydrologic model designed for this purpose.
- Quantify current and potential future rainwater percolation rates within the Log Yard capping area.
- Evaluate how changes to the percolation rates affect groundwater discharge rates to Wapato Creek.
- Document key parameters useful for estimating performance of a contingent permeable reactive barrier (PRB), including hydraulic residence time within the PRB and the quantity of water treated by the PRB under the different capping scenarios.

2 Hydrologic Modeling of Capping Alternatives

When properly designed for site-specific conditions, physical barriers are effective and reliable methods for preventing direct contact exposures and migration or erosion of impacted solid media. Long-term physical barrier integrity can be ensured through implementation of appropriate institutional controls and routine inspection and maintenance. The ability of a physical barrier to reduce the potential for groundwater impacts is dependent on the design of the barrier—the main purpose being the reduction in infiltration of surface water through the isolated media. This is achieved through a balance of surface water conveyance (i.e., runoff) at the top of the barrier, water percolation or evaporation within the barrier, lateral water conveyance (i.e., drainage) within the barrier, and infiltration retardation (i.e., permeability reduction) at the base of the barrier. To evaluate the effectiveness of a range of physical barrier process options, a preliminary quantitative analysis was performed to evaluate the relative performance of the three cap alternatives shown on Figure 1.

The quantitative analysis was performed using the Hydrologic Evaluation of Landfill Performance (HELP) model. Developed by the U.S. Army Corps of Engineer Waterways Experiment Station, the HELP computer program is a quasi-two-dimensional hydrologic model of water movement across, into, through, and out of landfills (Schroeder et al. 1994). It accepts weather, soil, and design data and uses solution techniques to calculate items such as runoff volume (which is a function of material and slope), material permeability (*k*; saturated and unsaturated), and evaporation rate. Landfill systems with several types of designs may be modeled. The primary purpose of the model is to assist in the comparison of landfill design alternatives.

The HELP weather generator module was used to simulate two categories of rainfall events: 1) annual accumulations simulated over a theoretical 100-year period; and 2) during the 25-year, 24-hour design return period event (3.5 inches). For the 100-year simulation, precipitation data from the nearest representative observation location (Olympia, Washington, which has a slightly higher average annual precipitation than Tacoma) was input to the HELP model to develop a rainfall record. The single year from the standard Olympia simulation that most closely represented the average annual rainfall in Tacoma was then manually modified to include the 25-year, 24-hour precipitation event.[1] This type of event is predicted to occur once every 25 years on average; in any given year, the probability of occurrence is 4%. Details of the analyses, including input parameters and summary results produced by the HELP model, are presented in Attachments 1 and 2.

Table 1 summarizes the total rainfall and average predicted cap infiltration for the existing site conditions (i.e., base case) and the three cap types during the 25-year return period event. The purpose of this evaluation was to provide a relative assessment of the performance of each cap's

[1] The 25-year, 24-hour precipitation event was obtained from the 2016 City of Tacoma *Stormwater Management Manual* (City of Tacoma 2016).

performance that could also be integrated into the groundwater model discussed in subsequent sections of this report. The results indicate that a marginal reduction of infiltration through the cap (i.e., precipitation infiltration through the cap layers into the groundwater) would be achieved with Alternatives 1/4 and 2 in comparison to the base case. The base case cap hydraulic conductivity was selected based on the percolation calculations that are representative of existing site conditions (see Section 3.3.4 discussion). Marginal increases were modeled for Alternatives 1/4 and 2 to account for the improvements and increased maintenance that cap will undergo under those alternatives. As expected, the greatest infiltration reduction is provided from Alternative 3, which includes a very low-permeability geosynthetic clay layer (GCL).

Table 1
Summary of Comparative Cap Performance Evaluation using HELP Model Results

	Annual Precipitation (inches/year)	Infiltration Through Cap (gallons/year)	Infiltration Through Cap (percent of precipitation)	Effective Hydraulic Conductivity of Cap (cm/s)
Base Case	40.31	1,969,611	6.1%	$1x10^{-6}$
Alternative 1 and 4 – Refurbish Existing		1,405,604	4.4%	$5x10^{-7}$
Alternative 2 – Enhance Existing		778,047	2.4%	$1x10^{-7}$
Alternative 3 – Reduce Permeability		27,362	0.1%	$3x10^{-9}$

Note:
1. Average annual precipitation for Tacoma, Washington. Simulation included the 25-year, 24-hour precipitation event.

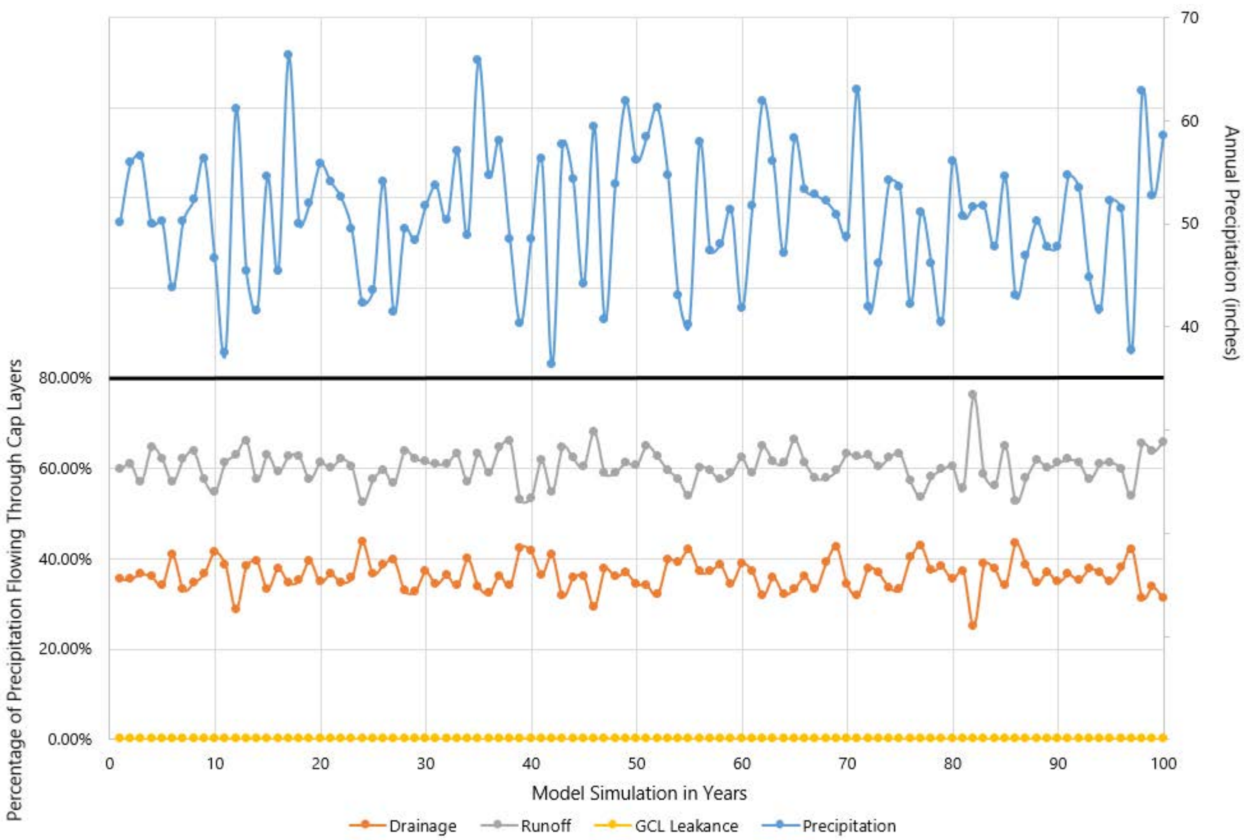
To further assess the expected performance of the proposed Alternative 3 cap, the HELP model was run using a 100-year precipitation record based on data from Olympia, Washington. As shown on the top graph on Figure 2, the average annual precipitation record includes several years with precipitation much higher than the average Tacoma record. Running the model was therefore assumed to be sufficient to account for uncertainty with respect to cap performance and potential future impacts associated with climate change.

The lower graph on Figure 2 depicts the water balance among the various cap layers, described as follows:

- The upper surface of the cap will be designed and constructed to consistently promote runoff of approximately 60% of the water that encounters the cap.
- Other mechanisms, such as evaporation (no indicated on Figure 2), will occur within the cap.

- The subsurface drainage layers located immediately above the GCL will capture and convey an additional 36% of water away from the cap area.
- The resulting infiltration through the GCL is predicted to be consistently less than 0.5%, even during high precipitation years and storm events.

Figure 2
100-year Simulation of Alternative 3 Cap Performance



3 Groundwater Modeling

3.1 Geologic Conceptual Model

The conceptual model for the formation and flow of perched groundwater is described as follows (Figure 3; modified from Todd and Mays 2004):

- Rainwater percolates through cracks in the asphalt and RCC in the Log Yard.
- Percolated water travels downward in the unsaturated zone until its vertical migration is restricted by a low-permeability restricting layer above the groundwater table. When there are cracks in the stormwater collection system, some percolated water travels laterally and discharges into the stormwater collection system as seeps. Under future conditions when the cracks in the stormwater collection system are sealed, percolated water only travels downward.
- Percolated water accumulates above the low-permeability unit, and forms the perched zone. Perched groundwater infiltrates through the restricting layer and discharges to underlying groundwater. As the height of perched groundwater increases, infiltration through the restricting layer increases.
- When the rate of percolation from ground surface and rate of infiltration through the restricting layer reaches an equilibrium, the height of perched groundwater above the restricting layer reaches steady-state.
- When the rate of percolation from ground surface is reduced, there is a net outflow from the perched zone. As a result, the height of perched groundwater decreases until a new equilibrium is reached. The height of perched groundwater under the new equilibrium depends on the reduced percolation rate.

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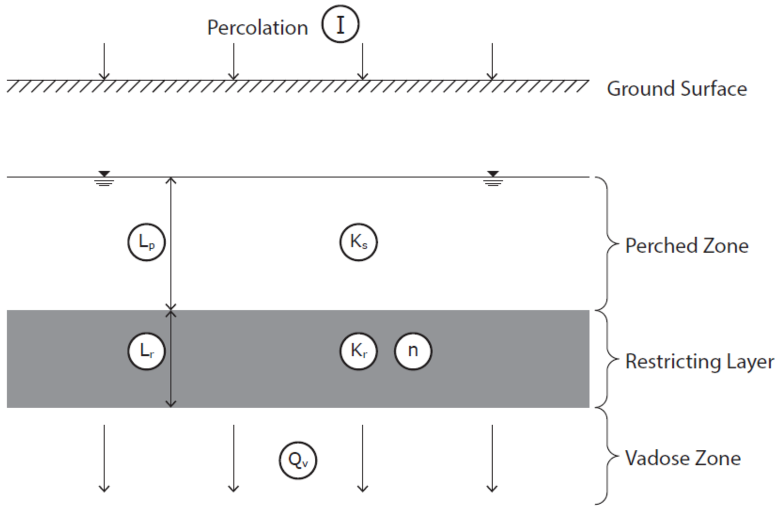
Figure 3
Conceptual Model for Perched Groundwater Flow (modified from Todd and Mays 2004)



3.2 Methodology and Model Parameters

The method of groundwater evaluation is to use analytical solutions to groundwater flow equations based on the above conceptual model.

Model parameters include top elevation of restricting layer, thickness of restricting layer, effective porosity of restricting layer, and vertical hydraulic conductivity (K) of restricting layer.

3.2.1 Elevation and Thickness of Restriction Layer

The top elevation and thickness of the restricting layer in the study area are estimated from the boring logs for wells MW-10 and MW-13, as presented in Table 2. The average top elevation of the restricting layer is 13.0 feet. The average thickness of the restricting layer is 2.75 feet.

Table 2
Elevation and Thickness of Restricting Layer

Elevation/Thickness	MW-10	MW-13	Average
Top Elevation of Silt (feet MLLW)	13.5	12.5	13.0
Bottom Elevation of Silt (feet MLLW)	10.5	10.0	10.25
Thickness of Silt (feet)	3.0	2.5	2.75

3.2.2 Effective Porosity of Restriction Layer

The effective porosity is assumed to be 0.20.

3.2.3 *Vertical K of Restricting Layer*

The vertical K of the restricting layer is estimated by matching the simulated perched water levels with observed data within the first 3 years of installation of the current cap. After the current cap was installed in March 1989, percolation of rainwater was reduced to nearly zero while perched water continued to infiltrate through the restricting layer. As a result, the height of perched groundwater began to decline. The rate of perched water level decline is a function of the vertical K and effective porosity of the restricting layer.

The perched water level is simulated using a one-dimensional solution to groundwater flow equation. Actual flow patterns are likely more complex due to variability of soil stratigraphy within the site, and the release of some of the perched water via leakage into the existing storm drains. However, the one-dimensional flow assumption can be used to approximate site conditions and estimate groundwater recharge and flow rates. Under the one-dimensional assumption, when there is no inflow to the domain, the rate of perched water level decline is related to vertical specific discharge and effective porosity by Equations 1 and 2:

Equation 1

$$\frac{dL}{dt} = -\frac{q_v}{n}$$

Equation 2

$$\frac{dL}{dt} = -\left(\frac{L}{L_r} + 1\right) \times \frac{K_r}{n}$$

Initial condition: $L = L_0$ at $t = 0$

where:

q_v	=	vertical specific discharge
L	=	height of perched water above top elevation of restricting layer
L_0	=	height of perched water at the time of capping (i.e., $t = 0$)
t	=	time since cap installation
L_r	=	thickness of restricting layer
K_r	=	vertical hydraulic conductivity of restricting layer
n	=	effective porosity of restricting layer

The term $\left(\frac{L}{L_r}+1\right)$ is the vertical hydraulic gradient across the restricting layer. Strictly speaking, the vertical hydraulic gradient should also include the suction head by the coarse-grained alluvium below the restricting layer. However, because the suction head for coarse-grained alluvium is relatively small (e.g., 2 to 8 inches of head depending on grain size; Bouwer et al. 1999), it is omitted in Equation 2 for simplicity.

Integrating Equation 2 and rearrangement yields Equation 3.

Equation 3

$$L = (L_0 + L_r)e^{\frac{-K_r \times t}{n * L_r}} - L_r$$

The height of perched water calculated using Equation 3 for various time is compared with the observed data between September 1989 and April 1992 (Hart Crowser 1992). The initial height of water (L_0) and vertical K (K_r) are adjusted to achieve the best fit to observed data. An L_0 of 6 feet and K_r of 2x10^{-7} centimeters per second (cm/s) or 5x10^{-4} feet per day (ft/day) provide the best fit to the observed data (Figure 4). Therefore, K_r of 2x10^{-7} cm/s is carried forward in subsequent evaluations.

The curve-matching on Figure 4 is able to approximate the value of K_r within an order of magnitude with the available data. An order of magnitude change from the estimated value of 2x10^{-7} cm/s would have made the slope of the model curve substantially steeper or flatter. Limitations of available data preclude refining assumptions regarding one-dimensional flow and the assumption of no inflow during the 1989 to 1992 period precludes achieving a reliable match to individual data points. For example, some thermal cracking of the RCC may have resulted in percolation of some rainwater, which could have contributed to the plateauing of perched water height after the first year.

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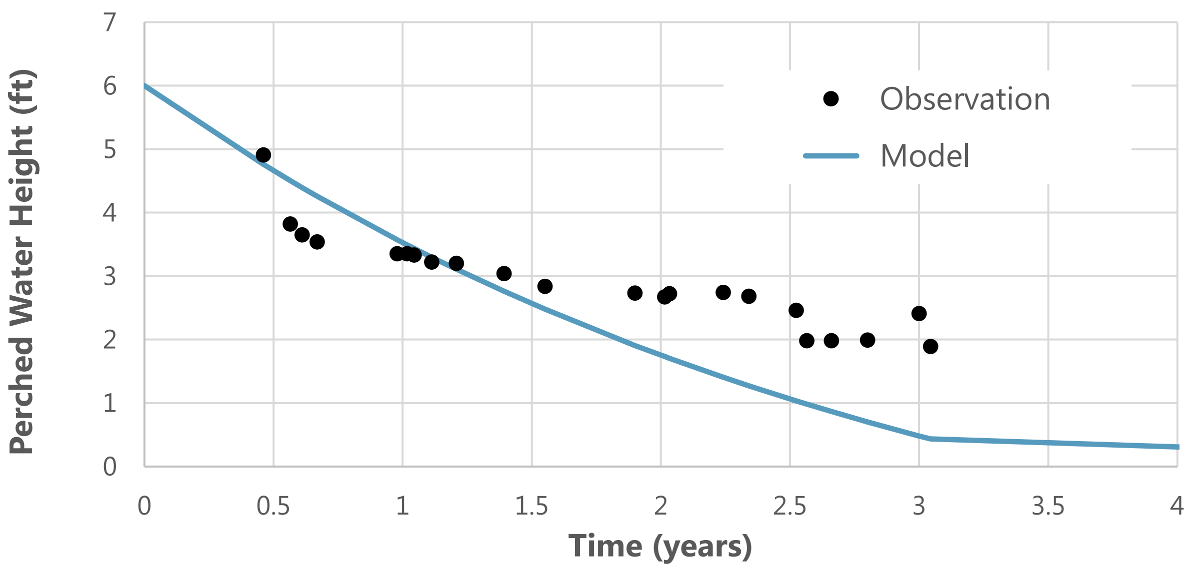
Figure 4
Match between Modeled and Observed Perched Water Height



3.3 Estimate of Percolation Rates

Estimation of the percolation rate under current condition is described in this section. Percolation rates under capping alternatives are simulated using the HELP model (see above Hydrologic Modeling section).

Percolation through the existing cap in the Log Yard has two destinations. It either seeps into the stormwater collection system or flows vertically into the perched zone (and ultimately discharges to groundwater). The two components are estimated separately below.

3.3.1 Estimate of Percolation that Becomes Stormwater Drain Seepage

Percolation that becomes stormwater drain seepage is approximated by the measured flow in the stormwater system under the dry weather condition of 1 gallon per minute, which is 1,440 gallons per day (gal/day) or 525,000 gallons per year (gal/yr).

3.3.2 Estimate of Percolation that Becomes Infiltration to Groundwater

Groundwater monitoring data suggest that there are likely more than one perched zones within the Log Yard. The groundwater evaluation focuses on a "modeling study area" that covers the north-south length of the Log Yard along the Wapato Creek and is of the west-east width of 400 feet, as shown on Figure 5. The evaluation results for the modeling study area are then extrapolated to the whole Log Yard.

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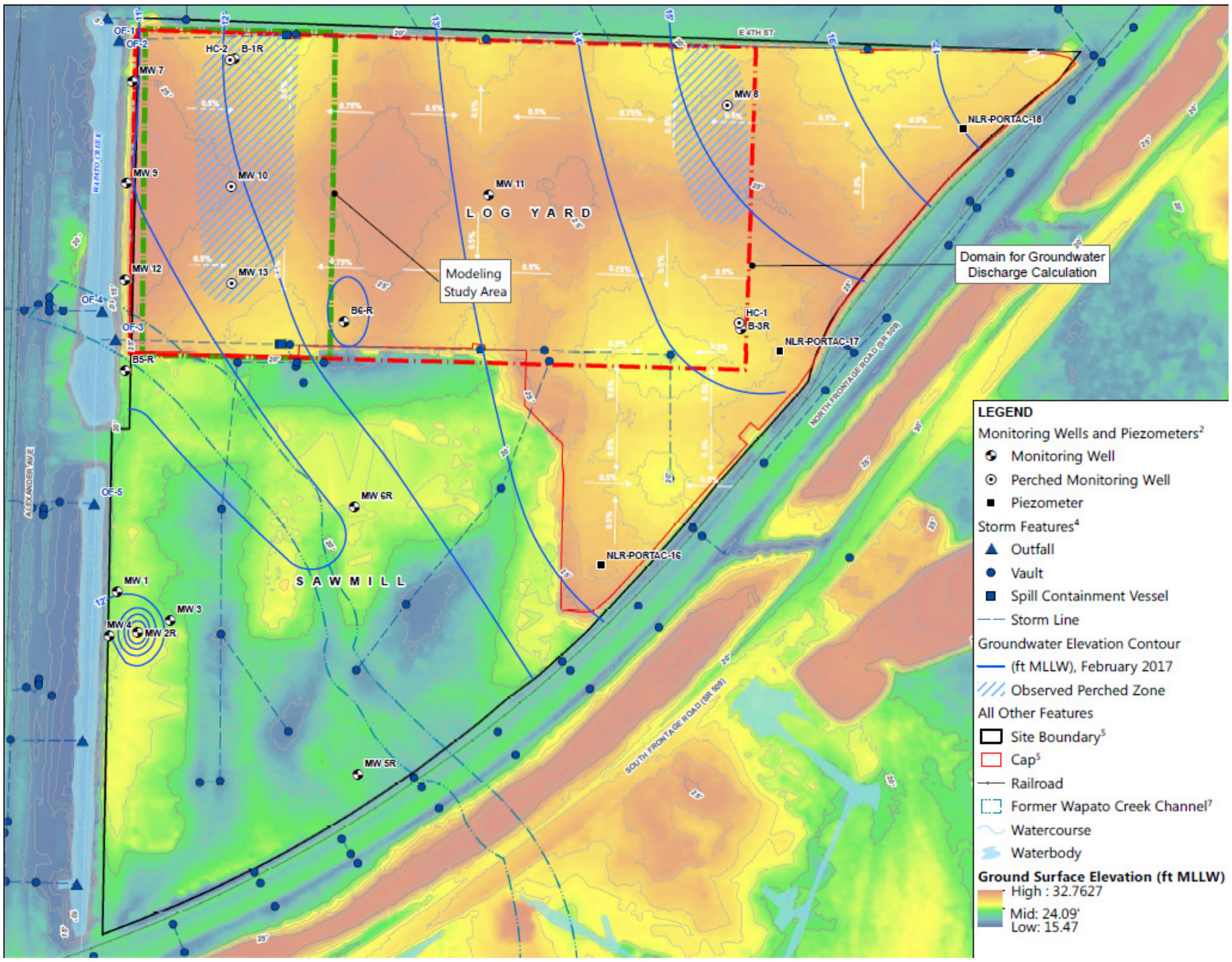
It is assumed that percolation within the modeling study area only occurs over a perched zone, instead of all of the study area. The perched zone within the study area is assumed to have the same north-south length as the study area, but is half the width in the west-east direction (i.e., 200 feet). Based on topography, the perched zone corresponds to a topographically low area that receives runoff from the west and east before directing it toward the catch basins to the north and south.

Figure 5
Groundwater Modeling Domain (modified from GSI 2017)



3.3.3 *Estimate of Percolation Rate Within Study Area*

Because recent monitoring data suggest that the height of perched water is stable in the study area, it is assumed that the perched zone under the study area is in steady state. Therefore, infiltration rate is equal to percolation rate through the restricting layer.

Percolation through the restricting layer is estimated with a one-dimension solution. Vertical flow through the saturated portion of the fill and the restricting layer can be calculated based on Darcy's Law using a vertical hydraulic gradient of 1, as shown in Equation 4.

Equation 4

$$I = \frac{L_p + L_r}{\frac{L_p}{K_s} + \frac{L_r}{K_r}}$$

where:

I	=	infiltration rate over perched zone
L_p	=	height of perched groundwater above the top of restricting layer
K_s	=	vertical K of fill

Equation 4 is the same equation as Equation 13.5.1 in *Groundwater Hydrolog*y (Todd and Mays 2004). Because the vertical K for the fill is much higher than that for the restricting layer, Equation 4 is simplified to Equation 5.

Equation 5

$$I = (\frac{L_p}{L_r} + 1)K_r$$

Based on perched zone water level data collected in 2016 to 2017 (Table 3), the average perched groundwater elevation is 16.4 feet mean lower low water (MLLW). Because the top elevation of the restricting layer is 13.0 feet MLLW (Table 2), the height of perched groundwater (L_p) is 3.4 feet. Using the K_r estimated from above ($2x10^{-7}$ cm/s), the infiltration rate over the perched zone is $1.1x10^{-3}$ ft/day or 4.9 inches per year (in/yr). Based on the infiltration rate and the area of perched zone (700 feet x 200 feet = 140,000 square feet [ft^2]), the percolation within the study area is 1,170 gal/day or 427,000 gal/yr.

Table 3
Elevation of Perched Groundwater Under Current Condition

Perched Zone Well	May 2016	August 2016	November 2016	February 2017
HC-2	16.8	16.2	16.0	16.3
MW-10	15.4	15.9	16.4	17.2

Perched Zone Well	May 2016	August 2016	November 2016	February 2017
MW-13	16.6	16.1	16.5	17.3

Note:
Elevations are in feet MLLW.

The area of the modeling study is 700 feet x 400 feet = 280,000 ft^2 or 6 acres. For the modeling study area, the percolation rate per unit area (whether within or outside perched zone) is 182 gal/day/acre. The area-weighted percolation rate is 2.5 in/yr, which is equivalent to 6% of annual precipitation of 40 in/yr (GSI 2017).

3.3.4 Estimate of Percolation Rate Within the Log Yard

Percolation that becomes infiltration to groundwater within the Log Yard is estimated through proportionating by area. Using percolation per unit area (182 gal/day/acre) and a total Log Yard area of 29.5 acres, this component is estimated to be 5,374 gal/day (1,962,000 gal/yr).

The assumption for this calculation is that the rest of the Log Yard has similar percolation characteristics as the study area. Actual percolation may vary by area due to differences in cap condition and soil condition.

3.4 Estimate of Groundwater Discharge Rates to Wapato Creek

Groundwater discharge to Wapato Creek is conceptualized as two-dimensional flow. Ambient groundwater in alluvium is assumed to flow from east to west for simplicity. The upper portion of ambient groundwater discharges to the Wapato Creek. The lower portion of ambient groundwater bypasses the Wapato Creek and discharges to the Blair Waterway. Perched water infiltrates across the restricting layer into the upper portion of groundwater, which discharges to the Wapato Creek.

The assumptions for the calculations include the following:

- Groundwater flow is from east to west.
- Hydraulic property is spatially uniform.
- A restricting layer of uniform thickness separates the perched zone from the alluvium.
- The only sink for perched water is vertical percolation to the alluvium. In other words, there is no horizontal discharge to the Wapato Creek from the perched zone.

Based on the conceptual model and assumptions, groundwater discharge to the creek is calculated as the sum of two components: horizontal flow of ambient groundwater, and percolated water from perched zone that reaches the alluvium. Ambient groundwater discharge is the same regardless of capping alternatives. Groundwater discharge due to percolation of perched water varies with capping alternatives.

The conceptualization of groundwater discharge as two-dimensional flow may overestimate groundwater discharge to Wapato Creek. Because the restricting layer extends the full depth of some of the exploratory borings, the alluvial aquifer may be missing in the northern portions of the Log Yard. Therefore, the groundwater discharge in the northern portions of the Log Yard may be lower than the estimates based on two-dimensional flow. However, the magnitude of uncertainty introduced by the two-dimensional conceptualization is smaller than other uncertainties such as hydraulic conductivity.

3.4.1 Groundwater Discharge Rate due to Ambient Groundwater Flow

Ambient groundwater discharge is calculated using Darcy's Law, as shown in Equation 6.

Equation 6

$$q_a = K_a \times i$$

where:

q_a	=	Darcy flux of ambient groundwater discharge
K_a	=	horizontal hydraulic conductivity of alluvium
i	=	ambient horizontal hydraulic gradient

The alluvium is described as silty sand. The mid-range of literature values (Freeze and Cherry 1979; Fetter 2004) of $1\text{x}10^{-4}$ cm/s (0.3 ft/day) is used. Horizontal hydraulic gradient is calculated as between 0.003 and 0.004 using water level data for wells MW-11, MW-7, and B-1R. An upper-range value of 0.004 is used in the calculation. Equation 6 yields a Darcy flux of $1.1\text{x}10^{-3}$ ft/day.

The volumetric flux of groundwater is calculated as follows in Equation 7:

Equation 7

$$Q_a = q_a \times L \times b$$

where:

Q_a	=	volumetric ambient groundwater discharge
L	=	north-south length of discharge area
b	=	saturated thickness of discharge zone

The north-south length of the area where groundwater discharge occurs is 700 feet. The bottom elevation of discharge zone is assumed to be 0 feet MLLW, which is approximately 5 feet below the bottom of the creek. Because the top of alluvium is at 10 feet MLLW, the saturated thickness of the discharge zone is 10 feet. Equation 7 yields a volumetric flux of 59 gal/day. This estimate agrees with similar calculations in the past (Hart Crowser 1988), which estimated the average ambient groundwater discharge as 56 gal/day.

3.4.2 Groundwater Discharge Rate Due to Percolation of Perched Groundwater

Vertical Darcy flux of perched water is converted into horizontal Darcy flux using Equation 8.

Equation 8

$$q_p = q_v \times \frac{W}{b}$$

where:

q_p	=	horizontal Darcy flux due to perched water
q_v	=	vertical Darcy flux of perched groundwater
W	=	west-east width of Log Yard

For the purpose of estimating groundwater discharge to the Wapato Creek, the west-east width of Log Yard (W) is approximately 1,300 feet (Figure 5). The saturated thickness of discharge zone (b) is 10 feet. For the current condition, the area-weighted percolation rate (q_v) is 2.5 in/yr. For the three capping alternatives, vertical Darcy flux of perched groundwater (q_v) is obtained from HELP modeling (see above Hydrologic Modeling section).

3.4.3 Groundwater Discharge Rate to Wapato Creek

The groundwater Darcy flux to Wapato Creek is calculated using Equation 9.

Equation 9

$$q = q_a + q_p$$

where:

q	=	Darcy flux to Wapato Creek

The combined volumetric groundwater discharge rate is calculated using Equation 10.

Equation 10

$$Q = q \times L \times b$$

where:

Q = volumetric groundwater discharge to Wapato Creek

The calculations of groundwater discharge for the current condition and the three capping alternatives are presented in Table 4.

Table 4
Groundwater Discharge Rate

Scenario	Gal/day	Gal/yr
Current Condition	3,900	1,400,000
Alternative 1 Cap	2,800	1,000,000
Alternative 2 Cap	1,600	580,000
Alternative 3 Cap	150	55,000

3.5 Estimate of Permeable Reactive Barrier Design Parameters

PRB design parameters include hydraulic residence time and treatment medium loading rate, as summarized in Table 5.

Hydraulic residence time is calculated using Equation 11.

Equation 11

$$t_r = \frac{T_{PRB} \times \theta}{q}$$

where:

t_r = hydraulic residence time
T_{PRB} = thickness of PRB, assumed to be 3 feet
q = Darcy flux to Wapato Creek
θ = PRB porosity, assumed to be 0.25

Reactive medium loading rate is calculated using Equation 12.

Equation 12

$$L_{PRB} = \frac{Q}{T_{PRB} \times W_{PRB} \times B \times (1 - \theta)}$$

where:

L_{PRB} = Loading rate of treatment medium

W_{PRB} = width of PRB, equal to 678 feet

B = effective depth of treatment medium, assumed to be 10 feet

Table 5
PRB Design Parameters

Scenario	Hydraulic Residence Time (days)	Treatment Medium Loading Rate (gal/yr/ft^3)
Current Condition	10	93
Alternative 1 Cap	14	68
Alternative 2 Cap	25	38
Alternative 3 Cap	261	4

4 Summary of Groundwater Modeling

The three capping alternatives provide various degrees of reduction in percolation rate and, consequently, in groundwater discharge rate to the Wapato Creek compared with the current condition, as summarized in Table 6.

Table 6
Summary of Groundwater Evaluation of Capping Alternatives

Scenario	Infiltration Rate Through Cap (percent precipitation)	Percent Reduction in Infiltration Rate
Current Condition	6.1%	--
Alternative 1 Cap	4.4%	28%
Alternative 2 Cap	2.4%	60%
Alternative 3 Cap	0.1%	98%

Note:
Reduction percentage is based on current condition as 100%.

5 References

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Todd, D. K. and L. W. Mays, 2004. *Groundwater Hydrology*, 3rd Edition. Hobokon, New Jersey: Wiley.

Attachment 1
HELP Model Documentation for 100-Year Simulation

Attachment 1 – 100-year Simulation
Project : Portac_Final Alts

Cap design options for former log yard at Portac site, Tacoma, WA

Alt1: 4 in. HMA; 13 in. RCC (intact); 30 in. gravel

Alt2: 5 in. HMA; 6-32 in. gravel w/ TxGG; 13 in. RCC (intact); 30 in. gravel

Alt3: 5 in. HMA; 8-34 in. gravel w/ TxGG; 4 in. sand &

Model : HELP
An US EPA model for predicting landfill hydrologic processes and testing of effectiveness of landfill designs

Author : Kim Slack/Rebecca Gardner

Client : Portac – Parcel 15

Location : Tacoma, WA

10/15/2017

1. Profile. Option 3 - HMA over GCL

Model Settings

[HELP] Case Settings

Parameter	Value	Units
Initial Moisture Settings	User specified	(-)
Runoff Method	User modified	(-)

[HELP] Surface Water Settings

Parameter	Value	Units
Runoff Area	100	(%%)
Initial Surface Water	0	(ft)
Runoff Curve Number	98	(-)

Profile Structure

Layer	Top (ft)	Bottom (ft)	Thickness (ft)
Dummy gravel layer	0.0000	-0.0100	0.0100
HMA	-0.0040	-5.0040	5.0000
Class 2 Agg Base	-4.9980	-12.9980	8.0000
Bentonite mat	-12.9920	-15.3542	2.3622
Gravel Base	-15.3477	-37.3477	22.0000

1.1. Layer. Dummy gravel layer

Top Slope Length: 2400.0000
Bottom Slope Length: 2400.0000
Top Slope: 1.0000
Bottom Slope : 1.0000

[HELP] Lateral Drainage Layer Parameters

Parameter	Value	Units
total porosity	1.0	(vol/vol)
field capacity	0.032	(vol/vol)
wilting point	0.013	(vol/vol)
sat.hydr.conductivity	0.3	(cm/sec)
subsurface inflow	0	(mm/year)
Initial moisture content	0.03	(vol/vol)

1.2. Layer. HMA

Top Slope Length: 2400.0000
Bottom Slope Length: 2400.0000
Top Slope: 1.0000
Bottom Slope : 1.0000

[HELP] Barrier Soil Liner Parameters

Parameter	Value	Units
total porosity	0.05	(vol/vol)
field capacity	0.01	(vol/vol)
wilting point	0.01	(vol/vol)
sat.hydr.conductivity	1E-5	(cm/sec)
subsurface inflow	0	(mm/year)

1.3. Layer. Class 2 Agg Base

Top Slope Length: 2400.0000
Bottom Slope Length: 2400.0000
Top Slope: 1.0000
Bottom Slope : 1.0000

[HELP] Lateral Drainage Layer Parameters

Parameter	Value	Units
total porosity	0.397	(vol/vol)
field capacity	0.032	(vol/vol)
wilting point	0.013	(vol/vol)
sat.hydr.conductivity	0.3	(cm/sec)
subsurface inflow	0	(mm/year)
Initial moisture content	0.03	(vol/vol)

1.4. Layer. Bentonite mat

Top Slope Length: 2400.0000
Bottom Slope Length: 2400.0000
Top Slope: 1.0000
Bottom Slope : 1.0000

[HELP] Geomembrane Liner Parameters

Parameter	Value	Units
sat.hydr.conductivity	3E-9	(cm/sec)
pinhole density	0	(#/acre)
installation defects	0	(#/acre)
placement quality	5	(-)
geotextile transmissivity	0	(cm2/sec)

1.5. Layer. Gravel Base

Top Slope Length: 2400.0000
Bottom Slope Length: 2400.0000
Top Slope: 1.0000
Bottom Slope : 1.0000

[HELP] Lateral Drainage Layer Parameters

Parameter	Value	Units
total porosity	0.397	(vol/vol)
field capacity	0.032	(vol/vol)
wilting point	0.013	(vol/vol)
sat.hydr.conductivity	0.3	(cm/sec)
subsurface inflow	0	(mm/year)
Initial moisture content	0.03	(vol/vol)

2. Profile. Option 2 - HMA/TxGG over existing

Model Settings

[HELP] Case Settings

Parameter	Value	Units
Initial Moisture Settings	User specified	(-)
Runoff Method	User modified	(-)

[HELP] Surface Water Settings

Parameter	Value	Units
Runoff Area	100	(%%)
Initial Surface Water	0	(ft)
Runoff Curve Number	98	(-)

Profile Structure

Layer	Top (ft)	Bottom (ft)	Thickness (ft)
Dummy gravel layer	0.0000	-0.0100	0.0100
HMA	-0.0040	-5.0040	5.0000
Class 2 Agg Base	-4.9980	-10.9980	6.0000
RCC	-10.9920	-23.9920	13.0000
Gravel Base	-23.9860	-53.9860	30.0000

2.1. Layer. Dummy gravel layer

Top Slope Length: 2400.0000
Bottom Slope Length: 2400.0000
Top Slope: 1.0000
Bottom Slope : 1.0000

[HELP] Lateral Drainage Layer Parameters

Parameter	Value	Units
total porosity	1.0	(vol/vol)
field capacity	0.032	(vol/vol)
wilting point	0.013	(vol/vol)
sat.hydr.conductivity	0.3	(cm/sec)
subsurface inflow	0	(mm/year)
Initial moisture content	0.03	(vol/vol)

2.2. Layer. HMA

Top Slope Length: 2400.0000
Bottom Slope Length: 2400.0000
Top Slope: 1.0000
Bottom Slope : 1.0000

[HELP] Barrier Soil Liner Parameters

Parameter	Value	Units
total porosity	0.05	(vol/vol)
field capacity	0.01	(vol/vol)
wilting point	0.01	(vol/vol)
sat.hydr.conductivity	.00001	(cm/sec)
subsurface inflow	0	(mm/year)

2.3. Layer. Class 2 Agg Base

Top Slope Length: 2400.0000
Bottom Slope Length: 2400.0000
Top Slope: 1.0000
Bottom Slope : 1.0000

[HELP] Lateral Drainage Layer Parameters

Parameter	Value	Units
total porosity	0.397	(vol/vol)
field capacity	0.032	(vol/vol)
wilting point	0.013	(vol/vol)
sat.hydr.conductivity	0.3	(cm/sec)
subsurface inflow	0	(mm/year)
Initial moisture content	0.03	(vol/vol)

2.4. Layer. RCC

Top Slope Length: 2400.0000
Bottom Slope Length: 2400.0000
Top Slope: 1.0000
Bottom Slope : 1.0000

[HELP] Barrier Soil Liner Parameters

Parameter	Value	Units
total porosity	0.1	(vol/vol)
field capacity	0.01	(vol/vol)
wilting point	0.01	(vol/vol)
sat.hydr.conductivity	1E-7	(cm/sec)
subsurface inflow	0	(mm/year)

2.5. Layer. Gravel Base

Top Slope Length: 2400.0000
Bottom Slope Length: 2400.0000
Top Slope: 1.0000
Bottom Slope : 1.0000

[HELP] Lateral Drainage Layer Parameters

Parameter	Value	Units
total porosity	0.397	(vol/vol)
field capacity	0.032	(vol/vol)
wilting point	0.013	(vol/vol)
sat.hydr.conductivity	0.3	(cm/sec)
subsurface inflow	0	(mm/year)
Initial moisture content	0.03	(vol/vol)

3. Profile. Option 1 - HMA over existing

Model Settings

[HELP] Case Settings

Parameter	Value	Units
Initial Moisture Settings	User specified	(-)
Runoff Method	User modified	(-)

[HELP] Surface Water Settings

Parameter	Value	Units
Runoff Area	100	(%%)
Initial Surface Water	0	(ft)
Runoff Curve Number	98	(-)

Profile Structure

Layer	Top (ft)	Bottom (ft)	Thickness (ft)
Dummy gravel layer	0.0000	-0.0100	0.0100
HMA	-0.0040	-4.0040	4.0000
Gravel	-3.9980	-4.0980	0.1000
RCC	-4.0920	-17.0920	13.0000
Gravel Base	-17.0860	-47.0860	30.0000

3.1. Layer. Dummy gravel layer

Top Slope Length: 2400.0000
Bottom Slope Length: 2400.0000
Top Slope: 1.0000
Bottom Slope : 1.0000

[HELP] Lateral Drainage Layer Parameters

Parameter	Value	Units
total porosity	1.0	(vol/vol)
field capacity	0.032	(vol/vol)
wilting point	0.013	(vol/vol)
sat.hydr.conductivity	1E-05	(cm/sec)
subsurface inflow	0	(mm/year)
Initial moisture content	0.03	(vol/vol)

3.2. Layer. HMA

Top Slope Length: 2400.0000
Bottom Slope Length: 2400.0000
Top Slope: 1.0000
Bottom Slope : 1.0000

[HELP] Barrier Soil Liner Parameters

Parameter	Value	Units
total porosity	0.05	(vol/vol)
field capacity	0.01	(vol/vol)
wilting point	0.01	(vol/vol)
sat.hydr.conductivity	0.00001	(cm/sec)
subsurface inflow	0	(mm/year)

3.3. Layer. Gravel

Top Slope Length: 2400.0000
Bottom Slope Length: 2400.0000
Top Slope: 1.0000
Bottom Slope : 1.0000

[HELP] Lateral Drainage Layer Parameters

Parameter	Value	Units
total porosity	0.397	(vol/vol)
field capacity	0.032	(vol/vol)
wilting point	0.013	(vol/vol)
sat.hydr.conductivity	0.3	(cm/sec)
subsurface inflow	0	(mm/year)
Initial moisture content	0.03	(vol/vol)

3.4. Layer. RCC

Top Slope Length: 2400.0000
Bottom Slope Length: 2400.0000
Top Slope: 1.0000
Bottom Slope : 1.0000

[HELP] Barrier Soil Liner Parameters

Parameter	Value	Units
total porosity	0.1	(vol/vol)
field capacity	0.01	(vol/vol)
wilting point	0.01	(vol/vol)
sat.hydr.conductivity	1.5E-7	(cm/sec)
subsurface inflow	0	(mm/year)

3.5. Layer. Gravel Base

Top Slope Length: 2400.0000
Bottom Slope Length: 2400.0000
Top Slope: 1.0000
Bottom Slope : 1.0000

[HELP] Lateral Drainage Layer Parameters

Parameter	Value	Units
total porosity	0.397	(vol/vol)
field capacity	0.032	(vol/vol)
wilting point	0.013	(vol/vol)
sat.hydr.conductivity	0.3	(cm/sec)
subsurface inflow	0	(mm/year)
Initial moisture content	0.03	(vol/vol)

4. Profile. Base Case

Model Settings

[HELP] Case Settings

Parameter	Value	Units
Initial Moisture Settings	User specified	(-)
Runoff Method	User modified	(-)

[HELP] Surface Water Settings

Parameter	Value	Units
Runoff Area	100	(%%)
Initial Surface Water	0	(ft)
Runoff Curve Number	98	(-)

Profile Structure

Layer	Top (ft)	Bottom (ft)	Thickness (ft)
Dummy gravel layer	0.0080	-0.0100	0.0180
RCC	0.0080	-12.9920	13.0000
Gravel Base	-12.9860	-42.9860	30.0000

4.1. Layer. Dummy gravel layer

Top Slope Length: 2400.0000
Bottom Slope Length: 2400.0000
Top Slope: 1.0000
Bottom Slope : 1.0000

[HELP] Lateral Drainage Layer Parameters

Parameter	Value	Units
total porosity	1.0	(vol/vol)
field capacity	0.032	(vol/vol)
wilting point	0.013	(vol/vol)
sat.hydr.conductivity	0.3	(cm/sec)
subsurface inflow	0	(mm/year)
Initial moisture content	0.03	(vol/vol)

4.2. Layer. RCC

Top Slope Length: 2400.0000
Bottom Slope Length: 2400.0000
Top Slope: 1.0000
Bottom Slope : 1.0000

[HELP] Barrier Soil Liner Parameters

Parameter	Value	Units
total porosity	.1	(vol/vol)
field capacity	0.01	(vol/vol)
wilting point	0.01	(vol/vol)
sat.hydr.conductivity	5.5E-7	(cm/sec)
subsurface inflow	0	(mm/year)

4.3. Layer. Gravel Base

Top Slope Length: 2400.0000
Bottom Slope Length: 2400.0000
Top Slope: 1.0000
Bottom Slope : 1.0000

[HELP] Lateral Drainage Layer Parameters

Parameter	Value	Units
total porosity	0.397	(vol/vol)
field capacity	0.032	(vol/vol)
wilting point	0.013	(vol/vol)
sat.hydr.conductivity	0.3	(cm/sec)
subsurface inflow	0	(mm/year)
Initial moisture content	0.03	(vol/vol)

Attachment 2
HELP Model Documentation for 25-Year Storm Simulation

Attachment 2 – 25-year Storm
Project : Portac_Final Alts_1YR

Cap design options for former log yard at Portac site, Tacoma, WA

Alt1: 4 in. HMA; 13 in. RCC (intact); 30 in. gravel

Alt2: 5 in. HMA; 6-32 in. gravel w/ TxGG; 13 in. RCC (intact); 30 in. gravel

Alt3: 5 in. HMA; 8-34 in. gravel w/ TxGG; 4 in. sand &

Model : HELP
An US EPA model for predicting landfill hydrologic processes and testing of effectiveness of landfill designs

Author : Kim Slack/Rebecca Gardner

Client : Portac – Parcel 15

Location : Longview, WA

10/15/2017

1. Profile. Option 3 - HMA over GCL

Model Settings

[HELP] Case Settings

Parameter	Value	Units
Initial Moisture Settings	User specified	(-)
Runoff Method	User modified	(-)

[HELP] Surface Water Settings

Parameter	Value	Units
Runoff Area	100	(%%)
Initial Surface Water	0	(ft)
Runoff Curve Number	98	(-)

Profile Structure

Layer	Top (ft)	Bottom (ft)	Thickness (ft)
Dummy gravel layer	0.0000	-0.0100	0.0100
HMA	-0.0040	-5.0040	5.0000
Class 2 Agg Base	-4.9980	-12.9980	8.0000
Bentonite mat	-12.9920	-15.3542	2.3622
Gravel Base	-15.3477	-37.3477	22.0000

1.1. Layer. Dummy gravel layer

Top Slope Length: 2400.0000
Bottom Slope Length: 2400.0000
Top Slope: 1.0000
Bottom Slope : 1.0000

[HELP] Lateral Drainage Layer Parameters

Parameter	Value	Units
total porosity	1.0	(vol/vol)
field capacity	0.032	(vol/vol)
wilting point	0.013	(vol/vol)
sat.hydr.conductivity	0.3	(cm/sec)
subsurface inflow	0	(mm/year)
Initial moisture content	0.03	(vol/vol)

1.2. Layer. HMA

Top Slope Length: 2400.0000
Bottom Slope Length: 2400.0000
Top Slope: 1.0000
Bottom Slope : 1.0000

[HELP] Barrier Soil Liner Parameters

Parameter	Value	Units
total porosity	0.05	(vol/vol)
field capacity	0.01	(vol/vol)
wilting point	0.01	(vol/vol)
sat.hydr.conductivity	1E-5	(cm/sec)
subsurface inflow	0	(mm/year)

1.3. Layer. Class 2 Agg Base

Top Slope Length: 2400.0000
Bottom Slope Length: 2400.0000
Top Slope: 1.0000
Bottom Slope : 1.0000

[HELP] Lateral Drainage Layer Parameters

Parameter	Value	Units
total porosity	0.397	(vol/vol)
field capacity	0.032	(vol/vol)
wilting point	0.013	(vol/vol)
sat.hydr.conductivity	0.3	(cm/sec)
subsurface inflow	0	(mm/year)
Initial moisture content	0.03	(vol/vol)

1.4. Layer. Bentonite mat

Top Slope Length: 2400.0000
Bottom Slope Length: 2400.0000
Top Slope: 1.0000
Bottom Slope : 1.0000

[HELP] Geomembrane Liner Parameters

Parameter	Value	Units
sat.hydr.conductivity	3E-9	(cm/sec)
pinhole density	0	(#/acre)
installation defects	0	(#/acre)
placement quality	5	(-)
geotextile transmissivity	0	(cm2/sec)

1.5. Layer. Gravel Base

Top Slope Length: 2400.0000
Bottom Slope Length: 2400.0000
Top Slope: 1.0000
Bottom Slope : 1.0000

[HELP] Lateral Drainage Layer Parameters

Parameter	Value	Units
total porosity	0.397	(vol/vol)
field capacity	0.032	(vol/vol)
wilting point	0.013	(vol/vol)
sat.hydr.conductivity	0.3	(cm/sec)
subsurface inflow	0	(mm/year)
Initial moisture content	0.03	(vol/vol)

2. Profile. Option 2 - HMA/TxGG over existing

Model Settings

[HELP] Case Settings

Parameter	Value	Units
Initial Moisture Settings	User specified	(-)
Runoff Method	User modified	(-)

[HELP] Surface Water Settings

Parameter	Value	Units
Runoff Area	100	(%%)
Initial Surface Water	0	(ft)
Runoff Curve Number	98	(-)

Profile Structure

Layer	Top (ft)	Bottom (ft)	Thickness (ft)
Dummy gravel layer	0.0000	-0.0100	0.0100
HMA	-0.0040	-5.0040	5.0000
Class 2 Agg Base	-4.9980	-10.9980	6.0000
RCC	-10.9920	-23.9920	13.0000
Gravel Base	-23.9860	-53.9860	30.0000

2.1. Layer. Dummy gravel layer

Top Slope Length: 2400.0000
Bottom Slope Length: 2400.0000
Top Slope: 1.0000
Bottom Slope : 1.0000

[HELP] Lateral Drainage Layer Parameters

Parameter	Value	Units
total porosity	1.0	(vol/vol)
field capacity	0.032	(vol/vol)
wilting point	0.013	(vol/vol)
sat.hydr.conductivity	0.3	(cm/sec)
subsurface inflow	0	(mm/year)
Initial moisture content	0.03	(vol/vol)

2.2. Layer. HMA

Top Slope Length: 2400.0000
Bottom Slope Length: 2400.0000
Top Slope: 1.0000
Bottom Slope : 1.0000

[HELP] Barrier Soil Liner Parameters

Parameter	Value	Units
total porosity	0.05	(vol/vol)
field capacity	0.01	(vol/vol)
wilting point	0.01	(vol/vol)
sat.hydr.conductivity	.00001	(cm/sec)
subsurface inflow	0	(mm/year)

2.3. Layer. Class 2 Agg Base

Top Slope Length: 2400.0000
Bottom Slope Length: 2400.0000
Top Slope: 1.0000
Bottom Slope : 1.0000

[HELP] Lateral Drainage Layer Parameters

Parameter	Value	Units
total porosity	0.397	(vol/vol)
field capacity	0.032	(vol/vol)
wilting point	0.013	(vol/vol)
sat.hydr.conductivity	0.3	(cm/sec)
subsurface inflow	0	(mm/year)
Initial moisture content	0.03	(vol/vol)

2.4. Layer. RCC

Top Slope Length: 2400.0000
Bottom Slope Length: 2400.0000
Top Slope: 1.0000
Bottom Slope : 1.0000

[HELP] Barrier Soil Liner Parameters

Parameter	Value	Units
total porosity	0.1	(vol/vol)
field capacity	0.01	(vol/vol)
wilting point	0.01	(vol/vol)
sat.hydr.conductivity	1E-7	(cm/sec)
subsurface inflow	0	(mm/year)

2.5. Layer. Gravel Base

Top Slope Length: 2400.0000
Bottom Slope Length: 2400.0000
Top Slope: 1.0000
Bottom Slope : 1.0000

[HELP] Lateral Drainage Layer Parameters

Parameter	Value	Units
total porosity	0.397	(vol/vol)
field capacity	0.032	(vol/vol)
wilting point	0.013	(vol/vol)
sat.hydr.conductivity	0.3	(cm/sec)
subsurface inflow	0	(mm/year)
Initial moisture content	0.03	(vol/vol)

3. Profile. Option 1 - HMA over existing

Model Settings

[HELP] Case Settings

Parameter	Value	Units
Initial Moisture Settings	User specified	(-)
Runoff Method	User modified	(-)

[HELP] Surface Water Settings

Parameter	Value	Units
Runoff Area	100	(%%)
Initial Surface Water	0	(ft)
Runoff Curve Number	98	(-)

Profile Structure

Layer	Top (ft)	Bottom (ft)	Thickness (ft)
Dummy gravel layer	0.0000	-0.0100	0.0100
HMA	-0.0040	-4.0040	4.0000
Gravel	-3.9980	-4.0980	0.1000
RCC	-4.0920	-17.0920	13.0000
Gravel Base	-17.0860	-47.0860	30.0000

3.1. Layer. Dummy gravel layer

Top Slope Length: 2400.0000
Bottom Slope Length: 2400.0000
Top Slope: 1.0000
Bottom Slope : 1.0000

[HELP] Lateral Drainage Layer Parameters

Parameter	Value	Units
total porosity	1.0	(vol/vol)
field capacity	0.032	(vol/vol)
wilting point	0.013	(vol/vol)
sat.hydr.conductivity	1E-05	(cm/sec)
subsurface inflow	0	(mm/year)
Initial moisture content	0.03	(vol/vol)

3.2. Layer. HMA

Top Slope Length: 2400.0000
Bottom Slope Length: 2400.0000
Top Slope: 1.0000
Bottom Slope : 1.0000

[HELP] Barrier Soil Liner Parameters

Parameter	Value	Units
total porosity	0.05	(vol/vol)
field capacity	0.01	(vol/vol)
wilting point	0.01	(vol/vol)
sat.hydr.conductivity	0.00001	(cm/sec)
subsurface inflow	0	(mm/year)

3.3. Layer. Gravel

Top Slope Length: 2400.0000
Bottom Slope Length: 2400.0000
Top Slope: 1.0000
Bottom Slope : 1.0000

[HELP] Lateral Drainage Layer Parameters

Parameter	Value	Units
total porosity	0.397	(vol/vol)
field capacity	0.032	(vol/vol)
wilting point	0.013	(vol/vol)
sat.hydr.conductivity	0.3	(cm/sec)
subsurface inflow	0	(mm/year)
Initial moisture content	0.03	(vol/vol)

3.4. Layer. RCC

Top Slope Length: 2400.0000
Bottom Slope Length: 2400.0000
Top Slope: 1.0000
Bottom Slope : 1.0000

[HELP] Barrier Soil Liner Parameters

Parameter	Value	Units
total porosity	0.1	(vol/vol)
field capacity	0.01	(vol/vol)
wilting point	0.01	(vol/vol)
sat.hydr.conductivity	1.5E-7	(cm/sec)
subsurface inflow	0	(mm/year)

3.5. Layer. Gravel Base

Top Slope Length: 2400.0000
Bottom Slope Length: 2400.0000
Top Slope: 1.0000
Bottom Slope : 1.0000

[HELP] Lateral Drainage Layer Parameters

Parameter	Value	Units
total porosity	0.397	(vol/vol)
field capacity	0.032	(vol/vol)
wilting point	0.013	(vol/vol)
sat.hydr.conductivity	0.3	(cm/sec)
subsurface inflow	0	(mm/year)
Initial moisture content	0.03	(vol/vol)

4. Profile. Base Case

Model Settings

[HELP] Case Settings

Parameter	Value	Units
Initial Moisture Settings	User specified	(-)
Runoff Method	User modified	(-)

[HELP] Surface Water Settings

Parameter	Value	Units
Runoff Area	80	(%%)
Initial Surface Water	0	(ft)
Runoff Curve Number	85	(-)

Profile Structure

Layer	Top (ft)	Bottom (ft)	Thickness (ft)
Dummy gravel layer	0.0080	-0.0100	0.0180
RCC	0.0080	-12.9920	13.0000
Gravel Base	-12.9860	-42.9860	30.0000

4.1. Layer. Dummy gravel layer

Top Slope Length: 2400.0000
Bottom Slope Length: 1.0000
Top Slope: 0.0000
Bottom Slope : 0.0000

[HELP] Lateral Drainage Layer Parameters

Parameter	Value	Units
total porosity	1.0	(vol/vol)
field capacity	0.032	(vol/vol)
wilting point	0.013	(vol/vol)
sat.hydr.conductivity	0.3	(cm/sec)
subsurface inflow	0	(mm/year)
Initial moisture content	0.03	(vol/vol)

4.2. Layer. RCC

Top Slope Length: 1.0000
Bottom Slope Length: 1.0000
Top Slope: 0.0000
Bottom Slope : 0.0000

[HELP] Barrier Soil Liner Parameters

Parameter	Value	Units
total porosity	.5	(vol/vol)
field capacity	0.01	(vol/vol)
wilting point	0.01	(vol/vol)
sat.hydr.conductivity	10E-7	(cm/sec)
subsurface inflow	0	(mm/year)

4.3. Layer. Gravel Base

Top Slope Length: 1.0000
Bottom Slope Length: 1.0000
Top Slope: 0.0000
Bottom Slope : 0.0000

[HELP] Lateral Drainage Layer Parameters

Parameter	Value	Units
total porosity	0.397	(vol/vol)
field capacity	0.032	(vol/vol)
wilting point	0.013	(vol/vol)
sat.hydr.conductivity	0.3	(cm/sec)
subsurface inflow	0	(mm/year)
Initial moisture content	0.03	(vol/vol)

APPENDIX C
Cost Estimating Tables

COST ESTIMATE
SUMMARY TABLE

Remedial Alternatives		Net Present Value[2]
Sawmill		
Alternative 1	MNA	$495,000
Alternative 2	Enhanced Bioremediation, MNA	$539,000
Alternative 3	Excavation & Off-site Disposal, MNA	$742,000
Log Yard		
Alternative 1	Asphalt Overlay, Stormwater System Repair, MNA, PRB Contingency	$9,505,000
Alternative 2	Enhanced Cap, Stormwater System Repair, MNA, PRB Contingency	$10,549,000
Alternative 3	Low Permeability Cap, Stormwater System Replacement, MNA, PRB Contingency	$12,185,000
Alternative 4	Asphalt Overlay, Stormwater System Repair, Ex Situ Treatment, MNA, PRB Contingency	$12,069,000
Alternative 5	Excavation & Off-site Disposal, Stormwater System Replacement, MNA, PRB Contingency	$30,964,000

Notes:

1. Estimated costs are in 2017 dollars
2. Net present value (NPV) based on reasonable return on investment (ROI) estimate (5.5%) subtracted from average City of Tacoma consumer price index (CPI) between 1998 and 2016 (2.4%) for a discount rate of (3.1%).

Initial and Annual Costs[1]

Item	Quantity	Unit	Rate/ %	Total
Initial (Year 1) Costs				
Mobilization			20%	$4,000
Well Installation	4	ea	$2,500	$10,000
Well abandonment	8	ea	$1,500	$12,000
Design and Permitting			35%	$9,000
Construction Management			25%	$7,000
Project Management			10%	$4,000
Ecology Review/Oversight for Implementation			5%	$2,000
Sales Tax (City of Tacoma)			10.1%	$3,000
			Construction Costs Subtotal	**$51,000**
Initial Other Costs				
Institutional controls	1	LS	$10,000	$10,000
			Initial Other Cost Subtotal	**$10,000**
			Initial Construction and Other Costs Contingency[2] (20%)	**$12,200**
			Total Initial Construction and Other Costs	**$73,200**

Annual Long Term Costs	No. of Events	Unit	Rate/ %	Annual Total	Years	Total
Annual Costs - Yrs 1-5						
Maintain Inst. Controls	1	LS	$1,000	$1,000	5	$5,000
Groundwater Sampling and Reporting	1	LS	$35,680	$35,680	5	$178,400
Ecology Review/Oversight for annual events			5%	$1,834	5	$9,170
Annual Costs - Yrs 5-10						
Maintain Inst. Controls	1	LS	$1,000	$1,000	5	$5,000
Groundwater Sampling and Reporting	1	LS	$22,840	$22,840	5	$114,200
Ecology Review/Oversight for annual events			5%	$1,192	5	$5,960
Annual Costs - Yrs 10-15						
Maintain Inst. Controls	1	LS	$1,000	$1,000	10	$10,000
Groundwater Sampling and Reporting	1	LS	$16,420	$16,420	10	$164,200
Ecology Review/Oversight for annual events			5%	$871	10	$8,710
Other Periodic Costs						
Abandon wells	4	LS	$1,500	$6,000	yr 20	$6,000
Closure Report	1	LS	$20,000	$20,000	yr 20	$20,000
					Subtotal Long Term Costs	**$526,640**
					Long Term Cost Contingency[2] (20%)	**$105,328**
					Total Long Term Costs	**$631,968**
					Total Construction and Other Initial Costs	**$73,200**
					Total Construction, Other, and Long Term Costs	**$705,168**
					Total Net Present Value[3]	**$495,000**

Notes:
1. Estimated costs are in 2017 dollars
2. Contingency rates and design/permitting, etc. percentage cost estimates based upon EPA cost estimating guidance (EPA 540-R-00-002). Relative percentages were altered based upon professional judgement.
3. Net present value (NPV) based on reasonable return on investment (ROI) estimate (5.5%) subtracted from average City of Tacoma consumer price index (CPI) between 1998 and 2016 (2.4%) for a discount rate of (3.1%).

Net Present Value Calculation

Year	Initial/One Time Costs	Annual	Contingency (20%)	Total	Inflated Cost (2.4%)	NPV Cost (ROI 5.5%)
1	$61,000	$38,514	$19,903	$119,417	$122,283	$115,908
2	$0	$38,514	$7,703	$46,217	$48,462	$43,541
3	$0	$38,514	$7,703	$46,217	$49,625	$42,261
4	$0	$38,514	$7,703	$46,217	$50,816	$41,019
5	$0	$38,514	$7,703	$46,217	$52,035	$39,814
6	$0	$25,032	$5,006	$30,038	$34,632	$25,117
7	$0	$25,032	$5,006	$30,038	$35,463	$24,379
8	$0	$25,032	$5,006	$30,038	$36,314	$23,662
9	$0	$25,032	$5,006	$30,038	$37,186	$22,967
10	$0	$25,032	$5,006	$30,038	$38,078	$22,292
11	$0	$18,291	$3,658	$21,949	$28,492	$15,810
12	$0	$18,291	$3,658	$21,949	$29,175	$15,346
13	$0	$18,291	$3,658	$21,949	$29,876	$14,895
14	$0	$18,291	$3,658	$21,949	$30,593	$14,457
15	$26,000	$18,291	$8,858	$53,149	$75,857	$33,979
16	$0	$0	$0	$0	$0	$0
17	$0	$0	$0	$0	$0	$0
18	$0	$0	$0	$0	$0	$0
19	$0	$0	$0	$0	$0	$0
20	$0	$0	$0	$0	$0	$0
21	$0	$0	$0	$0	$0	$0
22	$0	$0	$0	$0	$0	$0
23	$0	$0	$0	$0	$0	$0
24	$0	$0	$0	$0	$0	$0
25	$0	$0	$0	$0	$0	$0
26	$0	$0	$0	$0	$0	$0
27	$0	$0	$0	$0	$0	$0
28	$0	$0	$0	$0	$0	$0
29	$0	$0	$0	$0	$0	$0
30	$0	$0	$0	$0	$0	$0
31	$0	$0	$0	$0	$0	$0
32	$0	$0	$0	$0	$0	$0
33	$0	$0	$0	$0	$0	$0
34	$0	$0	$0	$0	$0	$0
35	$0	$0	$0	$0	$0	$0
36	$0	$0	$0	$0	$0	$0
37	$0	$0	$0	$0	$0	$0
38	$0	$0	$0	$0	$0	$0
39	$0	$0	$0	$0	$0	$0
40	$0	$0	$0	$0	$0	$0
41	$0	$0	$0	$0	$0	$0
42	$0	$0	$0	$0	$0	$0
43	$0	$0	$0	$0	$0	$0
44	$0	$0	$0	$0	$0	$0
45	$0	$0	$0	$0	$0	$0
46	$0	$0	$0	$0	$0	$0
47	$0	$0	$0	$0	$0	$0
48	$0	$0	$0	$0	$0	$0
49	$0	$0	$0	$0	$0	$0
50	$0	$0	$0	$0	$0	$0
					Net Present Value[3]	**$495,000**

COST ESTIMATE
SAWMILL ALTERNATIVE 2

Initial and Annual Costs[1]

Item	Quantity	Unit	Rate/ %	Total
Initial (Year 1) Costs				
Mobilization			20%	$17,000
Well Installation	4	ea	$2,500	$10,000
Well abandonment	8	ea	$1,500	$12,000
Bioremediation Ammendment Injections	1	LS	$65,000	$65,000
Design and Permitting			35%	$36,000
Construction Management			25%	$35,000
Project Management			10%	$18,000
Ecology Review/Oversight for Implementation			5%	$10,000
Sales Tax (City of Tacoma)			10.1%	$11,000
Construction Costs Subtotal				**$214,000**
Initial Other Costs				
Institutional controls	1	LS	$10,000	$10,000
Initial Other Cost Subtotal				**$10,000**
Initial Construction and Other Costs Contingency[2] (20%)				**$44,800**
Total Initial Construction and Other Costs				**$268,800**

Annual Long Term Costs	No. of Events	Unit	Rate/ %	Annual Total	Years	Total
Annual Costs - Yrs 1-2						
Maintain Inst. Controls	1	LS	$1,000	$1,000	2	$2,000
Groundwater Sampling and Reporting	1	LS	$35,680	$35,680	2	$71,360
Ecology Review/Oversight for annual events			5%	$1,834	2	$3,668
Annual Costs - Yrs 2-5						
Maintain Inst. Controls	1	LS	$1,000	$1,000	3	$3,000
Groundwater Sampling and Reporting	1	LS	$22,840	$22,840	3	$68,520
Ecology Review/Oversight for annual events			5%	$1,192	3	$3,576
Annual Costs - Yrs 5-10						
Maintain Inst. Controls	1	LS	$1,000	$1,000	5	$5,000
Groundwater Sampling and Reporting	1	LS	$16,420	$16,420	5	$82,100
Ecology Review/Oversight for annual events			5%	$871	5	$4,355
Other Periodic Costs						
Abandon wells	4	LS	$1,500	$6,000	yr 10	$6,000
Closure Report	1	LS	$20,000	$20,000	yr 10	$20,000
					Subtotal Long Term Costs	**$261,579**
					Long Term Cost Contingency[2] (20%)	**$52,316**
					Total Long Term Costs	**$313,895**
					Total Construction and Other Initial Costs	**$268,800**
					Total Construction, Other, and Long Term Costs	**$582,695**
					Total Net Present Value[3]	**$539,000**

Notes:
1. Estimated costs are in 2017 dollars
2. Contingency rates and design/permitting, etc. percentage cost estimates based upon EPA cost estimating guidance (EPA 540-R-00-002). Relative percentages were altered based upon professional judgement.
3. Net present value (NPV) based on reasonable return on investment (ROI) estimate (5.5%) subtracted from average City of Tacoma consumer price index (CPI) between 1998 and 2016 (2.4%) for a discount rate of (3.1%).

Net Present Value Calculation

Year	Initial/One Time Costs	Annual	Contingency (20%)	Total	Inflated Cost (2.4%)	NPV Cost (ROI 5.5%)
1	$224,000	$38,514	$52,503	$315,017	$322,577	$305,760
2	$0	$38,514	$7,703	$46,217	$48,462	$43,541
3	$0	$25,032	$5,006	$30,038	$32,253	$27,468
4	$0	$25,032	$5,006	$30,038	$33,028	$26,660
5	$0	$25,032	$5,006	$30,038	$33,820	$25,877
6	$0	$18,291	$3,658	$21,949	$25,306	$18,353
7	$0	$18,291	$3,658	$21,949	$25,913	$17,814
8	$0	$18,291	$3,658	$21,949	$26,535	$17,290
9	$0	$18,291	$3,658	$21,949	$27,172	$16,782
10	$26,000	$18,291	$8,858	$53,149	$67,375	$39,443
11	$0	$0	$0	$0	$0	$0
12	$0	$0	$0	$0	$0	$0
13	$0	$0	$0	$0	$0	$0
14	$0	$0	$0	$0	$0	$0
15	$0	$0	$0	$0	$0	$0
16	$0	$0	$0	$0	$0	$0
17	$0	$0	$0	$0	$0	$0
18	$0	$0	$0	$0	$0	$0
19	$0	$0	$0	$0	$0	$0
20	$0	$0	$0	$0	$0	$0
21	$0	$0	$0	$0	$0	$0
22	$0	$0	$0	$0	$0	$0
23	$0	$0	$0	$0	$0	$0
24	$0	$0	$0	$0	$0	$0
25	$0	$0	$0	$0	$0	$0
26	$0	$0	$0	$0	$0	$0
27	$0	$0	$0	$0	$0	$0
28	$0	$0	$0	$0	$0	$0
29	$0	$0	$0	$0	$0	$0
30	$0	$0	$0	$0	$0	$0
31	$0	$0	$0	$0	$0	$0
32	$0	$0	$0	$0	$0	$0
33	$0	$0	$0	$0	$0	$0
34	$0	$0	$0	$0	$0	$0
35	$0	$0	$0	$0	$0	$0
36	$0	$0	$0	$0	$0	$0
37	$0	$0	$0	$0	$0	$0
38	$0	$0	$0	$0	$0	$0
39	$0	$0	$0	$0	$0	$0
40	$0	$0	$0	$0	$0	$0
41	$0	$0	$0	$0	$0	$0
42	$0	$0	$0	$0	$0	$0
43	$0	$0	$0	$0	$0	$0
44	$0	$0	$0	$0	$0	$0
45	$0	$0	$0	$0	$0	$0
46	$0	$0	$0	$0	$0	$0
47	$0	$0	$0	$0	$0	$0
48	$0	$0	$0	$0	$0	$0
49	$0	$0	$0	$0	$0	$0
50	$0	$0	$0	$0	$0	$0
					Net Present Value[3]	**$539,000**

Initial and Annual Costs[1]

Item	Quantity	Unit	Rate/ %	Total
Initial (Year 1) Costs				
Mobilization			20%	$35,000
Excavation and Off-Site Disposal	1	LS	$174,000	$174,000
Design and Permitting			20%	$42,000
Construction Management			15%	$31,000
Project Management			10%	$21,000
Ecology Review/Oversight for Implementation			5%	$15,000
Sales Tax (City of Tacoma)			10.1%	$21,000
			Construction Costs Subtotal	**$339,000**
Initial Other Costs				
Institutional controls	1	LS	$10,000	$10,000
			Initial Other Cost Subtotal	**$10,000**
			Initial Construction and Other Costs Contingency[2] (30%)	**$104,700**
			Total Initial Construction and Other Costs	**$453,700**

Annual Long Term Costs	No. of Events	Unit	Rate/ %	Annual Total	Years	Total
Annual Costs - Yrs 1-2						
Maintain Inst. Controls	1	LS	$1,000	$1,000	2	$2,000
Groundwater Sampling and Reporting	1	LS	$35,680	$35,680	2	$71,360
Ecology Review/Oversight for annual events			5%	$1,834	2	$3,668
Annual Costs - Yrs 2-5						
Maintain Inst. Controls	1	LS	$1,000	$1,000	3	$3,000
Groundwater Sampling and Reporting	1	LS	$22,840	$22,840	3	$68,520
Ecology Review/Oversight for annual events			5%	$1,192	3	$3,576
Annual Costs - Yrs 5-10						
Maintain Inst. Controls	1	LS	$1,000	$1,000	5	$5,000
Groundwater Sampling and Reporting	1	LS	$16,420	$16,420	5	$82,100
Ecology Review/Oversight for annual events			5%	$871	5	$4,355
Other Periodic Costs						
Abandon wells	4	LS	$1,500	$6,000	yr 10	$6,000
Closure Report	1	LS	$20,000	$20,000	yr 10	$20,000
					Subtotal Long Term Costs	**$269,579**
					Long Term Cost Contingency[2] (30%)	**$80,874**
					Total Long Term Costs	**$350,453**
					Total Construction and Other Initial Costs	**$453,700**
					Total Construction, Other, and Long Term Costs	**$804,153**
					Total Net Present Value[3]	**$742,000**

Notes:
1. Estimated costs are in 2017 dollars
2. Contingency rates and design/permitting, etc. percentage cost estimates based upon EPA cost estimating guidance (EPA 540-R-00-002). Relative percentages were altered based upon professional judgement.
3. Net present value (NPV) based on reasonable return on investment (ROI) estimate (5.5%) subtracted from average City of Tacoma consumer price index (CPI) between 1998 and 2016 (2.4%) for a discount rate of (3.1%).

Net Present Value Calculation

Year	Initial/One Time Costs	Annual	Contingency (30%)	Total	Inflated Cost (2.4%)	NPV Cost (ROI 5.5%)
1	$349,000	$38,514	$116,254	$503,768	$515,859	$488,966
2	$0	$38,514	$11,554	$50,068	$52,500	$47,169
3	$0	$25,032	$7,510	$32,542	$34,941	$29,756
4	$0	$25,032	$7,510	$32,542	$35,780	$28,882
5	$0	$25,032	$7,510	$32,542	$36,639	$28,033
6	$0	$18,291	$5,487	$23,778	$27,415	$19,882
7	$0	$18,291	$5,487	$23,778	$28,072	$19,298
8	$0	$18,291	$5,487	$23,778	$28,746	$18,731
9	$0	$18,291	$5,487	$23,778	$29,436	$18,181
10	$26,000	$18,291	$13,287	$57,578	$72,989	$42,730
11	$0	$0	$0	$0	$0	$0
12	$0	$0	$0	$0	$0	$0
13	$0	$0	$0	$0	$0	$0
14	$0	$0	$0	$0	$0	$0
15	$0	$0	$0	$0	$0	$0
16	$0	$0	$0	$0	$0	$0
17	$0	$0	$0	$0	$0	$0
18	$0	$0	$0	$0	$0	$0
19	$0	$0	$0	$0	$0	$0
20	$0	$0	$0	$0	$0	$0
21	$0	$0	$0	$0	$0	$0
22	$0	$0	$0	$0	$0	$0
23	$0	$0	$0	$0	$0	$0
24	$0	$0	$0	$0	$0	$0
25	$0	$0	$0	$0	$0	$0
26	$0	$0	$0	$0	$0	$0
27	$0	$0	$0	$0	$0	$0
28	$0	$0	$0	$0	$0	$0
29	$0	$0	$0	$0	$0	$0
30	$0	$0	$0	$0	$0	$0
31	$0	$0	$0	$0	$0	$0
32	$0	$0	$0	$0	$0	$0
33	$0	$0	$0	$0	$0	$0
34	$0	$0	$0	$0	$0	$0
35	$0	$0	$0	$0	$0	$0
36	$0	$0	$0	$0	$0	$0
37	$0	$0	$0	$0	$0	$0
38	$0	$0	$0	$0	$0	$0
39	$0	$0	$0	$0	$0	$0
40	$0	$0	$0	$0	$0	$0
41	$0	$0	$0	$0	$0	$0
42	$0	$0	$0	$0	$0	$0
43	$0	$0	$0	$0	$0	$0
44	$0	$0	$0	$0	$0	$0
45	$0	$0	$0	$0	$0	$0
46	$0	$0	$0	$0	$0	$0
47	$0	$0	$0	$0	$0	$0
48	$0	$0	$0	$0	$0	$0
49	$0	$0	$0	$0	$0	$0
50	$0	$0	$0	$0	$0	$0
					Net Present Value[3]	**$742,000**

Initial and Annual Costs[1]

Item	Quantity	Unit	Rate/ %	Total
Initial (Year 1) Costs				
Mobilization			6%	$19,000
Stormwater System Repair	1	LS	$314,000	$314,000
Design and Permitting			15%	$47,000
Construction Management			10%	$31,000
Project Management			8%	$25,000
Ecology Review/Oversight for Implementation			2%	$6,000
Sales Tax (City of Tacoma)			10.1%	$34,000
Year 1 Costs Subtotal				**$476,000**
Cap Improvement (Year 5) Costs				
Mobilization			4%	$93,000
Cap Resurfacing (4" HMA Overlay)	1	LS	$2,292,412	$2,292,412
Monitoring well repairs/replacement	18	EA	$2,500	$45,000
Design and Permitting			4%	$97,000
Construction Management			3%	$69,000
Project Management			2%	$51,000
Ecology Review/Oversight for Implementation			1%	$25,000
Sales Tax (City of Tacoma)			10.1%	$245,000
Year 5 Costs Subtotal				**$2,917,000**
PRB Contingency (Year 10) Costs				
Mobilization			6%	$60,000
PRB Installation (10% ZVI @ 25'-10'bgs)	1,000	LF	$1,000	$1,000,000
Design and Permitting			8%	$80,000
Construction Management			4%	$40,000
Project Management			3%	$30,000
Ecology Review/Oversight for Implementation			1%	$10,000
Sales Tax (City of Tacoma)			10.1%	$107,000
Year 10 Costs Subtotal				**$1,327,000**
Initial Other Costs				
Institutional controls	1	LS	$10,000	$10,000
Initial Construction and Other Costs Subtotal				**$4,730,000**
Initial Construction Costs Contingency[2] (20%)				**$946,000**
Total Initial Construction and Other Costs				**$5,676,000**

Annual Long Term Costs	No. of Events	Unit	Rate/ %	Annual Total	Years	Total
Annual Costs - Yr 1-5						
Maintain Inst. Controls	1	LS	$1,000	$1,000	5	$5,000
Cap Inspections	1	LS	$8,500	$8,500	5	$42,500
Cap Repairs	1	LS	$54,000	$54,000	5	$270,000
Ground/Surface Water Sampling & Annual Reporting (YR 1)	4	LS	$11,500	$46,000	1	$46,000
Ground/Surface Water Sampling & Annual Reporting	2	LS	$14,500	$29,000	4	$116,000
Porewater Sampling (YR 4)	2	LS	$14,500	$29,000	1	$29,000
Ecology Review/Oversight for annual events		5%	$5,500	$5,500	5	$27,500
Annual Costs - Yrs 6-15						
Maintain Inst. Controls	1	LS	$1,000	$1,000	10	$10,000
Cap Inspections	1	LS	$8,500	$8,500	10	$85,000
Groundwater Sampling and Annual Reporting	2	LS	$13,500	$27,000	10	$270,000
Porewater Sampling (YR 9)	2	LS	$14,500	$29,000	1	$29,000
Ecology Review/Oversight for annual events		5%	$3,300	$3,300	10	$33,000
Annual Costs - Yrs 16-100						
Maintain Inst. Controls	1.0	LS	$1,000	$1,000	85	$85,000
Cap Inspections	1.0	LS	$8,500	$8,500	85	$722,500
Reduced Groundwater Sampling & Reporting (YRs 16-21)	1.0	LS	$17,000	$17,000	5	$85,000
Reduced Groundwater Sampling & Reporting (Twice/5YR)	0.4	LS	$17,000	$6,800	85	$578,000
Ecology Review/Oversight for annual events		5%	$1,700	$1,700	85	$144,500
Other Periodic Costs						
Cap Resurfacing (Grinding and 3"HMA)	1	LS	$2,058,000	$2,058,000	yr 25, 45, 65, 85	$8,232,000
Cap Repairs	1	LS	$54,000	$54,000	yr 15, 35, 55, 75, 95	$270,000
PRB Maintenance/Repair		25%	$331,750	$331,750	yr 25, 45, 65, 85	$1,327,000
Abandon wells	12	EA	$1,500	$18,000	yr 100	$18,000
					Subtotal Long Term Costs	**$11,081,500**
					Long Term Cost Contingency[2] (20%)	**$2,216,300**
					Total Long Term Costs	**$13,297,800**
					Total Construction, Other, and Long Term Costs	**$18,973,800**
					Total Net Present Value[3]	**$9,505,000**

Net Present Value Calculation

Year	Initial/One Time Costs	Annual	Contingency (20%)	Total	Inflated Cost (2.4%)	NPV Cost (ROI 5.5%)	Year	Initial/One Time Costs	Annual	Contingency (20%)	Total	Inflated Cost (2.4%)	NPV Cost (ROI 5.5%)
1	$476,000	$115,000	$118,200	$709,200	$726,221	$688,361	51	$0	$18,000	$3,600	$21,600	$72,402	$4,719
2	$0	$98,000	$19,600	$117,600	$123,313	$110,790	52	$0	$18,000	$3,600	$21,600	$74,140	$4,581
3	$0	$98,000	$19,600	$117,600	$126,272	$107,535	53	$0	$18,000	$3,600	$21,600	$75,919	$4,446
4	$0	$127,000	$25,400	$152,400	$167,566	$135,262	54	$0	$18,000	$3,600	$21,600	$77,741	$4,315
5	$2,927,000	$98,000	$605,000	$3,630,000	$4,087,017	$3,127,117	55	$54,000	$18,000	$14,400	$86,400	$318,428	$16,754
6	$0	$39,800	$7,960	$47,760	$55,064	$39,935	56	$0	$18,000	$3,600	$21,600	$81,518	$4,065
7	$0	$39,800	$7,960	$47,760	$56,385	$38,761	57	$0	$18,000	$3,600	$21,600	$83,474	$3,946
8	$0	$39,800	$7,960	$47,760	$57,738	$37,622	58	$0	$18,000	$3,600	$21,600	$85,477	$3,830
9	$0	$68,800	$13,760	$82,560	$102,204	$63,124	59	$0	$18,000	$3,600	$21,600	$87,529	$3,718
10	$1,327,000	$39,800	$273,360	$1,640,160	$2,079,150	$1,217,198	60	$0	$18,000	$3,600	$21,600	$89,630	$3,608
11	$0	$39,800	$7,960	$47,760	$61,996	$34,402	61	$0	$18,000	$3,600	$21,600	$91,781	$3,502
12	$0	$39,800	$7,960	$47,760	$63,484	$33,391	62	$0	$18,000	$3,600	$21,600	$93,983	$3,399
13	$0	$39,800	$7,960	$47,760	$65,008	$32,410	63	$0	$18,000	$3,600	$21,600	$96,239	$3,299
14	$0	$39,800	$7,960	$47,760	$66,568	$31,458	64	$0	$18,000	$3,600	$21,600	$98,549	$3,203
15	$54,000	$39,800	$18,760	$112,560	$160,651	$71,961	65	$2,389,750	$18,000	$481,550	$2,889,300	$13,498,634	$415,796
16	$0	$28,200	$5,640	$33,840	$49,457	$20,999	66	$0	$18,000	$3,600	$21,600	$103,336	$3,017
17	$0	$28,200	$5,640	$33,840	$50,644	$20,382	67	$0	$18,000	$3,600	$21,600	$105,816	$2,928
18	$0	$28,200	$5,640	$33,840	$51,860	$19,783	68	$0	$18,000	$3,600	$21,600	$108,355	$2,842
19	$0	$28,200	$5,640	$33,840	$53,104	$19,201	69	$0	$18,000	$3,600	$21,600	$110,956	$2,759
20	$0	$28,200	$5,640	$33,840	$54,379	$18,637	70	$0	$18,000	$3,600	$21,600	$113,619	$2,678
21	$0	$18,000	$3,600	$21,600	$35,543	$11,547	71	$0	$18,000	$3,600	$21,600	$116,346	$2,599
22	$0	$18,000	$3,600	$21,600	$36,396	$11,207	72	$0	$18,000	$3,600	$21,600	$119,138	$2,523
23	$0	$18,000	$3,600	$21,600	$37,269	$10,878	73	$0	$18,000	$3,600	$21,600	$121,997	$2,449
24	$0	$18,000	$3,600	$21,600	$38,164	$10,558	74	$0	$18,000	$3,600	$21,600	$124,925	$2,377
25	$2,389,750	$18,000	$481,550	$2,889,300	$5,227,470	$1,370,819	75	$54,000	$18,000	$14,400	$86,400	$511,694	$9,227
26	$0	$18,000	$3,600	$21,600	$40,018	$9,947	76	$0	$18,000	$3,600	$21,600	$130,994	$2,239
27	$0	$18,000	$3,600	$21,600	$40,978	$9,655	77	$0	$18,000	$3,600	$21,600	$134,138	$2,173
28	$0	$18,000	$3,600	$21,600	$41,962	$9,371	78	$0	$18,000	$3,600	$21,600	$137,357	$2,109
29	$0	$18,000	$3,600	$21,600	$42,969	$9,096	79	$0	$18,000	$3,600	$21,600	$140,653	$2,047
30	$0	$18,000	$3,600	$21,600	$44,000	$8,828	80	$0	$18,000	$3,600	$21,600	$144,029	$1,987
31	$0	$18,000	$3,600	$21,600	$45,056	$8,569	81	$0	$18,000	$3,600	$21,600	$147,486	$1,929
32	$0	$18,000	$3,600	$21,600	$46,137	$8,317	82	$0	$18,000	$3,600	$21,600	$151,025	$1,872
33	$0	$18,000	$3,600	$21,600	$47,245	$8,073	83	$0	$18,000	$3,600	$21,600	$154,650	$1,817
34	$0	$18,000	$3,600	$21,600	$48,378	$7,836	84	$0	$18,000	$3,600	$21,600	$158,362	$1,764
35	$54,000	$18,000	$14,400	$86,400	$198,158	$30,421	85	$2,389,750	$18,000	$481,550	$2,889,300	$21,691,468	$228,997
36	$0	$18,000	$3,600	$21,600	$50,729	$7,382	86	$0	$18,000	$3,600	$21,600	$166,054	$1,662
37	$0	$18,000	$3,600	$21,600	$51,946	$7,165	87	$0	$18,000	$3,600	$21,600	$170,040	$1,613
38	$0	$18,000	$3,600	$21,600	$53,193	$6,954	88	$0	$18,000	$3,600	$21,600	$174,121	$1,565
39	$0	$18,000	$3,600	$21,600	$54,469	$6,750	89	$0	$18,000	$3,600	$21,600	$178,299	$1,519
40	$1,327,000	$18,000	$269,000	$1,614,000	$4,167,751	$489,557	90	$0	$18,000	$3,600	$21,600	$182,579	$1,475
41	$0	$18,000	$3,600	$21,600	$57,115	$6,359	91	$0	$18,000	$3,600	$21,600	$186,960	$1,431
42	$0	$18,000	$3,600	$21,600	$58,486	$6,172	92	$0	$18,000	$3,600	$21,600	$191,448	$1,389
43	$0	$18,000	$3,600	$21,600	$59,890	$5,991	93	$0	$18,000	$3,600	$21,600	$196,042	$1,349
44	$0	$18,000	$3,600	$21,600	$61,327	$5,815	94	$0	$18,000	$3,600	$21,600	$200,747	$1,309
45	$2,389,750	$18,000	$481,550	$2,889,300	$8,400,221	$754,971	95	$54,000	$18,000	$14,400	$86,400	$822,261	$5,082
46	$0	$18,000	$3,600	$21,600	$64,306	$5,478	96	$0	$18,000	$3,600	$21,600	$210,499	$1,233
47	$0	$18,000	$3,600	$21,600	$65,849	$5,317	97	$0	$18,000	$3,600	$21,600	$215,551	$1,197
48	$0	$18,000	$3,600	$21,600	$67,430	$5,161	98	$0	$18,000	$3,600	$21,600	$220,724	$1,162
49	$0	$18,000	$3,600	$21,600	$69,048	$5,009	99	$0	$18,000	$3,600	$21,600	$226,021	$1,128
50	$0	$18,000	$3,600	$21,600	$70,705	$4,862	100	$18,000	$18,000	$7,200	$43,200	$462,892	$2,189
												Net Present Value[3]	$9,505,000

Notes:
1. Estimated costs are in 2017 dollars
2. Contingency rates and design/permitting, etc. percentage cost estimates based upon EPA cost estimating guidance (EPA 540-R-00-002). Relative percentages were altered based upon professional judgement.
3. Net present value (NPV) based on reasonable return on investment (ROI) estimate (5.5%) subtracted from average City of Tacoma consumer price index (CPI) between 1998 and 2016 (2.4%) for a discount rate of (3.1%).

Initial and Annual Costs[1]

Item	Quantity	Unit	Rate/ %	Total
Initial (Year 1) Costs				
Mobilization			6%	$19,000
Stormwater System Repair	1	LS	$314,000	$314,000
Design and Permitting			15%	$47,000
Construction Management			10%	$31,000
Project Management			8%	$25,000
Ecology Review/Oversight for Implementation			2%	$6,000
Sales Tax (City of Tacoma)			10.1%	$34,000
			Year 1 Costs Subtotal	**$333,000**
Cap Improvement (Year 5) Costs				
Mobilization			4%	$186,000
Enhanced Cap (geogrid, gravel, 5" HMA cover)	1	LS	$4,610,000	$4,610,000
Monitoring well repairs/replacement	18	EA	$2,500	$45,000
Design and Permitting			4%	$184,000
Construction Management			3%	$138,000
Project Management			2%	$92,000
Ecology Review/Oversight for Implementation			1%	$46,000
Sales Tax (City of Tacoma)			10.1%	$489,000
			Year 5 Costs Subtotal	**$5,790,000**
PRB Contingency (Year 10) Costs				
Mobilization			6%	$60,000
PRB Installation (10% ZVI @ 25'-10'bgs)	1,000	LF	$1,000	$1,000,000
Design and Permitting			8%	$80,000
Construction Management			4%	$40,000
Project Management			3%	$30,000
Ecology Review/Oversight for Implementation			1%	$10,000
Sales Tax (City of Tacoma)			10.1%	$107,000
			Year 10 Costs Subtotal	**$1,327,000**
Initial Other Costs				
Institutional controls	1	LS	$10,000	$10,000
			Initial Construction and Other Costs Subtotal	**$7,460,000**
			Initial Construction Costs Contingency[2] (20%)	**$1,490,000**
			Total Initial Construction and Other Costs	**$8,950,000**

Annual Long Term Costs	No. of Events	Unit	Rate/ %	Annual Total	Years	Total
Annual Costs - Yr 1-5						
Maintain Inst. Controls	1	LS	$1,000	$1,000	5	$5,000
Cap Inspections	1	LS	$8,500	$8,500	5	$42,500
Cap Repairs	1	LS	$54,000	$54,000	5	$270,000
Ground/Surface Water Sampling & Annual Reporting (YR 1)	4	LS	$11,500	$46,000	1	$46,000
Ground/Surface Water Sampling & Annual Reporting	2	LS	$14,500	$29,000	4	$116,000
Porewater Sampling (YR 4)	2	LS	$14,500	$29,000	1	$29,000
Ecology Review/Oversight for annual events		5%	$5,500	$5,500	5	$27,500
Annual Costs - Yrs 6-15						
Maintain Inst. Controls	1	LS	$1,000	$1,000	10	$10,000
Cap Inspections	1	LS	$8,500	$8,500	10	$85,000
Groundwater Sampling and Annual Reporting	2	LS	$13,500	$27,000	10	$270,000
Porewater Sampling (YR 9)	2	LS	$14,500	$29,000	1	$29,000
Ecology Review/Oversight for annual events		5%	$3,300	$3,300	10	$33,000
Annual Costs - Yrs 16-100						
Maintain Inst. Controls	1.0	LS	$1,000	$1,000	85	$85,000
Cap Inspections	1.0	LS	$8,500	$8,500	85	$722,500
Reduced Groundwater Sampling & Reporting (YRs 16-21)	1.0	LS	$17,000	$17,000	5	$85,000
Reduced Groundwater Sampling & Reporting (Twice/5YR)	0.4	LS	$17,000	$6,800	85	$578,000
Ecology Review/Oversight for annual events		5%	$1,700	$1,700	85	$144,500
Other Periodic Costs						
Cap Resurfacing (Grinding and 3"HMA)	1	LS	$2,058,000	$2,058,000	yr 35, 65,95	$6,174,000
PRB Maintenance/Repair		25%	$331,750	$331,750	yr 40, 70, 100	$995,250
Abandon wells	12	EA	$1,500	$18,000	yr 100	$18,000
				Subtotal Long Term Costs		**$9,765,250**
				Long Term Cost Contingency[2] (20%)		**$1,953,050**
				Total Long Term Costs		**$11,718,300**
				Total Construction, Other, and Long Term Costs		**$20,668,300**
				Total Net Present Value[3]		**$10,549,000**

Net Present Value Calculation

Year	Initial/One Time Costs	Annual	Contingency (20%)	Total	Inflated Cost (2.4%)	NPV Cost (ROI 5.5%)	Year	Initial/One Time Costs	Annual	Contingency (20%)	Total	Inflated Cost (2.4%)	NPV Cost (ROI 5.5%)
1	$333,000	$115,000	$89,600	$537,600	$550,502	$521,803	51	$0	$18,000	$3,600	$21,600	$72,402	$4,719
2	$0	$98,000	$19,600	$117,600	$123,313	$110,790	52	$0	$18,000	$3,600	$21,600	$74,140	$4,581
3	$0	$98,000	$19,600	$117,600	$126,272	$107,535	53	$0	$18,000	$3,600	$21,600	$75,919	$4,446
4	$0	$127,000	$25,400	$152,400	$167,566	$135,262	54	$0	$18,000	$3,600	$21,600	$77,741	$4,315
5	$5,800,000	$98,000	$1,179,600	$7,077,600	$7,968,669	$6,097,103	55	$0	$18,000	$3,600	$21,600	$79,607	$4,189
6	$0	$39,800	$7,960	$47,760	$55,064	$39,935	56	$0	$18,000	$3,600	$21,600	$81,518	$4,065
7	$0	$39,800	$7,960	$47,760	$56,385	$38,761	57	$0	$18,000	$3,600	$21,600	$83,474	$3,946
8	$0	$39,800	$7,960	$47,760	$57,738	$37,622	58	$0	$18,000	$3,600	$21,600	$85,477	$3,830
9	$0	$68,800	$13,760	$82,560	$102,204	$63,124	59	$0	$18,000	$3,600	$21,600	$87,529	$3,718
10	$1,327,000	$39,800	$273,360	$1,640,160	$2,079,150	$1,217,198	60	$0	$18,000	$3,600	$21,600	$89,630	$3,608
11	$0	$39,800	$7,960	$47,760	$61,996	$34,402	61	$0	$18,000	$3,600	$21,600	$91,781	$3,502
12	$0	$39,800	$7,960	$47,760	$63,484	$33,391	62	$0	$18,000	$3,600	$21,600	$93,983	$3,399
13	$0	$39,800	$7,960	$47,760	$65,008	$32,410	63	$0	$18,000	$3,600	$21,600	$96,239	$3,299
14	$0	$39,800	$7,960	$47,760	$66,568	$31,458	64	$0	$18,000	$3,600	$21,600	$98,549	$3,203
15	$0	$39,800	$7,960	$47,760	$68,165	$30,534	65	$2,058,000	$18,000	$415,200	$2,491,200	$11,638,735	$358,506
16	$0	$28,200	$5,640	$33,840	$49,457	$20,999	66	$0	$18,000	$3,600	$21,600	$103,336	$3,017
17	$0	$28,200	$5,640	$33,840	$50,644	$20,382	67	$0	$18,000	$3,600	$21,600	$105,816	$2,928
18	$0	$28,200	$5,640	$33,840	$51,860	$19,783	68	$0	$18,000	$3,600	$21,600	$108,355	$2,842
19	$0	$28,200	$5,640	$33,840	$53,104	$19,201	69	$0	$18,000	$3,600	$21,600	$110,956	$2,759
20	$0	$28,200	$5,640	$33,840	$54,379	$18,637	70	$331,750	$18,000	$69,950	$419,700	$2,207,679	$52,031
21	$0	$18,000	$3,600	$21,600	$35,543	$11,547	71	$0	$18,000	$3,600	$21,600	$116,346	$2,599
22	$0	$18,000	$3,600	$21,600	$36,396	$11,207	72	$0	$18,000	$3,600	$21,600	$119,138	$2,523
23	$0	$18,000	$3,600	$21,600	$37,269	$10,878	73	$0	$18,000	$3,600	$21,600	$121,997	$2,449
24	$0	$18,000	$3,600	$21,600	$38,164	$10,558	74	$0	$18,000	$3,600	$21,600	$124,925	$2,377
25	$0	$18,000	$3,600	$21,600	$39,080	$10,248	75	$0	$18,000	$3,600	$21,600	$127,924	$2,307
26	$0	$18,000	$3,600	$21,600	$40,018	$9,947	76	$0	$18,000	$3,600	$21,600	$130,994	$2,239
27	$0	$18,000	$3,600	$21,600	$40,978	$9,655	77	$0	$18,000	$3,600	$21,600	$134,138	$2,173
28	$0	$18,000	$3,600	$21,600	$41,962	$9,371	78	$0	$18,000	$3,600	$21,600	$137,357	$2,109
29	$0	$18,000	$3,600	$21,600	$42,969	$9,096	79	$0	$18,000	$3,600	$21,600	$140,653	$2,047
30	$0	$18,000	$3,600	$21,600	$44,000	$8,828	80	$0	$18,000	$3,600	$21,600	$144,029	$1,987
31	$0	$18,000	$3,600	$21,600	$45,056	$8,569	81	$0	$18,000	$3,600	$21,600	$147,486	$1,929
32	$0	$18,000	$3,600	$21,600	$46,137	$8,317	82	$0	$18,000	$3,600	$21,600	$151,025	$1,872
33	$0	$18,000	$3,600	$21,600	$47,245	$8,073	83	$0	$18,000	$3,600	$21,600	$154,650	$1,817
34	$0	$18,000	$3,600	$21,600	$48,378	$7,836	84	$0	$18,000	$3,600	$21,600	$158,362	$1,764
35	$2,058,000	$18,000	$415,200	$2,491,200	$5,713,564	$877,144	85	$0	$18,000	$3,600	$21,600	$162,162	$1,712
36	$0	$18,000	$3,600	$21,600	$50,729	$7,382	86	$0	$18,000	$3,600	$21,600	$166,054	$1,662
37	$0	$18,000	$3,600	$21,600	$51,946	$7,165	87	$0	$18,000	$3,600	$21,600	$170,040	$1,613
38	$0	$18,000	$3,600	$21,600	$53,193	$6,954	88	$0	$18,000	$3,600	$21,600	$174,121	$1,565
39	$0	$18,000	$3,600	$21,600	$54,469	$6,750	89	$0	$18,000	$3,600	$21,600	$178,299	$1,519
40	$331,750	$18,000	$69,950	$419,700	$1,083,770	$127,303	90	$0	$18,000	$3,600	$21,600	$182,579	$1,475
41	$0	$18,000	$3,600	$21,600	$57,115	$6,359	91	$0	$18,000	$3,600	$21,600	$186,960	$1,431
42	$0	$18,000	$3,600	$21,600	$58,486	$6,172	92	$0	$18,000	$3,600	$21,600	$191,448	$1,389
43	$0	$18,000	$3,600	$21,600	$59,890	$5,991	93	$0	$18,000	$3,600	$21,600	$196,042	$1,349
44	$0	$18,000	$3,600	$21,600	$61,327	$5,815	94	$0	$18,000	$3,600	$21,600	$200,747	$1,309
45	$0	$18,000	$3,600	$21,600	$62,799	$5,644	95	$2,058,000	$18,000	$415,200	$2,491,200	$23,708,522	$146,528
46	$0	$18,000	$3,600	$21,600	$64,306	$5,478	96	$0	$18,000	$3,600	$21,600	$210,499	$1,233
47	$0	$18,000	$3,600	$21,600	$65,849	$5,317	97	$0	$18,000	$3,600	$21,600	$215,551	$1,197
48	$0	$18,000	$3,600	$21,600	$67,430	$5,161	98	$0	$18,000	$3,600	$21,600	$220,724	$1,162
49	$0	$18,000	$3,600	$21,600	$69,048	$5,009	99	$0	$18,000	$3,600	$21,600	$226,021	$1,128
50	$0	$18,000	$3,600	$21,600	$70,705	$4,862	100	$349,750	$18,000	$73,550	$441,300	$4,728,567	$22,361
												Net Present Value[3]	$10,549,000

Notes:
1. Estimated costs are in 2017 dollars
2. Contingency rates and design/permitting, etc. percentage cost estimates based upon EPA cost estimating guidance (EPA 540-R-00-002). Relative percentages were altered based upon professional judgement.
3. Net present value (NPV) based on reasonable return on investment (ROI) estimate (5.5%) subtracted from average City of Tacoma consumer price index (CPI) between 1998 and 2016 (2.4%) for a discount rate of (3.1%).

Initial and Annual Costs[1]

Item	Quantity	Unit	Rate/ %	Total
Initial (Year 1) Costs				
Mobilization			10%	$10,000
Stormwater System Repair (no slip line)	1	LS	$104,000	$104,000
Design and Permitting			15%	$16,000
Construction Management			10%	$10,000
Project Management			8%	$8,000
Ecology Review/Oversight for Implementation			2%	$2,000
Sales Tax (City of Tacoma)			10.1%	$12,000
			Year 1 Costs Subtotal	**$162,000**
Cap Improvement (Year 5) Costs				
Mobilization			4%	$283,000
Low Permeability Cap (GCL, 5" HMA cover)	1	LS	$6,360,000	$6,360,000
Stormwater System Replacement	1	LS	$672,000	$672,000
Monitoring well repairs/replacement	18	EA	$2,500	$45,000
Design and Permitting			4%	$254,000
Construction Management			3%	$191,000
Project Management			2%	$127,000
Ecology Review/Oversight for Implementation			1%	$64,000
Sales Tax (City of Tacoma)			10.1%	$743,000
			Year 5 Costs Subtotal	**$8,739,000**
PRB Contingency (Year 10) Costs				
Mobilization			6%	$60,000
PRB Installation (10% ZVI @ 25'-10'bgs)	1,000	LF	$1,000	$1,000,000
Design and Permitting			8%	$80,000
Construction Management			4%	$40,000
Project Management			3%	$30,000
Ecology Review/Oversight for Implementation			1%	$10,000
Sales Tax (City of Tacoma)			10.1%	$107,000
			Year 10 Costs Subtotal	**$1,327,000**
Initial Other Costs				
Institutional controls	1	LS	$10,000	$10,000
	Initial Construction and Other Costs Subtotal			**$10,238,000**
	Initial Construction Costs Contingency[2] (20%)			**$2,047,600**
	Total Initial Construction and Other Costs			**$12,285,600**

Annual Long Term Costs	No. of Events	Unit	Rate/ %	Annual Total	Years	Total
Annual Costs - Yr 1-5						
Maintain Inst. Controls	1	LS	$1,000	$1,000	5	$5,000
Cap Inspections	1	LS	$8,500	$8,500	5	$42,500
Cap Repairs	1	LS	$54,000	$54,000	5	$270,000
Ground/Surface Water Sampling & Annual Reporting (YR 1	4	LS	$11,500	$46,000	1	$46,000
Ground/Surface Water Sampling & Annual Reporting	2	LS	$14,500	$29,000	4	$116,000
Porewater Sampling (YR 4)	2	LS	$14,500	$29,000	1	$29,000
Ecology Review/Oversight for annual events		5%	$5,500	$5,500	5	$27,500
Annual Costs - Yrs 6-15						
Maintain Inst. Controls	1	LS	$1,000	$1,000	10	$10,000
Cap Inspections	1	LS	$8,500	$8,500	10	$85,000
Groundwater Sampling and Annual Reporting	2	LS	$13,500	$27,000	10	$270,000
Porewater Sampling (YR 9)	2	LS	$14,500	$29,000	1	$29,000
Ecology Review/Oversight for annual events		5%	$3,300	$3,300	10	$33,000
Annual Costs - Yrs 16-100						
Maintain Inst. Controls	1.0	LS	$1,000	$1,000	85	$85,000
Cap Inspections	1.0	LS	$8,500	$8,500	85	$722,500
Reduced Groundwater Sampling & Reporting (YRs 16-21)	1.0	LS	$17,000	$17,000	5	$85,000
Reduced Groundwater Sampling & Reporting (Twice/5YR)	0.4	LS	$17,000	$6,800	85	$578,000
Ecology Review/Oversight for annual events		5%	$1,700	$1,700	85	$144,500
Other Periodic Costs						
GCL Liner Repair		3%	$190,800	$190,800	yr 15, 45, 75	$572,400
PRB Maintenance/Repair		25%	$331,750	$331,750	yr 50, 90	$663,500
Abandon wells	12	EA	$1,500	$18,000	yr 100	$18,000
				Subtotal Long Term Costs		**$3,831,900**
				Long Term Cost Contingency[2] (20%)		**$766,380**
				Total Long Term Costs		**$4,598,280**
				Total Construction, Other, and Long Term Costs		**$16,883,880**
				Total Net Present Value[3]		**$12,185,000**

Net Present Value Calculation

Year	Initial/One Time Costs	Annual	Contingency (20%)	Total	Inflated Cost (2.4%)	NPV Cost (ROI 5.5%)	Year	Initial/One Time Costs	Annual	Contingency (20%)	Total	Inflated Cost (2.4%)	NPV Cost (ROI 5.5%)
1	$162,000	$115,000	$55,400	$332,400	$340,378	$322,633	51	$0	$18,000	$3,600	$21,600	$72,402	$4,719
2	$0	$98,000	$19,600	$117,600	$123,313	$110,790	52	$0	$18,000	$3,600	$21,600	$74,140	$4,581
3	$0	$98,000	$19,600	$117,600	$126,272	$107,535	53	$0	$18,000	$3,600	$21,600	$75,919	$4,446
4	$0	$127,000	$25,400	$152,400	$167,566	$135,262	54	$0	$18,000	$3,600	$21,600	$77,741	$4,315
5	$8,749,000	$98,000	$1,769,400	$10,616,400	$11,953,004	$9,145,654	55	$0	$18,000	$3,600	$21,600	$79,607	$4,189
6	$0	$39,800	$7,960	$47,760	$55,064	$39,935	56	$0	$18,000	$3,600	$21,600	$81,518	$4,065
7	$0	$39,800	$7,960	$47,760	$56,385	$38,761	57	$0	$18,000	$3,600	$21,600	$83,474	$3,946
8	$0	$39,800	$7,960	$47,760	$57,738	$37,622	58	$0	$18,000	$3,600	$21,600	$85,477	$3,830
9	$0	$68,800	$13,760	$82,560	$102,204	$63,124	59	$0	$18,000	$3,600	$21,600	$87,529	$3,718
10	$1,327,000	$39,800	$273,360	$1,640,160	$2,079,150	$1,217,198	60	$0	$18,000	$3,600	$21,600	$89,630	$3,608
11	$0	$39,800	$7,960	$47,760	$61,996	$34,402	61	$0	$18,000	$3,600	$21,600	$91,781	$3,502
12	$0	$39,800	$7,960	$47,760	$63,484	$33,391	62	$0	$18,000	$3,600	$21,600	$93,983	$3,399
13	$0	$39,800	$7,960	$47,760	$65,008	$32,410	63	$0	$18,000	$3,600	$21,600	$96,239	$3,299
14	$0	$39,800	$7,960	$47,760	$66,568	$31,458	64	$0	$18,000	$3,600	$21,600	$98,549	$3,203
15	$190,800	$39,800	$46,120	$276,720	$394,948	$176,910	65	$0	$18,000	$3,600	$21,600	$100,914	$3,108
16	$0	$28,200	$5,640	$33,840	$49,457	$20,999	66	$0	$18,000	$3,600	$21,600	$103,336	$3,017
17	$0	$28,200	$5,640	$33,840	$50,644	$20,382	67	$0	$18,000	$3,600	$21,600	$105,816	$2,928
18	$0	$28,200	$5,640	$33,840	$51,860	$19,783	68	$0	$18,000	$3,600	$21,600	$108,355	$2,842
19	$0	$28,200	$5,640	$33,840	$53,104	$19,201	69	$0	$18,000	$3,600	$21,600	$110,956	$2,759
20	$0	$28,200	$5,640	$33,840	$54,379	$18,637	70	$0	$18,000	$3,600	$21,600	$113,619	$2,678
21	$0	$18,000	$3,600	$21,600	$35,543	$11,547	71	$0	$18,000	$3,600	$21,600	$116,346	$2,599
22	$0	$18,000	$3,600	$21,600	$36,396	$11,207	72	$0	$18,000	$3,600	$21,600	$119,138	$2,523
23	$0	$18,000	$3,600	$21,600	$37,269	$10,878	73	$0	$18,000	$3,600	$21,600	$121,997	$2,449
24	$0	$18,000	$3,600	$21,600	$38,164	$10,558	74	$0	$18,000	$3,600	$21,600	$124,925	$2,377
25	$0	$18,000	$3,600	$21,600	$39,080	$10,248	75	$190,800	$18,000	$41,760	$250,560	$1,483,913	$26,759
26	$0	$18,000	$3,600	$21,600	$40,018	$9,947	76	$0	$18,000	$3,600	$21,600	$130,994	$2,239
27	$0	$18,000	$3,600	$21,600	$40,978	$9,655	77	$0	$18,000	$3,600	$21,600	$134,138	$2,173
28	$0	$18,000	$3,600	$21,600	$41,962	$9,371	78	$0	$18,000	$3,600	$21,600	$137,357	$2,109
29	$0	$18,000	$3,600	$21,600	$42,969	$9,096	79	$0	$18,000	$3,600	$21,600	$140,653	$2,047
30	$0	$18,000	$3,600	$21,600	$44,000	$8,828	80	$0	$18,000	$3,600	$21,600	$144,029	$1,987
31	$0	$18,000	$3,600	$21,600	$45,056	$8,569	81	$0	$18,000	$3,600	$21,600	$147,486	$1,929
32	$0	$18,000	$3,600	$21,600	$46,137	$8,317	82	$0	$18,000	$3,600	$21,600	$151,025	$1,872
33	$0	$18,000	$3,600	$21,600	$47,245	$8,073	83	$0	$18,000	$3,600	$21,600	$154,650	$1,817
34	$0	$18,000	$3,600	$21,600	$48,378	$7,836	84	$0	$18,000	$3,600	$21,600	$158,362	$1,764
35	$0	$18,000	$3,600	$21,600	$49,540	$7,605	85	$0	$18,000	$3,600	$21,600	$162,162	$1,712
36	$0	$18,000	$3,600	$21,600	$50,729	$7,382	86	$0	$18,000	$3,600	$21,600	$166,054	$1,662
37	$0	$18,000	$3,600	$21,600	$51,946	$7,165	87	$0	$18,000	$3,600	$21,600	$170,040	$1,613
38	$0	$18,000	$3,600	$21,600	$53,193	$6,954	88	$0	$18,000	$3,600	$21,600	$174,121	$1,565
39	$0	$18,000	$3,600	$21,600	$54,469	$6,750	89	$0	$18,000	$3,600	$21,600	$178,299	$1,519
40	$0	$18,000	$3,600	$21,600	$55,777	$6,552	90	$331,750	$18,000	$69,950	$419,700	$3,547,603	$28,656
41	$0	$18,000	$3,600	$21,600	$57,115	$6,359	91	$0	$18,000	$3,600	$21,600	$186,960	$1,431
42	$0	$18,000	$3,600	$21,600	$58,486	$6,172	92	$0	$18,000	$3,600	$21,600	$191,448	$1,389
43	$0	$18,000	$3,600	$21,600	$59,890	$5,991	93	$0	$18,000	$3,600	$21,600	$196,042	$1,349
44	$0	$18,000	$3,600	$21,600	$61,327	$5,815	94	$0	$18,000	$3,600	$21,600	$200,747	$1,309
45	$190,800	$18,000	$41,760	$250,560	$728,467	$65,471	95	$0	$18,000	$3,600	$21,600	$205,565	$1,270
46	$0	$18,000	$3,600	$21,600	$64,306	$5,478	96	$0	$18,000	$3,600	$21,600	$210,499	$1,233
47	$0	$18,000	$3,600	$21,600	$65,849	$5,317	97	$0	$18,000	$3,600	$21,600	$215,551	$1,197
48	$0	$18,000	$3,600	$21,600	$67,430	$5,161	98	$0	$18,000	$3,600	$21,600	$220,724	$1,162
49	$0	$18,000	$3,600	$21,600	$69,048	$5,009	99	$0	$18,000	$3,600	$21,600	$226,021	$1,128
50	$331,750	$18,000	$69,950	$419,700	$1,373,842	$94,474	100	$18,000	$18,000	$7,200	$43,200	$462,892	$2,189
												Net Present Value[3]	$12,185,000

Notes:
1. Estimated costs are in 2017 dollars
2. Contingency rates and design/permitting, etc. percentage cost estimates based upon EPA cost estimating guidance (EPA 540-R-00-002). Relative percentages were altered based upon professional judgement.
3. Net present value (NPV) based on reasonable return on investment (ROI) estimate (5.5%) subtracted from average City of Tacoma consumer price index (CPI) between 1998 and 2016 (2.4%) for a discount rate of (3.1%).

Initial and Annual Costs[1]

Item	Quantity	Unit	Rate/ %	Total
Initial (Year 1) Costs				
Mobilization			6%	$19,000
Stormwater System Repair	1	LS	$314,000	$314,000
Design and Permitting			15%	$47,000
Construction Management			10%	$31,000
Project Management			8%	$25,000
Ecology Review/Oversight for Implementation			2%	$6,000
Sales Tax (City of Tacoma)			10.1%	$34,000
			Year 1 Costs Subtotal	**$476,000**
Cap Improvement (Year 5) Costs				
Mobilization			4%	$93,000
Cap Resurfacing (4" HMA Overlay)	1	LS	$2,292,412	$2,292,412
Monitoring well repairs/replacement	18	EA	$2,500	$45,000
Design and Permitting			4%	$97,000
Construction Management			3%	$69,000
Project Management			2%	$51,000
Ecology Review/Oversight for Implementation			1%	$25,000
Sales Tax (City of Tacoma)			10.1%	$245,000
			Year 5 Costs Subtotal	**$2,917,000**
Perched Water Ex Situ Treatment (Year 5) Costs				
Mobilization			4%	$61,000
Ex Situ Treatment System (French Drains) Install	1	LS	$1,517,000	$1,517,000
Design and Permitting			4%	$61,000
Construction Management			3%	$46,000
Project Management			2%	$30,000
Ecology Review/Oversight for Implementation			1%	$15,000
Sales Tax (City of Tacoma)			10.1%	$159,000
			Year 5 Costs Subtotal	**$1,889,000**
PRB Contingency (Year 10) Costs				
Mobilization			6%	$60,000
PRB Installation (10% ZVI @ 25'-10'bgs)	1,000	LF	$1,000	$1,000,000
Design and Permitting			8%	$80,000
Construction Management			4%	$40,000
Project Management			3%	$30,000
Ecology Review/Oversight for Implementation			1%	$10,000
Sales Tax (City of Tacoma)			10.1%	$107,000
			Year 10 Costs Subtotal	**$1,327,000**
Initial Other Costs				
Institutional controls	1	LS	$10,000	$10,000
			Initial Construction and Other Costs Subtotal	**$5,292,000**
			Initial Construction Costs Contingency[2] (20%)	**$1,058,400**
			Total Initial Construction and Other Costs	**$6,350,400**

Annual Long Term Costs	No. of Events	Unit	Rate/ %	Annual Total	Years	Total
Annual Costs - Yrs 1-5						
Maintain Inst. Controls	1	LS	$1,000	$1,000	5	$5,000
Cap Inspections	1	LS	$8,500	$8,500	5	$42,500
Cap Repairs	1	LS	$54,000	$54,000	5	$270,000
Ex Situ Treatment Maintenance	1	LS	$31,000	$31,000	5	$155,000
Ground/Surface Water Sampling & Annual Reporting (YR 1)	4	LS	$11,500	$46,000	1	$46,000
Ground/Surface Water Sampling & Annual Reporting	2	LS	$14,500	$29,000	4	$116,000
Porewater Sampling (YR 4)	2	LS	$14,500	$29,000	1	$29,000
Ecology Review/Oversight for annual events		5%	$6,200	$6,200	5	$31,000
Annual Costs - Yrs 6-15						
Maintain Inst. Controls	1	LS	$1,000	$1,000	10	$10,000
Cap Inspections	1	LS	$8,500	$8,500	10	$85,000
Ex Situ Treatment Maintenance	1	LS	$31,000	$31,000	10	$310,000
Groundwater Sampling and Annual Reporting	2	LS	$13,500	$27,000	10	$270,000
Porewater Sampling (YR 9)	2	LS	$14,500	$29,000	1	$29,000
Ecology Review/Oversight for annual events		5%	$3,400	$3,400	10	$34,000
Annual Costs - Yrs 16-100						
Maintain Inst. Controls	1	LS	$1,000	$1,000	85	$85,000
Cap Inspections	1	LS	$8,500	$8,500	85	$722,500
Ex Situ Treatment Maintenance	1	LS	$31,000	$31,000	85	$2,635,000
Reduced Groundwater Sampling & Reporting (YRs 16-21)	1	LS	$17,000	$17,000	5	$85,000
Reduced Groundwater Sampling & Reporting (Twice/5YR)	0.4	LS	$17,000	$6,800	85	$578,000
Ecology Review/Oversight for annual events		5%	$2,400	$2,400	85	$204,000
Other Periodic Costs						
Cap Resurfacing (Grinding and 3"HMA)	1	LS	$2,058,000	$2,058,000	yr 25, 45, 65, 85	$8,232,000
Cap Repairs	1	LS	$54,000	$54,000	yr 15, 35, 55, 75, 95	$270,000
Ex Situ Treatment Maintenance (periodic)	1	LS	$30,000	$30,000	yr 10, 15, 20, 25...	$570,000
PRB Maintenance/Repair		25%	$331,750	$331,750	yr 50, 90	$663,500
Abandon wells	12	EA	$1,500	$18,000	yr 100	$18,000
					Subtotal Long Term Costs	**$15,495,500**
					Long Term Cost Contingency[2] (20%)	**$3,099,100**
					Total Long Term Costs	**$18,594,600**
					Total Construction, Other, and Long Term Costs	**$24,945,000**
					Total Net Present Value[3]	**$12,069,000**

Net Present Value Calculation

Year	Initial/One Time Costs	Annual	Contingency (20%)	Total	Inflated Cost (2.4%)	NPV Cost (ROI 5.5%)	Year	Initial/One Time Costs	Annual	Contingency (20%)	Total	Inflated Cost (2.4%)	NPV Cost (ROI 5.5%)
1	$476,000	$146,700	$124,540	$747,240	$765,174	$725,283	51	$0	$49,700	$9,940	$59,640	$199,910	$13,030
2	$0	$129,700	$25,940	$155,640	$163,200	$146,628	52	$0	$49,700	$9,940	$59,640	$204,708	$12,648
3	$0	$129,700	$25,940	$155,640	$167,117	$142,319	53	$0	$49,700	$9,940	$59,640	$209,621	$12,276
4	$0	$158,700	$31,740	$190,440	$209,391	$169,024	54	$0	$49,700	$9,940	$59,640	$214,652	$11,915
5	$4,806,000	$129,700	$987,140	$5,922,840	$6,668,525	$5,102,318	55	$84,000	$49,700	$26,740	$160,440	$591,303	$31,112
6	$0	$70,900	$14,180	$85,080	$98,091	$71,140	56	$0	$49,700	$9,940	$59,640	$225,079	$11,225
7	$0	$70,900	$14,180	$85,080	$100,445	$69,049	57	$0	$49,700	$9,940	$59,640	$230,481	$10,895
8	$0	$70,900	$14,180	$85,080	$102,855	$67,020	58	$0	$49,700	$9,940	$59,640	$236,013	$10,575
9	$0	$99,900	$19,980	$119,880	$148,404	$91,659	59	$0	$49,700	$9,940	$59,640	$241,677	$10,265
10	$1,357,000	$70,900	$285,580	$1,713,480	$2,172,094	$1,271,610	60	$30,000	$49,700	$15,940	$95,640	$396,860	$15,977
11	$0	$70,900	$14,180	$85,080	$110,440	$61,284	61	$0	$49,700	$9,940	$59,640	$253,417	$9,670
12	$0	$70,900	$14,180	$85,080	$113,091	$59,484	62	$0	$49,700	$9,940	$59,640	$259,499	$9,386
13	$0	$70,900	$14,180	$85,080	$115,805	$57,736	63	$0	$49,700	$9,940	$59,640	$265,727	$9,110
14	$0	$70,900	$14,180	$85,080	$118,584	$56,039	64	$0	$49,700	$9,940	$59,640	$272,104	$8,843
15	$84,000	$70,900	$30,980	$185,880	$265,297	$118,835	65	$2,088,000	$49,700	$427,540	$2,565,240	$11,984,645	$369,161
16	$0	$59,900	$11,980	$71,880	$105,053	$44,603	66	$0	$49,700	$9,940	$59,640	$285,322	$8,331
17	$0	$59,900	$11,980	$71,880	$107,574	$43,293	67	$0	$49,700	$9,940	$59,640	$292,169	$8,086
18	$0	$59,900	$11,980	$71,880	$110,156	$42,021	68	$0	$49,700	$9,940	$59,640	$299,181	$7,848
19	$0	$59,900	$11,980	$71,880	$112,800	$40,786	69	$0	$49,700	$9,940	$59,640	$306,362	$7,618
20	$30,000	$59,900	$17,980	$107,880	$173,356	$59,414	70	$30,000	$49,700	$15,940	$95,640	$503,079	$11,857
21	$0	$49,700	$9,940	$59,640	$98,138	$31,881	71	$0	$49,700	$9,940	$59,640	$321,244	$7,176
22	$0	$49,700	$9,940	$59,640	$100,493	$30,944	72	$0	$49,700	$9,940	$59,640	$328,954	$6,966
23	$0	$49,700	$9,940	$59,640	$102,905	$30,035	73	$0	$49,700	$9,940	$59,640	$336,848	$6,761
24	$0	$49,700	$9,940	$59,640	$105,375	$29,153	74	$0	$49,700	$9,940	$59,640	$344,933	$6,562
25	$2,088,000	$49,700	$427,540	$2,565,240	$4,641,164	$1,217,070	75	$84,000	$49,700	$26,740	$160,440	$950,188	$17,135
26	$0	$49,700	$9,940	$59,640	$110,493	$27,465	76	$0	$49,700	$9,940	$59,640	$361,688	$6,182
27	$0	$49,700	$9,940	$59,640	$113,145	$26,658	77	$0	$49,700	$9,940	$59,640	$370,369	$6,001
28	$0	$49,700	$9,940	$59,640	$115,861	$25,874	78	$0	$49,700	$9,940	$59,640	$379,258	$5,824
29	$0	$49,700	$9,940	$59,640	$118,641	$25,114	79	$0	$49,700	$9,940	$59,640	$388,360	$5,653
30	$30,000	$49,700	$15,940	$95,640	$194,822	$39,090	80	$30,000	$49,700	$15,940	$95,640	$637,729	$8,799
31	$0	$49,700	$9,940	$59,640	$124,405	$23,660	81	$0	$49,700	$9,940	$59,640	$407,225	$5,326
32	$0	$49,700	$9,940	$59,640	$127,390	$22,965	82	$0	$49,700	$9,940	$59,640	$416,998	$5,169
33	$0	$49,700	$9,940	$59,640	$130,448	$22,290	83	$0	$49,700	$9,940	$59,640	$427,006	$5,017
34	$0	$49,700	$9,940	$59,640	$133,578	$21,635	84	$0	$49,700	$9,940	$59,640	$437,254	$4,870
35	$84,000	$49,700	$26,740	$160,440	$367,969	$56,490	85	$2,088,000	$49,700	$427,540	$2,565,240	$19,258,582	$203,313
36	$0	$49,700	$9,940	$59,640	$140,067	$20,382	86	$0	$49,700	$9,940	$59,640	$458,494	$4,588
37	$0	$49,700	$9,940	$59,640	$143,429	$19,783	87	$0	$49,700	$9,940	$59,640	$469,498	$4,453
38	$0	$49,700	$9,940	$59,640	$146,871	$19,202	88	$0	$49,700	$9,940	$59,640	$480,766	$4,322
39	$0	$49,700	$9,940	$59,640	$150,396	$18,638	89	$0	$49,700	$9,940	$59,640	$492,304	$4,195
40	$30,000	$49,700	$15,940	$95,640	$246,966	$29,009	90	$361,750	$49,700	$82,290	$493,740	$4,173,442	$33,711
41	$0	$49,700	$9,940	$59,640	$157,702	$17,558	91	$0	$49,700	$9,940	$59,640	$516,219	$3,952
42	$0	$49,700	$9,940	$59,640	$161,486	$17,042	92	$0	$49,700	$9,940	$59,640	$528,608	$3,836
43	$0	$49,700	$9,940	$59,640	$165,362	$16,542	93	$0	$49,700	$9,940	$59,640	$541,294	$3,724
44	$0	$49,700	$9,940	$59,640	$169,331	$16,056	94	$0	$49,700	$9,940	$59,640	$554,286	$3,614
45	$2,088,000	$49,700	$427,540	$2,565,240	$7,458,063	$670,294	95	$84,000	$49,700	$26,740	$160,440	$1,526,893	$9,437
46	$0	$49,700	$9,940	$59,640	$177,556	$15,126	96	$0	$49,700	$9,940	$59,640	$581,211	$3,405
47	$0	$49,700	$9,940	$59,640	$181,817	$14,681	97	$0	$49,700	$9,940	$59,640	$595,160	$3,305
48	$0	$49,700	$9,940	$59,640	$186,181	$14,250	98	$0	$49,700	$9,940	$59,640	$609,443	$3,208
49	$0	$49,700	$9,940	$59,640	$190,649	$13,831	99	$0	$49,700	$9,940	$59,640	$624,070	$3,113
50	$361,750	$49,700	$82,290	$493,740	$1,616,204	$111,141	100	$48,000	$49,700	$19,540	$117,240	$1,256,237	$5,941
												Net Present Value[3]	$12,069,000

Notes:
1. Estimated costs are in 2017 dollars
2. Contingency rates and design/permitting, etc. percentage cost estimates based upon EPA cost estimating guidance (EPA 540-R-00-002). Relative percentages were altered based upon professional judgement.
3. Net present value (NPV) based on reasonable return on investment (ROI) estimate (5.5%) subtracted from average City of Tacoma consumer price index (CPI) between 1998 and 2016 (2.4%) for a discount rate of (3.1%).

Initial and Annual Costs[1]

Item	Quantity	Unit	Rate/ %	Total
Initial (Year 1) Costs				
Mobilization			10%	$10,000
Stormwater System Repair (no slip line)	1	LS	$104,000	$104,000
Design and Permitting			15%	$16,000
Construction Management			10%	$10,000
Project Management			8%	$8,000
Ecology Review/Oversight for Implementation			2%	$2,000
Sales Tax (City of Tacoma)			10.1%	$12,000
			Year 1 Costs Subtotal	**$162,000**
Excavation, Removal, Repave (Year 5) Costs				
Mobilization			1.0%	$214,000
Excavation to Cleanup Level & Offsite Disposal	1	LS	$17,963,000	$17,963,000
Repave Site (Alt 2 Cap)	1	LS	$3,424,000	$3,424,000
Design and Permitting			1.0%	$214,000
Construction Management			1.5%	$321,000
Project Management			0.5%	$107,000
Ecology Review/Oversight for Implementation			0.1%	$21,000
Sales Tax (City of Tacoma)			10.1%	$2,182,000
			Removal (Year 5) Costs Subtotal	**$24,446,000**
Stormwater System Replacement (Year 5) Costs				
Mobilization			10%	$55,000
Stormwater System Replacement	1	LS	$553,000	$553,000
Design and Permitting			12%	$66,000
Construction Management			8%	$44,000
Project Management			6%	$33,000
Ecology Review/Oversight for Implementation			2%	$11,000
Sales Tax (City of Tacoma)			10.1%	$61,000
			Stormwater (Year 5) Costs Subtotal	**$823,000**
PRB Contingency (Year 10) Costs				
Mobilization			6%	$60,000
PRB Installation (10% ZVI @ 25'-10'bgs)	1,000	LF	$1,000	$1,000,000
Design and Permitting			8%	$80,000
Construction Management			4%	$40,000
Project Management			3%	$30,000
Ecology Review/Oversight for Implementation			1%	$10,000
Sales Tax (City of Tacoma)			10.1%	$107,000
			Year 10 Costs Subtotal	**$1,327,000**
Initial Other Costs				
Institutional controls	1	LS	$10,000	$10,000
	Initial Construction and Other Costs Subtotal			**$26,606,000**
	Initial Construction Costs Contingency[2] (30%)			**$7,981,800**
	Total Initial Construction and Other Costs			**$34,587,800**

Annual Long Term Costs	No. of Events	Unit	Rate/ %	Annual Total	Years	Total
Annual Costs - Yrs 1-5						
Maintain Inst. Controls	1	LS	$1,000	$1,000	5	$5,000
Cap Inspections	1	LS	$8,500	$8,500	5	$42,500
Cap Repairs	1	LS	$54,000	$54,000	5	$270,000
Ground/Surface Water Sampling & Annual Reporting (YR 1	4	LS	$11,500	$46,000	1	$46,000
Ground/Surface Water Sampling & Annual Reporting	2	LS	$14,500	$29,000	4	$116,000
Porewater Sampling (YR 4)	2	LS	$14,500	$29,000	1	$29,000
Ecology Review/Oversight for annual events		5%	$5,200	$5,200	5	$26,000
Annual Costs - Yrs 6-15						
Maintain Inst. Controls	1	LS	$1,000	$1,000	10	$10,000
Groundwater Sampling and Annual Reporting	2	LS	$13,500	$27,000	10	$270,000
Porewater Sampling (YR 9)	2	LS	$14,500	$29,000	1	$29,000
Ecology Review/Oversight for annual events		5%	$1,500	$1,500	10	$15,000
Annual Costs - Yrs 16-30						
Maintain Inst. Controls	1	LS	$1,000	$1,000	15	$15,000
Reduced Groundwater Sampling & Reporting (YRs 16-21)	1.0	LS	$17,000	$17,000	5	$85,000
Reduced Groundwater Sampling & Reporting (Twice/5YR)	0.4	LS	$17,000	$6,800	10	$68,000
Ecology Review/Oversight for annual events		5%	$1,800	$1,800	15	$27,000
Annual Costs - Yrs 30-100						
Maintain Inst. Controls	1	LS	$1,000	$1,000	70	$70,000
Other Periodic Costs						
PRB Maintenance/Repair		25%	$331,750	$331,750	yr 60	$331,750
Abandon wells	12	EA	$1,500	$18,000	yr 100	$18,000
				Subtotal Long Term Costs		**$1,473,250**
				Long Term Cost Contingency[2] (30%)		**$441,975**
				Total Long Term Costs		**$1,915,225**
				Total Construction, Other, and Long Term Costs		**$36,503,025**
				Total Net Present Value[3]		**$30,964,000**

Notes:
1. Estimated costs are in 2017 dollars
2. Contingency rates and design/permitting, etc. percentage cost estimates based upon EPA cost estimating guidance (EPA 540-R-00-002). Relative percentages were altered based upon professional judgement.
3. Net present value (NPV) based on reasonable return on investment (ROI) estimate (5.5%) subtracted from average City of Tacoma consumer price index (CPI) between 1998 and 2016

Net Present Value Calculation

Year	Initial/One Time Costs	Annual	Contingency (30%)	Total	Inflated Cost (2.4%)	NPV Cost (ROI 5.5%)	Year	Initial/One Time Costs	Annual	Contingency (30%)	Total	Inflated Cost (2.4%)	NPV Cost (ROI 5.5%)
1	$162,000	$114,700	$83,010	$359,710	$368,343	$349,140	51	$0	$1,000	$300	$1,300	$4,358	$284
2	$0	$97,700	$29,310	$127,010	$133,180	$119,656	52	$0	$1,000	$300	$1,300	$4,462	$276
3	$0	$97,700	$29,310	$127,010	$136,376	$116,140	53	$0	$1,000	$300	$1,300	$4,569	$268
4	$0	$126,700	$38,010	$164,710	$181,101	$146,187	54	$0	$1,000	$300	$1,300	$4,679	$260
5	$25,279,000	$97,700	$7,613,010	$32,989,710	$37,143,111	$28,419,471	55	$0	$1,000	$300	$1,300	$4,791	$252
6	$0	$29,500	$8,850	$38,350	$44,215	$32,066	56	$0	$1,000	$300	$1,300	$4,906	$245
7	$0	$29,500	$8,850	$38,350	$45,276	$31,124	57	$0	$1,000	$300	$1,300	$5,024	$237
8	$0	$29,500	$8,850	$38,350	$46,362	$30,210	58	$0	$1,000	$300	$1,300	$5,144	$231
9	$0	$58,500	$17,550	$76,050	$94,145	$58,147	59	$0	$1,000	$300	$1,300	$5,268	$224
10	$1,327,000	$29,500	$406,950	$1,763,450	$2,235,438	$1,308,694	60	$331,750	$1,000	$99,825	$432,575	$1,794,977	$72,262
11	$0	$29,500	$8,850	$38,350	$49,781	$27,624	61	$0	$1,000	$300	$1,300	$5,524	$211
12	$0	$29,500	$8,850	$38,350	$50,976	$26,812	62	$0	$1,000	$300	$1,300	$5,656	$205
13	$0	$29,500	$8,850	$38,350	$52,199	$26,025	63	$0	$1,000	$300	$1,300	$5,792	$199
14	$0	$29,500	$8,850	$38,350	$53,452	$25,260	64	$0	$1,000	$300	$1,300	$5,931	$193
15	$0	$29,500	$8,850	$38,350	$54,735	$24,518	65	$0	$1,000	$300	$1,300	$6,074	$187
16	$0	$19,800	$5,940	$25,740	$37,619	$15,972	66	$0	$1,000	$300	$1,300	$6,219	$182
17	$0	$19,800	$5,940	$25,740	$38,522	$15,503	67	$0	$1,000	$300	$1,300	$6,369	$176
18	$0	$19,800	$5,940	$25,740	$39,446	$15,047	68	$0	$1,000	$300	$1,300	$6,521	$171
19	$0	$19,800	$5,940	$25,740	$40,393	$14,605	69	$0	$1,000	$300	$1,300	$6,678	$166
20	$0	$19,800	$5,940	$25,740	$41,363	$14,176	70	$0	$1,000	$300	$1,300	$6,838	$161
21	$0	$9,600	$2,880	$12,480	$20,536	$6,671	71	$0	$1,000	$300	$1,300	$7,002	$156
22	$0	$9,600	$2,880	$12,480	$21,029	$6,475	72	$0	$1,000	$300	$1,300	$7,170	$152
23	$0	$9,600	$2,880	$12,480	$21,533	$6,285	73	$0	$1,000	$300	$1,300	$7,342	$147
24	$0	$9,600	$2,880	$12,480	$22,050	$6,100	74	$0	$1,000	$300	$1,300	$7,519	$143
25	$0	$9,600	$2,880	$12,480	$22,579	$5,921	75	$0	$1,000	$300	$1,300	$7,699	$139
26	$0	$9,600	$2,880	$12,480	$23,121	$5,747	76	$0	$1,000	$300	$1,300	$7,884	$135
27	$0	$9,600	$2,880	$12,480	$23,676	$5,578	77	$0	$1,000	$300	$1,300	$8,073	$131
28	$0	$9,600	$2,880	$12,480	$24,245	$5,414	78	$0	$1,000	$300	$1,300	$8,267	$127
29	$0	$9,600	$2,880	$12,480	$24,826	$5,255	79	$0	$1,000	$300	$1,300	$8,465	$123
30	$0	$9,600	$2,880	$12,480	$25,422	$5,101	80	$0	$1,000	$300	$1,300	$8,668	$120
31	$0	$1,000	$300	$1,300	$2,712	$516	81	$0	$1,000	$300	$1,300	$8,876	$116
32	$0	$1,000	$300	$1,300	$2,777	$501	82	$0	$1,000	$300	$1,300	$9,089	$113
33	$0	$1,000	$300	$1,300	$2,843	$486	83	$0	$1,000	$300	$1,300	$9,308	$109
34	$0	$1,000	$300	$1,300	$2,912	$472	84	$0	$1,000	$300	$1,300	$9,531	$106
35	$0	$1,000	$300	$1,300	$2,982	$458	85	$0	$1,000	$300	$1,300	$9,760	$103
36	$0	$1,000	$300	$1,300	$3,053	$444	86	$0	$1,000	$300	$1,300	$9,994	$100
37	$0	$1,000	$300	$1,300	$3,126	$431	87	$0	$1,000	$300	$1,300	$10,234	$97
38	$0	$1,000	$300	$1,300	$3,201	$419	88	$0	$1,000	$300	$1,300	$10,479	$94
39	$0	$1,000	$300	$1,300	$3,278	$406	89	$0	$1,000	$300	$1,300	$10,731	$91
40	$0	$1,000	$300	$1,300	$3,357	$394	90	$0	$1,000	$300	$1,300	$10,989	$89
41	$0	$1,000	$300	$1,300	$3,437	$383	91	$0	$1,000	$300	$1,300	$11,252	$86
42	$0	$1,000	$300	$1,300	$3,520	$371	92	$0	$1,000	$300	$1,300	$11,522	$84
43	$0	$1,000	$300	$1,300	$3,604	$361	93	$0	$1,000	$300	$1,300	$11,799	$81
44	$0	$1,000	$300	$1,300	$3,691	$350	94	$0	$1,000	$300	$1,300	$12,082	$79
45	$0	$1,000	$300	$1,300	$3,780	$340	95	$0	$1,000	$300	$1,300	$12,372	$76
46	$0	$1,000	$300	$1,300	$3,870	$330	96	$0	$1,000	$300	$1,300	$12,669	$74
47	$0	$1,000	$300	$1,300	$3,963	$320	97	$0	$1,000	$300	$1,300	$12,973	$72
48	$0	$1,000	$300	$1,300	$4,058	$311	98	$0	$1,000	$300	$1,300	$13,284	$70
49	$0	$1,000	$300	$1,300	$4,156	$301	99	$0	$1,000	$300	$1,300	$13,603	$68
50	$0	$1,000	$300	$1,300	$4,255	$293	100	$18,000	$1,000	$5,700	$24,700	$264,663	$1,252
												Net Present Value[3]	$30,964,000

Unit Costs Item	Unit Cost ($)	Units	# of Units		Source/Notes
Discount Rate	3.1	%			
Consumer Price Index (CPI) Rate	2.4	%			1998-2016 average CPI in Seattle
Return on Investment (ROI) Rate	5.5	%			
Permeable Reactive Barrier				*Sub-totals*	
Zero valent iron (ZVI)	$1,125	CY	0	*$0*	$0.30 - $0.45/lb of coarse ZVI, from ITRC, June 2011: http://www.itrcweb.org/GuidanceDocuments/PRB-5-1.pdf. Not escalated to 2017, assumed cost competition.
ZVI Delivery	$143	TN	833	*$119,048*	From 2010 cost estimating at $3000/21tons in container shipment
Sand Purchase	$7.00	TN	0	*$0*	Dickson Company (Waller Road Gravel Pit): January 2017 price list
Sand Transport and Place	$11.40	CY	0	*$0*	2016 RS Means (Tacoma, WA): Hauling - Line #312323200134 assuming haul from Dickson @ 5mi/1-way; Backfill - Line #312323170020
Trenching w/single pass continuous trenching (25' depth)	$350	LF	1000	*$350,000*	Escalated from 2005 PRB installation cost, from ITRC, June 2011: http://www.itrcweb.org/GuidanceDocuments/PRB-5-1.pdf.
ZVI Backfill Mixture	$132	CY	1667	*$220,350*	Assumes 15' of ZVI sand mixture at 10/90 ZVI to Sand. Unit costs above.
Low Perm Backfill Mixture	$145	CY	1111	*$161,111*	Assumes CDF is used from 10'bgs to surface. Contractor bid price on similar project
Media and Cover Placement	$4	CY	2778	*$11,500*	Contractor bid on similar project
Cold Mix Asphalt	$100	TN	56	*$5,556*	Assumes 3" asphalt patch over 4' x 1500'
Pavement Repair	$62	SY	444	*$27,733*	Assumes 3" asphalt patch over 4' x 1500' , costs from G&O below
Subtitle D Trucking and Disposal	$54	CY	1667	*$90,634*	From cost below, assumes all native material removed and disposed
Permeable Reactive Barrier Installation (rolled up as LF)	$985.93	LF		*$985,932*	Assumes a 25' deep trench, 3' wide, 1000' long. Assumes a 50/50 ZVI & fine sand mix.
Stormwater System Replacement				*Sub-totals*	
Removing drainage structure	$800	EA	4	*$3,200*	WSDOT Cost Database (bid dated 4/2017) $500-$800 for 4 units in project, $700 for 9 unit project (1/2016)
Removing manhole	$1,400	EA	8	*$11,200*	WSDOT Cost Database (bid dated 8/2014) 1 unit in project
Abandon existing stormwater system	$17	LF	2400	*$40,492*	Assumes existing stormwater system would be plugged and filled with CDF at a cost of $145/cy, 2400 LF of stormline, and an average diameter of 24".
Sawcut Pavement	$5	LF	5280	*$23,760*	From Port of Tacoma bid
Pavement Demolition	$20	SY	1067	*$21,333*	From Port of Tacoma bid
New Pipeline Excavation	$12	CY	1800	*$21,600*	From estimate below, assumes 4' wide and 4' to 7' excavation for 2 x 1200lf runs.Assumes excavator loading trucks, from Stratus 2017 estimate
Type II Catch Basin	$3,250	EA	4	*$13,000*	Escalated from 2005 Gray and Osborne unit costs for Friday Harbor, WA. CCI 8194.11 (2005) to 10699 (April, 2017).
12" HDPE Install	$85	LF	600	*$51,000*	Average of Tacoma area bids for similar projects
18" HDPE Install	$135	LF	600	*$81,000*	Average of Tacoma area bids for similar projects
24" HDPE Install	$145	LF	600	*$87,000*	Average of Tacoma area bids for similar projects
36" HDPE Install	$200	LF	600	*$120,000*	Average of Tacoma area bids for similar projects
Connections to Existing Catch Basins	$1,300	EA	8	*$10,400*	Escalated from 2005 Gray and Osborne unit costs for Friday Harbor, WA. CCI 8194.11 (2005) to 10699 (April, 2017).
Pipe Bedding (6")	$50	CY	180	*$9,000*	Seattle Public Utilities. 2014.
Trench Backfill and Pavement Base Course	$40	TN	1080	*$43,200*	Port of Tacoma 2016 bid.
HMA Paving	$100	TN	296	*$29,630*	From Port of Tacoma on call rate. Assumes 5" repave over 5' wide area through full length of excavation. Asphalt at 2tn/1cy
Trench Safey System	$8,600	LS	1	*$8,600*	Port of Tacoma 2016 bid.
Waste Disposal Haul and Disposal	$54	CY	1800	*$97,885*	From estimate below.
Stormwater System Replacement (Rolled up to LF)	$280	LF	1	*$672,300*	
Stormwater System Replacement (post removal action)	$230	LF	1	*$553,081*	Assumes no offsite disposal
Stormwater System Repair (Characterization and Incremental Improvement)				*Sub-totals*	
Initial Characterization (Workplan, SAP, Sampling)	$39,000	LS	1	*$39,000*	Assumes $10k for SAP/Work Plan, 15 samples for Diss/Total Metals ($200/s), 2 staff x 40hrs for collection, $10k for reporting with 20% contingency
Storm System Sediment Cleaning	$8	LF	2500	*$20,000*	Port of Tacoma contractor verbal estimate
Sediment Disposal	$54	CY	46	*$2,502*	Assumes 3" x 2' x 2500LF of sediment throughout system. Cost from estimate below.
Slip line (assume 36") with HDPE	$350	LF	600	*$210,000*	Verbal quote from a Vancouver, WA ($200/lf) and a Tacoma, WA contractor ($700/lf). City of Olympia cost of ~$150/lf for 32".
Seal Vaults	$21,000	LS	1	*$21,000*	Assumes 40 hrs of labor x 4 staff at $125/hr + $1000 materials
Verification Sampling and Report	$21,000	LS	1	*$21,000*	Assume 8 samples for Diss/Total Metals ($200/s), 2 staff x 24 hrs for collection, $10k for reporting with 20% contingency
Stormwater Improvement Total	$314,000	LS	1	*$314,000*	

Stormwater System Repair - no slip line (Alt 3 and 5)				*Sub-totals*	
Initial Characterization (Workplan, SAP, Sampling)	$39,000	LS	1	*$39,000*	Assumes $10k for SAP/Work Plan, 15 samples for Diss/Total Metals ($200/s), 2 staff x 40hrs for collection, $10k for reporting with 20% contingency
Storm System Sediment Cleaning	$8	LF	2500	*$20,000*	Port of Tacoma contractor verbal estimate
Sediment Disposal	$54	CY	46	*$2,502*	Assumes 3" x 2' x 2500LF of sediment throughout system. Cost from estimate below.
Seal Vaults	$21,000	LS	1	*$21,000*	Assumes 40 hrs of labor x 4 staff at $125/hr + $1000 materials
Verification Sampling and Report	$21,000	LS	1	*$21,000*	Assume 8 samples for Diss/Total Metals ($200/s), 2 staff x 24 hrs for collection, $10k for reporting with 20% contingency
Stormwater Improvement Total	$104,000	LS	1	*$104,000*	
Perched Water Ex Situ Treatment (French Drains)					
New Pipeline Excavation	$12	CY	76500	*$918,000*	From estimate below, assumes 15' deep x3' wide excavation for 2400lf.Assumes excavator loading trucks, from Stratus 2017 estimate
Trench Safety Equipment	$1,950	LS	2	*$3,900*	Escalated from 2005 Gray and Osborne unit costs for Friday Harbor, WA. CCI 8194.11 (2005) to 10699 (April, 2017).
12" Drain Pipe and Fittings Install	$85	LF	1700	*$144,500*	Assumes 3 french drain line installs per FS TM. Use 12" HDPE costs per Tacoma area bids
Connections to Existing Catch Basins	$1,300	EA	8	*$10,400*	Escalated from 2005 Gray and Osborne unit costs for Friday Harbor, WA. CCI 8194.11 (2005) to 10699 (April, 2017).
Drain Rock/Gravel Base Puchase and Place	$25	CY	944	*$23,517*	Dickson's rates for materials with RS Means for delivery and placement = $24.90 total for drain rock
Backfill and Compaction	$2.35	CY	75,556	*$177,556*	Assuming this is placement and compaction of on-site materials; units were revised to match RS Means; if import is required we recomment Gravel Borrow from Dickson
Media Treatment (below grade) Vault and Install	$52,629	EA	3	*$157,888*	Escalated from 2008 City of Tacoma evaluation. Contech syle concrete vault with heavy traffic load rating.
Treatment Media Replacement (Initial)	$651	CY	5	*$3,257*	From PRB calcs costs above. Assumes 50/50 ZVI/sand mixture.
HMA (conventional) Pavement (5-inch)	$100	TN	262	*$26,235*	From Port of Tacoma on call rate. Assumes 5" repave over 5' wide area through full length of excavation. Asphalt at 2tn/1cy
Waste Disposal Haul and Disposal	$54	CY	944	*$51,359*	Assumes drain rock volume is equivalent to waste, slag left in place otherwise and recapped. Disposal costs below.
French Drain and Ex Situ Treatment Vault Total		LS		*$1,516,611*	
Ex Situ Treatment Maintenance (Annual)					
ZVI/Sand Mix Replacement	$651	CY	5	*$3,257.14*	From PRB calcs costs above. Assumes 50/50 ZVI/sand mixture.
Spent Media Disposal	$54	CY	5	*$1,000*	Estimate below or minimum of $1000, assumes media is non-haz
Vac Truck - Media Removal	$3,272	LS	1	*$3,272*	From Port of Tacoma's stormline jetting verbal estimate
3 submersible pump power usage	6,000	kW-h/yr	0.07	*$420*	Assume 2000 kWh/a per pump (Grunfos .5HP pump at 20'and 5gpm)
2 2HP transfer pumps at 20% service	2,000	kW-h/yr	0.07	*$140*	Assume 5000 kWh/a per pump
NPDES Annual Sampling Cost	1	LS	$8,000	*$8,000*	Costs from ALS, only metals analysis ($166/sample). Assumes monthly samples. Assumes 4hrs labor x $120/hr per sampling.
Operations Labor	1	LS	$6,500	*$6,500*	Estimate for 1hr/wk @ $125/hr operations and monitoring.
NPDES Monthly Reporting	1	LS	$6,000	*$6,000*	Assumes 4hrs labor/month @ $125/hr
NPDES Annual Reporting	1	LS	$2,500	*$2,500*	Est. 20hrs at $125/hr
Annual Ex Situ Treatment Maintenance O&M total				*$31,089*	
Ex Situ Treatment Maintenance (periodic, 5-yr)		`			
NPDES Permit Re-Application	1	LS	$7,500	*$7,500*	Estimate from 2014/15 GSI permit re-application effort. Assume re-appication every 5 years
NPDES Permit Remewal Fee	1	LS	$5,200	*$5,200*	Assumes individaul water plant permit fee schedule. http://apps.leg.wa.gov/wac/default.aspx?cite=173-224-040
Quarterly Samples for Renewal	1	LS	$2,987	*$2,987*	NPDES renewal analytical costs (assumes 4 quarterly samples) from Eugene Project. Costs from Test America.
.5HP submersible pump replacement	1	EA	$1,250	*$1,250*	Est. for a grundfos 0.5HP submersible pump. Assume 1 one replacement every 5 yrs
Valve, pipe, and controls replacements	1	LS	$3,000	*$3,000*	Budget for miscellaneous replacements
O&M Labor	1	LS	$10,000	*$10,000*	Budget for miscellaneous repair
Periodic Ex Situ Treatment Maintenance O&M total				*$29,937*	
Subtitle D Disposal (no stabilization)					
Haul to LRI in Graham WA	$15	TN	1		Assume $125/hr per truck, 4 turns at 10 hr days. Assume 14cy trucks.
Disposal at LRI	$21	TN	1		From Port of Tacoma 2015 contract rates, add 3.6% for WA waste tax.
	$36.25	TN			Assumes excavation and disposal takes 6 days for 1800cy
Disposal (rolled up as CY)	$54.38	CY			Assumes waste density of 1.5 ton/CY

Source Removal (Alternative 5)				*Sub-totals*	
Rubbilize existing RCC	$2	SY	142,780	*$285,560*	Assumes 13" average of RCC (from RI) across property (30ac). $2/SY value provided by Jerry Thayer (Mat-Con) via email April to June 2017
Excavation	$12	CY	337,119	*$4,045,433*	Assumes excavator loading trucks, from contractor bid on similar project.
Haul and Subtitle D Disposal (no stabilization)	$54	CY	237,967	*$12,940,770*	From above, assumes disposal w/LRI
Import gravel layer (purchase/place)	$25	CY	27,763	*$691,293*	Assumes placement of equivalent excavated material minus rubbilized concrete. Dickson's rates for materials with RS Means for delivery and placement = $24.90 total for drain rock
Total Removal Cost				$17,963,056	
Repave Site (Alt 2)	$116,056.52	Ac	29.5	*$3,423,667*	Repave site as Alt 2, minus gravel layer. Includes compaction, HMA, and triaxial grid over 29.5 ac
Total Construction Cost				*$21,386,723*	
Cap Resurfacing/Asphalt Overlay (Alt 1)				*Sub-totals*	
HMA (conventional) Pavement (4-inch)	$70	TN	31,729	*$2,221,022*	Averaged price of WSDOT 2016 state average HMA cost and local vendor quote. 29.5 acres, HMA = 2tns/CY
Asphalt Tack Coat	$0.50	SY	142,780	*$71,390*	Jerry Thayer (Mat-Con) via email April to June 2017
Total Construction Cost				$2,292,412	
Enhanced Cap (Alt 2)				*Sub-totals*	
HMA (conventional) Pavement (5-inch)	$70	TN	39,661	*$2,776,278*	Averaged price of WSDOT 2016 state average HMA cost and local vendor quote. 29.5 acres, HMA = 2tns/CY
Import 12 inch gravel layer (purchase/place)	$25	CY	47,593	*$1,185,074*	Dickson's rates for materials with RS Means for delivery and placement = $24.90 total for drain rock
Compact gravel (2passes)	$0.30	CY	47,593	*$14,278*	2016 RS Means (Tacoma, WA): Line #312323235050 - compaction, riding, vibrating roller, 8-in lifts, 2 passes
Stripdrain for drainage layer over RCC	$215.00	Roll	30	*$6,450*	Rolls are 150' long; Vendor quote @$215/roll
Triaxial Grid (purchase/deliver/install)	$3.99	SY	157,058	*$626,661*	Jordan Rabin & Garrett Fountain (Tensar Corp) via email 7/27/17 , 29.5 acres plus 10%
Total Construction Cost				$4,608,741	
Enhanced Cap (Alt 3)				*Sub-totals*	
HMA (conventional) Pavement (5-inch)	$70	TN	39,661	*$2,776,278*	Averaged price of WSDOT 2016 state average HMA cost and local vendor quote. 29.5 acres, HMA = 2tns/CY
Triaxial Grid (purchase/deliver/install)	$3.99	SY	157,058	*$626,661*	Jordan Rabin & Garrett Fountain (Tensar Corp) via email 7/27/17
Sand Purchase (above and below GCL layer)	$7.00	TN	41,938	*$293,566*	Dickson Company (Waller Road Gravel Pit): January 2017 price list
Sand Transport and Place	$11.40	CY	23,828	*$271,639*	2016 RS Means (Tacoma, WA): Hauling - Line #312323200134 assuming haul from Dickson @ 5mi/1-way; Backfill - Line #312323170020
GCL Liner @ k =10^-8 to 10^-9 cm/s	$0.63	SF	1,413,522	*$890,519*	Jeff Boys (ACF West) via email 6/15/17
Rubbilize existing RCC	$2	SY	142,780	*$285,560*	Assumes 13" average of RCC (from RI) across property (30ac). $2/SY value provided by Jerry Thayer (Mat-Con) via email April to June 2017
Stripdrain for drainage layer over GCL	$215	Roll	30	*$6,450*	Rolls are 150' long; Vendor quote @$215/roll
Excavate 13" thick existing RCC and 18" gravel (stockpile)	$6.62	CY	122,949	*$813,925*	2016 RS Means (Tacoma, WA): Line #312316464400 dozer excavation, 300-ft haul, sand & gravel
Construct Stockpile area (labor, geosynthetic, ecology block)	$42,000	LS	1	*$42,000*	BTL Liner (liner materials), 48Barriers (ecology blocks), and RS Means 2016 (Tacoma, WA) for labor & equipment
Backfill placement w/stockpiled RCC and Gravel	$2.56	CY	122,949	*$314,751*	2016 RS Means (Tacoma, WA): Line #312323144400 - backfill, structural, 300'haul sand & gravel from existing stockpile, 200HP, B10B crew
RCC and Gravel Compaction (2 passes)	$0.30	CY	122,949	*$36,885*	2016 RS Means (Tacoma, WA): Line #312323235050 - compaction, riding, vibrating roller, 8-in lifts, 2 passes
Total Construction Cost				$6,358,234	
Conventional HMA Resurfacing (3" HMA)				*Sub-totals*	
HMA (conventional) Pavement (3-inch)	$70	TN	23,797	*$1,665,767*	Averaged price of WSDOT 2016 state average HMA cost and local vendor quote. 29.5 acres, HMA = 2tns/CY
Asphalt Tack Coat	$0.50	SY	142,780	*$71,390*	Jerry Thayer (Mat-Con) via email April to June 2017
Planing Bitumious Pavement	$2.25	SY	142,780	*$320,855*	Average WSDOT first bid price between 2013-2017 for projects greater than 100K SY.
Total Construction Cost				$2,058,012	
Sawmill Bioremediation (Alt 2) Enhanced Bio	thickness (ft)				
Treatment Area Volume & Weight Calculation	5	LB	427,606		5' thick "target zone" (see FS TM Figure 5) at 35' radius. Assume 5' of crushed recycle concrete is being neutralized at 20% pure CaCO3.
Benchscale Test	$31,000	LS	1	*$31,000*	Assumes 8 core field samples composite for 3 for bio & oxidant benchscale testing. Samples collected @$1500 ea, tests at $3000/ea + Report @ $10k
Injection Well Points by Geoprobe	$7,700	Day	2	*$15,400*	From contractor bid cost on similar project. 2 days to perform injections on 22 points. Assume oversight cost of $115/staff/hr @12hr days.
Ammonia Sulfate	$0.20	LB	3,887	*$777*	From SC 2017 AG report for dry bulk pricing $310/ton. Assume $400/ton. Assume neutralization potential of 110 lb pure CaCO3 per Purdue Extension Doc.
Chemical Mixing Equipment Materials and Ops	$800	point	15	*$12,000*	From 2016 cost estimating, Washington PCP chemox injection project
Water	$4.00	CCF	44	*$176*	From 2016 cost estimating, Washington PCP chemox injection project
Oversight	$3,000	Day	2	*$6,000*	Assumes 2 staff oversight at $125/hr@ 12hr day.
Bioremediation Injection Cost				$65,353	

Sawmill Excavation (Alt 3)	thickness (ft)				
Treatment Area Volume Calculation	12	CY	1,780		Per FS TM Figure 13 assume excavation around historical dig area. Approximately 15' beyond former extent to a maximum depth of 12'
Extract Well Installation (6", 20' deep)	$2,500	per well	3	*$7,500*	From contractor 2016 bid, includes mob fee ($500), stard card ($65), vault ($375), drilling at $35/ft. Assumes consultant oversight at $500/well. Assumes 1 solid and 1 liquid drum disposal ($175 + $185)
Excavation	$12	CY	1,780	*$21,363*	From contractor bid on similar project.
Haul and Subtitle D Disposal (no stabilization)	$54	CY	1,780	*$96,810*	From above, assumes disposal with LRI
Import gravel layer (purchase/place)	$25	CY	1,780	*$44,322*	Assumes placement of equivalent excavated material minus rubbilized concrete. Dickson's rates for materials with RS Means for delivery and placement = $24.90 total for drain rock
Carbon Treatment Unit Rental (dewatering)	$2,000	week	2	*$4,000*	Assumed cost for rental carbon units, https://clearcreeksystems.com/services/system-rentals/
Total Removal Cost				$173,995	
Periodic Maintenance and Costs				*Sub-totals*	
Well Installation (2", 20' deep)	$2,500	ea	1		From contractor 2016 bid, includes mob fee ($500), stard card ($65), vault ($375), drilling at $35/ft. Assumes consultant oversight at $500/well. Assumes 1 solid and 1 liquid drum disposal ($175 + $185)
Well Abandonment	$1,500	ea	1		From contractor bid on similar project.
Cap Inspections	$8,500	ea	1		From Port of Tacoma 2017 costs. $6.5K contract, $2k Port staff
Cap Repairs (crack repairs)	$3.40	LF	16000	$54,400.00	Assumes crack repair at 10x the width of the property . Approximate WSDOT Bid Item Database Low Bid Average for 2015-2017, range from $2.20 to $4.60
GCL Liner Repair	3	%	1	$190,747.02	Assumes 3% cap liner repair at 3% installation cost (see above)
Monitoring and Characterization					
Sampling mobilization	$4,140	per event	1		Assumes an 6hr mob/demob + 12hr prep x 2 staff at $115/hr
Groundwater sampling (labor)	$270	per well	1		Assumes 2.5hr per well x 1 staff @ $115/hr + equipment surcharge of $40/well (assuming $160 day rate/ 4 wells)
Surface/OF Surface Water Sampling (labor)	$98	per location	1		Assumes 0.5hr per well x 1 staff @ $115/hr + equipment surcharge of $40/location
NMDS Porewater Sampling (labor)	$3,500	per location	1		Assumes up to 14 jars planted at each transect. Based on RI budgeting.
Analytical (Sawmill)	$300	per well	1		Assumes PCP (8270D) $225/sample and total metals analysis (6020A) $75/sample from ALS 2017 quote
Analytical (Log Yard)	$75	per well	1		Assumes total metals analysis (6020A) $75/sample from ALS 2017 quote
Annual data reporting	$10,000	per event	1		From inccurred costs on similar projects.
Annual GW Sampling Event (Sawmill)	$16,420	yr	1		Assumes 4 wells and unit costs above
Semi-Annual GW Sampling Event (Sawmill)	$22,840	yr	1		Assumes 4 wells and unit costs above
Quarterly GW Sampling Event (Sawmill)	$35,680	yr	1		Assumes 4 wells and unit costs above
Bi-Annual GW Sampling Event (Log Yard) - 9 Wells	$6,898	yr	1		Assumes 9 wells and unit costs above . Annualized on 5yr review periods or 2/5's annual monitoring cost.
Annual GW Sampling Event (Log Yard) - 12 Wells	$18,280	yr	1		Assumes 12 wells and unit costs above
Semi-Annual GW Sampling Event (Log Yard)	$26,560	yr	1		Assumes 12 wells and unit costs above
Quarterly GW and SW Sampling Event (Log Yard)	$45,903	yr	1		Assumes 12 wells + 4 SW locations, + 3 OF locations, and unit costs above
Maintain Institutional Controls	$1,000	LS	1		Budget for annual controls maintenance.
Semi-annual SW and OF sampling - 7 locations	$2,415	yr	1		Assumes 7 sample locations, unit costs above
Semi-annual Porewater NMDS Sampling - 4 Locations	$28,600	yr	1		Assumes 4 sample locations, unit costs above
Reduced Annual GW Sampling Event (Log Yard) - 9 Wells	$17,245	yr	1		Assumes 9 wells and unit costs above