South Park Landfill Remedial Investigation/ Feasibility Study June 2014 Draft

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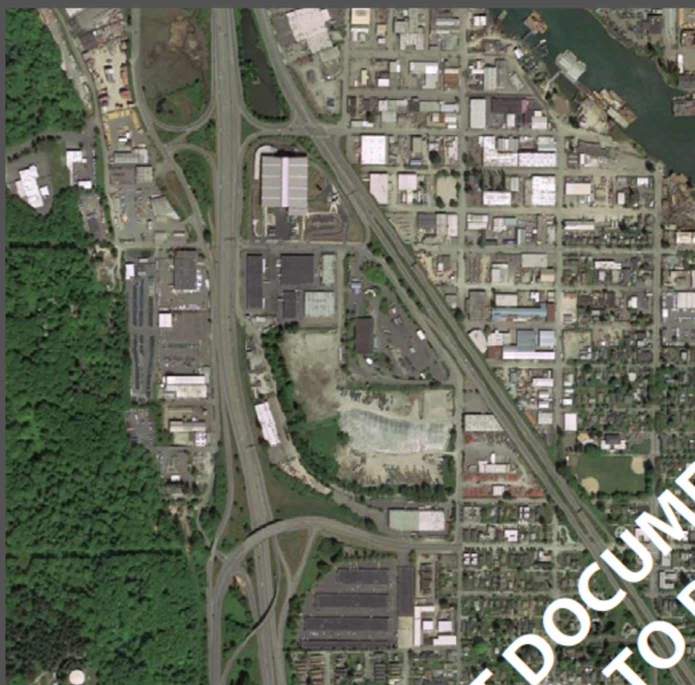
South Park Landfill

Remedial Investigation/ Feasibility Study



Prepared for

City of Seattle
South Park Property Development, LLC

June 2014

DRAFT FINAL

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City of Seattle
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Prepared by

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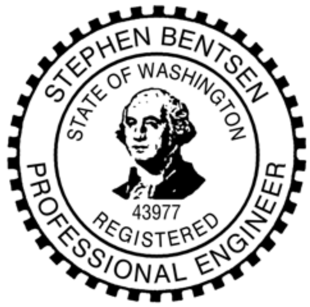
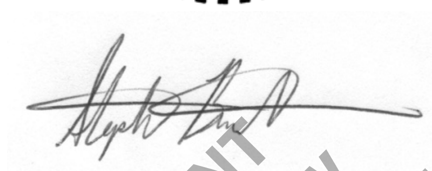
CERTIFICATION

This document has been prepared for the City of Seattle under the direction of:





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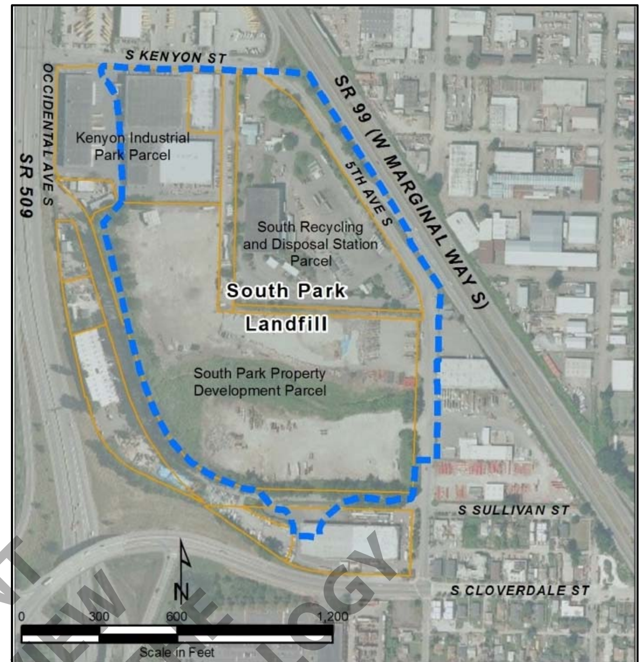
Executive Summary



The South Park Landfill (Landfill) is a closed solid waste landfill in the South Park neighborhood of Seattle, Washington. It is located in the Lower Duwamish Valley near the western valley wall between State Routes 509 and 99. The landfill operated from the 1930s until 1966 when it was closed. By 1970, the City of Seattle (City) South Recycling and Disposal Station (SRDS), Kenyon Industrial Park (KIP), and several other facilities had been built on top of the Landfill and were operating.

In February 2007, the site was added to Washington State's Hazardous Sites List. Soil, groundwater, surface water, and landfill gas (LFG) monitoring began in the late 1980s and has continued to the present day.

This Remedial Investigation/Feasibility Study (RI/FS) of the Landfill has been conducted under Washington State Model Toxics Control Act (MTCA) Agreed Order No. 6706 (Agreed Order) with the Washington State Department of Ecology (Ecology). The RI/FS determined the nature and extent of contamination associated with the Landfill and evaluated the necessary remedial actions. This RI/FS was conducted in accordance with MTCA, as established in Chapter 173-340 of the Washington Administrative Code (WAC).

Sections 1.0 through 7.0 of this document present the RI findings for the site. Sections 8.0 through 16.0 present alternatives for the different actions that make up remedial action, and Section 17.0 presents the preferred Remedial Alternative. An overview of the RI/FS findings are discussed below.

SOUTH PARK LANDFILL CONCEPTUAL SITE MODEL

The native soils beneath the Landfill, and across the entire Lower Duwamish Valley, consist of river- and estuarine-deposited silts and sands. Beginning in the 1890s and intensifying in the 1930s, human activities further raised the land surface throughout the valley by the placement of fill. At the Landfill, the fill consisted of solid wastes, much of which was burned to reduce its volume and promote more rapid settling and compaction. When the Landfill was closed in 1966, additional general-purpose (unclassified) fill was brought in, and the surface was regraded to allow the development of the KIP parcel, the SRDS parcel, and land for other industrial operations. Since 2013, the largest remaining parcel, the South Park Property Development (SPPD) parcel, has been undergoing cleanup and redevelopment according to an Ecology-approved Interim Action Work Plan that was prepared and approved in 2013 under the Agreed Order.

Solid waste landfills, which have been extensively studied across the country and are well understood, can be classified into five main stages on the basis of the aging, or breakdown, of wastes within the landfill. Active landfill cells begin in Stage 1, in which the refuse/waste is largely intact, and progress through Stage 4 as the refuse decomposes and the cell is closed. An old, Stage 5 landfill, on the other hand, is one in which the wastes are so degraded that the landfill processes are negligible.

According to the data collected at the Landfill, it is in late Stage 4 to early Stage 5, depending on the location within the Landfill. The specific findings of the RI are the following:

- Solid waste was disposed of in the Landfill from the 1930s through the mid-1960s. Much of the solid waste was burned to reduce its volume. The Landfill is now old, and the contents are heavily degraded.
- The Landfill was, and is, unlined. Much of the solid waste lies above a silt deposit, and deeper sections of the solid waste have breached the silt deposit and are in direct contact with regional groundwater.
- Of the entire Landfill, 40 percent is already developed with buildings, a pavement cover, and in-place stormwater controls; and 60 percent is being developed with buildings, pavement, and stormwater controls. The cleanup and stabilization aspects of the redevelopment activities are included in the Ecology-approved Interim Action Work Plan.
- Ongoing monitoring of LFG and groundwater confirms that the Landfill is in late Stage 4/early Stage 5, depending on the location, as evidenced by the following characteristics:
  - o The Landfill is still producing low concentrations of methane and remains anaerobic (lacking oxygen), but the rate of LFG production is so low that there is no measurable pressure buildup (late Stage 4). In some areas, the methane production is so low that normal air is entering the Landfill, and the air within the Landfill contains low but measurable concentrations of oxygen (early Stage 5).
  - o The leachate has a neutral pH, with a salt content that is trending downward and less than the naturally occurring salinity found deeper in the groundwater system.
- Methane, which is the primary concern related to LFG, was not detected in the structures on top of the Landfill, but it is still measurable within the Landfill. Benzene and xylenes, both constituents of petroleum products and solvents, are present in LFG near a known petroleum source that post-dates the Landfill and is slightly upgradient of the Landfill. Other than the volatile organic compounds (VOCs) near this source, no other VOCs of concern in terms of vapor intrusion are present in the LFG.
- Vinyl chloride is the chemical of concern for groundwater at the Landfill. The concentrations in on-site wells ranged from no detection at a detection limit of 0.02 micrograms per liter (µg/L) to a detected concentration of 1.4 µg/L. Samples of groundwater were also collected along Riverside Drive, where groundwater from the Landfill would discharge into the waterway; in these samples, vinyl chloride was not detected at a detection limit of 0.1 µg/L. Ecology has established a cleanup level of 0.29 µg/L for vinyl chloride in groundwater. This value was selected to protect potential drinking water uses, but it is also protective of surface water quality. There are no current or anticipated drinking water wells between the Landfill and the Lower Duwamish Waterway, which is located approximately 1,600 feet downgradient; therefore, there is no exposure to the groundwater.

The potential exposure pathways at the Landfill are (1) incidental direct contact with contaminated soil or solid waste that is not under a controlled landfill cap, (2) incidental direct contact with contaminated groundwater (because there are no drinking water wells, this would be limited to contact during construction activities below the water table), and (3) direct contact with/inhalation of indoor air that may be contaminated as a result of LFG entry into structures.

MTCA REQUIREMENTS FOR LANDFILLS

Under MTCA, closed landfills are considered to be sites that have used "containment of hazardous substances" as the preferred remedy. To meet the requirements of MTCA, the selected remedy must be protective of human health and the environment under specified exposure conditions. WAC 173-340-360(2)(a) specifies four threshold criteria that must be satisfied by all cleanup actions:

1. Protect human health and the environment.
2. Comply with cleanup standards (WAC 173-340-700 through 173-340-760).
3. Comply with applicable local, state, and federal laws (WAC 173-340-710).
4. Provide for compliance monitoring (WAC 173-340-410 and WAC 173-340-720 through 173-340-760).

In addition, WAC 173-340-360(2)(b) specifies three other criteria that cleanup actions must achieve:

5. Use permanent solutions to the maximum extent practicable.
6. Provide for a reasonable restoration time frame.
7. Consider public concerns (WAC 173-340-600).

PREFERRED REMEDIAL ALTERNATIVE

The FS establishes the remedial action goals and describes how the landfill containment requirements will be met in accordance with the MTCA regulatory requirements. The study relied on a large volume of experience with the successful closure and/or cleanup of solid waste landfills. The preferred alternative for the Landfill closure consists of the following elements:

- A **landfill cap/cover** to prevent people, animals, and stormwater from coming into direct contact with the solid waste. The landfill cap will also decrease the amount of stormwater infiltration relative to conditions before the remedial action is implemented.
- **Stormwater controls** to prevent stormwater from coming in contact with solid waste and to protect the landfill cap/cover. Stormwater controls will also need to meet regulatory requirements, including the City's stormwater code and any applicable regulations related to the National Pollutant Discharge Elimination System.
- **LFG controls** to prevent subsurface migration of LFG into on-site or nearby buildings and structures. Because of the low rate of methane production, either active or passive systems or ongoing monitoring are appropriate LFG controls, depending on the parcel.
- **Monitored natural attenuation** of groundwater to confirm that the residual vinyl chloride in the groundwater system continues to degrade over time.
- **Long-term monitoring** of the cap/cover, the LFG controls, and groundwater to ensure that the remedy is effective and provides long-term protection of human health and the environment. Additional details of the monitoring will be presented in the Cleanup Action Plan (CAP).

- **Environmental Covenants** to ensure long-term compliance with regulations and maintenance of the remedy. Draft Environmental Covenants will be included in the CAP.

REGULATORY PROCESS

Ecology has approved this Draft Final RI/FS and prepared a Draft CAP identifying its preferred remedy for the Landfill. The Draft CAP and its associated Consent Decree will be available for public review and comment in 2014. This Draft Final RI/FS will be available as a supporting document at that time. After the public comment period, the RI/FS, CAP, and Consent Decree will be finalized. Ecology will also determine whether the actions completed for the Interim Action on the SPPD parcel are equivalent to the required final remedial action; if they are, the Interim Action will become the final action for that parcel.

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List of Abbreviations and Acronyms

Abbreviation/ Acronym	Definition
7901	7901 2nd Avenue, LLC
AESI	Associated Earth Sciences
Agreed Order	Agreed Order No. 6706
ARAR	Applicable or Relevant and Appropriate Requirement
bgs	Below ground surface
BMP	Best Management Practice
CAP	Cleanup Action Plan
CDD	Chlorinated dibenzo-p-dioxin congeners
CDF	Chlorinated dibenzofuran congeners
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
City	City of Seattle
CKD	Cement kiln dust
cm/sec	Centimeters per second
COC	Chemical of concern
COPC	Chemical of potential concern
County	King County
CPAH	Carcinogenic polycyclic aromatic hydrocarbon
CSCS	Confirmed or Suspected Contaminated Site
CUL	Cleanup level
DCE	Dichloroethene
DNAPL	Dense non-aqueous phase liquid
DU	Decision Unit
Ecology	Washington State Department of Ecology
FID	Flame ionization detector
FS	Feasibility Study
ft/day	Feet per day
GIS	Geographic Information System
Glitsa	Glitsa American, Inc.
HDPE	High density polyethylene
IA	Interim Action

Abbreviation/ Acronym	Definition
IB	Industrial Buffer
IG2	General Industrial 2
KIP	Kenyon Industrial Park
L3	Lowrise 3
Landfill	South Park Landfill
LEL	Lower explosive limit
LFG	Landfill gas
LUST	Leaking underground storage tank
MCL	Maximum Contaminant Level
µg/kg	Micrograms per kilogram
µg/L	Micrograms per liter
µg/m^3	Micrograms per cubic meter
µS/cm	Microsiemens per centimeter
mg/kg	Milligrams per kilogram
mg/L	Milligrams per liter
MFS	Minimum Functional Standards
MI	Multi-increment
MNA	Monitored natural attenuation
MSL	Mean sea level
MTCA	Model Toxics Control Act
mV	Millivolts
NAVD 88	North American Vertical Datum of 1988
ng/kg	Nanograms per kilogram
NMOC	Non-methane organic compound
NPDES	National Pollutant Discharge Elimination System
NRDS	North Recycling and Disposal Station
OSHA	Occupational Safety and Health Administration
PAH	Polycyclic aromatic hydrocarbon
PCB	Polychlorinated biphenyl
PCE	Tetrachloroethene
PEL	Permissible exposure limit
PID	Photoionization detector

Abbreviation/ Acronym	Definition
PLP	Potentially liable person
POC	Point of compliance
ppb	Parts per billion
ppbv	Parts per billion by volume
ppm	Parts per million
ppmv	Parts per million by volume
PQL	Practical Quantification Limit
PSCAA	Puget Sound Clean Air Agency
PVC	Polyvinyl chloride
RCW	Revised Code of Washington
redox	Oxidation-reduction
RETS	Renton Effluent Transfer System
RI	Remedial Investigation
RI/FS	Remedial Investigation/Feasibility Study
ROW	Right-of-way
SF 5000	Residential Single Family 5000
Site	MTCA-regulated site
SPU	Seattle Public Utilities
SPPD	South Park Property Development, LLC
SR	State Route
SRDS	South Recycling and Disposal Station
SVOC	Semivolatile organic compound
SWPPP	Stormwater Pollution Prevention Plan
TCE	Trichloroethene
TCLP	Toxicity Characteristic Leaching Procedure
TDS	Total dissolved solids
TEF	Toxicity equivalency factor
TEQ	Toxicity equivalency quotient
TPH	Total petroleum hydrocarbons
TSCA	Toxic Substances Control Act
UECA	Uniform Environmental Covenants Act
USACE	U.S. Army Corps of Engineers

Abbreviation/ Acronym	Definition
USEPA	U.S. Environmental Protection Agency
UST	Underground storage tank
VOC	Volatile organic compound
WAC	Washington Administrative Code
WISHA	Washington Industrial Safety and Healthy Act
Work Plan	Remedial Investigation/Feasibility Study Work Plan
WSDOT	Washington State Department of Transportation

1.0 Introduction

The South Park Landfill (Landfill) is a former municipal solid waste landfill located in the South Park neighborhood of Seattle, Washington. It received solid wastes from the 1930s until 1966, when it was closed under existing landfill closure laws. In February 2007 the Landfill was added to Washington State's Hazardous Sites List, based on concerns related to groundwater contamination, and the presence of potentially flammable landfill gas (LFG). Groundwater, surface water, soil, and LFG investigations began in the late 1980s and have continued to the present day.

A Remedial Investigation/Feasibility Study (RI/FS) of the Landfill has been conducted under Washington State Model Toxics Control Act (MTCA) Agreed Order No. 6706 (Agreed Order) with the Washington State Department of Ecology (Ecology) in order to determine the nature and extent of contamination associated with the Landfill and evaluate any remedial actions necessary for the site. The City of Seattle (City), King County (County), and South Park Property Development, LLC (SPPD) were originally identified by Ecology as the potentially liable persons (PLPs) for the Landfill. The City and SPPD were signatories of the Agreed Order and have expanded the scope of work to include implementation of an Interim Action (IA). The scope of work for completing the RI/FS can be found in the Remedial Investigation/Feasibility Study Work Plan (Work Plan; Farallon 2010a). This RI/FS has been conducted in accordance with MTCA, as established in Chapter 173-340 of the Washington Administrative Code (WAC).

1.1 MTCA REQUIREMENTS FOR LANDFILLS

The Landfill is a historical municipal landfill that was originally closed in 1966 under the County's Title 10 provisions for landfills—the only applicable regulations at the time. Washington State's first Minimum Functional Standards (MFS) for solid waste landfills, Chapter 173-301 WAC, became effective in 1972. In November 1985, Chapter 173-301 was replaced by Chapter 173-304 as Washington State's MSF for solid waste landfills. MTCA allows for containment to be the preferred remedy for historical landfill sites and uses MFS (WAC 173-304) as a relevant and appropriate requirement.[1] Closed landfills are considered under MTCA to be sites that have used "containment of hazardous substances" as the preferred remedy. Under WAC 173-340-740(6)(f), MTCA states that containment sites will comply with cleanup standards if they meet the following requirements:

> *"WAC 173-340-740(6)(f) The department recognizes that, for those cleanup actions selected under this chapter that involve containment of hazardous substances, the soil cleanup levels will typically not be met at the points of compliance specified in (b) through (e) of this subsection. In these cases, the cleanup action may be determined to comply with cleanup standards, provided:*
>
> > *(i) The selected remedy is permanent to the maximum extent practicable using the procedures in WAC 173-340-360;*
> >
> > *(ii) The cleanup action is protective of human health. The department may require a site-specific human health risk assessment conforming to the*

[1] Refer to WAC 173-340-370(3), where Ecology recognizes the need to use engineering controls such as containment for sites that contain large volumes of materials with relatively low levels of hazardous substances and WAC 173-340-350(8)(c), which allows for the FS to be focused appropriate for the site. WAC 173-340-710(7)(c) indicates that MFS (WAC 173-304) is an Applicable or Relevant and Appropriate Requirement (ARAR) for closed solid waste landfills.

requirements of this chapter to demonstrate that the cleanup action is protective of human health;

(iii) The cleanup action is demonstrated to be protective of terrestrial ecological receptors under WAC 173-340-7490 through 173-340-7494;

(iv) Institutional controls are put in place under WAC 173-340-440 that prohibit or limit activities that could interfere with the long-term integrity of the containment system;

(v) Compliance monitoring under WAC 173-340-410 and periodic reviews under WAC 173-340-430 are designed to ensure the long-term integrity of the containment system; and

(vi) The types, levels, and amount of hazardous substances remaining on-site and the measures that will be used to prevent migration and contact with those substances are specified in the draft cleanup action plan."

For closed solid waste landfills, Ecology allows for containment to be the remedial action with MFS as an ARAR. It is not necessary to evaluate removal actions or perform a disproportionate cost analysis; however, the specific remedy selected for the Landfill must demonstrate that the other elements of containment are met as defined by sections (ii) through (iv) above.

MFS (WAC 173-304) then acts as a starting point and a relevant and appropriate requirement for defining the MTCA remedy for the Landfill. Approximately 10 years after MFS was developed, the U.S Environmental Protection Agency (USEPA) published their *Presumptive Remedy for CERCLA Municipal Landfill Sites Directive* (OSWER Directive 9355.3-11). This document was based on their experiences on multiple solid waste landfill sites and reflected a growing body of knowledge regarding the key components that were necessary to build long-term containment remedies at solid waste landfills. This RI/FS uses ideas from USEPA's presumptive remedy to refine the MTCA remedial action for the Landfill, while continuing to treat MFS as a key ARAR. The remedy described in the FS follows the concepts in MTCA, MFS, and USEPA's guidance and uses the term "presumptive remedy" to remind the reader of the large body of knowledge that exists regarding solid waste landfills and their long-term care.

1.2 TERMINOLOGY

The following terms are used throughout the document and it is helpful to distinguish them from the beginning:

- **South Park Landfill (Landfill):** Landfill refers to the extent of refuse or solid waste that was placed during the operation of the South Park Landfill from the 1930s until it was closed in 1966.
- **Site (capitalized):** Site is intended to be used consistent with the MTCA definition of the site and includes the Landfill and other areas where contamination has come to be located.
- **Parcel:** The term parcel is used to refer to tax parcels with specific ownership. The Landfill occurs on several parcels that are owned by different parties. Several parcels contain areas where the Landfill is present and other areas where it is not. Likewise, several parcels, such as the Kenyon Industrial Park, include areas that are part of the MTCA Site and other areas that are not. Many of the figures within the report include

both parcel boundaries and the Landfill boundary to help the reader understand the relationship between the two when both are discussed.

The MTCA Site definition is also intended to include the West Ditch component of the stormwater system. This ditch is located outside of refuse and is not part of the Landfill (as defined by the extent of solid waste), but has been a key component of the stormwater system at the Landfill for decades and is considered part of the MTCA Site.

1.3 REMEDIAL INVESTIGATION/FEASIBILITY STUDY OBJECTIVE

The purpose of the Remedial Investigation (RI) is to collect, evaluate, and document the data necessary to adequately characterize the environmental conditions associated with the Landfill in support of the Feasibility Study (FS). The purpose of the FS is to develop and evaluate cleanup alternatives and recommend a cleanup action for the Landfill in accordance with Chapters 173-340-350 through 173-340-390 WAC. Based on the results documented in the RI/FS, a Draft Cleanup Action Plan (CAP) will be prepared for submittal to Ecology in order to satisfy the requirements of the Agreed Order.

The specific objectives of this RI include the following:

- Identify the extent of refuse that is to be "contained" as part of the Landfill cleanup.
- Identify the nature and extent of soil contamination related to releases from the Landfill, but outside of area of refuse.
- Identify the nature and extent of LFG present within and surrounding the Landfill.
- Identify the potential for ongoing leachate production and the need for leachate controls.
- Identify the nature and extent of groundwater contamination coming from the Landfill.
- Develop appropriate cleanup levels (CULs) for contamination that is not contained within the Landfill.

All of the RI objectives have been met for this Site, as will be discussed in Sections 2.0 through 6.0 of this document.

The specific objectives of the FS include the following:

- Identify remedial action objectives appropriate for closed solid waste landfills, including identification of landfill-related ARARs.
- Evaluate alternatives and selection of the preferred alternative for the presumptive remedy components that are consistent with solid waste landfill closure and the redevelopment of the site.
- Identify the mechanism that will ensure that the preferred alternative will function effectively and will be operated and maintained in a manner that will ensure protection of human health and the environment in a long-term manner.
- Provide a schedule for the implementation of the preferred alternative.

The objectives of the FS have also been met, as will be discussed in Sections 8.0 through 17.0.

1.4 REPORT ORGANIZATION

The RI is presented in Sections 2.0 through 6.0. Sections 2.0 and 3.0 define the physical, historical, and geographical setting of the site. Section 4.0 identifies the extent of refuse and the nature and extent of soil contamination that is outside of the extent of refuse. Soil CULs developed under MTCA provisions are then used to identify areas of soil contamination that require remedial action. Section 5.0 describes the groundwater system, develops CULs for detected chemicals, and identifies the nature, extent, and fate of groundwater contamination associated with the Landfill. Section 6.0 describes the current condition of LFG formation and migration, and identifies any toxic chemicals (volatile organic compounds [VOCs]) present in the LFG.

Section 7.0 is the bridge between the RI and FS sections, summarizing the key RI findings, identifying critical exposure pathways, and defining the remedial action objectives for the cleanup.

Sections 8.0 through 16.0 present the requirements for the MTCA cleanup action at the Site. Each section evaluates a different component of the cleanup action with respect to technologies, and then screens alternatives that are appropriate for the Site. Section 17.0 then combines all of the cleanup action components into a single preferred alternative and discusses how this alternative meets the MTCA cleanup requirements.

The appendices provide additional information supplemental to the RI and FS sections and include the following:

- Appendix A – A historical analysis of the evolution of the Landfill and surrounding parcels including historical aerial photographs
- Appendix B – A collection of supporting field and sampling documentation including lithologic descriptions, construction completion reports, and indoor air monitoring details
- Appendix C – A summary of analytical data including frequency of detections, chemicals tested, and sample counts for soil, solids, groundwater, soil gas, and indoor air
- Appendix D – A summary of deviations from the Work Plan
- Appendix E – Analytical laboratory data reports for samples collected during the RI for soil, solids, groundwater, soil gas, and indoor air
- Appendix F – Analytical laboratory data validation reports for RI chemical analyses
- Appendix G – Field documentation for the West Ditch sampling and grain size analyses
- Appendix H – Dioxin/furan sample photographs and multi-increment (MI) sample composite process
- Appendix I – Hydrogeological data, including slug tests and groundwater elevation contour maps
- Appendix J – Groundwater quality trend plots and maps and data tables of results from specific groundwater sampling events from 2011 through March 2014.
- Appendix K –Model Restrictive (Environmental) Covenant supplied by Ecology

2.0 Site Setting

The following sections provide general information about the Landfill, including: the physical setting, the location and description of the various parcels that constitute the Landfill, a discussion of current conditions and redevelopment plans, and a description of previous environmental investigations and cleanup actions conducted in the vicinity of the Landfill. Section 3.0 describes the Landfill's physical setting in further detail.

2.1 DUWAMISH VALLEY HISTORY

The Landfill is located within the glacially-carved Duwamish Valley, which extends from Elliott Bay to the confluence of the Green River, and contains floodplains, freshwater wetlands, and tidal marshes. The valley was originally inhabited by Native American tribal communities before becoming settled by Euro-Americans in the 1850s. These settlers drained and filled the wetlands with various fill materials and cleared the lowland forests for agricultural and logging purposes. The subsequent channelization of the river, in the early 1900s, lead to an increase in commercial, industrial, and residential developments within the valley (Windward Environmental 2010). Two mixed industrial, commercial, and residential communities, Georgetown and South Park, later developed within the valley. In the mid-1960s, the South Park neighborhood was rezoned as industrial with some low-density residential areas. Industrial operations in the area include cargo handling and storage, marine construction, boat manufacturing, marina operations, paper and metals fabrications, food processing, and airplane parts manufacturing. Currently, approximately 3,700 people reside in the South Park neighborhood and work in the wholesale trade, transportation and utilities, construction/resources, manufacturing, and service industries (Ecology 2009a).

2.2 SITE AND SURROUNDING AREA DESCRIPTION

The Landfill consists of several parcels situated in the South Park neighborhood, located in Section 32 of Township 24 North, Range 4 East. It consists of several parcels that were initially added to the King County Tax Rolls via foreclosure in the 1920s and were later purchased by the City and the County in the 1950s. The Landfill was operated by the City until it closed in 1966 and included disposal and burning of municipal, commercial, and industrial waste (SPU 1997; Ecology and Environment, Inc. 1988). Since that time, the Landfill has undergone filling and grading activities and has been redeveloped; nearly half of the Landfill is currently covered with existing structures. A detailed description of the history of the Landfill and its owners is provided in Table 2.1 and Appendix A. Appendix A also includes historical aerial photographs illustrating changes to the Landfill boundary and land use over time.

The Landfill covers approximately 39 acres and is roughly bounded to the north by South Kenyon Street, to the east by State Route (SR) 99 and 5th Avenue South, to the south by South Sullivan Street, and to the west by Occidental Avenue South, as illustrated on Figure 2.1. The County tax assessor parcels and relevant parcel information are included on Figure 2.2. The red dashed line shown on Figure 2.2 depicts the approximate demarcation of the solid waste boundary as identified in the Work Plan (Farallon 2010b). A summary of parcel information is provided in Table 2.1, and a discussion of the individual parcels is provided below. Information presented in Section 4.0 will be used to define the final "extent of landfill solid waste;" therefore, the red dashed line shown on Figure 2.2 should be considered a preliminary demarcation of the Landfill boundary.

2.2.1 South Park Property Development Parcel

The SPPD property (County Tax Parcel No. 3224049005) includes 19.4 acres of open land purchased from the County in 2006. The property was purchased out of tax title by the County in 1957 and leased to the City from 1958 to 1978 for rubbish disposal. After disposal operations ended in 1966, additional unclassified fill was added and the parcel was graded. The County later leased portions of the property to a variety of tenants from the mid-1980s through the late 1990s, primarily for truck and equipment storage. In 2008, the property was largely cleared of vegetation and, in some areas, a layer of crushed concrete was added as ballast and the parcel was regraded. Portions of the eastern half of the property were recently used for truck parking and storage of empty-box storage containers. Because portions of the property perimeter are fenced, access to the property is through two gates along 5th Avenue South. The property is not currently served by municipal water, sewer, electricity, or other utilities and is zoned for industrial use. Future property development plans are discussed in Sections 2.4 and 8.3. These plans are in the early stage of implementation, with additional clearing and grading in process prior to full-scale construction during the summer of 2014.

2.2.2 South Recycling and Disposal Station Parcel

The South Recycling and Disposal Station (SRDS), a 10.3-acre parcel, is located at 8100 2nd Avenue South on County Tax Parcel No. 7328400005. This parcel was sold out of tax title status to the City in 1951. The SRDS was constructed in 1966 on top of the closed Landfill and includes the main waste disposal building, a small maintenance facility, a scale house, two vehicle-fueling systems, and several additional small buildings used for offices and household hazardous waste collection. Several of these structures, including the old scale houses and the main waste disposal building, are pile-supported. These piles extend to depths of more than 96 feet below ground surface (bgs; City of Seattle DOE 1965). The facility is paved except for some perimeter landscaping and small areas in the interior of the property. Two right-of-ways were added to this parcel in 2003 through the ordinance provided in Appendix A.

The current truck fueling systems at the SRDS consist of 2,000- and 3,000-gallon aboveground storage tanks (ASTs) used to store diesel fuel, and a dispenser island. In 1999, an earlier fueling system was decommissioned. It had consisted of two underground storage tanks (USTs; one 10,000-gallon diesel tank and one 3,000-gallon gasoline tank), dispensers, and underground piping. In 1999, Herrera Environmental Consultants, Inc. indicated that a release of petroleum hydrocarbons had occurred and that about 250 cubic yards of petroleum-contaminated soil were removed from an excavation beneath the former fuel dispensers during the decommissioning activities. (Herrera 1999) Some residual petroleum hydrocarbons, attributed to the former fueling system, remained in the soil. Heavy oil-range petroleum hydrocarbons were also detected and attributed to disposal practices when the property was operated as a landfill.

The property also contains a localized French drain system beneath the compactor structure on the east side of the tipping building, which discharges to the municipal sanitary sewer. The system is designed to capture the seasonal build-up of groundwater beneath the foundation, but operates infrequently. The utilities serving the SRDS are located primarily along 2nd Avenue South, with the exception of utilities located along 5th Avenue South. Future development plans for the parcel are discussed in Section 2.4 of the RI.

2.2.3 Kenyon Industrial Park and the 7901 2nd Avenue South Parcels

The northwest quadrant of the Landfill is occupied by two parcels with privately owned buildings leased for primarily industrial use. The larger is the Kenyon Industrial Park (KIP), a 6.5-acre parcel (County Tax Parcel No. 3224049007) owned by Harsch Investment Properties, LLC. The smaller is the 7901 2nd Avenue South parcel, a 0.7-acre parcel (County Tax Parcel No. 3224049077) owned by 7901 2nd Avenue South, LLC (7901). The buildings at the KIP have addresses ranging from 111 to 129 South Kenyon Street and from 7900 to 8100 Occidental Avenue South. These parcels were sold out of tax title status to the City in 1951, who later sold the northwest corner of the KIP in 1958. The 7901 parcel and the eastern half of the KIP parcel were part of the Landfill. The western half of the KIP parcel was not part of the Landfill. This will be discussed further in Section 4.2.

By 1960, active disposal in this area of the Landfill had ceased, and the future KIP/7901 parcels were being used as an auto-wrecking facility. Sometime between 1965 and 1974, the five existing buildings were constructed and occupied as shown in time lapse aerial photographs of the KIP/7901 development presented on Figure 2.3. The KIP parcel buildings cover approximately 127,000 square feet and house light industrial operations including warehouse space and commercial outlets. A single 17,000–square-foot slab-on-grade building, constructed in 1965, is located on the 7901 parcel.

The KIP/7901 parcels are serviced by electricity, water, and sanitary sewer lines located along South Kenyon Street. The parcels appear to be paved and have a stormwater collection system that discharges through a central pipe to a municipal system along South Kenyon Street. A further discussion of the existing development of the KIP/7901 parcels is presented in Section 2.4 of the RI.

2.2.4 Public Roads and Rights-of-Way

Sections of Occidental Avenue South, South Sullivan Street, 2nd Avenue South, and 5th Avenue South are within the footprint of or adjacent to the Landfill. The roadways are paved and have adjacent gravel parking strips and/or unlined ditches, but no curbs, gutters, or sidewalks. Several subsurface utilities are located within the City rights-of-way (ROWs) of these streets.

SR 99 (also known as West Marginal Way South near the Landfill) was constructed along the northeastern edge of solid waste, adjacent to the SRDS parcel, as illustrated on Figure 2.2. SR 99 is a multi-lane, limited access "highway" in this area and acts as the Landfill's boundary with refuse abutting the nearside of SR 99 and extending a few feet into the ROW (based on aerial photographs). As discussed in later sections, edge of solid waste wells along this boundary are, by necessity, either installed in solid waste on the Landfill side of the ROW or on the other side of the ROW.

2.2.5 Southern Parcels

A review of aerial photographs and historical maps indicates that a lobe of solid waste may extend south of the current location of South Sullivan Street to the historical location of South Sullivan Street. City records indicate that the material may have included sawdust fill, but several borings also indicated the presence of solid waste. A further discussion of this material is discussed in Section 4.2.3.2.

The solid waste is potentially beneath two other tax parcels:

- County Tax Parcel No. 3224049045, owned by Lenci Frank Corporation and occupied by Emerson Power Products
- County Tax Parcel No. 3224049084, an undeveloped property owned by Gordian Development located to the west of Emerson Power Products [2]

The parcel occupied by Emerson Power Products comprises 2.8 acres of developed land with a 50,417-square-foot building constructed in 1980 that is surrounded by an asphalt parking lot and perimeter landscaping. Utilities located on South Cloverdale Street service this facility. The adjacent undeveloped 0.6-acre parcel owned by Gordian Development has been used as an auto-wrecking yard and a used auto sales lot. No permanent structures occupy this fenced, gravel-surfaced property.

2.2.6 Occidental Avenue South Properties

There are several properties located along Occidental Avenue South that are immediately adjacent to the western boundary of the Landfill. These properties are not part of the Landfill. Additionally, as discussed in more detail in Section 3.0, these parcels are upgradient of the Landfill; that is, groundwater from these parcels flows onto the Landfill. Therefore, these parcels are not part of the MTCA Site, but are adjacent to it.

These properties include the following tax parcels, which are identified on Figure 2.2:

- County Tax Parcel No. 3224049068 is a 0.4-acre parcel owned by W.G. Clark Construction Company. This parcel was used as farmland until sometime after 1946. A structure was built on the property in 1983 and is currently being used as a service building. The property has both stormwater and sanitary sewer lines. Similar to the western half of the KIP parcel, this parcel was not part of the Landfill and is not part of the Site.
- County Tax Parcel No. 3224049008 is a 0.5-acre property currently owned by International Construction Equipment that was developed in 1986 and used for light industrial purposes. The property is connected to the sanitary line along Occidental Avenue South for interior plumbing. In addition, the property has a stormwater collection system along the northern and eastern perimeters of the property that drains into a detention system and through a sand filter before discharging into the West Ditch via a culvert, which passes underneath Occidental Avenue South. Additional information about the property's stormwater management can be found in Section 2.4.5.
- County Tax Parcel No. 3224049102 is a 0.6-acre property currently owned by John McFarland. This parcel was a farm until sometime after 1946 when several additional structures were built on the property. This property, zoned for industrial use, is currently vacant. The property does not have any known stormwater or sanitary sewer lines.
- County Tax Parcel No. 3224049010 is a 2.5-acre property owned by Rainier Northwest JFK, LLC. This property is not within the Landfill. This parcel was farmland until sometime after 1946, when it was developed into a log sort yard. A structure was built on the property in 1974 and is currently being used by North Star Ice Equipment as a

[2] Further field investigations discussed in Section 4.0 indicate that the extent of solid waste does not extend beneath this property as suspected at the time of the Work Plan.

warehouse. The property is an Ecology-regulated UST site that had one unleaded gasoline UST closed in place in 1964. The property has one confirmed and another suspected, but unconfirmed, stormwater line that discharge to the West Ditch.

2.2.7 5th Avenue South Properties

There are also several properties to the east of 5th Avenue South that are immediately adjacent to the Landfill. These properties were not part of the Landfill, and are downgradient of the Landfill. They do, however, have their own fill history as discussed in Section 4.2.1.2. These properties, which are identified on Figure 2.2, include the following:

- County Tax Parcel No. 7883600005 is a 1.3-acre property owned by JYS4, LLC. This property was undeveloped prior to 1969 when filling activities occurred. In 1990, a structure was built on the property and currently is used as a warehouse. The property is served by both stormwater and sanitary sewer lines.
- County Tax Parcel No. 7883600350 is a 2.4-acre property owned by Ness Manitowoc Property, LLC. The property was undeveloped until 1969, when cement kiln dust (CKD),—a fine-grained, highly alkaline solid waste (that may contain metals) that is removed from the cement kiln exhaust gas—was used as fill on the property. Additional information about the subsurface materials for this parcel can be found on the Renton Effluent Transfer System (RETS) Line boring logs in Appendix B. A structure was built on the property in 1973 and is currently being used as a garage and service building. The property is an Ecology-regulated Confirmed or Suspected Contaminated Site (CSCS) that had two gasoline (unleaded and leaded) USTs removed in 1996. The property is serviced by the sanitary sewer.
- County Tax Parcel No. 7883600600 is a 1.9-acre property zoned as Industrial Buffer (IB) and owned by White Sands, LLC. This property was undeveloped until 1969. CKD fill was also discovered on this property and additional information is presented in the RETS Line boring logs found in Appendix B. A structure was built on the property in 1974 and is currently being used as a service building. This property is an Ecology regulated UST site that had four USTs removed in 1964. The USTs contained diesel, oil, and used/waste oil. This property is served by stormwater and sanitary sewer lines.

2.2.8 Former Glitsa Property

The former Glitsa American, Inc. (Glitsa) property is immediately northeast of the Landfill on the far side (east) of SR 99. This 1.2-acre property, County Tax Parcel No. 7328400740, is owned by Tenor Company, LLC. The property was undeveloped until approximately 1946, when fill material was placed on-site. A structure was built on the property in 1959 and a 7,500-gallon UST was installed in 1964 (Environmental Associates 2009b) while the property was owned by Farwest Paint Manufacturing Company. In addition, an auto-wrecking yard may have historically operated in the northwest corner of the property (Environmental Associates 2009a). Additional support structures were later added, including modular offices, an equipment storage shed, and an equipment maintenance area. The property was later occupied by a floor finishing products manufacturer (Glitsa; Eco Compliance Corporation 2007), before being bought by the Tenor Company, LLC.

The former Glitsa property is currently listed as a MTCA Site (Facility Identification No. 63168342) with confirmed petroleum- and solvent-impacted soil and groundwater. Impacted soil had Stoddard-solvent, ethylbenzene, and total xylene concentrations greater than the MTCA Method

A CULs. There were also detected concentrations of toluene, arsenic, chromium, and lead. Impacted groundwater had Stoddard-solvent, benzene, and vinyl chloride concentrations greater than the MTCA Method A CULs. In addition, there were detected concentrations of toluene, ethylbenzene, total xylenes, trichloroethene (TCE), and *cis*-1,2-dichloroethene (DCE).

Remedial measures at this property have been implemented, including removal of the leaking underground storage tank (LUST) and approximately 180 tons of Stoddard-solvent contaminated soil as of March 2009 (Environmental Associates 2009b). Because of the relatively close proximity of the contamination to the existing warehouse, not all of the impacted soil could be removed. An active remediation system initially consisting of three soil vapor extraction wells and one groundwater extraction well began operation in July 2009. The remediation system was later expanded to include 10 additional dual-purpose vapor and groundwater extraction wells, which began operation in February 2010. By the end of April 2010, approximately 17.82 million cubic feet of air and approximately 118,500 gallons of water had been treated, with reportedly over a 97 percent contaminant mass removal from the groundwater (Environmental Associates 2010).

2.3 ZONING AND LAND USE

The Landfill, with the exception of the southeastern corner in the vicinity of the intersection of 5th Avenue South and South Sullivan Street, is zoned by the City as General Industrial 2 (IG2; Figure 2.4). This zoning designation includes general and heavy manufacturing, commercial uses subject to certain limitations, transportation and utility services, and salvage and recycling uses. The areas to the west, north, and northeast of the Landfill are also designated as IG2. The southeastern corner of the Landfill is designated as IB, which is intended to provide buffering between industrial areas and adjacent residential areas. Further to the east, southeast, and south of the Landfill, the area is designated as either Lowrise 3 (L3) or Residential Single Family 5000 (SF 5000). The nearest residential property to the Landfill is an L3 apartment building located at the southeastern corner of 5th Avenue South and South Sullivan Street, which is approximately 100 feet southeast of the Landfill. The nearest residential property is located approximately 200 feet southeast of the Landfill (Figure 2.4).

Major roadways surrounding the Landfill are shown on Figure 2.4 and include the following:

- SR 99, adjacent to the northeastern portion of the Landfill
- SR 509, approximately 200 feet west of the Landfill

Based on zoning characteristics and review of the available aerial photographs, both the IG2- and IB-zoned areas of the Landfill can be reasonably designated as industrial properties.

2.4 CURRENT CONDITIONS AND REDEVELOPMENT PLANS

2.4.1 South Park Property Development Parcel

SPPD has begun an IA for cleanup at the parcel per the 2013 Ecology-approved Interim Action Work Plan (IAWP) under the existing Administrative Order for the Landfill. The IA is being performed as part of the development of the property. The property will contain an office building for employees and will have paved parking for employees and visitors. The design is preliminary and may be subject to revision. Redevelopment includes installing subsurface utilities, capping the Landfill surface, installing and operating an LFG control system, and constructing a stormwater collection and detention system prior to building construction. SPPD is working with Ecology and the City to ensure that development goals are consistent with the MTCA requirements, including the Environmental Covenant for the closed Landfill. Figure 2.5 presents the preliminary redevelopment plan for the SPPD property. Ecology's approval of the IA and associated design drawings helps to ensure that the actions are consistent with the requirements for the final cleanup of the Landfill as defined in the CAP.

2.4.2 South Recycling and Disposal Station Parcel

The SRDS has been in operation since 1966 as a transfer station for municipal solid waste and other recyclable materials. In 2012, a new solid waste transfer facility was completed across the street on South Kenyon Street. This new facility became operational in the spring of 2013. The existing SRDS closed until January 2014 when the City's North Recycling and Disposal Station (NRDS), located in the Fremont/Wallingford neighborhood, closed for a scheduled rebuild. The existing SRDS has been reopened to increase the City's solid waste handling capacity while the NRDS is modernized. Once the NRDS reopens (scheduled for 2016), the existing SRDS parcel would be available to undergo improvements for landfill upgrades and construction of permanent facilities including a recycling facility, a household hazardous waste collection site, a parking area to support the new transfer station, or other City uses. Renovation of the existing SRDS parcel would be consistent with the approved Landfill Draft CAP, and operations would be consistent with the Environmental Covenant for the closed Landfill.

2.4.3 Kenyon Industrial Park and the 7901 2nd Avenue South Parcels

The eastern half of the KIP/7901 parcels is part of the Landfill. The KIP parcel consists of a total of four buildings (three within the Landfill boundary) with paved areas covering the remaining surfaces outside of the building footprints. The buildings are a mixture of office and manufacturing/warehouse space. The offices generally have either carpet or tile floorings, while the warehouse areas have exposed concrete floors. The following buildings are located on the KIP parcel (Koll-Dove Venture I 1996):

- A 32,000-square-foot building built in 1966 and located at 7951–7953 2nd Avenue South
- A 15,624-square-foot building built in 1973 and located at 7929–7937 2nd Avenue South
- A 36,000-square-foot building built in 1973 and located at 7910–7936 Occidental Avenue South
- A 44,000-square-foot building built in 1970 and located at 121–129 South Kenyon Street

An approximately 20,000-square-foot building was constructed on the 7901 parcel in the late-1960s (refer to Figure 2.3 for its location).

There are currently no known redevelopment plans for the KIP/7901 parcels.

2.4.4 Lenci Frank Corporation Parcel

The Lenci Frank Corporation parcel has an existing 50,417-square-foot building, which was built in 1980 and has historically been leased by Emerson Power Products and used as warehouse space. The remaining surfaces outside of the building footprint are paved. There are currently no known redevelopment plans for this parcel.

2.4.5 Existing Stormwater Controls and Utilities

2.4.5.1 On-site Stormwater Systems

The existing stormwater drainage infrastructure at the Landfill includes elements for stormwater control on three different properties. The SRDS and KIP/7901 parcels have existing stormwater controls including sloped pavement, catch basins, and belowground piping. The undeveloped SPPD parcel has grading controls, open ditches, and swales. These stormwater control elements are illustrated on Figure 2.6 and details for each parcel are provided in the following sections. The structures on the SPPD parcel are undergoing development as part of the IA.

2.4.5.2 The Kenyon Industrial Park Parcel Stormwater System

The KIP parcel is completely covered in impervious surfaces (i.e., buildings, asphalt, and concrete). All stormwater within the parcel is collected in catch basins and conveyed to the 30-inch KIP main stormwater line that runs north through the property. The KIP main stormwater line connects the West Ditch on the SPPD parcel to the City's storm drain system located in 2nd Avenue South. This system ties in to the storm drain system on SR 509 that flows into the wetlands on the west side of SR 509.

Based on historical information, the KIP main stormwater line was installed in 1974 in a historical swale on the KIP property. The swale continued to the north, across South Kenyon Street, and onto the Former Kenyon Street Bus Yard parcel (refer to Figure 2.2), where approximately 10 to 12 feet of CKD was removed as part of a recent remedial action (AMEC 2009c). Therefore, it seems likely that CKD backfill was also used in the swale on the KIP parcel. Logs from the soil borings advanced along the KIP main stormwater line (HP-03, BH-19, GP-24, and GP-25) note the presence of concrete material and CKD in this area. These soil boring logs can be found in Appendix B.

2.4.5.3 The South Park Property Development Parcel Existing Stormwater System

The former East-West Channel was a steep-sloped, unlined channel that traversed the southern SPPD-owned portion of the Landfill. The channel was built sometime prior to 1963 (refer to Figure A.6) directly into the Landfill's solid waste and extends to depths between approximately 10 and 15 feet bgs. There is currently no apparent inlet into this feature, although prior to the stormwater upgrades made in 1995, the East-West Channel most likely received stormwater runoff from along 5th Avenue South and the properties to the east of 5th Avenue South. During seasonal high groundwater conditions, the East-West Channel occasionally contains standing water, which may be due to the high groundwater table in the area. The only apparent outlet from the East-West Channel is a reportedly blocked culvert on the western end of the channel, which may have historically discharged into the West Ditch (Beck 1999); however, this RI/FS did not assess the condition of the culvert or determine blockage, as redevelopment of the SPPD parcel beginning in 2013 eliminated the East-West Channel.

The West Ditch crosses the western SPPD-owned portion of the Landfill along Occidental Avenue South. The ditch has an outlet at the northern end that connects to the KIP main stormwater line (refer below for description). The West Ditch appears to be partially fed by a feature at its southernmost end that was identified during the RI to be a 6- to 8-inch-diameter culvert buried approximately 4.5 feet bgs. This culvert likely drains runoff from the North Star Ice Equipment Corporation facility (Figure 2.6). Several additional culverts enter the West Ditch prior to it discharging into the KIP main stormwater line (Figure 2.6), including:

- A confirmed 12-inch-diameter culvert draining additional stormwater from the North Star Ice Equipment Corporation facility
- A confirmed culvert from the stormwater collection and detention system at International Construction Equipment
- A suspected surface water drainage pipe from International Construction Equipment
- A remnant 12-inch-diameter culvert draining a small amount of runoff from Occidental Avenue South
- A 12-inch-diameter corrugated acrylonitrile butadiene styrene (ABS) pipe draining an unknown area

In addition, stormwater run-off from Occidental Avenue South appears to flow across an unimproved shoulder into the West Ditch. Some sections of the West Ditch also receive discharge from shallow groundwater during periods of high groundwater levels (i.e., the wet season). The inverts on the West Ditch are such that stormwater can be retained in the West Ditch until the level is high enough to discharge into the KIP main stormwater line.

The KIP main stormwater line is a 30-inch corrugated metal pipe. Although the condition of the KIP main stormwater line has been sufficient to handle stormwater from the KIP parcel and the unlined West Ditch, it may not sufficiently handle additional stormwater from the redeveloped SPPD parcel. This will be further discussed in the FS. The connection from the West Ditch to the KIP main line was eliminated in 2014 as part of the SPPD parcel IA and redevelopment.

2.4.5.4 The South Recycling and Disposal Station Stormwater System

The SRDS has been operating as a solid waste transfer station for the City since 1966. The SRDS was developed to receive commercial waste and residential vehicles. The property is almost entirely covered in impervious surfacing (i.e., buildings, asphalt, and concrete). Stormwater is collected into two systems. One system collects stormwater and liquids that may have come into contact with solid waste, and directs them to the sanitary sewer. The other system collects stormwater from around the parcel, and then connects to the City's storm drain system in 2nd Avenue South. This system ties in to the storm drain system on SR 509 that flows into the wetlands on the west side of SR 509.

A series of roadside ditches and catch basins collect stormwater runoff from South Kenyon Street and 5th Avenue South in front of the property. These stormwater systems also connect to the City's storm drain system in 2nd Avenue South. The SRDS stormwater system is illustrated on Figure 2.6.

2.4.5.5 Other On-site Utilities

The developed parcels (SRDS and KIP) associated with the Landfill are connected to the public sanitary sewer systems within 2nd Avenue South and South Kenyon Street. Seattle Public Utilities (SPU) Geographic Information System (GIS) mapping data show that the parcels appear to have been built to current stormwater/sewer separation standards.

The SPPD parcel is not connected to the sanitary sewer system. Sewer mains exist in Occidental Avenue South, South Sullivan Street, and 5th Avenue South, which all border the property. Natural gas and water mains are also located in the streets surrounding the SPPD parcel. A 12-inch-diameter water main and a natural gas main of unknown size are shown to be in Occidental Avenue South, South Sullivan Street, and 5th Avenue South.

2.4.5.6 Other Major Utilities in the Vicinity of the Landfill

Additional major utilities constructed in the vicinity of the Landfill include the RETS Line, which borders the northeastern boundary of the Landfill along the SR 99 ROW (refer to Figure 2.6).This 96-inch-diameter force main sewer line carries treated effluent from the County's South Treatment Plant in Renton, Washington, to an outfall in Elliott Bay. The RETS Line sits in concrete cradles and is surrounded by backfill that is similar to surrounding areas (mixed sands, silts, and fill).

2.5 PREVIOUS INVESTIGATIONS

Several regional studies and adjacent investigations have been conducted in the vicinity of the Landfill, and numerous previous investigations have been performed at the Landfill prior to this RI/FS. The following sections provide a brief summary of the relevant regional studies and previous investigations. Table 2.2 summarizes the regional studies, while Tables 2.3 and 2.4 summarize the adjacent property investigations and previous investigations at the Landfill, respectively.

2.5.1 Regional Studies

Several regional studies have been conducted in the Duwamish Valley to better understand groundwater flow patterns and determine contaminant contributions to the Duwamish Waterway. A summary of relevant reports is presented in Table 2.2. Information from these studies was used in the RI/FS process to improve the understanding of regional hydrogeology and potential environmental impacts on the Duwamish Waterway.

2.5.2 Adjacent Property Investigations

Ecology's Integrated Site Information System (ISIS) and the USEPA Envirofacts databases were queried for information about environmentally-impacted properties in the vicinity of the Landfill. These databases currently list a number of properties with known/suspected hazardous substance releases or properties with the potential for hazardous substance releases in the vicinity of the Landfill. The databases queried included the following:

- Comprehensive Environmental Response, Compensation and Liability Information System (CERCLIS)
- CSCSs
- LUSTs
- USTs
- Toxic Chemical Release Inventory System (TRIS)
- Resource Conservation and Recovery Information System (RCRIS) Large and Small Quantity Generators (LQG and SQG)

The properties in the vicinity of the Landfill with known/suspected hazardous substance releases or the potential for hazardous substance releases are shown on Figure 2.7. The figure shows the most significant designation for each of the properties. Previous environmental investigations of hazardous substance releases completed on properties immediately adjacent to the Landfill are summarized in Table 2.3 and a brief description of these investigations is provided in the following sections.

2.5.2.1 Former Glitsa Property

The former Glitsa property is located adjacent to the Landfill immediately east of SR 99 and south of South Kenyon Street. The property was historically used as an auto-wrecking facility and was occupied by a paint company (Farwest Paint Manufacturing Company) and a floor finishers/floor finishing products manufacturing company (Glitsa; Eco Compliance Corporation 2007). The property is currently owned by Tenor Company, LLC. A summary of investigative and remedial activities is presented in Table 2.3.

2.5.2.2 Former South Kenyon Street Bus Yard

The former South Kenyon Street Bus Yard is located immediately to the north of South Kenyon Street and the Landfill. The property was historically used for receiving dredge fill and as an auto-wrecking yard before being used by First Student, Starline, and Curtis Transportation for storage and maintenance of school buses and chartered motor coaches (AMEC 2009a). SPU recently purchased the parcel to expand its SRDS facilities and operations. A summary of investigative and remedial activities is presented in Table 2.3.

2.5.3 On-site Investigations

Numerous previous investigations have been conducted at the Landfill starting in 1984. A summary of the most relevant investigations can be found in Table 2.4 and the explorations from these environmental and geotechnical investigations are shown on Figure 2.8. Data from previous investigations have been used where appropriate; for example, historical groundwater data have been used to establish trends in concentrations over time, but are not used to describe current conditions. The following sections provide a brief summary of the previous soil gas (including LFGs and VOCs), indoor air, surface water (water collected in depressions at the Landfill), soil, and groundwater investigations conducted to date.

2.5.3.1 Soil Gas and Indoor Air Investigations

Due to the nature of the Landfill, both LFG (various gases produced at landfills as solid waste materials decompose, including methane) and VOCs in soil gas and indoor air have been an environmental and health and safety concern. Investigations have targeted monitoring the levels of methane to assess the environmental impact and public health risk of the closed Landfill. As the Landfill has been redeveloped and has aged, monitoring of LFGs has continued in an effort to characterize LFG generation (to describe evolution of the Landfill decomposition), monitor for explosive hazards, and monitor for health and safety concerns including the migration of LFG and VOCs into indoor air within the buildings constructed over and adjacent to the Landfill. A more detailed review of historical and current soil gas investigations will be discussed in Section 6.0 and soil gas probe construction logs, sampling locations, and other location descriptions for soil gas and indoor air sampling activities can be found in Appendix B.

2.5.3.2 Surface Water Investigations

As part of assessment work related to the closed Landfill, seasonally ponded water on the surface of the Landfill within topographic lows, like the West Ditch and East-West Channel, was investigated to determine the impact from underlying solid waste and/or leachate. The results were used to assess if this material posed a risk to the environment and human health. It should be noted that ponded water is intermittent and may also derive from groundwater that may infiltrate upward and intersect the ground surface during higher levels of precipitation. This water can be impacted by both the industrial nature of the Landfill and the surrounding area, and any solid waste that may be present in the subsurface potentially elevating concentrations of chemicals to levels greater than background.

2.5.3.3 Soil Investigations

Various soil investigations (both to investigate fill, native materials, and landfill cover) have been initiated at the Landfill since 1986 in order to assess the extent of the solid waste within the Landfill and determine if its contents posed a significant threat to public health and the environment. Elevated concentrations of some chemicals have been seen within the soils at the Landfill, have likely been impacted by both the industrial nature of the Landfill and the surrounding area, and may, in part, be derived from or contain solid waste material originally disposed of within the Landfill.

2.5.3.4 Groundwater Investigations

The earliest groundwater quality investigations were initiated in 1989. The quality of groundwater at the Landfill has been investigated to determine if groundwater quality poses a significant threat to public health and the environment. Groundwater investigations have primarily focused on the Landfill boundary and areas with specific known or suspected concerns. The groundwater monitoring network at the Landfill has been used to establish groundwater conditions at the Landfill boundary and downgradient. Some of the groundwater wells have been monitored periodically since the late 1980s and others from the mid-1990s, allowing for trends to be tracked over time through seasons and as the Landfill continues to age.

3.0 Physical Setting

3.1 REGIONAL GEOLOGY AND HYDROLOGY

3.1.1 Descriptive Geologic Overview

3.1.1.1 Regional Geology

The Duwamish Valley is a branch of Puget Sound that was created during the Vashon Stade (a recent, short period of regional glacial advance) of the Fraser Glaciation (a major period, approximately 10,000 years, of regional glacier coverage). The glaciation associated with the Vashon Stade occurred between about 13,000 and 15,000 years ago (Palmer 1997). The combined scouring action of the flowing ice and running glacial melt water flowing from underneath the glacier caused the erosion that created the Duwamish Valley, and the glacial outflow river covered this new valley with glacial deposits.

As the ice sheet retreated, the exposed valley became inundated with seawater, which until approximately 5,700 years ago extended to the city of Auburn, Washington. As the glacier continued to retreat, large mudflows from the flanks of Mount Rainier (the Osceola Mudflow) and erosion of the newly exposed Cascade Mountain Range deposited a tremendous volume of fine-grained sediments into the local marine waters of Puget Sound. Over geologic time, these sediments migrated downstream, filling in the submarine valley with the fine-grained sand and silt estuarine and alluvial deposits, and advancing the shoreline at the mouth of the Duwamish River from Auburn toward Elliott Bay (Hart Crowser 1998). Because Puget Sound is saline, the estuarine deposits were laid down in a saline or brackish environment and are often distinguished by abundant shell fragments, whereas the alluvial deposits tended to be laid down in a system influenced by the freshwater in the river.

With settlement of the area, the tidal flats and floodplains were filled and the meandering Duwamish River was dredged and straightened to form the present-day Duwamish Waterway. Dredged materials were used to fill old channels and lowlands above flood levels, including the old dredge fill site at the former South Kenyon Street Bus Yard immediately north of the Landfill.

As the area was settled, especially after the 1930s, additional filling occurred throughout the valley to raise the land above the seasonal water table and level the land for development. This has resulted in a surficial fill layer over most of the Duwamish Valley (Hart Crowser 1998).

3.1.1.2 Geologic Units

The types of geologic units found at the Landfill include the following: imported fill; alluvial deposits including overbank flood deposits; estuarine deposits; and glacial deposits. A plan view of the geologic units present in the vicinity of the Landfill is illustrated on Figure 3.1 and described in Table 3.1. The structure of the Duwamish Valley and the stratigraphy of these units are illustrated in the regional geologic cross section presented on Figure 3.2. As illustrated on Figure 3.2, the alluvial and glacial deposits can be more than 200 feet thick in the center of the Duwamish Valley (Hart Crowser 1998).

3.1.2 Topography

The topography in the area of the Landfill is controlled by the Duwamish Valley, which trends from the northwest to the southeast. The valley has steep-sided hills seen to the east in the Beacon Hill neighborhood and to the west in the Highland Park neighborhood with elevations ranging from approximately 214 to 420 feet elevation NAVD 88 (North American Vertical Datum of 1988), respectively. The area surrounding the Landfill is relatively flat, with a slight downward slope to the northeast, toward the Duwamish Waterway. The topography in the vicinity of the Landfill, based on the 1981 U.S. Geological Survey map of the Seattle South quadrangle, is illustrated on Figure 3.1.

The topography of the Landfill varies due to the fill and grading history, with elevations generally ranging between 14 and 44 feet elevation NAVD 88. The KIP/7901 and SRDS portions of the Landfill are generally lower with elevations ranging between 14 and 29 feet elevation NAVD 88. In comparison; the SPPD portion of the Landfill is slightly higher with elevations typically ranging between 29 and 44 feet elevation NAVD 88. The most prominent topographic feature on the SPPD portion of the Landfill is the East-West Channel, which was discussed in Section 2.4.5.3.

3.1.3 Regional Hydrology

3.1.3.1 Surface Water Occurrence

The Duwamish Waterway, at its closest point, is located approximately 1,600 feet northeast of the Landfill, as illustrated on Figure 2.2. The channelization and realignment moved the Duwamish Waterway from the present-day King County International Airport/Boeing Field to its current location closer to the Landfill. Between 1928 and 1931, the federally-authorized navigation channel was dredged, removing native alluvial deposits and creating a tidally influenced channel approximately 400 to 500 feet wide with bottom elevations of approximately -20 feet Mean Lower Low Water (MLLW; Evans 2006)

The dredging of the Duwamish Waterway allowed saline waters from Elliott Bay to intrude up channel, creating a tidally influenced estuary as far inland as the upper turning basin of the channel (to approximately River Mile 4.7). The Duwamish Waterway receives most of its freshwater discharge from the Green River and its tributaries, with less than 1 percent of the flow coming from surface water runoff within the Duwamish Valley (WindWard Environmental 2010). Locally, the Duwamish Waterway receives tidally-controlled recharge from both groundwater and a slough to the north of the Landfill (west of SR 509; shown on Figure 2.6) that was once likely a part of a natural surface water drainage feature, which was fed from the valley uplands to the south of the Landfill.

3.1.3.2 Regional Groundwater Flow

Groundwater within the Duwamish Valley generally occurs within the coarse-grained alluvial channel deposits (Alluvial Aquifer). The Shallow Aquifer identified at the Site is part of the large valley-wide Alluvial Aquifer.[3] For the purposes of this RI/FS, the Shallow Aquifer is further subdivided into an A-Zone and B-Zone (refer to Figure 3.2). Within the Alluvial Aquifer, in the uppermost portion of the Shallow Aquifer, discontinuous Silt Overbank Deposits are present at elevations generally between 0 and 10 feet elevation NAVD 88, and groundwater that persists

[3] When referring to the valley-wide system, the name Alluvial Aquifer will generally be used, while the term Shallow Aquifer will be used to refer to the groundwater system of interest at the South Park Site.

above this unit is within the Perched Zone. Although groundwater also occurs in the underlying estuarine deposits, it generally consists of a brackish water of lower quality (Hart Crowser 1998). Regional groundwater flow in the Shallow Aquifer in the central portion of the Duwamish Valley generally moves from the higher elevations of the uplands (recharge area) to the lower elevations of the Duwamish Waterway (discharge area). Groundwater flow in the vicinity of the Landfill is generally to the northeast, toward the Duwamish Waterway; however, in localized areas where fine-grained alluvial deposits or bedrock knobs are present, groundwater flow directions may be more variable. Also in the vicinity of the Landfill, the fine-grained overbank flood deposits may trap infiltrating rainwater and strand groundwater when the water table is high, resulting in perched groundwater conditions that can also cause variable groundwater flow directions when compared to the underlying Shallow Aquifer. A more detailed discussion of the groundwater conditions at the Landfill is presented in Section 5.4.

3.1.3.3 Groundwater and Surface Water Interactions

In general, groundwater in the Shallow Aquifer discharges into the Duwamish Waterway (as illustrated on Figure 3.2); however, high tides within Elliott Bay can cause an apparent groundwater flow reversal, with surface water from the Duwamish Waterway intermittently infiltrating inland. This area of tide-related temporal groundwater flow reversal generally occurs within about 500 feet of the Duwamish Waterway (Hart Crowser 1998). Recent tidal studies near the Boeing Isaacson property and the Great Western International property have noted tidal influences on groundwater levels in wells approximately 400 feet from the Duwamish Waterway. Similar studies conducted at the Boeing Plant 2 facility, which is located slightly upstream and across the Duwamish Waterway from the Landfill, noted tidal influences between 300 and 600 feet from the Duwamish Waterway (WindWard Environmental 2010), with measurable tidal fluctuations as much as 1,000 feet from the Duwamish Waterway.

Dawson and Tilley noted that the Duwamish Waterway contains a saltwater wedge that typically influences and extends upstream to approximately River Mile 7.5 (Dawson and Tilley 1972). This is approximately 4 miles upstream of the Landfill. The saltwater wedge is driven by the differences in density of fresh water and saltwater and consists of a dense lower layer of predominantly unmixed seawater overlain by a layer of less dense brackish water that progressively freshens up stream (or increases in salinity further downstream). The existence of the saltwater wedge within the Duwamish Waterway has a significant impact on the groundwater quality of the Shallow Aquifer, with the greatest impact occurring adjacent to the Duwamish Waterway.

Specific conductivity measurements made within the Shallow Aquifer at depths of less than 50 feet range from 2,000 to 3,000 microsiemens per centimeter (µS/cm) near the Duwamish Waterway and decrease to 500 to 1,500 µS/cm with distance away from the waterway. These relatively high specific conductivity values are indicative of groundwater mixing with the saltwater from in the Duwamish Waterway. Specific conductivity measurements taken within the lower alluvial aquifer (estuarine deposits) range from 820 to 24,000 µS/cm (Hart Crowser 1998). These specific conductivity measurements are equivalent to total dissolved solids (TDS) concentrations of 550 to 16,100 milligrams per liter (mg/L). At Boeing Plant 2, where there are approximately 10 wells completed in the lower alluvial aquifer (the C-level monitoring wells at Boeing Plant 2), all of the wells have TDS greater than 10,000 mg/L, irrespective of distance from the waterway (Environmental Partners, Inc. and Golder Associates, Inc. 2009). It is likely that the high TDS and specific conductance are due to connate (from the time of formation) water deposited with the sediments in an estuarine environment several thousand years ago.

3.2 LOCALIZED CONDITIONS

3.2.1 Hydrogeologic Conditions

The alluvial deposits that form the Shallow Aquifer are relatively thick, ranging from about 20 feet thick along the western edge to more than 50 feet thick along the eastern edge of the Landfill. In general, the alluvial deposits become thicker closer to the center of the valley. The alluvial deposits that form the Shallow Aquifer are generally composed of dark gray or black silty sand or sand. Under much of the Landfill, the Silt Overbank Deposits are fairly continuous within the uppermost portion of the alluvial deposits, which act as low permeability aquitards that separate infiltrating precipitation and overland flow into a Perched Zone within the Shallow Aquifer. The estuarine deposits are encountered at approximately sea level along the western edge of the Landfill and dip to the northeast, toward the center of the valley, where they are encountered at greater depths (deeper than -25 feet elevation NAVD 88). Beneath the southwestern edge of the Landfill, glacial deposits were encountered at approximately -5 feet elevation NAVD 88. These glacial deposits consisted primarily of hard silt and are representative of glacially consolidated lacustrine deposits. The maximum depth of the glacial deposits is unknown in the vicinity of the Landfill.

3.2.2 Groundwater Use

Groundwater in the vicinity of the Landfill is not currently used as a drinking water source. Potable water is instead provided by the City's municipal water supply, which is primarily derived from the Cedar River watershed. In order to confirm that groundwater is not currently being used as a potable water source, groundwater well logs from the Ecology Well Log database were examined for the areas downgradient of the Landfill and between the Landfill and the Duwamish Waterway, including the southwest quarter section of Section 29 and the northwest and northeast quarter sections of Section 32 in Township 24 North, Range 4 East. Review of these records indicated that all of the wells were either resource protection monitoring wells—used to collect subsurface information or to determine the existence or migration of pollutants—or dewatering wells. Because no groundwater supply wells are located downgradient of the Landfill, groundwater beneath the Landfill does not serve as a current source of municipal or domestic potable water.

Groundwater in the area is not forecast to be used as a source of potable water for the following reasons:

- As stated in Washington State's well regulations (WAC 173-160-171), a water supply well shall not be located within a minimum specified distance from known or potential sources of contamination, including landfills and areas affected by seawater intrusion.
    - This distance is 1,000 feet from a landfill.
    - Ecology has determined that groundwater near the Lower Duwamish Waterway has been or has the potential to be affected by seawater intrusion. This distance, based on decisions on other sites, is at least 500 feet from the waterway.
    - Groundwater beneath the B-Zone in the marine and estuarine deposits is saline with TDS concentrations that exceed 10,000 mg/L causing the deeper groundwater to qualify as not potable under WAC 173-340-720(2)(b)(ii).[4]

[4] Boeing Plant 2 contains the largest collection of wells in this zone. All 10 of the wells at Plant 2 constructed in this lower zone have measured TDS concentrations of greater than 10,000 mg/L.

- WAC 173-160-171 also states that the well shall not be located where it is subject to surface water ponding, and is not located in a floodway, except as provided in Revised Code of Washington (RCW) 86.16, Flood Management, which states that new and replacement water supply systems must be designed to eliminate or minimize infiltration of flood waters into the system, specifically:
  - No groundwater drinking water supply wells should be located within the Federal Emergency Management Agency 100-year floodplain unless they are protected from surface or subsurface water drainage capable of impairing the quality of the groundwater supply (RCW 86.16.041(3)(g)).

Waivers or variances are allowed under WAC 173-160; however, the most common variance is to allow installation in a deeper uncontaminated aquifer. In the case of the Landfill area, deeper groundwater is naturally saline due to the nature of the deposits and is not appropriate for drinking (refer to Section 5.0).

Figure 3.3 illustrates where these restrictions would apply. Based on these restrictions and the availability of a high-quality public water supply, no future groundwater wells are anticipated in the area.3.2.3 Climate

The maritime climate of the Seattle area is characterized by short, cool summers and mild winters without significant variation in temperatures or precipitation, which minimize strong seasonal effects on groundwater or surface water. Average annual minimum and maximum temperatures and average annual monthly precipitation from October through March from the National Climatic Data Center weather observation station located at Seattle-Tacoma International Airport (Station No. 457473) from 1948 through 2010 are illustrated on Figure 3.4.

3.2.4 Ecological Resources

3.2.4.1 Terrestrial Conditions

A description of the current and future terrestrial conditions of the various parcels of the Landfill was reviewed in order to determine if the Landfill could be excluded from a terrestrial ecological evaluation per Chapter 173-340-7491 WAC. The terrestrial conditions of the various parcels of the Landfill consist of the following:

- **KIP/7901 Parcels:** This area within the former Landfill boundary is currently paved and contains five developed structures and little to no landscaped areas. There are currently no known development plans for the KIP/7901 parcels.
- **SRDS:** Most of the facility is paved (approximately 80 percent) or covered by buildings, with the exception of some landscaped perimeter areas and small areas in the interior of the property. Redevelopment plans for the property include demolition of the waste transfer building and construction of new facilities (to occur during 2016 and 2017), including: parking, offices, hazardous waste collection area, roadways, and utility corridors. Based on the results of this RI/FS, the remaining landscaped areas on the SRDS property will be capped (additional information is presented in Section 9.0 of the FS).
- **SPPD:** The SPPD parcel has remained undeveloped and has historically been used for the dumping of municipal solid waste, auto-wrecking yards, and leased storage. Current redevelopment plans indicate that the property will be utilized for industrial

offices, as well as parking. As part of the redevelopment, the entire property would be capped with asphalt (refer to Figure 2.5).

Because contaminated soils on all three parcels will be covered by pavement, buildings, or other physical barriers that prevent plants or wildlife from being exposed to contaminated soils, the Landfill would receive exclusion from further terrestrial ecological evaluation based on Chapter 173-340-7491 WAC. Section 7.3.2 provides a further discussion on the terrestrial ecologic evaluation waiver.

3.2.4.2 Wetlands: Landfill Vicinity

Based on several consultant studies and a U.S. Army Corps of Engineers (USACE) evaluation, there are no wetlands in the immediate vicinity of the Landfill. A wetland evaluation was previously conducted by Associated Earth Sciences, Inc. (AESI) in order to determine if regulated wetlands occurred at the Landfill, as defined in the USACE Wetland Delineation Manual or the Ecology Wetlands Identification and Delineation Manual (Beck 1999). Based on the evaluation, it was determined that the East-West Channel did not appear to have flowing water and there appeared to be little to no infiltration. Because the feature was a non-vegetated, isolated, channel-like impoundment of surface water without significant infiltration, it was not identified as wetland habitat.

The West Ditch consists primarily of relatively sparse, non-native plant species. A letter from the USACE (Beck 1999) supported the determination that neither the East-West Channel nor the West Ditch was considered to be wetlands or other waters of the United States.

In 2007, the USACE again confirmed that the East-West Channel and the West Ditch are not waters of the United States, and review by Ecology (Ecology 2009b) and the City (City of Seattle 2008) determined that the East-West Channel and the West Ditch are not regulated as wetlands under Washington State or Seattle Municipal Code, respectively (Farallon 2010b).

3.2.4.3 Wetlands: North of Landfill

An existing slough, located west of SR 509 and approximately 1,000 feet north of the KIP parcel, is a tidally-influenced, constructed wetland that drains directly to the Duwamish Waterway. Stormwater runoff from the SPPD property, KIP/7901 parcels, SRDS, and other parcels not associated with the Landfill ultimately drain to this wetland and the Duwamish Waterway through a piped storm drain system. Tidal records for the Seattle waterfront in Elliott Bay indicate that Mean High Water inundates the base of the wetland all the way to its southern (upstream) end, and extends partially up the side slopes of the wetland. As a result, much of the wetland is inundated with tidal backwater on a daily basis, and thus its hydro-period, the length of time and portion of year the wetland holds ponded water, is strongly influenced by tides. Therefore, stormwater runoff from the Landfill has little impact on the hydro-period of this wetland. Because this is the ultimate receiving water body downstream of the Landfill, stormwater management requirements at the Landfill will be dictated by water quality restrictions for discharge to the wetland.

A stormwater pond east of SR 509 and north of South Holden Street is shown as a wetland on National Wetland Inventory maps. This pond was constructed to treat and control runoff as part of the First Avenue South Bridge improvement project in the 1990s, and is owned and operated as a stormwater control facility by Washington State Department of Transportation (WSDOT). Outflow from the pond is piped under SR 509 to the tidally-influenced wetland west of SR 509.

Because this pond was constructed and is maintained as a stormwater control facility, it is not considered to be a jurisdictional wetland. Stormwater runoff from the Landfill does not currently drain to this pond and is not planned to drain to this pond; therefore, development of the Landfill will not affect the pond.

4.0 The Extent of Solid Waste and Soil Contamination

4.1 CLOSED LANDFILLS AND MTCA CLEANUP LEVELS

Closed landfills are considered under MTCA to be sites that have used "containment of hazardous substances" as the preferred remedy, as discussed in Section 1.1. This means that the soil CULs developed under MTCA apply to soil that is within the MTCA Site, but outside of the contained area of the Landfill. The soil outside the Landfill containment must comply with MTCA CULs at the standard point of compliance (POC) of the upper 15 feet bgs. Soil and refuse within the contained area of the Landfill are considered to be compliant with MTCA CULs as long as the requirements for containment under WAC 173-340-740(6)(f) are met.

Properties within the Landfill are primarily zoned as IG2 with a small portion of the southeastern SPPD property zoned as IB (as discussed in Section 2.3, and shown on Figure 2.4). Therefore, soil CULs were identified for the Landfill based on direct contact industrial exposure levels defined in WAC 173-340-745. Because default values for MTCA Method C Industrial CULs are used, with the exception of petroleum hydrocarbons, the CULs can be found in the Cleanup Levels and Risk Calculation (CLARC) database on the Ecology website (https://fortress.wa.gov/ecy/clarc/CLARCHome.aspx). Landfill-specific CULs for petroleum hydrocarbons have been calculated using Ecology's Workbook Tools for Calculating Soil and Ground Water Cleanup Levels under the MTCA Cleanup Regulation (Version MTCATPH 11.1, Revised December 2007).

These values are applicable to any soil at the Landfill that is not contained within the closed Landfill. For example, landscaping above the Landfill cap would need to meet these levels. Soil contained within the Landfill is in compliance as long as the Landfill is closed consistent with the requirements listed above in WAC 173-340-740(6)(f).

Soil CULs were not developed for the cross-media protection of indoor air or groundwater because both MFS and the presumptive remedy include long-term monitoring of LFG and groundwater to demonstrate that containment is effective at the Landfill and that indoor air and groundwater CULs are met. This allows for empirical demonstration that CULs for cross-media pathways are met. Finally, the presumptive remedy for landfills is designed to bring a landfill into compliance with MTCA in a reasonable restoration time frame—the time needed to implement the presumptive remedy.

4.2 REFINEMENT OF THE EXTENT OF SOLID WASTE

In order to establish the location of the containment remedy, the extent of solid waste must be delineated. Any solid waste outside of the containment remedy would have to meet soil CULs or be removed. A thorough understanding of the extent of solid waste is necessary in order to specify the location and scope of groundwater and LFG monitoring requirements. The extent of solid waste resulting from the City's operations was determined by examining historical information, aerial photographs, and field investigations, as described in the following sections.

4.2.1 Historical Operations

Historical operations at the Landfill are based primarily on information available in the City and King County Solid Waste Division (KCSWD) files, as well as aerial photographs taken from 1936 to 2004. A detailed description of the historical operations and accompanying aerial photographs are provided in Appendix A. Table 4.1 provides a summary of the historical owners and operations. Figure 4.1 provides the historical footprint of operations and shows fill activities at the Landfill.

4.2.1.1 Historical Operations at the Landfill

This section is best understood by reviewing the aerial photographs and historical information in Appendix A. The information regarding the location of the historical operations and fill is summarized on Figure 4.1.

The historical Landfill operations primarily occurred on the following three tax parcels:

- **First Addition River Park:** This parcel included the SRDS parcel.
- **Tax Lot 5:** This parcel consisted of the present-day SPPD parcel, the Lenci Frank Corporation property, and the Gordian Development property, and extended to the centerline of 5th Avenue South and the old South Sullivan Street alignment.
- **Tax Lot 7:** This parcel included the KIP/7901 parcels.

The original disposal location, which became active sometime before 1936, was on the southeast portion of the Landfill, a large area located north of South Sullivan Street, east of Occidental Avenue, and west of 5th Avenue South on Tax Lot 5 (Figure A.1). A smaller disposal site was bounded by South Kenyon Street to the north, and was located east of 1st Avenue South on Tax Lot 7 (present-day KIP/7901 parcels, Figure A.2). Materials disposed of in the Landfill primarily consisted of municipal, commercial, and industrial waste (SPU 1997; Ecology and Environment, Inc. 1988) from south and west Seattle. Waste from some parts of nearby unincorporated King County may also have been disposed of, as allowed under the County's 1958 lease with the City. By 1946, active disposal in the northwestern corner of the Landfill expanded to the southeast into the parcel occupied by the present-day SRDS (formerly the First Addition River Park), and was bound to the east by West Marginal Way South. At this time, active burning of solid waste was occurring at the Landfill. In 1951, First Addition River Park and Tax Lot 7 were purchased by the City. In 1955, the northwest corner of Tax Lot 7 was purchased by a private owner, and the lot was converted to an auto-wrecking yard by 1956. The County purchased Tax Lot 5 in 1957 and began leasing the property to the City for rubbish disposal in 1958. Burning of rubbish ended in 1961.

After the Landfill was closed in 1966, changing use of the southern portion of Tax Lot 5 resulted in the realignment of South Sullivan Street approximately 150 feet northward from its original location, which is shown on Figure 4.1 and Figures A.1 through A.6 in Appendix A. As a result, the extent of waste extends south of the modern day South Sullivan Street.

By 1977, the KIP, 7901, and SRDS parcels were established facilities, closely resembling their current configuration and use today. On the SPPD property, there have been no other significant changes in historical operations since 2006, other than the clearing of site vegetation, the placement of crushed concrete to grade the land surface, and subsequent use of the SPPD parcel as a leased equipment and truck storage yard.

More detailed descriptions of the Landfill's development can be found in the text of Appendix A and on Figures A.1 through A.21.

4.2.1.2 Historical Operations in the Vicinity of the Landfill

In 1936, the parcels surrounding the Landfill consisted primarily of agricultural parcels and undeveloped land; however, by 1941 residential properties began to be developed to the east and the southeast of the Landfill (shown in Appendix A). By 1956, several additional agricultural properties surrounding the Landfill were developed (shown in Appendix A), including the following:

- Auto-wrecking yards to the south of South Kenyon Street and to the north of South Cloverdale Street extended onto the northwestern and southern portions of the Landfill.
- Gas stations with repair bays and pump islands developed on the southeast corner of Occidental Avenue South and 1st Avenue South and on the southeast corner of South Kenyon Street and 1st Avenue South.
- A log sort yard developed on one of the parcels to the west of Occidental Avenue South.

In 1959, an industrial warehouse building was developed on the former Glitsa property to the northeast of the Landfill, with a 7,500-gallon Stoddard-solvent UST installed in 1964 to the east of the warehouse building (Environmental Associates 2009a). By 1967, the auto-wrecking yard to the north of South Cloverdale Street shifted eastward, causing a portion of South Sullivan Street to move approximately 150 feet north of its original position onto the southern portion of the Landfill. In addition, the SR 509 and South Cloverdale Street interchange was completed by that time and the two gas stations located along 1st Avenue South were abandoned (as shown in Appendix A).

In 1969, filling activities were occurring to the east of 5th Avenue South (as shown on Figure 4.1 and in Appendix A); however, these filling activities occurred after the Landfill had been closed, and there is no indication that the City or the County either leased or owned this parcel or were involved in the filling. Therefore, the filling is believed to be unrelated to activities at the Landfill. In addition, CKD was likely being used as fill on the parcels east of 5th Avenue South, as indicated by the materials observed in the RETS Line borings (additional discussion can be found in Section 4.2.4 and illustrated on Figure 4.2).

With the development of the KIP/7901 parcels, the KIP main stormwater line was completed in the old swale west of the Landfill area in 1971. The portions of the swale on the KIP/7901 parcels were likely backfilled using CKD (additional information is presented in Section 4.2.4) and other unclassified fill materials. At this time, the West Ditch, which had historically discharged through the swale, was connected to the KIP main stormwater line. By 1974, development of the present-day KIP/7901 parcels was completed. Due to the potentially harmful chemical nature (associated contaminants and high pH) of CKD and its use as backfill along the KIP main stormwater line, the CKD has the potential to act as a source of contamination to the groundwater that flows under the Landfill. Figure 2.3 provides a time lapse series of aerial photographs taken during the development of the KIP/7901 parcels. This figure shows the sequence over time of the development of the auto-wrecking yard both on and off of the Landfill property, and the backfilling of the swale.

By 1977, the former log sort yard developed into the Northstar Ice Equipment Corporation property and by 1982 the auto-wrecking yard north of South Cloverdale Street was abandoned and developed into the Emerson Power Products facility (aerial photographs from this period can be found in Appendix A). From 1985 to 1997, parcels surrounding the Landfill remained relatively unchanged; however, sometime between 1997 and 2002 the parcel to the north of South Kenyon Street had started being used as a bus yard (shown in Appendix A). No other significant changes appeared to occur on the surrounding parcels through 2004.

The parcel to the north of South Kenyon Street was used as an auto-wrecking yard and container storage area. It is likely that CKD was also used as fill in this area as it has been observed in some locations to be as thick as 12 feet (AMEC 2009a). This property was redeveloped for the reconstruction of the SRDS. As part of the construction of the new facility, the CKD fill from this property was removed as the preferred method outlined in the *Focused Feasibility Study South Kenyon Street Bus Yard Site* (AMEC 2009b).

4.2.2 Extent of Solid Waste Investigations

One of the data gaps identified during development of the Work Plan (Farallon 2010a) was the refinement of the western and southern Landfill boundaries based on the extent of solid waste. To address this data gap, a series of direct push soil borings were advanced at 12 locations (RP-01 to RP-12) along Occidental Avenue South and South Sullivan Street to assess whether solid waste extends across the roadways.

The locations where the borings were advanced are illustrated on Figure 4.2. Boring locations were completed at the following times: RP-01 through RP-05 were completed on January 13, 2011; RP-06 to RP-11 were completed on December 29, 2010; and RP-12 was completed on January 17, 2011. With the exception of RP-12, boring locations were consistent with the proposed locations from the Work Plan (Farallon 2010a). The proposed location for RP-12 was beneath an immovable stack of semi-trailers on the Lenci Frank Corporation (Emerson Power Products) parcel (shown on Figure 2.2, Parcel No. 3224049045). Therefore, the location for RP-12 was relocated along the southern edge of South Sullivan Street, approximately 20 feet north of its proposed location. All borings were completed in accordance with the RI Sampling and Analysis Plan, presented in Appendix D of the Work Plan (Farallon 2010a).

Borings RP-01 through RP-12 were each advanced to a total depth of 15 feet bgs, and were continuously sampled to determine soil composition and to monitor field indicators for contamination. The soil samples collected from the borings were characterized by interbedded sands and silts with an occasional presence of gravels. Brick, wood debris, wood fibers, and plant roots were encountered periodically in core samples retrieved for soil logging. Saturated groundwater conditions were encountered from approximately 1.3 feet bgs to 6.5 feet bgs. Handheld field instruments were used to screen and monitor levels of methane, oxygen, carbon dioxide, hydrogen sulfide, and VOCs. Concentrations of methane encountered during drilling activities ranged from 0.1 to 3.1 percent. Based on field screening, VOCs were generally not detected; however, a single detection of 25 parts per million (ppm) was noted in Boring RP-11, at a depth of approximately 6 feet bgs, and was associated with petroleum odor. Soil boring locations were backfilled with hydrated bentonite chips and finished to match surface conditions.

In addition to the extent of solid waste borings, two of the reconnaissance groundwater sampling probes (FB-12 and FB-13), installed as part of the reconnaissance groundwater investigation, and seven of the new soil gas probes (GP-24, GP-25, and GP-27 to GP-32), installed as part of the LFG investigation, contained useful information for determining the edge of solid waste and exposing subsurface fill materials. Both GP-24 and GP-25 are located to the west of the western Landfill boundary within the KIP parcel, while GP-27 to GP-32, FB-12, and FB-13 are located to the east of the eastern Landfill boundary along 5th Avenue South. Additional information about groundwater conditions can be found in Section 5.0, and information about soil gas conditions can be found in Section 6.0. The following sections provide a summary of the modifications to the Landfill boundary and a description of the fill materials along the boundary.

4.2.3 Revised Landfill Boundary

The Landfill boundary, as shown on Figure 4.2, defines the extent of solid waste for the Landfill. This figure presents both the approximate Landfill boundary (red dashed line) from the Work Plan (Farallon 2010a) and the revised Landfill boundary (blue dashed line). The Landfill boundary was modified based on a careful review of aerial photographs and historical documents as discussed in Section 4.2.1, combined with a review of the boring logs of all soil borings, soil gas probes, and groundwater monitoring wells located around the Landfill. For the purposes of this RI/FS, solid waste is defined as materials that were historically disposed of in the Landfill, and includes: glass, ceramics, pieces of sneaker, window/door screens, and drywall/paper debris. Other materials, such as CKD, wood, and brick debris, are not necessarily related to disposal activities at the Landfill and are thus termed unclassified fill.

In addition to the subsurface explorations to determine the extent of solid waste along Occidental Avenue South and South Sullivan Street, the lithologic descriptions from previous subsurface explorations surrounding the revised Landfill boundary were evaluated to assess the presence of historical disposal of unclassified fill and/or fill activities outside of the Landfill boundary. This evaluation focused on three areas: (1) potential CKD fill around the KIP main stormwater line completed in the historical swale to the west of the Landfill; (2) potential disposal of unclassified fill after the closure of the Landfill to the east of 5th Avenue South; and (3) potential disposal of CKD fill on adjacent properties to the east of 5th Avenue South (as shown on Figure 4.1). A summary of the changes to the approximate Landfill boundary from the Work Plan (Farallon 2010a) are provided in the subsequent sections.

4.2.3.1 Southwestern Extent along Occidental Avenue South

Soil borings were completed at 12 locations (RP-01 to RP-12) to better delineate the extent of solid waste along Occidental Avenue South and South Sullivan Street. In addition, the lithologic descriptions from one of the gas probes (GP-32) and monitoring wells (MW-29), installed as part of this RI, were also used to evaluate the presence of solid waste. Figure 4.2 illustrates the extent of the solid waste along the Landfill boundary and provides a description of the solid waste (brown highlighted descriptions) encountered in the various explorations.

As depicted on Figure 4.2, unclassified fill was encountered in all of the extent of solid waste borings, as well as at GP-32 and MW-29; however, definitive solid waste was encountered only in GP-32 and MW-29. In MW-29, glass was encountered at a depth of 6 feet bgs, while in GP-32 ceramic debris and glass shards were encountered between 3.5 and 7 feet bgs and white and black layered unknown fill material with a sulfur smell was encountered between 7.5 and 8.5 feet bgs. With the exception of MW-29, no solid waste was encountered outside of the approximate Landfill boundary presented in the Work Plan. Because the solid waste encountered in MW-29 was a relatively thin layer at a depth of 6 feet bgs and no other solid waste was encountered in the adjacent explorations, the approximate Landfill boundary from the Work Plan along Occidental Avenue South and South Sullivan Street was modified to no longer include RP-01 to RP-07 and MW-29 (shown on Figure 4.2 as a blue dashed line). Instead the Landfill boundary was moved in slightly toward the SPPD parcel boundary to where there is an upward change in the slope, which is representative of historical disposal and filling activities (refer to Figure 4.2).

4.2.3.2 Southern Extent along South Sullivan Street

City records indicate that sawdust fill was placed on the southern portion of the Landfill, to the south of the present-day South Sullivan Street alignment, in the early 1930s (refer to Appendix A); however, the solid waste encountered in the sampling of Boring GP-32, at a thickness of about 4.5 feet, indicates that disposal of solid waste also likely occurred in this area. The aerial photographs also confirm that the ground was disturbed in this area during that time, and that disposal may have occurred (aerial photographs from this period are available in Appendix A). In addition to GP-32, solid waste was also historically encountered in GP-15, which is to the east of GP-32, at a thickness of about 4.5 feet. Although this solid waste was detected outside of the revised Landfill boundary (blue dashed line), it is bound to the west by RP-11 and TP-67, to the northwest by RP-11, and to the east by GP-30 and GP-31, all of which did not encounter any solid waste. This indicates that the solid waste historically encountered in GP-15 was likely isolated disposal of waste not associated with the Landfill operation. The aerial photographs (presented in Appendix A) also did not show any historical disposal in this area. Because no solid waste was encountered in RP-08 to RP-12, the approximate Landfill boundary from the Work Plan was modified to include GP-32, but not RP-09, RP-11, or RP-12 (shown on Figure 4.2).

4.2.3.3 Eastern Extent along 5th Avenue South

As previously discussed, several reconnaissance groundwater probes (FB-12 and FB-13) and soil gas probes (GP-27 to GP-31) were installed along 5th Avenue South as part of this RI. Both of the reconnaissance groundwater probes had indications of solid waste. At the location of FB-12, abundant brick, charred wood, glass, concrete, and metal fragments were observed from 6 to 11 feet bgs; while at location FB-13, scattered glass, brick, metal, and wood fragments were observed from 1 to 11 feet bgs (refer to Appendix B). In addition, several soil gas probes (GP-27, GP-28, and GP-29) located in close proximity to FB-12 and FB-13 also contained solid waste. Solid waste was found in the following locations: GP-27 had glass, concrete, and brick fragments (6.5 to 11 feet bgs); GP-28 had pieces of glass, concrete, and brick fragments (7 to 9 feet bgs); and GP-29 had glass and brick fragments (2 to 3 feet bgs), brick and glass fragments and a piece of a sneaker (3 to 8.5 feet bgs), and a window/door screen (8.5 to 9 feet bgs).

Slightly elevated methane concentrations were observed in both GP-28 (between 0 and 2.8 percent) and GP-29 (between 2.4 and 8.5 percent), as will be further discussed in Section 6.0. Therefore, the eastern edge of the Landfill boundary was extended to the far side of 5th Avenue South to include these boring locations (the locations of these borings are shown on Figure 4.2). The extension of the Landfill boundary is limited to the east by the geotechnical borings along the RETS Line, which did not encounter solid waste, and further to the south by the observed native materials in both GP-30 and GP-31, near the intersection of 5th Avenue South and South Sullivan Street.

4.2.3.4 Northeastern Extent along State Route 99

Based on review of the historical aerial photographs and the extent of disposal activities (Figure 4.1), the Landfill boundary was extended slightly onto SR 99 along the northeastern edge of the SRDS property. Solid waste thicknesses were determined along this boundary based on lithologic descriptions from geotechnical borings installed prior to the installation of the RETS Line along SR 99 (Boring Locations 7-3700 through 7-3803 and 7-3900 through 7-4641). Based on these borings, the solid waste had a thickness that ranged between 1.5 and 10.5 feet (AESI 1998).

4.2.4 Other Fill Materials outside the Landfill Boundary

An evaluation of other fill materials was conducted in several areas outside of the Landfill boundary to better understand potential impacts to groundwater quality at the site.

4.2.4.1 Kenyon Industrial Park Parcel Cement Kiln Dust Fill in the Historical Swale around the KIP Main Stormwater Line

A previous RI conducted by AMEC Earth and Environmental in 2009 indicated as much as 12 feet of CKD fill in an existing swale to the north of South Kenyon Street. This existing swale appeared to historically continue onto the KIP property in the vicinity of the present-day KIP main stormwater line. Based on lithologic descriptions from soil gas probes installed as part of this RI (GP-24 and GP-25), CKD fill was encountered at thicknesses of between 4.5 and 7 feet (Figure 4.2) on the KIP property. Several other borings installed during previous investigations (HP-03 and BH-19) indicated the presence of “concrete” rather than “cement or cement kiln dust”; however, groundwater at KMW-05 has a pH greater than 12, which is highly suggestive that the material is CKD rather than concrete (refer to Section 5.6.4).

4.2.4.2 5th Avenue South Post-closure Unclassified Fill

As previously discussed in Section 4.2.1 and presented in Appendix A, aerial photographs indicate that filling was occurring on a triangular property (Parcel No. 7883600005) to the east of 5th Avenue South in 1969 (shown on Figure 4.1). At this time, the Landfill was no longer accepting municipal solid waste and the SRDS had opened. Ownership records were reviewed for the parcel, and there is no indication of ownership and/or leasing of this property by the City or County. Therefore, the filling on this parcel is not related to activities at the Landfill.

Geotechnical borings installed prior to the installation of the RETS Line confirmed the presence of unclassified fill in several borings along the eastern boundary of this property (7-3450, 7-3550, 7-3597, 7-3600, 7-3647, and 7-3650), which suggests that the triangular property to the east of 5th Avenue South was at one time used for the disposal of unclassified fill. This debris had thicknesses of between approximately 5 and 16.5 feet. This unclassified fill placement occurred after the closure of the Landfill and is not related to the solid waste placed within the Landfill boundary. Figure 4.2 illustrates the occurrence of the unclassified fill in the various RETS Line borings.

4.2.4.3 5th Avenue South Cement Kiln Dust Fill

The geotechnical borings installed prior to the installation of the RETS Line indicate a consistent presence of CKD, with thicknesses ranging between 2 and 13 feet along the RETS Line on the parcels to the east of 5th Avenue South. A review of historical aerial photographs (presented in Appendix A) indicates that the fill was likely placed on the two parcels to the east of 5th Avenue South (Parcel Nos. 7883600350 and 7883600600) during 1969. This was approximately the same time that the swale was filled with CKD on the KIP parcel and to the north of South Kenyon Street. One soil gas monitoring probe (GP-28), which was installed as part of this RI, confirmed the presence of CKD from approximately 2.5 to 7 feet bgs. As with the triangular parcel to the north (discussed in Section 4.2.4.2), these parcels were filled after the Landfill closed and was under private ownership.

4.3 HISTORICAL SOIL CONDITIONS

4.3.1 Soil Samples

It is not customary to analyze samples within a closed landfill as these samples would be considered samples of solid waste, not soil; therefore, "soil" samples at the Landfill are limited to samples collected from the unpaved SPPD parcel, and a few samples from the landscaped areas at the SRDS parcel. The rest of the SRDS parcel, the KIP/7901 parcels, and the surrounding roadways are paved.

4.3.1.1 South Park Property Development Parcel

Historically, there have been between 70 and 80 soil samples collected on the SPPD parcel, which were analyzed for the following parameter groups.

Parameter Groups	Number of Samples
Volatile Organic Compounds	78
Semivolatile Organic Compounds	78
Pesticides	71
Polychlorinated Biphenyls	71 + 9
Total Petroleum Hydrocarbons	Over 80
Metals	73

Table C.1 of Appendix C, Analytical Data Summaries, lists the analytes that were never detected in the soil samples. Table 4.2 lists those chemicals that were detected in the soil samples and compares them to standard MTCA Method C Industrial CULs, as discussed in Section 4.1.

Lead and arsenic exceeded the industrial-based CULs in some of the samples collected from test pits in the late 1990s. Several of the samples were screened for leachable metals using the toxicity characteristics leaching procedure (TCLP) to determine whether the material was a hazardous waste. All TCLP results were less than the criteria for classification as a Characteristic Waste, indicating that the soils could remain on-site as long as they were placed below the Landfill cap/cover. Since the time when these samples were collected, the Landfill has been regraded and new surface fill has been placed, making it difficult to know the exact location of the soil with exceedances. The whole SPPD parcel is underlain by refuse; therefore, it is assumed that the whole parcel will be capped in such a way as to contain both the solid waste and the contaminated soil.

One of the 71 soil samples analyzed for polychlorinated biphenyls (PCBs), at TP-39, had a concentration of 18,000 micrograms per kilogram (µg/kg)—this value is less than the MTCA Method C Industrial CUL for PCBs, but greater than the Toxic Substances Control Act (TSCA) criterion of 10,000 µg/kg for unpaved industrial areas[5]—a relevant, but not applicable requirement. Farallon performed an investigation in 2007 with the intent of bounding the location (Farallon 2007). Nine samples forming a 10-foot grid around the location were analyzed for PCBs.

[5] Ecology makes the same distinction in the MTCA Method A Table, where they default to the TSCA limit of 10,000 µg/kg as a relevant, but not necessarily applicable requirement.

The results for eight of the nine samples were no detections with a detection limit of 50 µg/kg; the ninth sample had a PCB concentration of 90 µg/kg. An additional 25 test pit samples were collected in this area to delineate the area of concern. No other elevated concentrations were found. These results are consistent with the otherwise low concentrations of PCBs in the rest of the Landfill samples and indicate that PCBs are not a contaminant in the surface fill of the SPPD parcel. The most likely source of PCBs to the single sample with elevated concentrations was a fleck of PCB-containing paint or caulk, or a unit transcription error.

4.3.1.2 South Recycling and Disposal Station Surface Soil Sampling by Seattle Public Utilities

Based on previous exceedances of the MTCA Method A Industrial CULs for arsenic, cadmium, lead, and mercury, SPU decided to investigate the surface soil quality in the landscaped areas within the SRDS parcel. This work was completed at the same time as the 2011 RI data gaps investigations were being completed, but was not performed under the Work Plan. The additional surface soil sampling was completed on June 17, 2011 by Camp Dresser and McKee, Inc. (CDM 2011). These data were used to evaluate the soil quality in the landscaped areas.

A total of 28 sample increments were collected from Decision Unit (DU) 2 at approximately the same locations as the dioxin/furan sampling, as later described in Section 4.4.2 and as indicated on Figure 4.3. Approximately the top 2 inches of soil were collected from each of the sample increments. No sample increments were collected from DU2-4 and DU2-5. The sample increments from DU2 were submitted to Analytical Resources, Inc. and composited, dried, and split similar to the dioxin/furan sampling. The MI sample composite was then analyzed for the MTCA 5 Metals (arsenic, cadmium, lead, chromium, and mercury) by USEPA Method 6010/7000. The following table presents the DU2 surface soil sampling results.

Analyte	**Concentration (mg/kg)**
Arsenic	20
Cadmium	2.1
Lead	273
Mercury	0.23
Total Chromium	43
Hexavalent Chromium	<0.400

Abbreviation:
mg/kg Milligrams per kilogram

4.4 CURRENT SOIL CONDITIONS

Efforts to assess current soil conditions within areas identified by the Work Plan, and other areas that were identified during the field program to facilitate assessment of current conditions, are described below. A summary of chemicals analyzed for, but not detected, in soils encountered at the Landfill and a summary of the frequency of detections and exceedances of chemicals analyzed can be found in Tables C.1 through C.4 in Appendix C. A summary of work modifications and deviations from the Work Plan, as was necessary to characterize the extent of waste and adapt to changing field conditions at the Landfill, is summarized in Appendix D. None of the modifications adversely affected the quality or usability of the data. Analytical laboratory reports and data validation reports can be found in Appendices E and F, respectively.

4.4.1 West Ditch Investigation

Soil samples were collected along the West Ditch to assess the presence of hazardous substances and determine whether the excavated soils can be disposed of on-site. The following sections provide a summary of the procedures and findings of the investigation. The West Ditch is currently undergoing cleanup as part of the Ecology-approved IA on the SPPD parcel.

4.4.1.1 Investigative Approach

The West Ditch is part of an existing stormwater conveyance system for the Landfill. Over time, materials, primarily consisting of soil and vegetative matter, accumulated on the bottom of the ditch. As part of maintenance and/or redevelopment of the stormwater system, it is expected that some or all of this material may be removed and placed under the future landfill cap. To better characterize the lithology and chemical constituents of this material, samples were collected from the West Ditch. As indicated by the Work Plan and illustrated on Figure 4.4 of this report, samples were collected at three locations (SS-01, SS-02, and SS-03) along the West Ditch: (1) at the upstream end, near the confluence with the East-West Channel; (2) at the downstream end, where the drainage enters the storm drain system located on the KIP parcel; and (3) the midpoint between the first and second sampling locations. The sampling program targeted both recently deposited material and the underlying native soil. Each location was sampled with an 8-foot-long, 3-inch-diameter piston-core sampler. Each core was divided into up to four representative sections, and each section was containerized for laboratory analysis. As outlined in the Work Plan (Farallon 2010a), at least one native soil sample was collected 1 foot below the base of the recently deposited material at each location, with the exception of SS-02. At SS-02, the boring could not be advanced (refusal) 6 feet below the mud-line and was halted prior to reaching the underlying native material. The samples were analyzed for metals, semivolatile organic compounds (SVOCs), PCBs, petroleum hydrocarbons, pesticides/herbicides, and grain size. Appendix G provides a summary of the sampling procedures, photographs, and grain size analyses; the analytical data summaries are presented in Appendix C and the laboratory reports are in Appendix E.

In addition, a single sample (SS-P) was collected from a culvert discharging into the West Ditch, and analyzed for the same constituents.

4.4.1.2 Investigation Findings: Lithology and Hydraulic Connectivity

The West Ditch lithology consists of organic muck (SS-02) overlying native soil, and consists of either sand (SS-03) or organic silt (SS-01), as illustrated with depth on Figure 4.4. Based on the grain size analyses, the recently deposited material (organic muck) in all three of the West Ditch samples generally consisted of between 45 and 80 percent silt or clay. The underlying native material in SS-01 consisted of organic silt with almost 95 percent silt or clay. The underlying native material in SS-03 consisted of sand with less than 25 percent silt or clay.

The organic silt observed at SS-01 is indicative of the Silt Overbank Deposit and indicates that the West Ditch in this area is likely perched on the Silt Overbank Deposit. This is further supported by the boring log from nearby piezometer PZ-1 (piezometers PZ-2 and PZ-3 had poor recovery), which indicated the presence of a relatively thick Silt Overbank Deposit (about 8 feet thick). Somewhere between SS-01 and SS-03, however, the Silt Overbank Deposit either pinches out, or has been eroded. Therefore, at SS-03 the West Ditch is instead likely in hydraulic continuity with the A-Zone of the Shallow Aquifer.

4.4.1.3 Investigation Findings: Chemical Results

The West Ditch samples represent soils that will be removed or covered as part of the Landfill redevelopment and cleanup action. Table 4.3 presents a summary of the chemicals that were detected in these samples and the frequency at which they were detected. A summary of analytical results for each chemical is presented in Table 4.4. A list of all chemicals analyzed, but not detected, and their detection limits is presented in Appendix C, Table C.3. Table 4.4 summarizes the results and compares them to the MTCA Method C Industrial CULs and urban background soil values. This comparison is for informational purposes and will be considered in the cleanup remedy.

None of the samples exceeded the industrial limits. The samples with the highest lead and chromium results were also analyzed for TCLP metals. These results were less than the hazardous waste criteria.

Specific findings are as follows:

- **Carcinogenic polycyclic aromatic hydrocarbons (CPAHs):** With the exception of the sample collected at Boring Location SS-01 from 4 to 6 feet bgs, CPAHs were detected at all locations and all depths. Generally, concentrations were similar to Seattle background urban concentrations in soils (Ecology 2011a).
- **SVOCs:** Non-carcinogenic polycyclic aromatic hydrocarbons (PAHs) were detected in all samples, although concentrations were very low in the samples collected from Boring SS-01 from 4 to 6 feet bgs. Dibenzofuran (a PAH-like chemical) was detected in 3 of the 11 samples. Phthalates were detected in approximately half the samples, with bis(2-ethylhexyl)phthalate being the most common. Pentachlorophenol was detected in one sample. Concentrations for all detected SVOCs were low and orders of magnitude less than MCTA Method C levels.
- **PCBs:** PCBs were detected in all samples and at all depths. Total PCB concentrations ranged from 426 to 5,200 µg/kg. Concentrations did not show any specific trend with depth, but did vary with location. Concentrations of the Aroclors 1254 and 1260 were greatest in samples collected from Boring SS-02, while concentrations of Aroclor 1242 were greatest in samples collected from Boring SS-03. PCB concentrations were generally lowest in samples collected from Boring SS-01. The culvert sample (SS-P) had a PCB concentration of 630 µg/kg, which was less than all but one other sample. PCB concentrations in all samples were less than the MTCA Industrial soil CULs and the TSCA CULs for paved industrial areas.
- **Herbicides:** There were no detections of herbicides in any of the West Ditch or culvert samples.
- **Pesticides:** Chlordane and dichlorodiphenyltrichloroethane (DDT) isomers were detected in all West Ditch samples; however, concentrations in several samples were so low that confirmation or confirmation and quantification were difficult (as reflected in the J and JN qualifiers in Table 4.4). Samples from SS-02 were the most consistently contaminated samples. Concentrations were much less than MTCA Method C levels.

- **Petroleum hydrocarbons:** Diesel- and oil-range hydrocarbons were detected in all samples; gasoline-range hydrocarbons were not detected. The sum of the diesel- and motor oil-range petroleum hydrocarbons ranged from 125 to 3,980 milligrams per kilogram (mg/kg). A review of the chromatograms (included in Appendix C) indicates the sample collected from SS-01 at 4 to 6 feet bgs (125 mg/kg total petroleum hydrocarbons [TPH]) is in native materials. It also indicates that the measured residual fuel-range TPH concentration does not resemble petroleum-derived hydrocarbons and is most likely the quantification of biologically derived organic molecules that are extracted and quantified during the analytical procedure. The lowest samples in the other two borings are located in an area with residual, recognizable petroleum contamination, and may not represent underlying native materials. Concentrations are much less than MTCA petroleum-specific CULs (refer to Section 4.1 for additional discussion).
- **Metals:** Metals were detected in both the West Ditch and the culvert samples. All metal concentrations were less than MTCA Method C levels. Generally, the lowest metal concentrations were detected in the deepest sample (4 to 6 feet) at either SS-01 or SS-03, while the greatest metal concentrations were detected in the shallowest sample (0 to 2 feet) at SS-03 or in the middle sample (2 to 4 feet) at SS-02.
- **TCLP Metals:** Because material from the West Ditch is considered for placement within the Landfill, metal concentrations that are regulated in characteristic hazardous waste are compared to the “20 times” criterion. When the criterion is exceeded, the samples are tested using the TCLP test to determine if the materials are hazardous wastes.[6] The samples passed the TCLP test; therefore, the West Ditch soils, if removed from the ditch, are appropriate for reconsolidation on-site as part of the cleanup.

In summary, the soils from the West Ditch have concentrations that are less than the MTCA Method C Industrial CULs and may remain on-site either above or below the Landfill cap.

4.4.2 Dioxin/Furan Testing of Surface Soils

Site-wide surface soil sampling for three DUs was performed to evaluate the presence of dioxin/furan compounds that could be encountered by workers, visitors, or ecological receptors. A summary of the investigative procedures and findings is provided in the subsequent sections.

4.4.2.1 Investigative Approach

The RI field program included soil sampling across the Landfill to assess concentrations of dioxin and furan compounds that may be present in the upper 6 inches of surface soil, including soil deposited in the West Ditch. For this, Ecology recommended the use of MI sampling. In this technique, a site is divided into DUs. A large number of individual samples are collected in each

[6] The criterion for lead is 100 mg/kg, which is less than the MTCA Method B residential standard, but greater than background. In the West Ditch samples, the chromium concentration from the sample collected at SS-03 from 0 to 2 feet bgs exceeded the 20:1 dangerous waste standard; and 7 of the 11 samples had lead concentrations that exceeded the 20:1 dangerous waste standard. Therefore, the TCLP was used to re-analyze the sample with the greatest lead concentration (SS-02-6-8) and the sample with a chromium concentration (SS-03-0-2) that exceeded the 20:1 dangerous waste standard. Based on the TCLP results, both samples had chromium and lead concentrations that were less than the Maximum Concentration of Contaminants for the TCLP (Chapter 173-303-090 WAC) and would not be classified as a dangerous waste.

DU and combined to form a single sample that is representative of the specific DU. The sample represents the "average" exposure concentration for the DU.

Figure 4.3 shows the DUs (DU1, DU2, and DU3) for the Landfill and the location of the individual samples that were collected to form the MI sample for each DU. Each DU has a depth interval of 0 to 6 inches below current grade. Each sample increment was collected with a handheld, stainless steel split-tube sampler. Thirty sample increments (sub-samples) were collected from within DU1 and DU3, and 60 sample increments were collected from DU2, due to the larger area.

For the purposes of MI sampling, the Landfill was divided into three DUs to evaluate potential deposition of dioxins and furans in the following areas:

- **DU1:** The West Ditch was selected as DU1 to represent the quality of runoff from the Landfill and the properties immediately to the west of the Landfill (also discussed in to Section 2.4.5). Because dioxin/furans are strongly hydrophobic and partition onto fine particles, the deposition nature of the West Ditch was considered ideal to evaluate whether there was any indication that the Landfill could have acted as a historical source through stormwater. A total of 30 sample increments were collected at even intervals along the West Ditch, starting to the north, near the boundary of the KIP/7901 parcels, and ending to the south, near the confluence with the East-West Channel. Sample increment locations were cycled laterally by collecting samples in the center and to the right and left sides of the ditch (while facing downstream, to the north), as indicated on Figure 4.3 by a "C," "R," or "L," respectively.
- **DU2:** This DU was identified to represent the unpaved areas at the SRDS. About 20 percent of the area within the SRDS is unpaved. Each of the 12 unpaved areas was assigned a number of sample increments that were proportional to the size of the unpaved area. Within each of the unpaved areas, the sample increment locations were evenly distributed to provide consistent sampling coverage and density (Figure 4.3). A total of 30 sample increments were collected within DU2, most of which were collected from landscaped areas.
- **DU3:** This DU was identified to represent the SPPD parcel, the only unpaved section of the Landfill. Due to the large area of DU3, 60 sample increments were collected, with 30 sample increments to the north of the East-West Channel and 30 sample increments to the south of the East-West Channel. The sample increment locations were laid out on a systematic rectangular grid, aligned with the Landfill boundaries and a random starting point. Slight adjustments to individual sample increment locations were necessary during sample collection due to patches of thick blackberry bushes and the temporary storage of large construction waste containers to the south of the East-West Channel.

The individual samples (a total of 120 sample increments) were delivered to Analytical Resources, Inc. in 4-ounce glass jars. The sample increments from each DU were composited and passed through a 2-millimeter sieve to remove large particles. For DU1, a large quantity of leaves, twigs, and roots was removed, but this represented a small fraction of the mass of the overall sample increments in the ditch. For DU3, the sieved quantity removed was about half of the sample mass and was composed largely of coarse sand and fine gravel.

Next, the samples were dried at room temperature on trays in a dedicated room. The drying trays were protected by aluminum foil tents, and the soil was turned 2 to 3 times per day for approximately 3 days. After the samples had dried, sample splitting was first attempted using a

Jones-type, or chute, riffle splitter[7]; however, significant fines were present in the DU1 sample and easily became airborne while being placed in and falling from the riffle splitter. This loss of fines would have continued with each of multiple passes. Dioxin has been known to be preferentially present on very fine particles; therefore, this loss of fines was judged to be unacceptable and an alternate splitting method was selected.

Instead, the samples were split using the USACE MI sample splitting protocol. Each MI sample was placed in a tray, and a 30-section grid was overlaid on each tray. Samples were procured by taking approximately a 0.3 ± 0.1-gram subsample from each grid section to yield a final 10-gram sample for analysis. A lab technician used a stainless steel V-spatula to remove soil from a random location in each grid section for each sample. After a 10-gram sample aliquot was generated, the soil was smoothed before taking another round of 0.3-gram subsamples. For each MI sample, five 10-gram sample aliquots were combined for a single dioxin/furan analysis, and three 5-gram sample aliquots were combined for a single total organic carbon analysis. Appendix H provides a summary of the USACE MI sampling procedures and photographs.

For the dioxin/furan analysis, and per MTCA Chapter 173-340-708(8)(D) WAC, 7 chlorinated dibenzo-p-dioxin congeners (CDDs) and 10 chlorinated dibenzofuran congeners (CDFs) were analyzed per MI sample increment. These congener concentrations were used to calculate a toxicity equivalency quotient (TEQ) concentration of 2,3,7,8-tetrachloro-dibenzo-p-dioxin, based on the toxicity equivalency factors (TEFs) recommended by the World Health Organization (Vanden Berg et al. 2006). The reference chemical is 2,3,7,8-tetrachlorodibenzo-p-dioxin because it is the most toxic and best studied of the 210 CDDs and CDFs.

4.4.2.2 Investigation Findings: Chemical Results

The results of the three DU samples are summarized in Table 4.5. As seen in Table 4.5, the TEQs for the MI samples ranged from 28 nanograms per kilogram (ng/kg) in DU1 to 333 ng/kg in DU2 with the greatest TEQ occurring in the landscaped areas at the SRDS and the lowest TEQ occurring in the West Ditch. The TEQs in each of the DUs are summarized below.

Decision Unit	Description	TEQ Result (ng/kg dry wt.)	MTCA Method C Cleanup Level (ng/kg dry wt.)
DU1	West Ditch	27.9	1,500
DU2	SRDS	333	
DU3	SPPD Parcel	66.3	

Abbreviations:
- MTCA Model Toxics Control Act
- ng/kg Nanograms per kilogram
- SPPD South Park Property Development, LLC
- SRDS South Recycling and Disposal Station
- TEQ Toxicity equivalency factor
- wt Weight

Extensive soil sampling was recently conducted by Ecology (Ecology 2011b) in several neighborhoods in Seattle to determine urban background dioxin/furan concentrations. Samples were collected from City ROWs and five adjacent sub-samples at each location were

[7] The purpose of the riffle splitter is to ensure that the combined sample is thoroughly homogenized.

homogenized for analysis. As discussed in the report, the samples were selected to be representative of adjacent properties, many of which were residential. Results of the study are presented in the following table.

		2,3,7,8-TCDD TEQ (ng/kg)			
Area	**Number of Samples**	**Range**	**Average**	**Median**	**90th Percentile**
Georgetown	20	5–110	36	23	66
Ballard	20	2–62	26	22	47
Capitol Hill	20	3–96	18	8	53
Ravenna	20	5–50	15	10	30
South Park	20	4–23	12	12	19
West Seattle	20	2–33	8	4	13
All Areas (2011 study)	120	2–110	19	12	46

Abbreviations:
ng/kg Nanograms per kilogram
TCDD Tetrachlorodibenzo-p-dioxin
TEQ Toxicity equivalency factor

The reported TEQ concentrations at the Landfill for samples from DU1 (the West Ditch), DU2 (SRDS), and DU3 (SPPD) are orders of magnitude less than the Industrial CUL. Therefore, dioxins and furans are not a chemical of concern (COC) for soils at the Landfill. It should also be noted that the stormwater leaving the Landfill flows through the West Ditch, whose soils are within the background range; this would indicate that stormwater transport of the insoluble dioxins/furans from the Landfill is not occurring at measurable levels.

4.5 SOIL CHEMICALS OF CONCERN

The only COCs for Landfill soils are arsenic and lead at the SPPD parcel. Concentrations greater than the MTCA Method C Industrial CULs[8] will need to be either removed or contained within a closed section of the Landfill. This requirement is expected to be met by remediating the SPPD parcel in compliance with MTCA as discussed in the FS.

[8] MTCA Method A CULs were used for lead, PCBs, and TPH, consistent with normal practice under MTCA.

5.0 Groundwater

5.1 INVESTIGATION OF GROUNDWATER

Investigations to characterize groundwater conditions beneath the Landfill were primarily conducted through the installation of groundwater monitoring wells (and temporary groundwater monitoring probes) and the sampling and monitoring of groundwater. Monitoring wells were installed within the Shallow Aquifer to investigate the potential distribution of chemicals in a shallow perched water zone (Perched Zone) and two zones (A-Zone and B-Zone) that underlie the Perched Zone[9]. The Perched Zone rests on the Silt Overbank Deposit, which generally acts locally as an aquitard either trapping groundwater that becomes perched or slowing the downward migration of rainwater infiltrating from the surface. Beneath the Silt Overbank Deposit, the Shallow Aquifer has been divided into two zones for investigative purposes. The A-Zone extends from the base of the Silt Overbank Deposit for approximately 15 to 20 feet (generally to -15 feet elevation NAVD 88). The B-Zone extends from approximately -15 feet elevation NAVD 88 to either the top of the estuarine/marine deposits or approximately -35 feet elevation NAVD 88, whichever is first.

Most of the Landfill rests on the Silt Overbank Deposit in contact with the Perched Zone; however, the silt unit is not continuous beneath the Landfill, and solid wastes extend approximately 5 feet into the A-Zone, at least on the KIP parcel.

Groundwater wells have been installed into all three zones, and monitoring wells on the KIP parcel (where the Landfill extends into the A-Zone) are screened across both the Perched Zone and upper part of the A-Zone. Because the Silt Overbank Deposit is discontinuous in this area, screening across both the Perched Zone and A-Zone is appropriate to characterize groundwater conditions.

5.2 PREVIOUS FINDINGS

Groundwater monitoring has occurred at the KIP parcel since 1989, and in the perimeter monitoring well network surrounding the Landfill since 1998. A summary of previous investigations at the Landfill can be found in Section 2.5.3 and Table 2.4. The historical data from the monitoring of groundwater at the Landfill indicate the following:

- There is a historical upgradient source of chlorinated VOCs, including TCE and its degradation products (specifically vinyl chloride) to shallow groundwater under the Landfill as indicated by the chemicals detected in the upgradient Monitoring Well MW-12. This well is located in the vicinity of a historical gas station along SR 509.
- There are relatively low concentrations of chlorinated VOCs in groundwater, which have declined over time, at monitoring wells on the downgradient boundary of the Landfill.
- Concentrations of metals (arsenic, chromium, lead, manganese, and mercury) in groundwater have been detected at levels greater than the preliminary screening criteria at monitoring wells both upgradient and downgradient of the Landfill.

[9] The A-Zone and B-Zone designations are based on depth within the Shallow Aquifer and do not represent different aquifer stratigraphy. Similar designations (A-level and B-level) are used across the Duwamish Waterway at Boeing Plant 2 for the same purpose in the same valley-wide aquifer.

- Petroleum hydrocarbons and related compounds have been detected at monitoring wells upgradient and downgradient of the Landfill.

Based on these findings, critical data gaps were identified in the historical data that needed to be addressed for the completion of this RI/FS.

5.3 SCOPE OF INVESTIGATION

The scope of the RI field investigation was presented in Section 4.0 of the Work Plan (Farallon 2010a) and included the following:

- Collection of reconnaissance groundwater quality samples using temporary direct push well points to address data gaps identified in the Work Plan associated with upgradient contamination in MW-12 and downgradient contamination at MW-27 and MW-25.
- Installation of additional groundwater monitoring wells to give better downgradient and edge of solid waste coverage of groundwater quality.
- Collection of site-wide groundwater quality samples that were analyzed for chemicals of potential concern (COPCs), including ones that were reported as not detected at Practical Quantification Limits (PQLs) that exceeded the preliminary screening levels.
- Collection of downgradient groundwater quality samples that were analyzed for natural attenuation parameters to better understand the downgradient fate of chemical contamination.
- Performance of slug tests in downgradient A-Zone Shallow Aquifer monitoring wells to determine hydraulic properties and evaluate fate and transport of chemicals downgradient of the Landfill.

5.4 GROUNDWATER INVESTIGATIONS

5.4.1 Reconnaissance Groundwater Sampling

Reconnaissance groundwater sampling was completed at eight locations (FB-07 to FB-14), including five upgradient and three downgradient locations, to address data gaps discussed in the Work Plan. The locations where reconnaissance groundwater samples were collected are illustrated on Figure 5.1. Sampling locations FB-07 to FB-11 were completed upgradient of the Landfill in the A-Zone of the Shallow Aquifer to investigate the source of historical detections of arsenic, TCE, and vinyl chloride at Monitoring Well MW-12. These groundwater samples were collected along the SR 509 WSDOT ROW using the direct push drill rig procedures outlined in the Work Plan.

Reconnaissance groundwater samples were also collected downgradient of the Landfill at FB-12, FB-13, and FB-14. Groundwater samples were collected at FB-12 and FB-13 to determine whether the source of arsenic detected at MW-27 is associated with CKD fill known to exist within the parcels located to the east of 5th Avenue South (refer to Section 2.2.7). In addition, these reconnaissance groundwater samples were analyzed for VOCs. The FB-12 and FB-13 groundwater quality samples were collected from the A-Zone of the Shallow Aquifer at depths of 10 to 15 feet bgs and 15 to 20 feet bgs, respectively.

Groundwater samples were collected at FB-14 to evaluate the distribution of VOCs downgradient of the Landfill at three different depths: across the Silt Overbank Deposit (8 to 13 feet bgs), immediately below the Silt Overbank Deposit in the A-Zone of the Shallow Aquifer (17 to 22 feet bgs), and above the estuarine deposit in the B-Zone of the Shallow Aquifer (36 to 40 feet bgs). Ecology representatives provided oversight during the drilling and sampling of FB-14 and collected a set of split samples that were analyzed at Ecology's lab. Based on the analytical results at FB-14, a pair of wells was installed at that location, and two additional wells were installed upgradient within the Landfill. These wells are discussed in more detail below.

5.4.2 Monitoring Well Installation

To address groundwater data gaps outlined in the Work Plan, five new monitoring wells were installed during the RI field program. The locations of the new monitoring wells are illustrated on Figure 5.1, and the boring and construction logs are provided in Appendix B. The new monitoring wells were completed as follows:

- Monitoring Well MW-29 was installed within the Seattle Department of Transportation ROW along South Sullivan Street in the vicinity of MW-4 and completed in the A-Zone of the Shallow Aquifer to evaluate the occurrence of petroleum hydrocarbons previously noted in the MW-4 well log. Monitoring Well MW-29 was installed using a direct push drill rig with oversized tooling and was screened across the A-Zone of the Shallow Aquifer to a depth of 30 feet bgs.
- Monitoring Wells MW-30 and MW-31 were installed in the vicinity of FB-14 as a Perched Zone/A-Zone well pair completed above and below the Silt Overbank Deposit. The Perched-Zone completion was installed to better understand local conditions, while the A-Zone completion was installed to represent groundwater quality downgradient of the Landfill. This well pair was installed using standard hollow stem auger drilling methods to depths of 13 and 23 feet bgs, respectively.
- Monitoring Well MW-32 was installed as close to the edge of solid waste as possible and upgradient of MW-30 and MW-31. The purpose of this well is to evaluate potential contaminants migrating downgradient from the Landfill in the A-Zone of the Shallow Aquifer. Because MW-32 was completed within the Landfill's solid waste footprint, a temporary conductor casing with a 10¼-inch inner diameter was extended approximately 1 foot into the Silt Overbank Deposit and sealed with approximately a 1-foot bentonite seal. The remainder of the boring was drilled using 4¼-inch inner diameter hollow stem auger drilling methods. The monitoring well was installed to a depth of 24 feet bgs and completed in the A-Zone of the Shallow Aquifer.
- Monitoring Well MW-33 was installed as close to the edge of solid waste as possible and upgradient of the former Glitsa property. This well was completed immediately below the Silt Overbank Deposit in the A-Zone of the Shallow Aquifer, at a similar elevation to MW-31. MW-33 was also completed within the Landfill's solid waste footprint and was installed to a depth of 25 feet bgs with a 10¼-inch inner diameter temporary conductor casing sealed approximately 1 foot into the Silt Overbank Deposit.

5.4.3 Site-wide Groundwater Sampling

A complete round of groundwater quality samples was collected from the site-wide monitoring well network to test for COPCs, including those that were originally not detected at PQLs that exceeded the preliminary screening levels. Figure 5.1 illustrates monitoring well locations included in the site-wide groundwater sampling event, which was conducted from January 26 to 28, 2011. Groundwater quality samples were collected according to the Sampling and Analysis Plan presented in Appendix D of the Work Plan (Farallon 2010a). Based on the Work Plan, the groundwater quality samples were analyzed for TPHs, total and dissolved metals, pesticides/herbicides, SVOCs, and VOCs. The laboratory analytical method PQLs used for the analyses were either less than the preliminary screening levels, or, if not achievable, the lowest achievable PQL, in which case the lowest achievable PQL became the preliminary screening level.

In addition, groundwater quality samples were collected on July 8, 2011 from the new monitoring wells (MW-30 to MW-33) installed to address data gaps identified during this RI. These groundwater quality samples were only analyzed for TCE and its degradation products.

5.4.4 Natural Attenuation Sampling

In addition to the groundwater quality analyses discussed above, the biologically mediated process of reductive dechlorination of chlorinated VOCs was evaluated to assess whether the groundwater chemistry of the Shallow Aquifer can support the complete biodegradation of TCE through degradation of vinyl chloride and other harmless constituents.

The downgradient site-wide groundwater quality samples collected from the A-Zone Shallow Aquifer monitoring wells (MW-25, MW-26, and MW-27) and the B-Zone Shallow Aquifer monitoring wells (MW-8, MW-10, and MW-24) were analyzed for natural attenuation parameters. These natural attenuation parameters included: alkalinity, sulfate, sulfide, nitrate and nitrite, ferrous iron, manganese, methane, ethane, and ethene. In addition, natural attenuation parameters monitored as field parameters included: pH, dissolved oxygen, and oxidation-reduction (redox) potential.

5.4.5 Slug Testing

The hydraulic conductivity of the A-Zone and B-Zone of the Shallow Aquifer were evaluated by conducting slug tests in the following monitoring wells on January 19 and 20, 2011: MW-8, MW-10, MW-24, MW-25, MW-26, and MW-27. Each slug test was conducted using a solid displacement slug, and included rising and falling tests at two different initial displacements. Groundwater level responses to the slug tests were monitored at a resolution of 100 milliseconds, using a vented Instrumentation Northwest PT2X pressure transducer. The results of these slug tests are summarized in Table 5.1 and Appendix I.

5.4.6 Interim Groundwater Monitoring Events

An Interim Site-wide Groundwater Monitoring program was implemented to provide groundwater quality monitoring prior to the completion and submittal of the CAP and development of a Long-term Groundwater Monitoring Plan. Three complete rounds of groundwater quality and natural attenuation parameter samples were collected from the site-wide monitoring network from April 1 to 4, 2013, July 15 to 18, 2013, and March 17 to 19, 2014; the sampling included the 17 monitoring wells depicted on Figure 5.16.

Groundwater samples were collected according to the Interim Site-wide Groundwater Monitoring Plan (Floyd|Snider 2012), and were analyzed for the following COPCs:

- Vinyl chloride and its precursors: *cis*-1,2–DCE and TCE,

- Benzene (MW-25, KMW-05, and KMW-08 only)
- Dissolved and total fractions of iron and manganese

In addition, groundwater samples were analyzed for the following geochemical indicators and natural attenuation parameters that were not included in the Interim Site-wide Groundwater Monitoring Plan:

- Major cations, including sodium, potassium, calcium, and magnesium
- Major anions, including chloride, sulfate, nitrate, nitrite, and alkalinity (carbonate, bicarbonate, and hydroxide)
- Ammonia and sulfide

Detailed descriptions of the interim site-wide groundwater monitoring events and results are presented in three Interim Site-wide Groundwater Monitoring Reports (Floyd|Snider and Aspect 2013a, 2013b, and 2014).

5.5 GROUNDWATER CONDITIONS

5.5.1 Groundwater Occurrence

At the Landfill, there are three groundwater zones of interest; all are part of the Shallow Aquifer:

- The Perched Zone is a thin discontinuous layer of groundwater (and infiltrating rainwater) that exists above the Silt Overbank Deposit. In many places, the Perched Zone groundwater is in contact with solid waste and is conceptually equivalent to landfill leachate in those locations.
- The A-Zone of the Shallow Aquifer is immediately beneath the Silt Overbank Deposit and is the critical zone where leachate (and perched water) can enter the groundwater system and move off-site.
- The base of the Shallow Aquifer (B-Zone) immediately overlies the finer grained estuarine deposits and represents the area where dense non-aqueous phase liquids (DNAPLs) would have accumulated had they been present.[10]

The majority of the wells and direct push groundwater sample locations at the Landfill are installed in the Shallow Aquifer below the Perched Zone, except at the KIP parcel, where the wells are screened across both the Perched Zone and the upper 5 to 10 feet of the A-Zone of the Shallow Aquifer. Wells with the designation of "KMW" should be considered to represent a combination of Perched Zone and A-Zone Shallow Aquifer groundwater conditions.

A series of geologic cross sections were developed in the vicinity of the Landfill to clarify the relationships between solid waste, the Silt Overbank Deposit, and the various groundwater zones within the Shallow Aquifer. The locations of these cross sections are illustrated on Figure 5.2, and include two cross sections extending from west to east (Figures 5.3 and 5.4) and two cross sections extending from north to south (Figures 5.5 and 5.6) across the Landfill. Cross sections produced as part of the RI corroborate the stratigraphic understanding from earlier regional studies. The correlation between the local and regional lithology is illustrated on Figure 5.7.

[10] No indication of DNAPLs has ever been found at the Landfill or within the MTCA Site.

The solid waste at the Landfill is estimated to have a thickness that ranges from less than 5 to 25 feet, with the solid waste generally thinning near the Landfill boundary. In the Landfill portion of the KIP parcel, the solid waste appears to penetrate the underlying Silt Overbank Deposit and be in direct contact with the underlying alluvial soils (Figures 5.3 and 5.5).

Generally, the Silt Overbank Deposit is continuous across the Site except where the solid waste appears to penetrate it (illustrated on Figures 5.3 and 5.5), and along the northwestern edge (illustrated on Figure 5.3) and the southeastern edge (illustrated on Figure 5.4) of the Landfill where it appears to pinch out. Contaminants can move from the Perched Zone into the deeper zone through two different processes. Where the Silt Overbank Deposit is absent, groundwater is able to flow (convection) following the potentiometric pressure differences in the two zones. Contaminants in the groundwater can follow this flow path, although they will be retarded in their flow depending on how strongly they interact with the aquifer soils. Where the Silt Overbank Deposit is present, groundwater flow is restricted between the Perched Zone and deeper groundwater. Contaminants are able to move by diffusion into the Silt Overbank Deposit, and will slowly diffuse through the deposit, where they may enter the deeper groundwater system. This is a much slower process than convection. The alluvial deposits that form the Shallow Aquifer are relatively thick, ranging from about 20 feet thick along the western edge of the Site to more than 50 feet thick along the eastern edge of the Site. In general, the alluvial deposits become thicker closer to the center of the valley. The alluvial deposits that form the Shallow Aquifer are generally composed of dark gray or black silty sand or sand. Underlying the Shallow Aquifer are estuarine deposits, which consist of fine sand and silt, and are characterized by the presence of shell fragments. The estuarine deposits are encountered at approximately sea level along the western edge of the Site and dip to the northeast, toward the center of the valley, where they are encountered at greater depths (more than 35 feet below mean sea level [MSL]). Beneath the southwestern edge of the Site, near the edge of the alluvial valley, glacial deposits were encountered at approximately 9 feet below MSL, in Monitoring Well MW-14 (Figure 5.1). The glacial deposits are representative of the valley walls and deep valley floor.

Groundwater hydrographs were plotted for wells completed within the Perched Zone and both the A- and B-Zones within the Shallow Aquifer (refer to Figure 5.8). The hydrographs indicate seasonal fluctuations in groundwater levels of between 0.5 and 2.5 feet in the vicinity of the Landfill; however, fluctuations up to 5 feet have been observed during dewatering activities associated with construction at the SRDS. Groundwater level monitoring conducted by AESI (2000) also indicated that groundwater levels below the Silt Overbank Deposit are influenced by changes in barometric pressure, indicative of confined aquifer conditions.

5.5.2 Vertical Gradients

Vertical groundwater gradients (the change of hydraulic head per unit distance) were calculated based on water level measurements collected during the RI and interim site-wide groundwater monitoring in the downgradient Perched Zone/A-Zone pairs of the Shallow Aquifer (MW-30/MW-31) and the A- and B-Zones of the Shallow Aquifer (MW-27/MW-8, MW-25/MW-10, and MW-26/MW-24). These data are presented in Table 5.2. Within the Shallow Aquifer, there is no general, vertical gradient apparent from the water level data. During the four monitoring events, only two instances of vertical gradients were observed in the shallow aquifer: a slight upward gradient observed only in the MW-27/MW-8 well pair in January 2011 (0.006), and a slight downward gradient measured only in the MW-10/MW-25 well pair in March 2014 (0.008).

The MW-30/MW-31 well pair was specifically installed to distinguish between the Perched Zone and Shallow Aquifer systems. Downward vertical gradients were consistently observed in Well

Pair MW-30/MW-31 during the RI and interim site-wide groundwater monitoring, and ranged between 0.06 and 0.1. This confirms that the Silt Overbank Deposit is likely acting as a low permeability aquitard; however, in areas where the silt is not present, there would be a diffusion migration of contaminants into the A-Zone.

5.5.3 Aquifer Characteristics

Slug tests were performed in the A-Zone/B-Zone well pairs downgradient of the Landfill to determine the hydraulic conductivity—the quantitative measure of an aquifer's ability to transfer water. A summary of the slug test results is provided in Table 5.1 and the slug test analyses, performed using AQTESOLV Professional, are provided in Appendix I. The horizontal hydraulic conductivity of the Shallow Aquifer was estimated based on the geometric mean of individual slug test results, which gives greater relative contribution to numerically higher hydraulic conductivity values, as recommended in Bouwer (1978). The mean (geometric) hydraulic conductivity of the Shallow Aquifer was approximately 60 feet per day (ft/day; 2×10^{-2} centimeters per second [cm/sec]), with a range of values between 26 and 150 ft/day (0.9×10^{-2} to 5×10^{-2} cm/sec). These results are within the expected range of hydraulic conductivity values for clean sand and greater than expected for silty sands (Freeze and Cherry 1979); this is consistent with the aquifer soil characteristics.

A comparison of the slug test results with hydraulic conductivity values estimated from 1-hour pumping tests (AESI 2000), conducted in 2000, on the monitoring wells completed in the B-Zone of the Shallow Aquifer (MW-8, MW-10, and MW-24) can be found in Table 5.1. The pumping test results yielded hydraulic conductivity values that were about 1.5 times greater than the slug test results; however, it should be noted that the ranges in values for the slug test and pumping test results indicate considerable overlap. The slug test results are likely indicative of localized hydraulic characteristics of the aquifer material surrounding the well screen, while the pumping test results are more indicative of the hydraulic characteristics of a larger section of the Shallow Aquifer.

5.5.4 Groundwater Flow

As previously discussed in Section 3.1.3, the regional groundwater flow direction in the Shallow Aquifer is to the northeast, toward the Duwamish Waterway. This groundwater flow direction also occurs locally beneath the Landfill, as is shown by the differences in groundwater elevations across the Site during measurements collected in March and August 2009 (Farallon 2010b). Groundwater surface elevation contour maps for these monitoring periods are included as Figures I.7 and I.8 in Appendix I of this report. As part of this RI, additional groundwater level measurements were collected in January and June 2011. Groundwater surface elevation contour maps from these monitoring events are included as Figure I.9 (January 2011) and Figure I.10 (June 2011[11]) in Appendix I in order to further refine the groundwater flow direction in the A-Zone of the Shallow Aquifer beneath the Landfill.

In creating the groundwater elevation contour maps, it was concluded that groundwater levels measured in the West Ditch to the north of SS-02 are representative of groundwater in the A-Zone of the Shallow Aquifer. This is because the West Ditch is likely in hydraulic continuity with the A-Zone of the Shallow Aquifer due to the absence of the Silt Overbank Deposit (refer to Figure 5.4).

[11] The June 2011 contour map also included water level data from the newly installed MW-31 on the far side of SR 99, and was used to determine optimal locations for Monitoring Wells MW-32 and MW-33 so that they would be downgradient of landfill impacts, if any, and upgradient of MW-31 and the former Glitsa property.

To the south of SS-2, however, the Silt Overbank Deposit appears to be present beneath the West Ditch, as inferred from lithologic material observed at PZ-01, PZ-02, and SS-01. In this area, the Silt Overbank Deposit likely acts as a low permeability aquitard between the West Ditch and the underlying A-Zone of the Shallow Aquifer. Therefore, water levels in the West Ditch between SS-01 and SS-02 were not included in the creation of the groundwater elevation contour map.

Groundwater surface elevation contour maps from the dry and wet season are shown on Figures 5.9A (July 2013), and 5.9B (March 2014). Additional contours from other events are contained in Appendix I. These contours, representing both wet and dry season conditions indicate little seasonal variation in the general groundwater flow direction beneath the Landfill, with a general groundwater flow direction to the northeast, toward the Duwamish Waterway, beneath much of the Landfill (Figures 5.9A and 5.9B and Figures I.7 through I.13 in Appendix I). This is consistent with findings from previous investigations at the Landfill (as described in the RI/FS Work Plan) and with findings from other MTCA sites within the valley (such as those in discussed in the Section 5.5.5).

5.5.5 Groundwater Velocity

Groundwater flow velocities and travel times in the vicinity of the Landfill are estimated from the most recent groundwater elevation contour map information (refer to Figures 5.9A and 5.9B) and hydraulic conductivity estimates of the A-Zone of the Shallow Aquifer (refer to Table 5.1). Using these data, a horizontal groundwater flow velocity can be calculated from the following equation (Fetter 1994):

$$v = \frac{1}{n_{eff}} K \frac{\Delta H}{\Delta L}$$

Where:

v = Groundwater velocity [L/t]
K = Hydraulic conductivity [L/t]
$\Delta H/\Delta L$ = Hydraulic gradient [L/L]
n_{eff} = Effective porosity [dimensionless]

Due to differences in groundwater flow directions, soil descriptions, and hydraulic conductivity estimates, groundwater flow velocities were calculated for two areas of the Landfill: (1) the northern region of the Landfill (SRDS property), in the vicinity of MW-10/MW-25, with a northeasterly groundwater flow direction and slightly higher hydraulic conductivity estimate; and (2) the southern region of the Landfill (SPPD property), in the vicinity of MW-8/MW-27, with a easterly groundwater flow direction and slightly lower hydraulic conductivity estimate.

The following table summarizes the average groundwater flow velocity in the two areas of the Landfill:

Horizontal Hydraulic Conductivity[1] (ft/day)	Horizontal Hydraulic Gradient[2] (ft/ft)	Effective Porosity[3] (%)	Horizontal Groundwater Velocity (ft/day)	Average Groundwater Velocity (ft/day)
Northern Region				

Slug Test MW-25	150	0.0029	21 to 26	2.0 to 1.7	
Pumping Test MW-10	170	0.0029	21 to 26	2.3 to 1.9	
Average	160	0.0029	21 to 26	2.2 to 1.8	2.0
Southern Region					
Slug Test MW-27	42	0.0026	21 to 26	0.52 to 0.42	
Pumping Test MW-8	71	0.0026	21 to 26	0.88 to 0.71	
Average	57	0.0026	21 to 26	0.70 to 0.56	0.63

Notes:

1. Horizontal hydraulic conductivity values based on the January 19, 2011 slug test in MW-25 and MW-27 and historical pumping test data from MW-8 and MW-10 (AESI 2000).
2. Hydraulic gradient calculated in the vicinity of MW-32 and upgradient of MW-25, based on the June 2011 groundwater elevation contour map.
3. Effective porosity values for fine to medium sand (21 to 26 percent, respectively) from Fetter (1994) based on the MW-25 and MW-31 well log soil descriptions.

Abbreviations:

ft/day Feet per day
ft/ft Feet per foot

The groundwater velocity in the northern region of the Landfill is approximately 2 ft/day, while the groundwater velocity in the southern region is approximately 0.63 ft/day. The groundwater velocity in the southern region of the Landfill is slightly lower due to the higher silt observed content in the area. Given the average groundwater velocities, it is estimated that the travel time for groundwater to move across the Landfill is between 1.5 and 5 years. Similarly, the boundary of the Landfill and the Duwamish Waterway are separated by approximately 1,600 feet and, with these groundwater velocities, it would take 2 to 7 years for groundwater from the Landfill to reach the Duwamish Waterway. Other projects in the Duwamish Valley have similar calculated average groundwater velocities in the Shallow Aquifer. Reported values are tabulated below and are consistent with those found at the Landfill:

Site Name	Typical Reported Groundwater Velocity	Comment	Citation
Boeing Plant 2	2.4 ft/day	Shallow Aquifer, A- and B-Zones; across the Duwamish Waterway from the Landfill	Environmental Partners, Inc. and Golder Associates Inc. 2009
Fox Ave Site	2.0 ft/day	Shallow Aquifer, A- and B-Zones; across the Duwamish Waterway and slightly downstream of the Landfill	Calibre and Floyd|Snider 2009
EMF Plume	2.0 ft/day	Shallow Aquifer, B-Zone; across the Duwamish Waterway, behind Plant 2, and near the eastern valley wall	Calibre 2008

Abbreviations:
EMF Electronics Manufacturing Facility
ft/day Feet per day
Landfill South Park Landfill
RI/FS Remedial Investigation/Feasibility Study

5.6 NATURE AND EXTENT OF GROUNDWATER CONTAMINATION

5.6.1 Data Availability

The Landfill exists within an urban area of Seattle with a long history of filling and industrial operations. As such, groundwater contamination exists upgradient of the Landfill, as well as beneath and downgradient of the Landfill.

The Landfill locations for which groundwater data are available are shown on Figure 5.1. As is appropriate for landfills, the majority of the wells are along the perimeter (edge of solid waste) with additional wells downgradient as needed to assess possible groundwater plumes. The following list identifies how each of the wells and probes shown on Figure 5.1 is used to assess groundwater quality:

Well	Location	Zone	POC Well
KMW-01A	Upgradient	The Silt Overbank Deposit is discontinuous at KIP; All KMW series wells at KIP monitoring a combination of Perched and A-Zone groundwater.	No
KMW-02 (abandoned)	Interior well (In-waste)		No
KMW-02B	Interior well (In-waste)		No
KMW-03A	Downgradient well (edge of refuse)		No
KMW-04	Interior well (In-waste)		No
KMW-05	Upgradient well (known source area)		No
KMW-06	Upgradient		No
KMW-07	Upgradient well		No
KMW-08	Upgradient well		No
MW-01	Upgradient well	A-Zone	No
MW-03	Upgradient well	A-Zone	No
MW-04	Upgradient well	B-Zone	No
MW-06	Crossgradient well	B-Zone	No
MW-08	Downgradient well (beyond SR 99)	B-Zone	Yes
MW-10	Downgradient well (edge of refuse)	B-Zone	Yes
MW-12	Upgradient well	A-Zone[1]	No
MW-14	Upgradient well	A-Zone	No
MW-18	Downgradient well (edge of refuse)	B-Zone	Yes
MW-24	Downgradient well (beyond SR 99)	B-Zone	Yes
MW-25	Downgradient well (edge of refuse)	A-Zone	Yes
MW-26	Downgradient well (beyond SR 99)	A-Zone	Yes
MW-27	Downgradient well (beyond SR 99)	A-Zone	Yes
MW-29	Upgradient well	A-Zone	No
MW-30[2]	Represents conditions near former Glitsa property	Perched Zone	No
MW-31[3]	Represents conditions near former Glitsa property	A-Zone	No
MW-32	Downgradient well (edge of refuse)	A-Zone	Yes
MW-33	Downgradient well (edge of refuse)	A-Zone	Yes
Push Probe	**Location**	**Zone**	**POC Well**
FB-07	Upgradient probe	A-Zone[1]	

Well	Location	Zone	POC Well
FB-08	Upgradient probe	A-Zone[1]	These locations represent push probe locations where water samples were collected; they are not monitoring wells
FB-09	Upgradient probe	A-Zone[1]	
FB-10	Upgradient probe	A-Zone[1]	
FB-11	Upgradient probe	A-Zone[1]	
FB-12	Downgradient probe (edge of refuse)	Perched Zone and A-Zone	
FB-13	Downgradient probe (edge of refuse)	Perched Zone and A-Zone	
FB-14	Downgradient probe (beyond SR 99)	Perched Zone, A-Zone and B-Zone	

Notes:
1 The Silt Overbank Deposit was not observed in this location.
2 MW-30 is completed within the Perched Zone on South Kenyon Street and represents localized perched groundwater conditions adjacent to the former Glitsa property.
3 MW-31 is completed within the A-Zone on South Kenyon Street and represents A-Zone conditions adjacent to the former Glitsa property.

Abbreviations:
KIP Kenyon Industrial Park
POC Point of compliance
SR State Route

Groundwater at the Landfill has been tested for chemical contamination for over a decade. Analytes have included metals, VOCs, SVOCs, PCBs, pesticides and herbicides, and conventional landfill parameters. Many chemicals have never been detected in groundwater. Tables C.5 and C.7 list the chemicals tested for but not detected in groundwater samples along with the range of detection limits.

A summary of chemicals detected in on-site and downgradient groundwater is presented in Table 5.3. The table includes the minimum and maximum detections and the location and date of the maximum detection. The table includes data from 1998 forward and may not represent current conditions. Figures later in this section display current conditions for key chemicals. Data validation reports are provided in Appendix F.

This data compilation includes the results of three additional rounds of groundwater sampling that occurred after the 2012 Draft RI/FS was published. These additional rounds were collected under an Interim Groundwater Sampling Plan that was approved by Ecology in 2013 (Floyd|Snider and Aspect 2012).

5.6.2 Development of Cleanup Levels for Detected Chemicals

In order to facilitate discussion of the chemicals detected in groundwater, MTCA CULs were developed for all the chemicals presented in Table 5.3. These include all chemicals detected in on-site and downgradient groundwater.

CULs for groundwater COCs are MTCA standards based on protection of groundwater for drinking water use. Although the affected aquifer is not used for drinking water, these standards were incorporated based on discussions with Ecology. The CULs provide protection for potential future use of the aquifer for drinking water. These concentrations are also protective of surface water use where groundwater from the aquifer discharges to the Lower Duwamish Waterway.

Although CULs are based on protection of drinking water, there is no current or anticipated future use of the groundwater for drinking water and no exposure; this assessment of exposure is based on the following:

- No drinking water wells currently exist between the Landfill and the Duwamish Waterway. A summary of all downgradient groundwater wells is presented in Table 5.4.
- High-quality public water is available from the City of Seattle throughout the area.
- It is against King County Board of Health Code, Title 12, Section 12.24.010(c), to install new public drinking water wells within 1,000 feet of a sanitary or abandoned landfill.
- It is against state law (WAC 173-160-171) to install a drinking water well within 1,000 feet of an existing landfill.
- It is against state law (WAC 173-160-171) to install a drinking water well within a 100-year floodplain, and most of the area between the Landfill and the Lower Duwamish Waterway is within the floodplain as shown on Figure 3.3.
- Groundwater within approximately 500 feet of the Duwamish Waterway is brackish to saline even at shallow depths due to the extent of the salt water wedge that intrudes upstream and infiltrates into groundwater.
- Groundwater throughout the aquifer contains high concentrations of naturally occurring iron and manganese, making the groundwater unpalatable.
- Groundwater at depth within the aquifer (estuarine deposits) is saline reflecting its origin as a marine embayment.

After discussions with Ecology, the decision was made to use CULs based on the drinking water scenario because the edge of solid waste (the POC for landfills) is located approximately 1,600 feet from the Duwamish Waterway, and a private, shallow drinking water well is technically feasible, if not consistent with state law.

The following additional considerations affect the development of groundwater CULs at the Landfill:

- The CUL for arsenic is based on the state-wide natural background concentration as defined in the MTCA Method A table for groundwater (Table 720-1 in WAC 173-340).
- Background-based screening levels were developed for iron and manganese using the iron and manganese concentrations in the upgradient wells. Background concentrations were set at the 90 percent upper confidence limit of the 90th percentile. Upgradient wells were available only in the more shallow A-Zone because the B-Zone does not exist upgradient of the landfill (the aquifer is thin near the valley wall). The screening levels developed from the A-Zone wells may slightly underestimate the deeper B-Zone concentrations.
- Several COPCs have drinking water Maximum Contaminant Levels (MCLs). If the groundwater is considered a potential drinking water source, then these drinking water MCLs are applicable requirements. Consistent with MTCA (WAC 173-340-720(b)),

those CULs have been adjusted downward to reach 1.0×10^{-5} risk. The adjusted MCL was then chosen as the applicable standard (Ecology 2005).

Table 5.3 lists the CUL criteria under MTCA based on a drinking water scenario for the chemicals detected in the solid waste, edge of solid waste, and downgradient wells.

The POC for groundwater monitoring that is part of landfill closure is defined as the edge of solid waste under both state and federal regulations. Under MTCA, this is considered a conditional POC and is generally placed as close to the edge of solid waste as practicable. Because of the location of SR 99, some of the POC wells are located on the Landfill side of SR 99 where a thin layer of solid waste is present, and the wells are screened in the aquifer below the waste; other POC wells are located on the far side of SR 99, but as close to the edge of waste as possible.

5.6.3 Chemicals of Concern for Groundwater

Table 5.3 identifies the chemicals that have been detected in groundwater at the Landfill since monitoring began in 1998. The third column lists the groundwater CUL for the particular chemical; and the fourth column indicates whether it is a MTCA Method B calculation or a MTCA-modified drinking water MCL. The table summarizes the number of groundwater samples analyzed for that chemical, the percentage of the time it was detected, and the location and date of the maximum detection. If the maximum detection since 2005 is greater than the proposed CUL, then the chemical is discussed below:

- **Benzene:** Benzene exceedances have occurred twice in the last 10 years: one in upgradient well KMW-05 and once in MW-25, a POC well for the landfill. Current concentrations at MW-25 are non-detections at 0.2 µg/L versus a CUL of 5.0 µg/L. Using the compliance test in MTCA (WAC 173-340-720), this well is in compliance; therefore, <u>benzene is not a groundwater COC</u>. However, since the maximum detection at MW-25 occurred relatively recently (2011), the well will continue to be monitored for benzene. Representative benzene concentrations in groundwater are presented on Figure 5.10.
- ***cis*-1,2-Dichloroethene**: This precursor of vinyl chloride is in compliance in all groundwater monitoring wells at the Landfill (Figures 5.11A and 5.11B). One push probe (FB-14) contained a minor exceedance (23 versus a CUL of 16 µg/L); therefore, <u>*cis*-1,2-DCE is not retained as a groundwater COC.</u>
- **Vinyl chloride**: The discussion in Section 5.7 is helpful in understanding vinyl chloride concentrations. Concentrations within the Landfill range from non-detection (0.02 µg/L) to 1.4 µg/L (in MW-25) and are compared to a CUL of 0.29 µg/L. Across SR 99, near the former Glitsa property, the concentration increases to 9 µg/L. <u>Vinyl chloride is a groundwater COC</u> and is out of compliance in MW-31, MW-25, and MW-33, with occasional exceedances in other wells.
- **Arsenic:** Arsenic concentrations have not been measured since 2011, when they were elevated at two locations: KMW-03A (8.0 and 8.7 µg/L) and MW-27 (13.9 and 27.2 µg/L) as shown on Figure 5.12. The minor exceedance of the concentration detected at KMW-03A represents the downgradient edge of an upgradient arsenic plume originating in CKD in KMW-05. It indicates that the arsenic is rapidly attenuating and is bounded before the downgradient edge of solid waste. The arsenic in MW-27 is also sourced in a CKD deposit, but one that is downgradient of the Landfill on adjacent properties along 5th Avenue (refer to Section 4.2.1.2 and Figure 4.1). Arsenic

concentrations in the edge of solid waste direct push soil Boring Locations FB-12 and FB-13, located upgradient of the CKD deposit, have concentrations of 1.6 to 2.3 µg/L, which are less than background (5 µg/L). Arsenic is not retained as a COC for the Landfill. Groundwater at the Landfill is not elevated in arsenic greater than the regional background concentrations. Arsenic contamination in the study area is associated with the CKD deposits, which are not part of the Landfill.

- **Barium:** Total barium concentrations exceed the CUL in two wells at the KIP parcel, KMW-03A and KMW-4; there are no exceedances for dissolved barium. No edge of solid waste wells have barium exceedances. Barium is not retained as a COC because it does not exceed the CUL at the POC.
- **Lead:** There has been a single exceedance for lead. It occurred in Well KMW-01A, an interior monitoring well on the KIP parcel. There have been no exceedances in the edge of solid waste and downgradient wells. Lead is not retained as a COC.

Iron and manganese concentrations are routinely measured at landfills because they are often leached from soils by the anaerobic groundwater produced during landfill refuse decay. Because iron and manganese concentrations are naturally high, concentrations at the Landfill were compared to both upgradient concentrations and other known datasets in the aquifer. A groundwater screening level was developed using the upgradient concentrations to estimate a background concentration. Based on this, the downgradient concentrations are slightly greater than the upgradient concentrations, but by a factor of less than 2. As the Landfill continues to age, the iron and manganese concentrations will continue to decline as methane production decreases and the groundwater slowly becomes less anaerobic. Iron and manganese are not COCs at the Landfill, but will continue to be monitored for a number of years.

In summary, vinyl chloride is the only COC for groundwater at the Landfill. Benzene and *cis*-1,2-DCE are not retained as COCs, but will continue to be monitored for several years to confirm that they are in compliance. These chemicals are discussed further below.

5.6.4 Current Groundwater Conditions at the Landfill

5.6.4.1 Benzene and Petroleum Hydrocarbons

The most likely source of benzene in groundwater in the area is petroleum products. Benzene, ethylbenzene, toluene, xylenes, naphthalene, TPH, and other components of petroleum products have been detected at the Landfill, but are not common. Except for benzene in MW-25, all other petroleum constituents are at levels less than their CULs, as discussed above. Recent groundwater concentrations of TPH and benzene are presented on Figure 5.10, with trend plots for benzene that include more recent data.

There is a notable upgradient petroleum hot spot in KMW-05. This area of the KIP parcel is not part of the Landfill; contamination in this area is believed to be associated with a former auto-wrecking facility or from contaminated material used to fill a historical swale on the KIP parcel. The contamination is bounded in all directions by other KMW wells, as can be seen on Figure 5.1. Benzene associated with the TPH in the vicinity of KMW-05 is also bounded by the other KMW wells. Benzene concentrations have been detected in MW-25 further downgradient; detections in MW-25 are considered Landfill-related.

MW-25 is a downgradient edge of solid waste well that has contained low levels of benzene for as long as it has been measured. Concentrations generally range from 1 to 3 µg/L, but were as great as 5.8 µg/L in January 2011; the CUL is 5.0 µg/L. Since 2011, benzene concentrations have been between not detected at 0.2 µg/L and 0.40 µg/L. Benzene was not detected in the Perched Zone, A-Zone, or B-Zone of the Shallow Aquifer at reconnaissance Probe FB-14, which is located downgradient of MW-25.

5.6.4.2 Trichloroethene and Its Degradation Products, Including Vinyl Chloride

Although TCE was historically detected at the Landfill, its concentrations have been decreasing over the last decade as it continues to undergo reductive dechlorination to the DCE isomers (*cis*-1,2-DCE and *trans*-1,2-DCE) and then vinyl chloride. Reductive dechlorination is a primary pathway for TCE degradation at landfills where the high moisture content and methanogenic conditions favor rapid degradation. DCE isomers also degrade efficiently to vinyl chloride under these conditions; however, the degradation process, while still able to convert vinyl chloride to the harmless ethene, is slower and the mobile vinyl chloride is most likely to partition into the groundwater system. Current groundwater concentrations of TCE and its degradation products (*cis*-1,2-DCE, *trans*-1,2-DCE, and vinyl chloride) are presented on Figure 5.11.

TCE and the DCE isomers are at levels less than CULs and are no longer a concern at the Landfill.

In the central and southern parts of the Landfill, vinyl chloride concentrations at the edge of solid waste from 0.02 to 1.4 µg/L (refer to Well MW-18 and direct push Probes FB-12 and FB-13 on Figure 5.11). Downgradient vinyl chloride concentrations immediately on the other side of SR 99 are 0.04 to 0.31 µg/L versus a CUL of 0.29 µg/L (refer to Monitoring Wells MW-08, MW-24, MW-26, and MW-27 on Figure 5.11). Concentrations in the downgradient wells have been at these low levels since at least 2006 (refer to the trend plots in Appendix J).

In the northeast corner of the Site, vinyl chloride concentrations are confounded by what appears to be a second source that is not Landfill-related. Concentrations are highest in MW-31 (9.0 µg/L), in probe FB-14 (5.1 µg/L), and in Glitsa well LAR 2 (3.9 µg/L). FB-14 and MW-30 and MW-31 were installed in the South Kenyon Street ROW, across SR 99 from the Landfill. On the Landfill side of SR 99, there are four wells that are upgradient of this area: MW-10, MW-25, MW-32, and MW-33. Concentrations for vinyl chloride in these locations range from 0.2 to 1.4 µg/L, and the travel time for groundwater between these wells and MW-31 is approximately 6 months (refer to Section 5.5.4). Vinyl chloride has a field-measured retardation factor that ranges from less than 1.6 to 2.0 (Roberts et al. 1990; Davis 2003; Clement et al. 1999). This indicates that vinyl chloride would travel that same distance in the Shallow Aquifer in 9 to 12 months. Because historical data over the last 5 years indicate that concentrations have been lower at the Landfill than result at the new well across SR 99, the new result was surprising and is discussed further in Section 5.7.

Finally, two historical studies were also considered. Monitoring well ALN-493 was installed in the A-Zone of the Shallow Aquifer along Riverside Drive as part of an environmental investigation related to a planned pump station and water quality facility. This location is where groundwater, especially groundwater from the northwest corner of the Landfill, would discharge into the Lower Duwamish Waterway. Monitoring Well ALN-493 is screened in the top (A-Zone) of the Shallow Aquifer and represents groundwater quality near the discharge point. It was sampled for TCE, DCE isomers, and vinyl chloride in 2008 and 2009 (PGG 2008, 2009). The chlorinated ethenes, including vinyl chloride, were not detected. The vinyl chloride detection limits were 0.1 and 0.2 µg/L for the two events, which is less than the vinyl chloride CUL of 0.29 µg/L. These data support the degradation of TCE and its degradation products, including vinyl chloride, prior to reaching the waterway.

Multiple wells were installed during the RI of the historical bus barn property located immediately north of the Landfill; most were abandoned during the redevelopment. Two wells, BYMW-5 and BYMW-1, are located near the northwest corner of the Landfill and allow for further delineation of groundwater quality in that corner. BYMW-5 was sampled in February 2008 and BYMW-11 in July of 2008 (AMEC 2009a). The results indicated that TCE, the DCE isomers, and vinyl chloride were not detected at the detection limit of 0.2 µg/L. These data are further confirmation of groundwater quality at the Landfill.

5.6.4.3 Iron and Manganese

Iron and manganese are such common landfill COCs that they are required to be analyzed for under federal, state, and county landfill regulations. A halo of elevated concentrations typically forms at the downgradient edge of the Landfill due to a well-understood process of reductive leaching of iron and manganese from the soils within the aquifer (Tchobanoglous, Theisen, and Vigil 1993; Stumm and Morgan 1996). Anaerobic leachate and methane gas produced by the microbial degradation of landfill wastes enters the groundwater system and causes the groundwater to become depleted of oxygen, resulting in anaerobic groundwater and reducing conditions. This oxygen depletion process is occurring to some extent at the Landfill, resulting in downgradient iron and manganese concentrations that are slightly greater than upgradient/background concentrations. Because the Landfill is in late Stage 4, this is no longer a strong effect, and as the Landfill transitions into Stage 5, the iron and manganese concentrations will continue to decline as methane production decreases and the groundwater slowly becomes less anaerobic. Results are presented on Figures 5.13A and 13B (the most recent dry and wet seasons, respectively) and discussed further in Section 5.8.

Upgradient wells have been monitored at the Landfill in the shallow zone of the aquifer (the deeper zone does not exist upgradient of the Landfill). The 90^{th} upper tolerance limit of the 90^{th} percentile for iron is 27 mg/L and for manganese is 2.1 mg/L (Figure 5.14).

High iron and manganese concentrations exist in the Alluvial Aquifer throughout the valley and at all depths, as shown in Figure 5.15. However, it is thought that samples collected from greater than 45 feet bgs are most likely to represent naturally occurring concentrations of iron and manganese, as these data are least likely to be influenced by anthropogenic activity. As shown in Figure 5.15, iron and manganese concentrations at other locations in the Alluvial Aquifer would predict background concentrations that are slightly elevated greater than the upgradient concentrations at the Site. If the larger area-wide data set were used, downgradient iron and manganese concentrations would be within the background range.

Currently the majority of the wells are at background conditions for iron and manganese, with the maximum concentration (iron at MW-18) less than 2 times the background concentration.

5.6.4.4 Upgradient Plume at KMW-05

A series of groundwater monitoring wells (KMW-01A, KMW-03A, KMW-04, KMW-05, KMW-06, KMW-07, and KMW-08) installed during previous investigations (Golder 1989; Diagnostic Engineering 1992) were sampled in January 2011 to evaluate groundwater quality at the northwestern portion of the Landfill. A number of these wells are completed through the solid waste and monitor groundwater conditions beneath the Landfill. In addition, several wells are located west of the Landfill boundary (KMW-05, KMW-07, and KMW-08) and document upgradient groundwater quality. KMW-07 and KMW-08 are clean, whereas groundwater quality at KMW-05 is significantly degraded by pH, metals, and petroleum hydrocarbons.

Based on a careful review of aerial photographs (refer to Section 2.0 and Appendix A), well logs (refer to Appendix B), and groundwater quality data, the following information has emerged:

- Monitoring Well KMW-05 is installed in the area of a former drainage swale that is clearly visible from the earliest aerials in the 1930s through 1969; by the time of the 1974 aerial, the Landfill is level, paved, and contains buildings.
- The drainage swale was never part of the Landfill.
- The drainage swale was filled during the development of the KIP parcel from 1969 to 1974 by the KIP parcel owners. The main stormwater line was placed in the swale to continue to carry stormwater that previously drained into the swale. The other lateral stormwater lines from the KIP parcel may connect to it.
- The swale was back-filled with CKD, which is likely the source of the elevated pH (greater than 12) and metals concentrations.
- This section of the KIP parcel was used as an auto-wrecking yard for a number of years (at least 1956 to 1969 based on aerial photographs); during those years the Landfill appears to be unpaved, and the swale is present.
- There was also a gas station on the northwest corner of the KIP parcel for several decades (refer to aerial photographs in Appendix A, especially the 1967 photograph that shows the pump island, a large auto-wrecking yard, and the swale).
- The petroleum contamination would be consistent with the use of petroleum-contaminated fill in the swale or with contamination of the swale (before or after filling) by site operations (gas station or auto-wrecking).

Although groundwater quality at KMW-05 has been impacted by several chemicals, the important issue for the Landfill is that the lower quality groundwater conditions are bounded in all directions by other KMW wells, and that the only contaminant that is measured within the Landfill at levels greater than CULs is arsenic in KMW-03A (8 µg/L versus a CUL of 5 µg/L). In the case of the arsenic, this upgradient plume is bounded before it reaches the downgradient edge of solid waste well pair, MW-10/25. Based on existing information, a localized plume of contaminated groundwater migrates from the area of the filled swale on the KIP parcel onto the Landfill, but the plume is attenuated before it reaches the edge of solid waste POC for the Landfill, represented by the Well Pair MW-10/-25.[12]

5.6.5 Historical Upgradient Plume and MW-12

Upgradient Monitoring Well MW-12 has had historical concentrations of TCE as great as 14 µg/L in 2001 (Appendix J). TCE concentrations decreased to stable levels between 2001 and 2007. During March 2014 groundwater sampling, TCE was detected at 0.3 µg/L, *cis*-1,2-DCE was detected at 4.5 µg/L, and vinyl chloride was detected at 0.22 µg/L. Historical aerial photographs indicated that a former gas station facility was located west of MW-12, along the current SR 509 north-bound lanes (Farallon 2010b). To investigate this potential up-gradient source area, a series of reconnaissance groundwater sampling probes and a one-time groundwater sample were advanced during the RI in March 2011. Reconnaissance groundwater Probes FB-7, FB-8, FB-9, FB-10, and FB-11 were completed along the SR 509 ROW using direct push drilling methods. A

[12] Benzene is detected in MW-25 at similar concentrations to KMW-05, but the intervening Wells KMW-06, KMW-04, and KMW-03A have no detectable TPH or benzene, so the two detections of benzene do not appear to be related.

grab groundwater sample was collected from temporary ¾-inch-diameter wells with prepacked screens installed at each location.

Chlorinated VOCs (TCE, *cis*-1,2-DCE, *trans*-1,2-DCE, and vinyl chloride) and dissolved and total arsenic were analyzed at each groundwater sampling probe location. Levels of *cis*-1,2-DCE were detected at four locations (FB-08, FB-09, FB-10, and FB-11) at concentrations between 0.4 and 12 µg/L. Vinyl chloride was detected in FB-08 (1.2 µg/L), FB-09 (0.11 µg/L), and FB-10 (0.026 µg/L). These results indicate that the former gasoline service station could be a source of the chlorinated VOCs observed in background Monitoring Well MW-12. Although the MW-12 area may have historically contributed TCE and its degradation products to groundwater at the Landfill, it is no longer a source of contamination at levels greater than CULs.

In addition, arsenic was detected at all locations with dissolved arsenic concentrations detected between 0.0015 and 0.0028 mg/L and total arsenic concentrations detected between 0.0009 and 0.0034 mg/L. The detected arsenic concentrations were all less than the background concentration of 0.005 mg/L.

5.7 DOWNGRADIENT GROUNDWATER CONDITIONS AND NON-LANDFILL CONTRIBUTIONS

Monitoring wells were constructed outside of the extent of solid waste to monitor groundwater quality along the downgradient edge (along the eastern and northeastern boundary) of the Landfill. Because the Landfill abuts the south-bound lane of SR 99, the closest location for most downgradient monitoring wells (MW-08/MW-27, MW-24/MW-26, MW-30/MW-31, and FB-14) was along the east side of SR 99, within the street ROWs. An additional well pair, MW-10/MW-25, is located near the northeast corner of the Landfill in a vegetated strip at the intersection of 5th Avenue South and South Kenyon Street. The paired monitoring wells are completed at two depth intervals in the Shallow Aquifer, monitoring the A-Zone (between 10 to 27 feet bgs) and the B-Zone (between 35 to 45.5 feet bgs) of the aquifer. Monitoring wells MW-32 and MW-33 are located in the edge of refuse on the west side of 5th Avenue South and monitor the A-Zone also. Perched water encountered above the Silt Overbank Deposit was also sampled in FB-14 and MW-30 to evaluate the presence of VOCs along the east side of South Kenyon Street and SR 99.

5.7.1 Landfill Impacts

Benzene was detected, but in compliance, in MW-25 on the Landfill side of SR 99. No benzene was detected downgradient of this location at FB-14, immediately on the other side of SR 99. Benzene is not a downgradient COC.

Vinyl chloride concentrations detected in downgradient Well MW-31 (at the adjacent groundwater monitoring probe location FB-14) are greater than concentrations measured at the Landfill in a number of years. Because the travel time between the upgradient locations and MW-30 is less than a year and data exist for several of the wells since 2006, this finding was not expected, and will be discussed further in the next section. Vinyl chloride is a COC for downgradient groundwater.

5.7.2 MW-31 and Adjacent Properties

In groundwater samples collected from the temporary groundwater monitoring Probe FB-14 in 2011, contamination by TCE and its degradation products, DCE and vinyl chloride, was detected in the Perched-, A-, and B-Zones. Concentrations measured in the B-Zone samples were less than CULs. Groundwater monitoring wells were installed in the Perched Zone (MW-30) and the A-Zone (MW-31). Concentrations of TCE, DCE, and vinyl chloride detected in samples collected at these wells were in the low parts per billion (ppb) range, but were elevated compared to the Landfill wells. This finding triggered a review of Ecology files for adjacent sites and the installation of two additional groundwater monitoring wells on the downgradient edge of the Landfill, but directly upgradient of MW-31. These new wells, MW-32 (upgradient of MW-31) and MW-33, were located upgradient of the former Glitsa property.

The data are summarized in the table below. The minimum and maximum values are from the 2011 to 2014 time frame and represent the results of four events. Two findings are especially noteworthy:

- TCE, the parent compound of the DCE isomers and vinyl chloride, is no longer present at the Landfill POC wells, but is detected across SR 99 in MW-30. MW-30 is completed in the water perched on the Silt Overbank Deposit and represents local conditions. The Perched Zone is too thin to move from the Landfill to MW-30 and is more reflective of local rainwater infiltration. TCE was also detected in shallow wells on the Glitsa property (MW-6).
- Concentrations of both *cis*-DCE and vinyl chloride are consistently greater in MW-31 than in the upgradient POC wells. The travel time for vinyl chloride in the Shallow Aquifer, from the Landfill, across SR 99, and to MW-31 is approximately 9 to 12 months (refer to Section 5.6); therefore, the vinyl chloride concentrations at MW-31 cannot be explained as a historical release from the Landfill ("historical" in this context would mean 2010 for which data are available, and the concentrations are too low).

	Trichloroethene (µg/L)		*cis*-1,2-Dichloroethene (µg/L)		Vinyl Chloride (µg/L)	
	Criterion (MCL) = 5		Criterion (MTCA Method B) = 16		Criterion (MCL-modified) = 0.29	
Well	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum
Landfill POC Wells Upgradient of MW-31						
MW-10	0.2 U	0.2 U	1.1	1.9	0.26	1.2
MW-25	0.2 U	0.2 U	0.48	0.8	0.79	1.4
MW-32	0.2 U	0.2 U	1.5	2	0.2	0.36
MW-33	0.2 U	0.2 U	0.2 U	0.7	0.3	1.1
Monitoring Wells near Former Glitsa Site						
MW-30	0.49	0.75	0.64	3.2	0.12	2.2
MW-31	0.2 U	0.2 U	3.9	6.3	4.3	9

A review of Ecology's files, indicated that the former Glitsa property, located on the south side of South Kenyon Street within 20 feet of MW-30 and MW-31, had known solvent contamination, and an operating remedial action (solvent vapor extraction). Groundwater data from the former Glitsa property in 2009 indicated that TCE was present in the Perched Zone at MW-06; and TCE degradation products were present in another well (LAR-2). The review of site documents also indicated that several operators at the former Glitsa property would have used solvents in their business practices, and that a former equipment maintenance area was adjacent to MW-30/MW-31 (refer to Figures 5.11A and 5.11B). It is plausible that the former Glitsa property is contributing TCE and its degradation products to the downgradient conditions (seen in MW-30/MW-31). Their operating remedial action may help to control sources at the former Glitsa property.

Since 2011, TCE levels have remained generally the same and *cis*-1,2-DCE and vinyl chloride values have decreased in MW-30 and MW-31. Vinyl chloride levels in wells MW-10 and MW-25 increased in early 2013, potentially due to adjacent construction activities, but have since decreased again. Trend plots are shown in Appendix J.

5.8 GEOCHEMICAL CONDITIONS AND NATURAL ATTENUATION

Natural attenuation processes (biodegradation, mineralization, dispersion, sorption, volatilization, and stabilization) reduce the mass, toxicity, mobility, volume, or concentration of contaminants. These processes are controlled by the biogeochemical character of the aquifer and its constituents. This character is assessed through the monitoring of specific physical and chemical parameters, which define the chemical potential of the aquifer and its ability to promote natural attenuation of COCs.

Natural attenuation of chlorinated VOCs by reductive dechlorination is already known to be occurring at the Landfill based on the following:

1. TCE and tetrachloroethene (PCE) were ubiquitous solvents with historical uses in household and commercial cleaning products and dry-cleaning processes. They are common constituents at solid waste landfills and were present in groundwater at the Site; although concentrations today are less than their respective CULs.
2. TCE and PCE can degrade by a process known as reductive dechlorination in which DCE isomers and vinyl chloride are produced. The DCE isomers (*cis*-1,2-DCE and *trans*-1,2-DCE) and vinyl chloride are present in groundwater at the Landfill. The DCE isomers are present but at concentrations less than their CULs, and they are not COCs; vinyl chloride is a COC.
3. DCE isomers and vinyl chloride are specialized chemicals with no known industrial uses in western Washington. When present in groundwater at sites in western Washington, their source is the degradation of TCE and/or PCE by reductive dechlorination.
4. Vinyl chloride also undergoes degradation by reductive dechlorination to form non-toxic ethene. Ethene is present in groundwater at the Landfill, indicating that conditions are favorable for its production.
5. Groundwater conditions have been monitored at the Landfill since the late 1990s. During this time, concentrations of TCE and PCE have decreased until they are now at levels less than their respective CULs. Concentrations of the DCE isomers and vinyl chloride have also decreased; however, vinyl chloride concentrations in several wells still exceed CULs.

5.8.1 Natural Attenuation Sampling

Natural attenuation parameters were collected in groundwater monitoring well pairs located at the edge of solid waste (MW-10/MW-25) and downgradient from the Landfill (MW-24/MW-26 and MW-08/MW-27) to evaluate the geochemical conditions and assess the potential for the natural attenuation of COCs. The evaluation of natural attenuation as a potential cleanup alternative will support the FS in determining if monitored natural attenuation (MNA) is a viable cleanup alternative for COCs downgradient of the Landfill. The parameters presented in the following table were analyzed in the field or by the laboratory (as part of the RI or historically) and are typically used as part of the natural attenuation evaluation. A summary of field measurements and analytical results for select natural attenuation parameters is presented on Figure 5.16.

Additional natural attenuation sampling was conducted during the interim groundwater monitoring events. Results are presented in Appendix C.

Parameter	**Primary Use**
Dissolved Oxygen and Redox Potential	Direct measurements of the dissolved oxygen concentrations and oxidation-reduction (redox) potential of the groundwater sample.
pH and Alkalinity	pH needs to be near neutral for critical attenuation processes. Elevated alkalinity downgradient of a landfill often indicates that leachate or LFG (which contains carbon dioxide) is entering the groundwater system.
Sulfate/Sulfide	Redox couple that confirms the effective reducing conditions in the aquifer; sulfate is an effective electron donor for reductive dechlorination of chlorinated VOCs; sulfide precipitates iron, manganese, and arsenic.
Nitrate/Nitrite	Redox couple that confirms the effective reducing conditions in a landfill; nitrate can act as an electron donor.
Ferrous Iron	Iron state that confirms effective reducing conditions.
Manganese	Presence of dissolved manganese confirms effective reducing conditions.
Methane, Ethane, and Ethene	Presence indicates whether LFG is entering the groundwater system. The presence of ethene is also used to indicate that vinyl chloride is degrading; however, the vinyl chloride concentrations are so low at the Landfill that they would not generate detectable ethene.

The continued reductive dechlorination of vinyl chloride is dependent on the geochemical parameter of redox potential, and most of the natural attenuation parameters in the table above are examples of redox-sensitive compounds whose concentrations can be used to confirm the redox conditions in the aquifer. These parameters are key to evaluating geochemical conditions that support the degradation process of reductive dechlorination of chlorinated VOCs and assess the mobility of metals in groundwater (refer to Section 5.6.3).

The range of redox conditions and redox-sensitive chemical reactions that can occur in natural waters is presented on Figure 5.17. Well-oxygenated conditions, such as those found in shallow water aquifers and surface water, are found in the upper right-hand portion of the chart. The redox conditions described by decreasing oxygen concentrations, moving from the upper right toward the left side of the chart, show a progression of chemical reactions that move from the reduction of oxygen toward methane formation. These reactions occur at active landfill sites when leachate (containing simple organic nutrient chemicals—typically from food wastes) enters the groundwater system and consumes the available oxygen. Landfill leachate within active landfills has redox potentials that are more reducing than current conditions (shown by the orange band on Figure 5.17). Refer Section 7.0 for additional information on landfills. Under strongly reducing conditions, manganese and iron in soil are reduced to their more soluble forms, nitrate is reduced to ammonia, sulfate is reduced to sulfide, and methane is produced from the biological degradation of organic matter, especially food wastes (USEPA 1985).

As the Landfill ages, conditions become less reducing, less methane is produced, and redox conditions in the leachate move back to the right. The blue-hatched area highlighted on Figure 5.17 represents current groundwater conditions at the Landfill. The present geochemical character of groundwater conditions immediately downgradient of the Landfill is classified as slightly reducing with dissolved oxygen concentrations of less than 0.85 mg/L (mean value of 0.39 mg/L) and redox potential less than 130 millivolts (mV; mean value of 20.6 mV). As the conditions become less reducing, the reactions at the bottom of the chart begin to occur. Sulfide is oxidized to sulfate, and iron is oxidized to ferric iron, which precipitates onto soil particles. As the Landfill continues to age, the redox potential will move to the right (indicating an increasingly more oxidative environment) as shown with the gray arrows on Figure 5.17.

5.8.2 Natural Attenuation of Chlorinated Volatile Organic Compounds

The USEPA has developed a number of critical technical documents on the reductive dechlorination of TCE in groundwater to the DCE isomers, vinyl chloride, and non-toxic ethene and ethane. As part of this work, it was found that favorable conditions existed for reductive dechlorination when parameters fell within the threshold values in the table below.

Parameter	Threshold Value	Edge of Waste and Downgradient Monitoring Wells							
		MW-10	MW-25	MW-32	MW-33	MW-24	MW-26	MW-08	MW-27
Dissolved Oxygen	Less than 0.5 mg O_2/L	0.16 - 1.9	0.33 - 2.3	0.56 - 3.3	0.44 - 3	0.27 - 2.7	0.42 - 2.1	0.15 - 2.3	0.45 - 2
Redox Potential	Less than 50 mV	**-122 to -92**	**-100 to -22**	**-98 to -21**	**-101 to -24**	**-103 to -43**	**-13 to 32**	**-124 to -72**	**-94 to 25**
Nitrate	Less than 1 mg N/L	**0.1 U**	**0.1 U - 0.1**	**0.1 U - 0.1**	**0.1 U**	**0.1 U - 0.1**	**0.1 U - 0.1**	**0.1 U - 0.1**	**0.1 U - 0.2**
Sulfate	Less than 20 mg/L	56 - 180 J	**0.4 - 27 J**	13 - 71	**0.1 U - 1.4**	**0.3 - 5.8 J**	**5.8 J - 12**	**2.3 - 9.5 J**	**0.4 - 19 J**
Methane	Greater than 500 µg/L	51	**3,330 - 3,490**	NA	NA	**7,320**	11.6	**1,690**	494
Ethane	Greater than 10 µg/L	**18.2**	**53.9 - 57.3**	NA	NA	**12.1**	1.2 U	1.2 U	1.2 U

Note:
BOLD Concentrations meet the threshold values.

Abbreviations:
L Liter
µg/L Micrograms per liter
mg Milligram
mg/L Milligrams per liter
mV Millivolts
N Nitrogen
O_2 Oxygen

Qualifiers:
J Estimated value
U Parameter was not detected at levels greater than the detection limit

As shown in the table above, groundwater at the Landfill and directly downgradient is appropriate for the continued natural attenuation of TCE and its degradation products, the DCE isomers and vinyl chloride. The concentrations of TCE and the DCE isomers in groundwater are currently in compliance (concentrations are at levels less than their CULs). Vinyl chloride, which has the lowest CUL, continues to exceed the CUL in perimeter wells, but should continue to degrade naturally.

At some point downgradient of the landfill, it is possible that the groundwater will no longer favor reductive dechlorination of vinyl chloride. However, other pathways exist for vinyl chloride degradation to non-toxic constituents. Numerous studies have shown that an oxidative degradation pathway for vinyl chloride is more efficient than the reductive dechlorination pathway. The oxidative pathway, studied extensively by the U.S. Geological Survey, involves low levels of oxygen (typically less than 0.2 mg/L) and requires the presence of ferric iron oxides. This pathway oxidizes vinyl chloride to carbon dioxide. The conditions that favor this more efficient degradation pathway are exactly those found in groundwater at the Landfill (USGS 2010; Bradley and Chapelle 1996; Gossett 2010).

5.8.3 Natural Attenuation of Metals

Metals are most typically removed from groundwater by sorption to mineral and/or organic matter or through the formation of insoluble solids. Two factors that typically affect dissolved metals concentrations in groundwater are: (1) ion exchange and adsorption, and (2) oxidation or reduction reactions. Metals concentrations are controlled by ambient geochemical conditions—pH, redox potential, alkalinity, and the presence of binding ligands that cause them to precipitate on the surfaces of soil particles. The natural attenuation of metals occurs when conditions are favorable for limiting the mobility of metals, which typically occurs in an oxidative groundwater environment with neutral pH conditions. Specifically, ferrous iron begins to oxidize to ferric iron at redox potentials of approximately 0 mV and low oxygen concentrations (0.5 to 1.0 mg/L). Once iron is oxidized to ferric iron, it rapidly precipitates out as ferric oxide. Iron concentrations in groundwater are typically found at concentrations one to as many as four orders of magnitude greater than other metals in groundwater (except for the major cations like sodium, potassium, magnesium, and calcium). When ferric oxide precipitates begin to form on the surrounding soil particles, other metals will often be incorporated into the ferric oxide precipitate resulting in the attenuation of iron and other metals under the conditions that favor the attenuation of iron.

In general, groundwater conditions at the Landfill are too reducing for ferric oxide to form and will limit the iron attenuation. Groundwater conditions, however, are moving toward conditions that will favor the attenuation of iron and other metals and will continue to move in this direction as a result of the natural aging of the Landfill and due to remedial actions that control methane concentrations and reduce leachate production.

5.8.4 Summary

Conditions at the Landfill, both historically and currently, support the natural reductive dechlorination of TCE to DCE isomers and then to vinyl chloride. Concentrations of TCE and the DCE isomers are now less than their respective CULs. Vinyl chloride, which has the lowest CUL (0.29 µg/L), still exceeds at some locations, but not at all downgradient wells. The greatest vinyl chloride exceedance concentration attributable to the Landfill is 1.4 µg/L (at MW-25).

Groundwater conditions at the Landfill are considered, under USEPA guidance, to be conducive to the natural attenuation of vinyl chloride to non-toxic chemical species. The degradation pathway may be reductive dechlorination under methanogenic conditions as methane is still being formed at low concentrations at the Landfill, or it may occur as an oxidative pathway for vinyl chloride under anaerobic conditions. Geochemical conditions at the Landfill are currently appropriate for the anaerobic pathway, but that may change over time as the Landfill moves fully into Stage 5 behavior, at which point the oxidative pathway could become important. Conditions are consistent with the observation that vinyl chloride concentrations have been decreasing since at least 2006.

The geochemical conditions most favorable to the continued degradation of chlorinated VOCs are less favorable for attenuating elevated concentrations of iron and manganese in groundwater. The iron and manganese are not released from the Landfill per se; rather they are leaching from native soils found within the aquifer as the anaerobic groundwater passes beneath the Landfill. Iron and manganese concentrations are slightly elevated relative to the upgradient/background conditions, but all concentrations are less than 2 times the background concentrations. In order to reduce these concentrations through natural attenuation, the groundwater must become less anaerobic. When the redox potential reaches approximately +0 mV, conditions will favor the conversion of soluble ferrous iron to the less soluble ferric iron, which will precipitate onto the soil surfaces as rust.

5.9 CURRENT EXTENT OF CHEMICALS OF CONCERN IN GROUNDWATER

The only COC for groundwater is vinyl chloride. Two additional chemicals, benzene and *cis*-1,2-DCE, will continue to be monitored in groundwater for the next several years to confirm that they are not COCs (i.e., that their concentrations remain in compliance with the CULs).

Given the travel time to the waterway, the low concentrations of vinyl chloride at the edge of solid waste, and the favorable groundwater conditions for natural attenuation, it is unlikely that measurable concentrations of vinyl chloride will reach the waterway. This was confirmed by the results at ALN-493 along Riverside Drive, where TCE, the DCE isomers, and vinyl chloride were analyzed in two rounds of data. None of the three was detected at their respective detection limits, which are well below their CULs.

6.0 Landfill Gas, Soil Vapor, and Indoor/Ambient Air Quality

The following section provides general information about the LFG, soil vapor, and indoor ambient air quality at the Landfill. LFG and soil vapor have been monitored over time at the Landfill to identify the nature and extent of LFG and soil vapor present within and surrounding the Landfill. Indoor air monitoring has also been conducted over time to ensure the safety of workers within buildings within and near the Landfill. This section discusses the reason for this work, the results of the previous investigations and investigations conducted throughout the RI field work, and how they meet the remedial action.

6.1 LANDFILL GAS PRODUCTION AND SOIL VAPOR AT LANDFILLS

LFG is a complex mixture of gases produced by the microbial decomposition of putrescible wastes in a landfill. The two largest components of LFG at municipal landfills are methane and carbon dioxide, both produced as microbial by-products of waste degradation. Methane concentrations are typically between 40 and 60 percent by volume, with carbon dioxide making up the rest. LFG also contains the following components (Tchobanoglous, Theisen, and Vigil 1993):

- Varying amounts of nitrogen and oxygen gas from the atmosphere; the amount depends on how easy it is for atmospheric air to enter the landfill mass and how quickly the microbes consume the oxygen.
- Water vapor, hydrogen sulfide, and other organic degradation products, such as carbon monoxide, ethane, and ethene produced by the microbial decomposition of the waste. Most of these other contaminants are known as "non-methane organic compounds" (NMOCs). The non-methane organic compounds usually make up less than 1 percent of landfill gas.
- VOCs considered contaminants, such as benzene, TCE, and vinyl chloride that were present as trace components of the waste and have volatilized into the LFG mixture.

From a regulatory standpoint, LFG is most notable because of the presence of a large amount of methane combined with its flammability and potential explosiveness (lower explosive limit [LEL] at 5 percent volume in air). Out of concern related to this hazard, methane is monitored at landfills and adjoining areas.

As a landfill ages and methanogenic conditions persist, the quantity of LFG decreases, resulting in less internal pressure, and VOCs continue to break down into degradation products. By Stage 4, the stage that South Park Landfill is currently in, the putrescible wastes have been almost completely degraded.

As discussed in Section 7.0, solid waste landfills have predictable stages in the evolution of their behavior. During the early years when the waste is fresh and still contains putrescible components (primarily food wastes and plant debris), methane is produced at a faster rate than a landfill can naturally vent to the atmosphere, and significant LFG pressure builds up within the landfill. This pressure acts to push the LFG out of the landfill and into surrounding areas. During this stage, the LFG is approximately 50 percent methane and 50 percent carbon dioxide, with 1 percent NMOC and no measurable oxygen.

As the landfill ages, the rate of methane production decreases sharply. The presence of methane and carbon dioxide remains virtually unchanged, but there is no pressure build up and LFG leaves the landfill through diffusion. Effectively, during Stages 2 and 3, the landfill has LFG that is approximately 50 percent methane and has sufficient pressure to push the LFG out of the landfill mass. By Stage 4, the rate of LFG production has decreased and the composition is still approximately 50 percent methane, but there is no measurable pressure. At this stage, as confirmed by measurements at the Landfill, there is too little pressure for convective gas migration, and diffusion and barometric pumping drive LFG distribution.

In Stage 5, the LFG generation is so low that atmospheric gases (nitrogen and oxygen) can now diffuse into a landfill. There is no measurable pressure, the methane content is less than 50 percent, and oxygen is returning, with measured concentrations of up to 22 percent (atmospheric concentrations).

6.2 PREVIOUS FINDINGS

LFG has been monitored periodically at the Landfill for approximately 25 years. Limited data are available for LFG monitoring on some of the parcels within the Landfill footprint, specifically at the KIP/7901 and SRDS parcels. The County installed 16 LFG probes within and near the perimeter of the Landfill, which were monitored approximately quarterly for over 5 years starting in 1999. Several one-time sampling events have been conducted at the KIP parcel, generally in conjunction with due diligence assessments for property transactions.

Prior monitoring for LFG has demonstrated that methane levels were greater than the LEL of 5 percent by volume at some of the soil gas probes within the Landfill; however, methane levels had not exceeded the LEL at any of the LFG probes outside the Landfill (except for GP-24 and GP-25, which are discussed further in Section 6.4.2.2). Analysis of soil vapor samples for VOCs such as benzene and chlorinated solvents has been limited to a few samples collected at the KIP portion of the Landfill.

Data gaps identified in the RI/FS Work Plan for soil gas, including LFG and soil vapor and constituents volatilizing from other matrices, are summarized below:

8. The methane levels at existing probe locations were considered to be a data gap.
9. The current methane levels in the following areas and adjacent buildings that could be affected by LFG were considered to be a data gap, including:
   a. Areas of the KIP/7901 parcels.
   b. Areas south of the Landfill boundary along South Sullivan Street.
   c. Properties immediately east of 5th Avenue South and west of SR 99 (West Marginal Way South).
   d. Areas east of the SRDS and across SR 99.
10. The presence of VOCs in LFG and in groundwater that could be of concern for vapor intrusion was considered to be a data gap.

6.3 SCOPE OF INVESTIGATIONS

The scope of the RI field investigations was presented in Section 4.0 of the Work Plan (Farallon 2010a) and included the following:

- Installation of up to nine additional soil gas probes near the perimeter of the Landfill (and outside the Landfill footprint).

- Monitoring of existing and newly installed soil gas probes for methane and carbon dioxide.
- Collection of soil vapor samples for VOCs analyses from soil gas probe monitoring network locations in the vicinity of existing buildings to address vapor intrusion concerns.

6.4 SOIL GAS (LANDFILL GAS AND SOIL VAPOR) INVESTIGATIONS

Throughout the next two sections (and consistent with common terminology in LFG discussions), the term “monitoring” will refer to field measurements using calibrated meters, while the term “sampling” refers to the collection of a LFG, soil gas, or ambient air sample for analysis at a laboratory. Gas probes can be monitored with meters or sampled for later analysis at a laboratory.

6.4.1 Soil Gas Monitoring Probe Installation

Nine soil gas probes, GP-24 through GP-32, were installed by Cascade Drilling near the Landfill perimeter, between December 2010 and March 2011, with oversight provided by Herrera Environmental Consultants, Inc. or Aspect Consulting. The soil gas monitoring probe locations can be found on Figure 6.1. The soil gas probes were installed to supplement the existing soil gas monitoring system and provide additional data to supplement the identified data gaps and to address potential locations where the risk of methane accumulation is considered most likely. Construction details for the soil gas probes are provided in Appendix B.

As the soil gas probes were installed, subsurface materials were observed and lithologic descriptions recorded at each location. The soil gas probes were constructed of $^3/_4$-inch-diameter Schedule 40 poly-vinyl chloride (PVC) casing. The casing is screened with 0.010-inch machined slots and is installed within a $^2/_{12}$-sized sand filter pack that extends 2 feet above the top of the screened-interval. The remaining annular space is filled with hydrated bentonite chips and a concrete surface seal. Construction details and lithologic descriptions for each soil gas monitoring probe location can be found in Table B.3 in Appendix B.

Soil gas probes were constructed in landfill solid waste, unclassified fill, and in native material: three (GP-27, GP-29, and GP-32) of the nine are screened in solid waste material, four (GP-24, GP-25, GP-28, and GP-31) are screened in unclassified fill material, and two (GP-26 and GP-30) are screened in native materials. All soil gas probes are located at or just outside the Landfill boundary with the exception of GP-26. The GP-26 probe is located east of SR 99 opposite the Landfill and within the WSDOT ROW.

The soil gas probes are appropriate for monitoring for LFG and for the collection of samples that can be analyzed for the specific constituents of LFG and/or VOCs.

6.4.2 Landfill Gas

6.4.2.1 Landfill Gas Monitoring Approach

Soil gas monitoring for LFG was conducted according to procedures outlined in the Sampling and Analysis Plan (Farallon 2010b) and the South Park Custodial Landfill Monitoring Procedures (Aspect 2011). The monitoring events occurred in February, May, June, September, and November 2011, during periods of falling barometric pressure. Methane, carbon dioxide, and oxygen were measured using a LandTec GEM 2000 Gas Analyzer and values were recorded in percentages. Total VOCs were measured with a MiniRAE 2000 photoionization detector (PID 10.6 electron Volt [eV] lamp). Prior to the monitoring events, the field instruments were zeroed or calibrated. The gas standards used for calibration include a 4 percent oxygen span gas and a 50 percent methane calibration gas. The PID was calibrated using a 100 ppm isobutylene standard gas.

LFG and VOCs were measured in the field by connecting the two hand-held instruments in-parallel using silicone and polyethylene tubing. A minimum of one probe volume was evacuated before recording final instrument readings. An SKC, Inc.-branded universal pump was used to evacuate the 2-inch diameter PVC monitoring probes at a flow rate of 3 liters per minute (l/min) and the GEM™ 2000 Gas Analyzer and Extraction Monitor was used to evacuate the 0.75-inch-diameter probes at a purge rate of 300 milliliters per minute (ml/min). The soil gas probes were purged until methane, carbon dioxide, and oxygen percentages stabilized (varied by less than 10 percent for three consecutive measurements), to ensure that representative measurements were collected (Farallon 2010a; Aspect 2011).

Barometric and static pressures were measured at each probe prior to purging. Methane, carbon dioxide, oxygen, and VOC concentrations were monitored for every quarter casing volume purged from the respective soil gas monitoring probe. In cases where groundwater level elevations extended above the soil gas monitoring probe screened interval, barhole testing was done adjacent to the location. Barhole testing was performed by driving a 1-inch-diameter steel casing with a 6-inch steel mesh screen to a depth of 1.5 to 2 feet bgs with a slide hammer. A length of polyethylene tubing was extended from the screened interval to the surface and connected to the screening instruments. A minimum of one casing volume was evacuated prior to recording measurements. The suite of measurements during barhole testing includes methane, carbon dioxide, oxygen, VOC concentrations, static pressure, and barometric pressure.

6.4.2.2 Landfill Gas Monitoring Results

Methane concentrations ranged from not detected (zero) to 85 percent. Locations and corresponding concentration data are shown on Figure 6.2 and presented in Table 6.1 with other measured LFGs. Wellhead pressures were measured at all locations. The reproducibility of the meter is approximately +/- 0.25 inches of water. The only well with a measurable pressure was GP-15 in a single event, and it had no measurable methane. This confirms that the Landfill is at least in late Stage 4.

Field measurements of methane concentrations at soil gas monitoring probe locations GP-01, GP-02, GP-19, GP-20, GP-21, and GP-22 (within the Landfill boundary) show methane concentrations ranging from 3.3 to 21 percent. During the installation of these soil gas probes, solid waste was encountered and ranged in thickness from 13 to 18 feet. The low concentrations of methane in these locations indicate that the Landfill is in late Stage 4/early Stage 5, due to the age and decomposition of the wastes.

The North and South Piezometers located within the SRDS were monitored for methane in May 2011. No methane was detected in the North Piezometer, located near the Landfill perimeter, and 21 percent methane was detected in the South Piezometer located in an area with greater thickness of solid waste. Again, this is consistent with the waste in this area also being old and heavily aged.

The greatest methane concentrations were observed in soil gas probes GP-24 and GP-25, and Monitoring Well KMW-05, located in the western portion of the KIP parcel and outside of the

Landfill boundary. The elevated methane concentrations at these locations may be attributable to the Landfill or potentially to the biodegradation of an underlying petroleum hydrocarbon plume not associated with the Landfill. Petroleum hydrocarbons were detected in groundwater during the January 27, 2011 sampling of groundwater Monitoring Well KMW-05, located between the two soil gas monitoring probe locations. Monitoring Well KMW-05 was monitored for LFG parameters on May 11, 2011, as part of the current investigation, and methane was detected at a concentration of 50.4 percent, greater than any other soil gas monitoring probe location observed during this investigation. Monitoring Well KMW-04, located on the KIP parcel and within the Landfill boundary, was monitored for LFG parameters on May 12 and 26, 2011, and no methane was detected. All three monitoring locations with methane detections on the KIP parcel exhibited negligible concentrations of carbon dioxide ranging from 0 to 0.1 percent. The concentrations of carbon dioxide detected at these soil gas monitoring probe locations do not share the typical characteristic of elevated carbon dioxide concentrations within the Landfill, which range from 8.9 to 22.3 percent, often exceeding the methane concentrations. The simplest explanation for the high methane concentration (but no measurable pressure) and the low carbon dioxide concentrations is that the carbon dioxide has been scavenged from the soil vapor by the CKD deposited in the area when KIP filled the historical swale in the area. This area is outside of the Landfill, and its conditions are a function of the contamination in the filled swale and unrelated to the adjacent Landfill.

LFG was not monitored at soil gas probe locations GP-13 or GP-32, only once at GP-30, and twice at GP-15 due to elevated water levels. Barhole measurements were taken adjacent to GP-30 and near GP-32 and are reported in Table 6.1 as BH-30 and BH-32, respectively. No methane was detected in the barhole monitoring completed adjacent to GP-30 and 0.1 percent methane was detected in the barhole monitoring completed adjacent to GP-32. Barhole monitoring was not completed adjacent to GP-13 (located in the West Ditch) or GP-15 (drainage ditch), as surface elevations at these locations were significantly lower than elsewhere at the Landfill. A barhole measurement taken from a location within a topographic low and several feet bgs would not provide meaningful data. LFG migrating to the west from the Landfill in these areas would be short-circuited by the topographic lows and high water level, escaping to the atmosphere. Based on results of soil gas monitoring probe and barhole monitoring to the south and east of the Landfill, negligible methane concentrations were detected migrating off-site in these areas. Again, this is consistent with the advanced age of the Landfill.

The maximum methane concentrations detected at soil gas probe locations GP-27, GP-28, and GP-29 along the eastern perimeter of the Landfill were 6.5, 2.8, and 8.5 percent methane, respectively. Soil gas Probes GP-27 and GP-29 along the eastern perimeter of the Landfill are screened within solid waste, and methane concentrations occasionally exceeded the LEL of 5 percent.

Methane readings at the Landfill consistently indicate a landfill that has aged into late Stage 4 (where the methane concentration is greater than the LEL, but there is no measurable pressure) and early Stage 5 (where the methane concentrations are less than the LEL and oxygen is beginning to be measurable). The Landfill continues to produce low levels of methane but with no measurable pressure. Because the methane concentrations are still greater than 5 percent (the LEL for methane in air), targeted monitoring in buildings at the Landfill will still be warranted as discussed in Sections 6.5 and 12.0 to confirm that methane is not seeping into the buildings at a concentration of concern.

6.4.3 Soil Vapor Analysis for Volatile Organic Compounds

6.4.3.1 Soil Vapor Sampling Approach

Soil vapor sampling occurred on May 11 and 12, 2011, to identify potential VOCs of concern for vapor intrusion into nearby buildings. Soil vapor samples were collected at six locations based on the following criteria:

- Locations with the maximum LFG concentrations were sampled because LFG can act as a carrier for VOCs when concentrations are great enough to result in elevated LFG pressures. Soil gas probe locations GP-25 and GP-27 were sampled for VOCs because GP-25 generally had the greatest LFG (methane) concentrations and GP-27 had elevated methane concentrations occasionally at levels greater than the LEL and was located within 50 feet of a building.
- Areas with historical VOC contamination were sampled. Blasland, Bouck, and Lee, Inc. measured soil vapor at the KIP parcel (refer to Table 2.4) in 1995 using temporary soil gas probes. At that time, the greatest concentrations found were near Monitoring Wells KMW-04 and KMW-05. Although the temporary gas probes are gone, the monitoring wells remain and are screened across the water table allowing for the intrusion of soil vapor into the well casting. During the current investigation, vapor samples were collected from the two groundwater monitoring wells and the data are considered representative of VOCs entering the well casing from both the surrounding unsaturated soil (soil vapor) and from the groundwater.
- Areas lacking sufficient historical data were also sampled. For this, two piezometer locations were identified for sampling at the SRDS (the North and South Piezometers), where LFG had been detected.

Following the soil gas probe casing purging procedure discussed in the previous section, a specially-prepared 6-liter Summa canister with a flow controller was connected to a pressure fitting at the top of each sampling location. The flow controller allowed collection of a passively integrated sample over a 1-hour period. The canisters were provided by Air Toxics, LTD and the internal gas pressure of each canister was recorded prior to, during, and after soil vapor sample collection. The canisters were shipped to Air Toxics' Laboratory in Folsom, California, where they performed the VOC analyses by gas chromatography mass spectrometry in accordance with USEPA Method TO-15.

6.4.3.2 Soil Vapor Sampling Results for Volatile Organic Compounds

The results for chemicals that were detected are presented in Table 6.2. The frequency of detections and chemicals analyzed for but not detected in soil vapor samples are summarized in Table 6.3 and in Table C.12 in Appendix C, respectively. Data validation reports are provided in Appendix F. The soil vapor sampling results were compared to the soil gas screening levels developed by Ecology in their *Guidance for Evaluating Soil Vapor Intrusion in Washington State: Investigation and Remedial Action (October 2009).* Soil vapor samples from gas probe and monitoring well locations collected at the Landfill are representative of intermediate soil vapor conditions deeper than just below slab and less than the 15 feet bgs guideline depth for the MTCA deep soil vapor screening levels. Therefore, an intermediate site-specific screening level was calculated for each chemical and used to identify preliminary COCs. The site-specific soil vapor screening levels were determined by calculating half the difference between the MTCA Method

C below-slab and deep screening levels from Table B-1 in the guidance. Both the deep and site-specific screening levels are shown in Table 6.3 and were used to screen for preliminary COCs.

Using the deep screening levels, only one compound, benzene, exceeded its screening level. Its concentration of 460 $\mu g/m^3$ in Well KMW-05 located upgradient of the Landfill exceeded its screening level of 320 $\mu g/m^3$. Benzene has only rarely been detected at the Landfill, but is present in groundwater in KMW-05 upgradient of the Landfill. Soil contaminated with petroleum hydrocarbons and benzene is known from previous investigations on the KIP parcel to be present at KMW-05. Gas Probe GP-25, which is also located upgradient of the Landfill, contained benzene at 190 $\mu g/m^3$. In contrast, gas probes within the Landfill had much lower benzene concentrations ranging from not detected at 3.7 $\mu g/m^3$ to 22 $\mu g/m^3$; all well below Ecology's screening levels for soil gas.

Vinyl chloride and TCE at GP-27 near the downgradient edge of the Landfill exceeded the site-specific screening levels, but not the Ecology deep screening level. The nearest building is over 50 feet away from this location.

6.5 AMBIENT AND INDOOR AIR

6.5.1 Ambient and Indoor Landfill Gas Monitoring Approach

Air monitoring for LFG was performed in and around four buildings located in the KIP parcel, the building at the 7901 parcel, and five buildings located east of 5th Avenue South and the SPPD (refer to Figures 6.3A, 6.3B, and 6.4). Tables B.5 and B.6 in Appendix B provide the monitoring locations within each building. The buildings were monitored February 18 through 22, 2011, based on elevated methane measurements detected in soil gas probes located near the buildings. A LANDTEC GEM™ 2000 Gas Analyzer and Extraction Monitor was used to measure air quality in the buildings.

The monitoring of LFG in indoor air continued quarterly at the five buildings located along 5th Avenue South in conjunction with the monitoring of LFG in soil gas probes to develop baseline data. Decision trees were developed to determine conditions that would trigger the monitoring of additional buildings (Figure 6.5) and to determine what actions would occur if elevated methane concentrations were detected inside the buildings (Figure 6.6).

Indoor air monitoring was performed in the five buildings on 5th Avenue South on May 25, June 29, and September 23, 2011. The May and September monitoring periods were performed in conjunction with quarterly monitoring and the June monitoring was initiated due to the detection of methane concentrations greater than the LEL in a soil gas monitoring probe adjacent to the buildings. The methane for these two events was measured with a Photovac flame ionization detector (FID) that was able to reach a detection limit of 0.5 ppm methane.

6.5.2 Ambient and Indoor Landfill Gas Monitoring Results

More than 200 indoor and outdoor locations were monitored for methane between February 17 and February 22, 2011 at the KIP, 7901, and 5th Avenue South parcels as shown on Figures 6.3A and 6.3B. Methane was not detected at any of the monitoring locations. Additionally, Puget Sound Energy did not identify natural gas constituents within either of the soil gas probe locations at the KIP parcel (GP-24 or GP-25) and no leaks were identified. Puget Sound Energy also indicated that a natural gas pipeline survey had been completed in the area within the last 4 months and no leaks were detected.

Soil gas probe locations GP-24, GP-25, GP-27, and GP-29 were retested during the February building monitoring and the methane results for GP-24, GP-27, and GP-29 were less than the LEL of 5 percent. Retesting GP-25 detected methane concentrations of 30.2 percent and 32.9 percent on February 18 and 21, 2011, respectively.

Additional methane monitoring in the five buildings located on 5th Avenue South was conducted on May 25, June 29, and September 23, 2011. The FID used to monitor for methane had a detection limit of 0.5 ppm and no measurements were observed at levels greater than background.

6.5.3 Indoor Air Sampling Approach

The results of the soil gas sampling for VOCs indicated limited potential for vapor intrusion into buildings, with benzene being the largest concern. The benzene is believed to come from a known TPH hot spot in the KIP parcel immediately upgradient of the Landfill. To better understand the potential for vapor intrusion into the buildings on the KIP parcel, historical indoor air sampling results were reviewed.

On December 19, 2007, URS Corporation conducted indoor air monitoring at the KIP parcel buildings. Samples were collected in Buildings A, B, C, and D and analyzed by a modified USEPA TO-15 Method. A summary of the data results is presented in Table 6.4 and the location where the samples were collected are shown on Figure 6.4.

6.5.4 Indoor Air Cleanup Levels

Indoor air CULs were identified for VOCs detected in indoor air at the Landfill and are based on MTCA Method C inhalation industrial exposure levels as defined in WAC 173-340-750(4) due to the industrial property use and zoning at the Landfill. For carcinogenic compounds, the MTCA Method C calculations assume an exposed worker is present on-site 24 hours per day for 365 days per year for 30 years. Because the entire Landfill is zoned for industrial use and there are no residences, the exposure is over estimated and the values are very conservative.

Benzene exceeded the indoor air MTCA Method C value in two locations: B-4 in Building B and C-1 in Building C. Both are located over the Landfill along the upgradient edge near the area of a known petroleum hot spot upgradient of the Landfill. Xylene, another constituent of petroleum, also exceeds the indoor air MTCA Method C value at C-1.

Concentrations of VOCs in the other three samples, all located upgradient of the Landfill, are less than the MTCA Method C values. Indoor air CULs are presented in Table 6.5.

6.5.5 Soil Vapor and Air Chemicals of Concern

As discussed in Section 6.4.3, soil vapor samples were collected in 2011 at LFG probe and monitoring well locations and analyzed for VOCs. The decision was made to sample soil vapor prior to sampling indoor air because the soil vapor samples were more likely to be representative of contaminants associated with the Landfill, while ambient and indoor air samples would also have contributions from industrial activities in the vicinity and from urban background (especially from air emissions from the two adjacent highways).

Based on the evaluation of the soil vapor results, vapor intrusion would need to be considered for benzene, although its most likely source is from the petroleum hot spot at KMW-05 upgradient of the Landfill. Vinyl chloride and TCE are potential concerns depending on the screening level used.

Indoor air quality was assessed within the buildings at the KIP parcel in 2007 by URS Corporation. The indoor air samples represent the air quality in buildings where industrial operations are occurring and petroleum solvent use may be occurring. They are expected to be most informative for TCE and vinyl chloride, which are not believed to be used at the KIP facilities, and least informative for benzene, which is a constituent of common petroleum solvents. These data are compared to CULs and are presented in Table 6.5. Benzene and m-/p-xylene exceed their CULs in at least one sample. Vinyl chloride is not detected; TCE is detected at concentrations less than the CUL.

Typically, methane is present at much greater concentrations than VOCs in soil gas associated with a landfill. Buildings in and around the Landfill have been extensively tested for methane, but no methane has been detected. This would tend to support the idea that vapor intrusion from LFG is limited and that current operations may be the source of the detected benzene and xylene.

Based on these results, benzene and xylene have been retained as COCs for indoor air based on a potential pathway of vapor intrusion of LFG and soil vapor into the buildings. Because indoor air can have multiple sources of chemicals, it can be difficult to rely on indoor air sampling to separate chemicals originating through the vapor intrusion pathway from solvent sources used during normal operations at these facilities.

7.0 Conceptual Site Model

7.1 PHYSICAL CONCEPTUAL SITE MODEL

The Duwamish Valley consists of a relatively thick sequence of alluvial deposits overlain by a relatively extensive layer of imported fill. The alluvial deposits range from 30 to 50 feet thick near the edge of the valley to more than 100 feet thick in the center of the valley (Hart Crowser 1998). Groundwater generally occurs in the upper deposits within the Alluvial Aquifer. At the Site, the Alluvial Aquifer is referred to as the Shallow Aquifer and is subdivided into three zones (Perched Zone, A-Zone, and B-Zone) for investigating the environmental and hydrogeologic conditions of the Shallow Aquifer.

The Shallow Aquifer typically receives groundwater recharge from the uplands near the edge of the valley, and groundwater flows toward the center of the valley, before ultimately discharging into the Duwamish Waterway. Because groundwater flows from the higher topographic elevations of the uplands toward the lower topographic elevations of the Duwamish Waterway, the groundwater typically has a slight upward vertical gradient from the B-Zone to the A-Zone of the Shallow Aquifer. Within the A-Zone of the Shallow Aquifer, there is a Silt Overbank Deposit, which, due to its fairly consistent thickness and extent, acts as a low permeability aquitard across much of the valley. The Silt Overbank Deposit is generally located between 0 and +10 feet elevation NAVD 88 and represents an alluvial flood deposit surface likely from the 1800s. The Silt Overbank Deposit creates perched groundwater conditions because it limits downward groundwater migration.

As the groundwater in the Shallow Aquifer approaches the Duwamish Waterway, it enters a zone influenced by tidal action from Puget Sound, which can cause temporary groundwater flow reversals. These flow reversals introduce oxygen-rich, saline water into the Shallow Aquifer. Saline waters from Elliott Bay create a salt water wedge in the waterway that extends approximately 4 miles upstream of the Landfill to just past the turning basin (or approximately South 104th Street). This surface water feature also creates a corresponding salt water wedge in the aquifer. This results in elevated specific conductivity and TDS concentrations in the Shallow Aquifer due to the mixing of the groundwater and seawater.

At the base of the Shallow Aquifer (bottom of the B-Zone), there is a series of estuarine and marine deposits with abundant seashells and brackish to saline porewater. The water within these deposits moves slowly, if at all, resulting in elevated salinities of 7,000 to 10,000 parts per thousand still being present years after deposition along the submerged valley floor.

At the Landfill, groundwater has been investigated in three zones:

- **The Perched Zone:** A shallow zone of groundwater and infiltrating stormwater, typically less than 1 foot in thickness perched on top of the Silt Overbank Deposit where it is present. This zone reflects extremely localized conditions.
- **The A-Zone groundwater:** The groundwater in the Shallow Aquifer beneath the Silt Overbank Deposit, generally located from 0 to -15 feet elevation NAVD 88.
- **The B-Zone groundwater:** A groundwater deeper in the Shallow Aquifer generally from -15 to -40 feet elevation NAVD 88, but above the estuarine/marine deposits. This zone does not exist along the upgradient edge of the Landfill near the valley wall because the Shallow Aquifer thins and only the A-Zone is present.

Groundwater migration through the Shallow Aquifer is through both the A- and B-Zones.

7.2 LANDFILL "STAGE" CONCEPTUAL SITE MODEL

Solid waste landfills have been extensively studied across the country and are well understood by today's solid waste engineers. As part of their modern training, they are taught the concept that municipal solid waste landfills undergo well-defined stages as they age, and that understanding these stages allows the engineer to predict the characteristics of LFG and leachate production. The following section describes the five stages of solid waste landfills, and then discusses where the Landfill is within this scheme and what that means for future LFG and leachate production.

7.2.1 The Five Stage Model

Municipal solid waste landfills contain a high proportion of organic material that can be degraded by the range of micro-organisms found in landfills, including food and garden waste, paper and board, and wood and some textiles (Williams 2005). The processes of degradation of organic bioreactive wastes in landfills involve not only biological processes but also interrelated physical and chemical processes. Five main stages of degradation of biodegradable wastes have been identified and are routinely used by landfill engineers to understand performance and improve designs. The Five Stage Model is shown on Figure 7.1. The Landfill is in late Stage 4 (where methane is still present, but at low pressure) to Stage 5 (areas with little or no methane) of the Five Stage Model.

As shown in the figure, the stage of the landfill controls the composition of the LFG, the rate at which the LFG is produced, and the composition of the leachate coming from the landfill. Stage 4 conditions typically last the longest and involve the most pronounced changes. During Stage 4, LFG is dominated by methane and carbon dioxide, with little to no oxygen present. The leachate becomes anaerobic. Initially it is acidic due to the formation of organic acids from food decomposition, but later the pH returns to neutral and the carbon dioxide acts to buffer the pH. The anaerobic conditions within the landfill favor the reductive dechlorination of the solvents such as TCE to vinyl chloride and then further reduction occurs to the non-toxic ethene. If the anaerobic leachate enters groundwater, the groundwater will also become anaerobic and this will cause the dissolution of iron and manganese from the native soils. It is during this time that many unlined solid waste landfills develop groundwater contamination from iron, manganese, and vinyl chloride.

During late Stage 4, methane concentrations drop to levels less than 20 percent and, most importantly, the rate of methane production slows sufficiently enough that there is little or no buildup of pressure. Without a buildup of pressure, there is no mechanism to "push" LFG migration; rather the gas is emitted slowly from the landfill through a combination of diffusion and barometric pumping.[13] At Stage 5, methane production is so low, that the gas within the landfill begins to resemble atmospheric conditions, and both oxygen and nitrogen concentrations rise. The leachate has a neutral pH and is only slightly elevated in salts. The underlying groundwater system also starts to recover during this period. As the groundwater starts to become aerobic, iron and manganese redeposit on the native soils (from which they came). Vinyl chloride, if still present, will continue to degrade, but will use different biological pathways as discussed in Section 5.8.

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[13] Barometric pumping refers to the natural air flow in the unsaturated zone included in landfills without active gas control systems, in response to natural atmospheric pressure variations.

7.2.2 South Park Landfill Stage

The Landfill was opened in the 1930s and closed in 1966. It primarily accepted solid waste and much of the waste was burned to reduce volume. Today, the Landfill is in late Stage 4. LFG data since 1997 indicate that the concentrations in many of the wells are stable and range from 0 to 40 percent methane by volume. There is no measurable pressure. In areas where the methane production is now less than 20 percent, the Landfill is transitioning to Stage 5.

Specific conductance remains slightly elevated in wells completed in and downgradient of the Landfill at levels between 500 to 1600 µS/cm, relative to upgradient concentrations of 400 to 650 µS/cm. The pH has returned to neutral conditions with most wells between 6.6 and 6.9. The pH shows a distinct signature at the KIP parcel resulting from placement of CKD in the area, which is observed in groundwater from KMW-05 that is highly alkaline with a pH of 13. Groundwater monitoring wells downgradient of the KIP main stormwater line have pH values between 7.4 and 7.8. Wells completed within the Landfill show moderately anaerobic groundwater with dissolved oxygen at 0.23 to 0.27 mg/L (versus 9.0 mg/L for fully aerobic groundwater) and corresponding redox potential at -150.3 to -181.7. By the edge of waste, groundwater is already becoming less anaerobic than beneath the Landfill, with slightly higher dissolved oxygen between 0.45 to 0.78 mg/L and redox potential at -6 to -123.6.

In general, the concentration trend plots show either decreasing or stable concentrations for both TCE and its degradation products. TCE has historically been detected in upgradient Monitoring Well MW-12, which most likely results from sources associated with the former gas station located on SR 509. The trend plot for MW-12 shows an increasing trend between 1999 and 2001 when its peak concentration was 14 µg/L; followed by a declining tread to 0.6 µg/L in 2011. Concentrations for TCE and *cis*-1,2-DCE are now less than their CULs throughout the Site.

Reductive dechlorination, a naturally occurring biological process under anaerobic conditions, converts TCE to DCE then to vinyl chloride. Degradation continues beyond vinyl chloride to harmless constituents, but the rate of vinyl chloride degradation is slower than that of TCE and DCE; therefore, it is common at landfills to see vinyl chloride persist after TCE and DCE have degraded (USEPA 2011). This degradation process is further supported by vinyl chloride trends observed in the groundwater monitoring well network. Vinyl chloride has recently been detected in wells completed within the Landfill at the KIP parcel and SRDS at levels ranging between 0.09 µg/L and 0.79 µg/L. The trend plots for wells with a good historical record (MW-8 and MW-10) indicate a declining vinyl chloride trend from 1999 to 2005, with stable results ranging from not detected at 0.02 µg/L to between 0.15 µg/L and 0.26 µg/L in 2011. Another aspect of the anaerobic conditions that develop during Stage 4 is the development of an iron and manganese zone downgradient of landfills. The anaerobic conditions that develop in groundwater beneath a landfill leach naturally occurring iron and manganese from the soils in the aquifer. As soon as the anaerobic conditions lessen, the iron and manganese become oxidized and precipitate back onto the soil particles. This will continue to occur until the background conditions are reached. Currently the concentrations of iron and manganese are no greater than the background concentrations at many of the locations, and always less than 2 times the background concentration.

7.3 EXPOSURE PATHWAYS AND RECEPTORS

7.3.1 Human Health Exposure Pathways and Receptors

The Landfill is a closed solid waste landfill that has been redeveloped as industrial-zoned properties and public streets. The Landfill contains buildings, hard-packed surfaces, and paved areas. Streets within the Landfill are asphalt-covered and may contain utility ROWs. Currently a large section of the Landfill, the SPPD property, is undergoing redevelopment.

The following potential exposure pathways and human receptors are being considered at the Landfill:

Medium	Location	Exposure Route	Receptor
Ambient air	Buildings throughout Landfill	Inhalation of volatile organic compounds	Industrial worker
Ambient air	Buildings throughout Landfill	Explosive hazard from methane	
Surface soil	Above/outside of Landfill cap/cover	Direct contact, including dermal	
Confined air	Utility vaults adjacent to Landfill	Inhalation	Industrial maintenance worker
Confined air	Utility vaults adjacent to Landfill	Explosive hazard from methane	
Groundwater	No current uses of drinking water; potential future use is not anticipated	Drinking water use	Downgradient industrial worker

7.3.2 Ecological Receptors

The Landfill is exempt from assessment of terrestrial ecological evaluation consistent with Chapter 173-340-7491(1)(b) WAC because all contaminated soil "will be below existing buildings, paved roads, pavement, or other physical barriers that will prevent plants or wildlife from being exposed to soil contamination." To qualify for this exemption, an institutional control is required under WAC 173-340-440. This institutional control is already required as part of landfill closure and will be confirmed to be in place as part of the MTCA process (refer to Section 16.0).

7.4 REMEDIAL INVESTIGATION CONCLUSIONS

Based on the findings of the RI discussed in this document and the conceptual site model developed in this section, key components need to be considered in the FS to identify effective remedial actions for the Landfill.

These findings include the following:

11. Solid waste was disposed of in the Landfill from the 1930s through the mid-1960s; much of the waste was burned to reduce the volume. The Landfill was closed in 1966.
12. The Landfill is unlined and the bottom of waste is in direct contact with groundwater.
13. Forty percent of the Landfill surface is currently developed with buildings, pavement, and stormwater controls. This includes the KIP, 7901, and SRDS parcels.
14. Sixty percent of the Landfill is being developed as small light industrial, with buildings, pavement, and stormwater controls. This is the SPPD parcel.

15. Ongoing gas monitoring confirms that the Landfill is in late Stage 4 or early Stage 5, depending on the location. The characteristics of this are the following:
    a. The Landfill is still producing methane in some areas but with no measurable pressure buildup.
    b. Leachate/perched groundwater has neutral pH (6 to 8) and salinities that are typically between background and 3 times background and less than the salinity of the deeper groundwater in the aquifer.
16. The only groundwater COC is vinyl chloride. Vinyl chloride concentrations in the wells at the edge of the waste are less than the drinking water standards and approaching the MTCA CUL. Two additional chemicals, benzene and *cis*-1,2-DCE, will continue to be monitored in groundwater for the next several years to confirm that their concentrations remain less than the CULs.
17. Manganese and iron concentrations are also slightly greater than the background concentrations (less than 2 times) in some locations and will be monitored for the next several years.
18. The nearest current receptor to groundwater is at the Duwamish Waterway; there are no current or potential future drinking water receptors due to regulatory limits on the placement of new drinking water wells.
19. The active exposure pathways at the Landfill are incidental contact with contaminated soil that is not under a controlled landfill cap and inhalation of indoor air that may become contaminated due to LFG emissions into structures.

These concepts were used to develop the CULs and to help identify the preferred remedy for the Landfill in Sections 8.0 through 17.0.

7.5 SUMMARY OF CHEMICALS OF CONCERN, CLEANUP LEVELS, AND POINTS OF COMPLIANCE

7.5.1 Soil Cleanup Levels, Point of Compliance, and Compliance Requirements

The Landfill exists in an industrial-zoned area of Seattle, and has been redeveloped into industrial facilities, a few of which have limited on-site sales offices. CULs for on-site soil are MTCA Method C for industrial land use.[14] The POC for soils is within the upper 15 feet bgs; however, this site is a closed landfill that is undergoing further remedial action under MTCA with MFS as a relevant requirement. Therefore, removal of soil and solid waste at levels greater than the MTCA Method C CULs (refer to Tables 4.2 and 4.4) is not required as long as it can be demonstrated that containment of the Landfill solids is maintained consistent with Section 173-340-760(6)(f).

7.5.2 Groundwater Cleanup Levels and Point of Compliance

The POC for groundwater at the Site is along the downgradient edge of the Landfill (downgradient edge of waste). Compliance is monitored by a series of monitoring wells located as close as practical to this boundary; from north to south, the wells are MW-10, MW-25, MW-32, MW-33, MW-24, MW-26, MW-08, MW-27, and MW-18.

[14] Consistent with common practice, MTCA Method A Industrial CULs have been used for TPH, PCBs, and lead.

The maximum beneficial use of groundwater beneath and immediately downgradient of the Landfill was specified at this site as drinking water; therefore, the CULs (refer to Table 5.3) are based on the drinking water scenario. Because the groundwater eventually discharges to the Lower Duwamish Waterway, it is worth noting that groundwater concentrations at the POC for the Landfill already comply with the surface water standards for the Lower Duwamish Waterway, and that the well located along Riverside Drive (near the discharge point) contains no detectable chlorinated organics.

Benzene and *cis*-1,2-DCE are not groundwater COCs but will continue to be monitored for the next few years to confirm that their concentrations are less than their CULs.

7.5.3 Air Cleanup Levels and Point of Compliance

The Landfill has been partially redeveloped for years, and the final section of the Landfill, the SPPD parcel, is currently undergoing development. The facilities above the Landfill are industrial facilities with limited commercial access (offices allowing for limited retail/wholesale pickup and delivery). The appropriate CULs for the facility are the MTCA Method C Industrial standards and are presented in Table 6.5. The standard POC is air above the Landfill. Application of these standards at the POC is complicated by the inability of ambient air measurements to distinguish between chemicals released from the Landfill and those being used at the operational facilities. Therefore, it is customary for air standards at redeveloped landfills to monitor compliance with air CULs by monitoring the performance of the LFG system. This is discussed further in Section 9.6 of the FS.

8.0 Remedial Action Requirements

This section identifies the requirements that must be met by for an alternative to comply with MTCA. The Landfill is composed of multiple parcels, some of which have individual redevelopment goals and their own timelines and remedial action goals that need to be met both in pre- and post-development conditions. The redevelopment goals for the various properties are described below.

8.1 MTCA CLEANUP REQUIREMENTS

In order to meet the requirements of MTCA, the selected remedy must be protective of human health and the environment under specified exposure conditions. WAC 173-340-360(2)(a) specifies four threshold criteria that all cleanup actions must satisfy. The threshold criteria are:

1. Protect human health and the environment.
2. Comply with cleanup standards (WAC 173-340-700 through WAC 173-340-760).
3. Comply with applicable local, state, and federal laws (WAC 173-340-710).
4. Provide for compliance monitoring (WAC 173-340-410 and WAC 173-340-720 through WAC 173-340-760).

In addition, WAC 173-340-360(2)(b) specifies three other criteria that alternatives must achieve:

1. Use permanent solutions to the maximum extent practicable.
2. Provide for a reasonable restoration time frame.
3. Consider public concerns (WAC 173-340-600).

Because of the typical size and history of landfills, Washington State has determined that it is impracticable to treat or move a closed solid waste landfill and has outlined specific requirements that allow a solid waste landfill to be closed in place in a manner that meets the MTCA criteria identified above. As a starting point, MTCA uses the closure requirements promulgated in 1985 as Minimum Standard Functions for Landfills (WAC 173-304) as the preferred remedy requirements (refer to WAC 173-340-710(7)(c)) and then modifies them as needed to meet MTCA cleanup requirements.

Closed landfills are considered under MTCA to be sites that have used "containment of hazardous substances" as the preferred remedy. Under WAC 173-340-740(6)(f), MTCA defines the expectation for containment sites as follows:

> *"WAC 173-340-740(6)(f) The department recognizes that, for those cleanup actions selected under this chapter that involve containment of hazardous substances, the soil cleanup levels will typically not be met at the points of compliance specified in (b) through (e) of this subsection. In these cases, the cleanup action may be determined to comply with cleanup standards, provided:*
>
> *(i) The selected remedy is permanent to the maximum extent practicable using the procedures in WAC 173-340-360;*
>
> *(ii) The cleanup action is protective of human health. The department may require a site-specific human health risk assessment conforming to the*

requirements of this chapter to demonstrate that the cleanup action is protective of human health;

(iii) The cleanup action is demonstrated to be protective of terrestrial ecological receptors under WAC 173-340-7490 through 173-340-7494;

(iv) Institutional controls are put in place under WAC 173-340-440 that prohibit or limit activities that could interfere with the long-term integrity of the containment system;

(v) Compliance monitoring under WAC 173-340-410 and periodic reviews under WAC 173-340-430 are designed to ensure the long-term integrity of the containment system; and

(vi) The types, levels, and amount of hazardous substances remaining on-site and the measures that will be used to prevent migration and contact with those substances are specified in the draft cleanup action plan."

For closed solid waste landfills, Ecology allows for containment to be the remedial action with MFS as an ARAR. It is not necessary to evaluate removal actions or perform a disproportionate cost analysis (as otherwise required under WAC 173-340-360); however, the specific remedy selected for the Landfill must demonstrate that the other elements of containment are met as defined by sections (ii) through (iv) above. This FS focuses on screening alternative approaches consistent with the landfill closure ARAR that would meet the requirements of containment under MTCA as described above—for example, determining site-specific alternatives for LFG controls that would comply with WAC 173-340-740(6)(f).

The approach of this FS is to use MFS (WAC 173-304) as a starting point and a relevant and appropriate requirement for defining the MTCA remedy for the Landfill. Approximately 10 years after MFS was developed, USEPA published their *Presumptive Remedy for CERCLA Municipal Landfill Sites Directive* (OSWER Directive 9355.3–11[15]). This document was based on USEPA's experiences on multiple solid waste landfill sites and reflected a growing body of knowledge regarding the key components that were necessary to build long-term containment remedies at solid waste landfills. This FS uses ideas from USEPA's presumptive remedy to refine the MTCA remedial action for the Landfill, while continuing to treat MFS as a key ARAR. The remedy described in the FS follows the concepts in MTCA, MFS, and USEPA's guidance, and uses the term "presumptive remedy" to remind the reader of the large body of knowledge that exists regarding solid waste landfills and their long-term care.

8.2 LANDFILL CLOSURE REQUIREMENTS

The Landfill is a historical municipal landfill that was originally closed in 1966 under Title 10 of the Seattle-King County Health Code. In 1972, the State of Washington passed the first MFS for Solid Waste Landfills (WAC 173-301). In 1985, this was replaced by WAC 173-304, which is now referred to as the Minimum Functional Standards for Landfills, or simply MFS. Solid waste landfills operating after October 1991 are required to meet yet another set of the landfill requirements, WAC 173-351. Because the Landfill closed in 1966, none of the closure requirements in WAC 173-301, 173-304, or 173-351 are applicable requirements; however, MTCA

[15]Subsequent updates to the original Presumptive Remedy Guidance can be found at http://www.epa.gov/superfund/policy/remedy/presump/clms.htm.

(WAC 173-340-710(7)(c)) uses 173-304 to define a preferred remedy for closed, historical solid waste landfills (as discussed above).

The requirements described in MFS are designed to ensure that a landfill is closed in a manner that:

1. Minimizes the need for further maintenance.
2. Controls, minimizes, or eliminates threats to human health and the environment from post-closure escape of municipal solid waste constituents, leachate, LFGs, and contaminated rainfall or waste decomposition products to the ground, groundwater, surface water, and the atmosphere.
3. Prepares the site for the post-closure period. The post-closure period must allow for continued facility maintenance and monitoring of air, land, and water as long as necessary for the facility to stabilize and protect human health and the environment.

After MFS was promulgated at the state level, the USEPA, in 1991, defined in more detail the presumptive remedy for solid waste landfills that were undergoing cleanup under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). USEPA issued a directive (OSWER Directive 9355.3-11) that established containment as the presumptive remedy on CERCLA municipal landfills. The framework for the remedy was then presented in a manual, *Conducting Remedial Investigations/Feasibility Studies for CERCLA Municipal Landfill Sites,* February 1991 (USEPA 540/P-91/001). The framework in the USEPA guidance manual is used to structure the following discussion; individual sections discuss in more detail what considerations derive from the MFS citation in MTCA.

Components of the presumptive remedy for the source area (extent of solid waste) include the following:

- Landfill cap including stormwater controls
- Source area groundwater controls to contain plume including leachate collection and treatment, if needed
- LFG collection and treatment
- Institutional controls to supplement engineering controls

The presumptive remedy guidance does not address remedial actions for a groundwater plume beyond the source control area or long-term monitoring; however, these are required under MFS and under MTCA. This RI/FS, therefore, adds the following as components of the presumptive remedial action:

- Address downgradient groundwater contamination if necessary
- Implement long-term monitoring

The components of the containment presumptive remedy identified above meet both the MTCA requirements for cleanup and the closure and post-closure requirements of MFS. Each component is described in more detail in Section 9.0.

8.3 REDEVELOPMENT AND LAND USE GOALS

In order to meet the cleanup requirements identified above, it is important to identify the future redevelopment of the Landfill to ensure that the selected remedy meets the goals for the Landfill in both its present state and in the future configurations that are planned. All redevelopment of the Landfill will include components of the presumptive remedy as described above, will ensure protectiveness of human health and the environment, and need to be included as constraints throughout the redevelopment of the properties.

8.3.1 Redevelopment Goals for the South Park Property Development Parcel

As described in Section 2.4.1, the SPPD parcel is undergoing cleanup and redevelopment under a 2013 Ecology-approved IAWP. The current redevelopment plan is for a facility with paved parking for employees and visitors. It will contain one or more buildings for the SPPD tenant operations. The parcel will be served by customary utilities (water, sewer, electrical, and cable). The facility design, at this stage, is still preliminary and is subject to revision. Redevelopment will require installing subsurface utilities, capping the Landfill surface, installing LFG controls, and constructing a stormwater collection system as part of construction. SPPD is working with Ecology to ensure that their development goals are consistent with the MTCA requirements and with this RI/FS.

8.3.2 Redevelopment Goals for the South Recycling and Disposal Station Parcel

Since 1966, the SRDS has been in operation as a transfer station for municipal solid waste and other recyclable materials. In 2013, a new solid waste transfer facility was completed across the street on South Kenyon Street. This new facility became operational in the spring of 2013. The existing SRDS was closed until January 2014, when the City's NRDS, located in the Fremont/Wallingford neighborhood, was closed for a scheduled rebuild. The existing SRDS was reopened to increase the City's solid waste handling capacity while the NRDS is being modernized. Once the NRDS reopens, scheduled for 2016, the existing SRDS parcel would be available to undergo improvements for landfill upgrades and construction of permanent facilities, including a recycling facility, a household hazardous waste collection site, a parking area to support the new transfer station, or other City uses. Renovation of the existing SRDS parcel would be consistent with the approved Landfill Draft CAP, and operations would be consistent with the Environmental Covenant for the closed Landfill.

8.3.3 Redevelopment Goals for the Additional Properties within the Landfill

There are no known redevelopment goals for the KIP/7901 parcels or the Emerson Power Products property; however, this area is zoned for general industrial use and it is anticipated that these properties will remain as industrial facilities.

Some public streets and ROWs will likely be upgraded with the redevelopment of the SPPD and SRDS parcels. Upgrades to these areas will be done consistent with the selected remedy for the Landfill and will maintain any institutional controls imposed upon the properties.

9.0 Presumptive Landfill Remedy Components

This section describes each component of the presumptive remedy in more detail and identifies its purpose and how it relates to the conditions of landfills.

9.1 LANDFILL CAP INCLUDING STORMWATER CONTROLS

Implementing a landfill cap and managing surface water and stormwater at the Landfill is part of the containment remedy, as it minimizes infiltration of waters into the Landfill and the potential for contaminant leaching to groundwater, and prevents conveyed stormwater from coming into direct contact with the Landfill contents.

Landfill caps control the amount of infiltration that occurs due to stormwater runoff into any remaining solid waste still located at a site. The design of the cap and its required permeability is dependent on the stage of the landfill and the condition of the groundwater within and downgradient of the landfill. In all cases, the landfill cap must be designed in a manner to reduce the migration of contaminants from the solid waste to the groundwater.

As part of an effective cap design, the management of stormwater and its conveyance must be addressed. Typically, infiltration of stormwater should be minimized to prevent the formation of leachate and stormwater conveyed through a stormwater system to a central discharge point where it can be discharged to a nearby surface water body, infiltrated into an area that is not upgradient of the landfill, or discharged to a municipal sewer system. At the Landfill, groundwater is in contact with solid waste and controlling stormwater infiltration will have less of an effect on leachate production and is not a primary consideration.

A more detailed description of the existing and future landfill cap for the Landfill is provided in Section 10.0. Stormwater controls are described in further detail in Section 13.0.

9.2 SOURCE AREA GROUNDWATER CONTROL TO CONTAIN PLUME INCLUDING LEACHATE COLLECTION AND TREATMENT

As part of the containment remedy, groundwater at the edge of waste must meet the groundwater CULs unless the leachate already meets the groundwater CULs, then the amount of leachate entering groundwater must be limited. Two methods are typically implemented to prevent leachate intrusion into the groundwater system. The first is control of groundwater by minimizing the amount of groundwater interacting with the solid waste. This can be done by lining stormwater ditches or tight lining stormwater conveyance systems and designing site components to direct groundwater flow to areas outside of solid waste. The second method is done by collecting and treating contaminated leachate. If the groundwater is not contaminated, then leachate control may not be required.

The implementation of either method is dictated by the stage of a landfill and the condition of the groundwater. Leachate within older landfills may not be as impacted as newer landfills and may not require such controls in order to protect groundwater quality. If downgradient contaminant migration through groundwater can be proven to not be occurring through analytical sampling of groundwater, then the plume can be considered to be contained. If this can be sufficiently proven, then leachate control may not be required.

More detailed descriptions of the groundwater conditions and leachate controls are provided in Section 11.0.

9.3 LANDFILL GAS COLLECTION AND TREATMENT

An additional component of the presumptive remedy is ensuring that the LFG is addressed properly. This may be completed by a gas collection and treatment system or monitoring to ensure that the LFG levels are safe. Various gas systems can meet this requirement and, similar to the landfill cap, the final design is based on the stage of a landfill and the conditions of the LFG itself. The LFG system must be designed to capture the gas within a landfill and ensure that the gas does not migrate outside of the landfill boundary, and that the gas is discharged safely.

In addition to a collection system, the LFG controls may include provisions for the protection of buildings, utility corridors, and other surface and subsurface structures. Controls such as these, including vapor barriers and passive venting systems, ensure that the LFG does not enter these structures and provides safety to human health and the environment.

A more detailed description of the LFG controls is provided in Section 12.0.

9.4 INSTITUTIONAL CONTROLS TO SUPPLEMENT ENGINEERING CONTROLS

As part of the containment presumptive remedy, institutional controls are typically implemented at a landfill to ensure the integrity of the containment systems and to ensure the safety and health of the users of the landfill. Typical controls include long-term operation and maintenance plans, and activity restrictions and implementation procedures. The exact nature of the institutional controls is site-specific and is dependent upon the selected remedy for the landfill cap, stormwater controls, and leachate controls. There are numerous methods of implementing the selected institutional controls, one of which is a restrictive covenant that outlines the controls on a landfill in a legally binding document.

A more detailed description of the selected institutional controls and their implementation is included in Section 16.0.

9.5 DOWNGRADIENT GROUNDWATER

In addition to addressing the contaminated leachate within the Landfill as described in Section 9.2, it is necessary to identify and address any contaminated groundwater that is downgradient that can be attributed to the Landfill. Leachate control, if necessary, will address the future spread of contamination by limiting the contribution of contaminated groundwater to the downgradient area, while the downgradient groundwater cleanup will address any contamination that is already beyond the edge of waste.

Similar to the other components of the presumptive remedy, the scope of the downgradient groundwater cleanup is dependent upon the conditions of the groundwater and the downgradient areas.

A more detailed description of how downgradient groundwater will be addressed is included in Section 14.0.

9.6 LONG-TERM MONITORING

In order to ensure that the presumptive remedy of containment is effective and will provide long-term protection of human health and the environment, long-term monitoring of the cap and cover, gas, and groundwater is required. Long-term monitoring ensures that the systems implemented for the gas and groundwater, as described above, remain effective and have been designed properly. Stormwater monitoring is not required as part of the MTCA process for the Landfill because the conveyed stormwater will not come into contact with the solid waste.

A more detailed description of the planned monitoring and its implementation is included in Section 15.0.

10.0 Landfill Cap Control Alternatives

This section evaluates the landfill cap components of the presumptive remedy, which will be used to minimize infiltration of stormwater and prevent direct contact with the contents of the Landfill. This section identifies the design constraints that must be met during redevelopment of all the parcels within the Landfill boundary. The landfill cap is also an essential component of the LFG control systems and stormwater systems, which are described in Sections 11.0 and 13.0, respectively.

10.1 EXISTING CONDITIONS

All of the developed parcels that fall within the Landfill boundary, either entirely or partially, were developed prior to the establishment of WAC 173-304, which determines the MFS for capping and covering landfills. Because no specific MFS was required, the existing cap and cover conditions of the Landfill are highly dependent on the land use for which each parcel has been developed. The land use for the two largest developed parcels that fall within the Landfill boundary are discussed below.

The SRDS was completed in 1966 and has since been in use accepting solid waste from commercial haulers and local users. The majority of the parcel is paved, except for some landscaped areas along the eastern edge of the property adjacent to 5th Avenue South and a few landscape planter islands along the western side of the parcel. The parcel was partially filled and graded, both during the SRDS construction and during subsequent minor improvements. Other than the evident surface improvements, it is not known if other materials were incorporated into the parcel development for a landfill cap.

The KIP/7901 parcels have permits for below-grade infrastructure dating back to 1972. The parcels were apparently developed during that same time. The parcels consist of warehouse buildings constructed on slab-on-grade foundations, as well as asphalt parking and roads. Very little of the parcels are not covered in asphalt or buildings. It is not known if other cap materials were incorporated into the parcel during development.

Portions of other developed parcels are shown to lie within the Landfill boundary. Similar to the SRDS and KIP/7901 parcels, these parcels are mostly covered in structures and asphalt paving with minimal landscaping. These parcels include the following:

- Developed Parcels
  - 426 South Cloverdale Street (Lenci Frank Corporation [Emerson Power Products])—Across South Sullivan Street, south of the SPPD parcel
- Roadways and Shoulders
  - South Sullivan Street
  - 5th Avenue South
  - Occidental Avenue South
  - Portions of SR 99 and on-ramp from 5th Avenue South

The SPPD parcel is the remaining undeveloped portion of the Landfill. In recent years, the SPPD parcel has mainly been used for large vehicle staging and storage. Some areas have been used to stockpile fill and construction debris. Additional fill has been placed over the years to maintain access roads and facilitate drainage, but no permanent surface improvements (e.g., asphalt paving) have been constructed.

10.1.1 Existing Cover Material

The cover material used on the developed parcels within the Landfill boundary has not been specifically determined. It is assumed that these parcels would have received similar fill to the cover material currently visible on the SPPD parcel. The cover thickness would most likely vary similar to the SPPD parcel as well.

The SPPD parcel has remained relatively unimproved except for the import of cover material. A cover soil investigation was conducted by the County in 1997 on some of this material. The investigation showed that the cover thickness ranged from 0 to 4 feet in depth in 1997. Since 1997, the SPPD parcel has been recovered with concrete rubble and gravel, which has not been tested, except for the dioxin/furans MI sampling.

Driving surfaces consisting mainly of crushed concrete have been laid down in areas on the SPPD parcel to allow large trucks to access the parcel during wet weather. Vegetation and weed control has also been performed over the past 5 years either by herbicidal or mechanical means. A majority of the parcel, as it exists today, is void of any vegetative groundcover.

10.1.2 Groundwater

As discussed in more detail in Section 5.0, much of the Landfill is in direct contact with a thin layer of groundwater perched on top of the Silt Overbank Deposit, and deeper sections of the Landfill extend into A-Zone groundwater beneath the Silt Overbank Deposit. The perched groundwater is essentially leachate, which in areas where the Silt Overbank Deposit is absent, entered the deeper groundwater system. Fortunately, the Landfill is old and, as discussed in Section 7.2.2, is now well into the later part of Stage 4 to early Stage 5 behavior, depending on the location. Leachate produced by infiltrating rainwater and groundwater is now similar to the surrounding groundwater, with a neutral pH and few COCs.

As discussed in Section 5.6.3, the only groundwater COC is vinyl chloride at concentrations between not detected at 0.02 µg/L and 1.4 µg/L/. The residual vinyl chloride is likely associated with silt lenses that are already within the aquifer; therefore, restricting infiltration is expected to have little if any measurable effect on groundwater.

The cover material tested on the SPPD parcel in 1997 has allowed stormwater infiltration into the solid waste since the Landfill was first closed in the 1960s. The combination of the high groundwater table, decades of stormwater infiltration, and low levels of contaminants in the groundwater lead to the conclusion that <u>the primary goal for the landfill cap is to limit direct contact with solid waste</u>, and not necessarily the protection of groundwater.

10.2 LANDFILL CAP REQUIREMENTS

Under MTCA (WAC 173-340-710), solid waste landfill closure requirements shall be per the regulations set forth in WAC 173-304. The MFS for a landfill cap, per WAC 173-304, are intended to perform two functions:

1. Minimize infiltration of stormwater into the solid waste, which creates additional leachate.

2. Provide protection to mitigate the direct contact exposure pathway to humans and the environment (disease vector control).

To achieve these functions, two alternatives are prescribed for landfill caps in WAC 173-304-460. The first is placement of at least 2 feet of low permeability soil (permeability of less the 10^{-6} cm/sec). The second is a geomembrane layer with a 50-millimeter minimum thickness.

WAC 173-340-710(4)(f) allows for variances or waiver provisions that are included in other applicable regulations to be accessible as part of the MTCA process. Based on this allowance and the conditions in which the Landfill was originally closed and individual associated parcels were developed, a variance from the prescribed landfill cap alternatives in WAC 173-304-460 is being sought to allow cover material with greater permeability than 10^{-6} cm/sec.

10.2.1 Alternative Landfill Cap Requirement

A variance, as allowed by WAC 173-340-710, from the MFS for the cap material associated with WAC 173-304 is appropriate for the Landfill based on the following information:

1. The Landfill was closed in 1966 in accordance with applicable regulations at the time.
2. Those parcels that have been developed were done so prior to the issuance of the MFS set forth in WAC 173-304, which was adopted in 1985. These properties have operated without any documented incidents concerning the direct contact exposure pathway and have reduced stormwater infiltration into the Landfill.
3. The unlined Landfill extends into the water table and is in permanent contact with groundwater with or without stormwater infiltration, limiting the importance of stormwater in the production of leachate.

Any proposed variance still needs to maintain cleanup actions that protect human health and the environment (WAC 173-340-710). The functions of the landfill cap, listed above in Section 10.2, will need to be met as well.

Specific details of construction requirements for each type of section are included in Section 10.3, but are described in general below.

The following cap cross section is proposed to meet the alternative cap requirements for areas of the Landfill that will be covered by pavement, sidewalk, or buildings:

4. A minimum of 12 inches of fill material will be placed over the solid waste. This fill material does not need to meet a low permeability standard. Existing fill that meets this depth requirement will be considered acceptable.
5. Additional fill or fill of specific geotechnical specification will be placed in order to meet the structural section requirements of road base as required by the project geotechnical engineer.
6. A minimum thickness of 3 inches for asphaltic concrete or a minimum thickness of 4 inches for cement concrete will cover the fill the Seattle Department of Transportation has also requested that any sidewalks in the area be allowed to use a City of Seattle standard sidewalk section of 2 inches instead of 3 inches; the thinner section is expected to be protective, given the significantly lower weight loads of pedestrians. However, the sidewalks will be expected to be maintained to prevent direct contact with refuse.

7. The sections will be designed to support the inclusion of stormwater infrastructure to collect and convey the stormwater away from the Landfill. This will further limit the amount of infiltration. Stormwater controls are discussed in further detail in Section 13.0.

Other areas, such as landscaped buffers and slopes, planter islands, or gravel road shoulders that will not be paved or receive hardscape (i.e., concrete) will require a minimum 24-inch thick soil layer and a distinct visible barrier between the new improvements and the top of solid waste. On the SRDS parcel, there is an existing area with large, established trees. These cap requirements are not intended to require their removal. The requirement associated with the trees is to ensure that the landscaping at the base of the trees blocks direct contact with refuse.

Stormwater conveyance and treatment facilities above solid waste such as swales, ditches, or ponds on the Landfill will be required to have cover, as prescribed by WAC 173-304-460, consisting of a low permeability layer with a minimum 24-inch thickness of soil with permeability of 10^{-6} cm/sec or less, or a 50 millimeter or thicker impermeable geomembrane.

The current proposed land use for the SPPD parcel is for vehicle parking with some administrative buildings. This parcel, like the other properties associated with the Landfill, is to be developed to the maximum extent possible with impervious surfaces. The asphalt and concrete surfaces will act to both minimize stormwater infiltration and provide protection to mitigate direct contact exposures.

The variance from the MFS should be available to all future developments associated with the Landfill and should be applied retroactively to parcels already developed. If the existing surfacing on the parcels is changed, (e.g., removal of asphalt or installation of landscaping), then the landfill cap requirements described in this FS will apply.

The performance requirements described above in Section 10.2 have been met with the landfill caps already in place over the developed properties that are part of the Landfill (SRDS, KIP/7901 parcels, and portions of 5th Avenue South, 2nd Avenue South, Occidental Avenue South, and South Sullivan Street). All of these parcels have been developed with pavement and buildings over the maximum surface area practicable. These areas do not need to be modified; however, if redevelopment occurs they will have to meet the alternative landfill cap requirements as described above.

10.3 IMPLEMENTATION OF ALTERNATIVE LANDFILL CAP REQUIREMENT

The proposed alternative cap requirements described in Section 10.2 would be available to any future developments at the Landfill. This alternative cap is also similar to what is in place and functioning already on developed parcels. Redevelopment of parcels associated with the Landfill that is different from the landfill cap construction described in Section 10.2 will need to be submitted to Ecology for review.

10.3.1 Existing Developed Properties

The developed parcels associated with the Landfill are mostly covered with asphalt pavement, sidewalks, and buildings. These systems appear to be effective in preventing direct contact exposure with solid waste; no additional improvements are proposed unless the parcels are redeveloped. Routine maintenance is anticipated to repair pavement cracking and minimize ponded water. No landfill cap improvements are proposed for existing landscaped areas or vegetated roadway shoulders within the Landfill boundary unless the area is redeveloped. Environmental Covenants (refer to Section 16.0) are required as part of closure so that future parcel owners are aware these parcels are underlain by a closed landfill and that special precautions will be needed when performing subsurface work such as utility trenching or redeveloped.

10.3.2 Future Developments

Proposed developments, whether first time development of the SPPD parcel or redevelopment of a parcel, such as the SRDS parcel, will need to comply with the requirements set forth in Section 10.2. The application of these standards is further detailed below.

10.3.2.1 Road Surfacing/Hardscape

This section describes minimum cap requirements for areas of the Landfill that will be covered by pavement, sidewalk, or buildings. These minimum requirements may be exceeded due to Seattle Department of Transportation, WSDOT, or other site development requirements.

The following cap cross section is proposed to meet the alternative cap requirements for areas of the Landfill that will be covered by pavement, sidewalk, or buildings:

1. A minimum of 12 inches of fill material will be placed over solid waste. Fill material does not need a low permeability standard. Existing fill that meets this depth will be considered acceptable.
2. Additional structural fill will be placed as needed to meet the structural section of road base as required by the project geotechnical engineer.
3. A minimum thickness of 3 inches for asphaltic concrete or a minimum thickness of 4 inches for cement concrete will be placed on the fill layer.

10.3.2.2 Landscape Areas, Vegetated Slopes, and Gravel Road Shoulders

Landscape areas, vegetated slopes, gravel road shoulders, or areas not receiving road pavement, sidewalks, or buildings, will need to incorporate a means for limiting infiltration into the Landfill and provide a distinguishable barrier at the edge of waste. These areas will require the following:

1. A cap of a minimum 24-inch thick soil layer.
2. A distinct visible barrier between the new improvements and the top of solid waste.[16]

These measures will also act as a barrier to prevent a direct exposure pathway to the solid waste. Normal maintenance of landscaping (i.e., installation of trees or bushes) could bring humans into contact with the solid waste. In these areas of potential human contact, a visible barrier should be installed if a geomembrane is not utilized. The barrier should be a long-lasting material, distinctly colored to denote the transition of the cap material to the solid waste.

Workers should be informed of the purpose of the barrier and the procedures to follow if work has to be done below the barrier.

[16] The visible barrier may not be reasonable in the existing landscaped areas without removing existing trees. The barrier should be placed where practicable, and is not intended as a requirement to remove existing trees and large scrubs.

Existing road shoulders and medians have functioned adequately as a protective barrier for the solid waste. No work is required in these areas unless they are included in construction activities.

10.3.2.3 Stormwater Conveyance and Treatment Facilities

Biofiltration ponds, swales, or other engineered stormwater quality treatment facilities may be located within the Landfill boundary; however, the design of these facilities will need to include one of the alternative cross sections listed below to prevent increased stormwater from contacting solid waste and to limit infiltration.

Two alternative cross sections are proposed for these areas:

1. A minimum 50-millimeter geomembrane extended a minimum of 2 feet under the adjacent pavement to the Landfill boundary. The geomembrane must be buried a minimum of 18 inches below finished grade.
2. A minimum 24-inch-depth section of low-permeability soil (10^{-6} cm/sec or less) overlaid with a minimum of 6 inches of topsoil.

10.3.2.3.1 West Ditch

The proposed development of the SPPD parcel shows the continued use of the West Ditch to convey stormwater from the site to the outlet pipe located in the northeast corner of the parcel, either as an open conveyance system or a tightlined system. The bottom of the ditch is generally located outside of the Landfill boundary but is below the elevation of the top of the waste. This makes it possible for stormwater to infiltrate laterally (to the east) into the Landfill. The depth of the West Ditch also makes it possible for stormwater to accumulate during high groundwater periods.

Based on these elements, special consideration should be given when reconfiguring the West Ditch. The eastern side of the West Ditch is generally within the Landfill boundary, which means that it is in hydraulic contact with solid waste. The reconfigured ditch must meet the requirements listed above to ensure that stormwater in the ditch does not come into contact with the solid waste and to ensure that maintenance of the ditch does not exposure solid waste, allowing for future contact between solid waste and the stormwater conveyed in the system.

The material in the bottom of the West Ditch was sampled and the results are discussed in Section 4.4.1. The results indicated that the bottom material has contaminants that are typically only transient when disturbed and are not readily carried by ground- or stormwater. Material in the bottom of the West Ditch will either be stabilized in-place or will be excavated a minimum of 2 feet below finish grade and replaced with clean fill. If material is excavated, it may be reinterred on-site subject to Ecology approval or hauled off-site and properly disposed of.

Soils on the western side of the West Ditch have not been analyzed but may contain contaminants similar to what was detected in the bottom of the ditch. Soils on the western side of the West Ditch will be covered with a distinct visible barrier then overlain with a minimum of 18 inches in depth of clean fill material or top soil.

Landfill waste uncovered during the reconfiguration of the West Ditch will need be reinterred on-site subject to Ecology approval or hauled off-site and properly disposed of.

10.3.2.4 Building Foundations

Building foundations designed for new and/or future development on any of the parcels associated with the Landfill may be relatively shallow spread footings or slab on grade, or may include the use of piles. Regardless of the foundation style, mitigation of methane gas as discussed in Section 12.0 will need to be incorporated into the design. An impermeable vapor barrier will be required under all building foundations and floor slabs. If piles are used, provisions to accommodate differential settlement between the building and surrounding ground may need to be incorporated in the design.

Pile foundations are an acceptable alternative at the Landfill. The Landfill is unlined and solid waste is in direct contact with groundwater. The presence of pile foundations would not affect the interaction of solid waste and groundwater, nor create new migration pathways. Each pile type does have certain additional considerations for design and construction, however.

Auger cast, cast-in-drilled-hole, or other piles requiring the use of an auger to predrill a hole through soil and waste will require the proper handling and disposal of Landfill waste that is brought to the surface. Depending on the stage of construction and amount of waste, this material may need to be loaded and hauled off-site for proper disposal or reinterred on-site if approved by Ecology.

10.4 CONSTRUCTION PRACTICE REQUIREMENTS

This section describes considerations for construction practices on the Landfill to mitigate health and safety concerns for workers and maintain environmental controls. Exposure and contact with solid waste are of concern during any construction on a closed landfill site. Additionally, the presence of LFG is a concern during construction activities and needs to be recognized. All contractors should have a Health and Safety Plan in place during all construction activities that specifically addresses risks associated with construction on landfill sites. This plan should be created by a certified industrial hygienist to ensure that it meets all appropriate occupation and health standards.

Additional construction controls for future site development on any of the parcels associated with the Landfill should include the following:

- **Dust and windblown solid waste controls during construction:** In addition to the City's dust control requirements in the City of Seattle Standard Specifications (Section 212), exposed solid waste may need to be covered daily to prevent odors and material from leaving the parcel. A plan for handling, loading, and reinterring or off-site hauling of solid waste will need to be established and approximate quantities calculated.
- **Erosion control:** Stormwater Best Management Practices (BMPs) should be established to prevent stormwater from entering excavations or stockpiled solid waste. The use of earthen berms or other means should be implemented to control and collect stormwater during construction.
- **Health and safety requirements for construction crews:** Each contractor that works on the Landfill should be made aware that it is a closed landfill, and be made to understand the inherent risks involved. A Health and Safety Plan prepared by a licensed industrial hygienist should be prepared by each prime contractor. The prime contractor is responsible for subcontractor compliance with their Health and Safety Plan.

- **Construction dewatering procedures:** Excavation activities on the Landfill may encounter perched groundwater in solid waste that will need to be removed to facilitate construction. This water will need to be managed according to an approved Stormwater Pollution Prevention Plan (SWPPP) and to the pertinent water quality standards associated with a construction site.

  Testing of the water to meet the County's pretreatment standards or groundwater quality standards will need to be done prior to any discharges.

- **Construction performance monitoring and inspection:** Monitoring of all construction activities within the Landfill should be required. The contractor should have contingency plans in place to respond to odor, erosion, and dewatering activities.

10.5 LANDFILL GAS CONTROLS

LFG control systems are usually incorporated into the cover system for closed landfills. The combination of low-permeability materials and a negative (vacuum) pressure system helps to capture and control the gases generated from the solid waste. Consideration of the LFG control system should be made when determining appropriate cover thicknesses and materials. The LFG collection system is described in further detail in Section 12.0.

Utility trenches can become a conduit for LFG migration from a landfill to surrounding areas, because pipe bedding material can be more permeable than the surrounding soils. Where utility trenches cross the Landfill boundary, a low-permeability plug (lower than the surrounding soil) should be installed in place of pipe bedding material.

10.6 COMPLIANCE WITH MTCA REQUIREMENTS

The landfill cap component of the remedy described in this section complies with the MTCA requirements for a selected remedy. A description of how the MTCA requirements are met is included in Section 17.0.

11.0 Leachate Control Alternatives

This section addresses potential leachate control systems normally required under landfill closure in order to prevent the migration of contaminated leachate outside the landfill into the downgradient groundwater. This section provides the rationale for not requiring leachate controls based on the current condition of the groundwater within the Landfill.

11.1 LANDFILL CONDITIONS

The Landfill is an unlined landfill that extends into the groundwater table. As discussed in Section 2.2, solid wastes were deposited in the Landfill and were sometimes burned to reduce volume. The Landfill ranges from less than 10 feet in thickness to more than 30 feet in some areas. The thinner areas were placed on top of the Silt Overbank Deposit. Where present, this silt layer acts as a partial aquitard and slows the migration of leachate downward into regional groundwater. In deeper sections of the Landfill the solid waste was placed in direct contact with groundwater. The water table varies from 2 to 15 feet bgs depending on the season and surface topography. The deeper sections of the Landfill are within the water table and have been since at least the 1940s.

During the years of operation, rainfall fell directly onto the Landfill surface and infiltrated the solid waste. At Landfill closure in 1966, approximately 40 percent of the Landfill was paved, decreasing stormwater infiltration in those sections; the other 60 percent remains unpaved still today.

Placement of landfills in low-lying wet areas was common practice in western Washington until the 1980s. The conditions tended to result in fairly rapid degradation of landfill contents and transition of the landfill into methanogenic conditions, effectively allowing a landfill to age rapidly. The Landfill was closed in 1966, and today is well into late Stage 4 processes, with the southern sections in early Stage 5.

As discussed in Section 7.2.2, this means that the Landfill is still producing methane gas and maintaining anaerobic conditions, but that the rate of production has slowed sufficiently enough that very little pressure is able to build up. The mass of the solid waste, primarily municipal solid waste, has decomposed and degraded. The leachate no longer contains organic acids and is near neutral; its salt content is now less than concentrations naturally occurring at the base of the aquifer (approximately 20 to 30 feet below the Landfill).

Several monitoring wells were installed either through solid waste and are screened below the base of the Landfill or at the downgradient edge of the solid wastes. The groundwater wells represent leachate water quality.

11.2 LEACHATE AND GROUNDWATER CONDITIONS

As described in Section 5.0, leachate and groundwater directly beneath the Landfill are in compliance for all COCs except for vinyl chloride, manganese, and iron. Vinyl chloride is a biological degradation product of the common solvent TCE. TCE and its intermediate degradation products, the DCE isomers, have degraded to levels less than CULs. Vinyl chloride is the slowest to degrade and is still greater than CULs. Vinyl chloride concentrations, however, are not specifically a leachate issue. Where silts are present, such as in the Silt Overbank Deposit, TCE and other organic chemicals partition/sorb onto the silt particles and slowly diffuse back out of the deposit over time. This results in a long-term halo of very low concentrations of vinyl chloride at virtually all landfills in the U.S. If leachate controls were placed at the Landfill today, vinyl chloride concentrations in groundwater would remain unchanged because the vinyl chloride has already left the Landfill and is a residual halo in the underlying silts. Vinyl chloride will continue to diffuse slowly from the silts and degrade in the anaerobic groundwater. As the Landfill stops producing methane and the downgradient groundwater slowly picks up oxygen from the infiltrating stormwater downgradient of the Landfill, the degradation of residual vinyl chloride will convert from an anaerobic, microbial process to an even faster aerobic one (refer to Section 5.8).

Iron and manganese are naturally occurring metals that are elevated at landfills during Stage 4 landfill processes due to the anaerobic conditions created by a landfill. The aquifer beneath the Landfill also contains naturally high concentrations of iron and manganese. The downgradient concentrations are slightly greater than the upgradient concentrations, but by less than a factor of 2. As Stage 4 continues and the Landfill transitions into Stage 5, the iron and manganese concentrations will continue to fall as methane production decreases and the groundwater slowly becomes less anaerobic.

Additional analysis of downgradient groundwater conditions have also been addressed and are described in Section 14.0; however, improvements of leachate conditions will not change downgradient conditions as the on-site wells are already in compliance, or close to compliance in the case of vinyl chloride.

11.3 ALTERNATIVES FOR LEACHATE CONTROL

Two alternatives were considered for leachate control. The first alternative was “no further action” and the second alternative was landfill capping and LFG controls. Because the quality of the leachate already meets or is close to meeting the CULs, the alternatives identified here are not designed to improve leachate quality, but are designed to be consistent with the future development and uses of the parcels on the Landfill.

11.3.1 No Further Action Alternative

For this alternative, no additional actions would be taken to address leachate at the Landfill. This alternative would continue to allow stormwater to infiltrate into the former Landfill at the undeveloped parcels and be conveyed into the existing stormwater conveyance systems at the developed parcels. Under this alternative the leachate quantity would remain unchanged, and the leachate quality would likely remain consistent or potentially improve as natural attenuation occurs.

This alternative is not compatible with the need to install a landfill cap to prevent direct contact with refuse and a LFG system to control methane releases.

11.3.2 Landfill Capping and Landfill Gas Controls

The second alternative considered employs the controls that will likely be implemented as part of the preferred remedial alternative and the proposed development, and includes the development of a landfill cap (as described in Section 10.0) and implementation of LFG controls (as described in Section 12.0).

Caps on the Landfill will be designed to prevent direct contact with the solid waste, in conjunction with the stormwater controls, would convey stormwater away from the solid waste and reduce the quantity of leachate being generated through infiltration, particularly on the SPPD parcel, and the proposed IA.

This alternative also includes any LFG controls that may be installed at the Landfill, which will address the LFG that will be produced by the Landfill. The LFG controls will have little impact on the quality of the leachate, but are a necessary part of the cap and cover and are therefore part of this alternative.

This alternative is consistent with the proposed development and use of the Landfill and is an acceptable alternative to address leachate at the Landfill.

11.4 COMPLIANCE WITH MTCA REQUIREMENTS

The leachate control component of the remedy described in this section complies with the MTCA requirements for a selected remedy. A description of how the MTCA requirements are met is included in Section 17.0.

12.0 Landfill Gas Control Alternatives

This section evaluates the LFG control component of the presumptive remedy that will be used to manage LFG, particularly methane, with concentrations at levels greater than the explosive limits. This section identifies the design constraints for the LFG control systems and identifies the options that may be used as part of the selected remedy for the Landfill.

12.1 LANDFILL GAS COMPOSITION AND CONCERNS

LFG can present a health and safety concern if methane and carbon dioxide are not controlled. Methane, which normally occurs in air at 2 ppm, is an explosion and fire hazard in air at concentrations greater than 5 percent by volume (50,000 ppm). The American Conference of Governmental Industrial Hygienists (ACGIH) has established a permissible exposure limit (PEL) of 1,000 ppm for methane. Also, carbon dioxide, which occurs normally in air at 300 ppm, is a health hazard at concentrations greater than 5,000 ppm (Occupational Safety and Health Administration [OSHA]/Washington Industrial Safety and Health Act [WISHA] time-weighted average PEL). In addition to this, both of these compounds can pose an asphyxiation hazard by displacing air in confined spaces, such as underground vaults or rooms with no air circulation.

In addition to LFG constituents, toxic VOCs, such as vinyl chloride, may be present and their intrusion into ambient air will need to be controlled. Section 6.5 addressed the indoor air data for structures over the Landfill and found that only benzene and xylenes were COCs for this pathway. These two chemicals are major components of petroleum solvents. Because solvents are believed to be in use at KIP, and are rarely detected at the Landfill in groundwater, the presence of these chemicals in indoor air may be due to solvent use at KIP and not related to Landfill emissions.

12.2 APPLICABLE OR RELEVANT AND APPROPRIATE REGULATIONS

The following text presents pertinent regulations related to LFG applicable or relevant to: (1) owners of contaminated sites and (2) owners of landfills.

Chapter 70.105D of the RCW (MTCA) requires Ecology to establish a program to identify sites potentially contaminated with hazardous substances. That program is set forth in WAC 173-340-300. Owners of contaminated sites are required to follow notification, characterization, cleanup, and documentation processes stipulated in the regulation. The Landfill is considered a contaminated site according to MTCA; the cleanup process, including LFG issues, will be negotiated based on MTCA requirements.

Development will need to satisfy building occupant safety and building permit conditions imposed by the City. Public safety (building permits) and King County Board of Health regulations do require mitigating actions.

The King County Board of Health Title 10 regulations will require a permit from the Puget Sound Clean Air Agency (PSCAA) to install a LFG control system at the Landfill. PSCAA requirements are negotiable, depending on proposed changes to existing emissions from a site. They will require a permit or Notice of Construction in order to receive an Order of Approval for an active LFG control system, but not for a passive system. If the system is installed as part of the remedial action under a MTCA Consent Decree, Order, or Agreed Order, a permit exemption will be requested; although the system will still be designed to be substantially equivalent to what would have been required under the permit.

Mitigating actions associated with LFG control should take current landfill regulations (WAC Chapter 173-351-200(4)) into account. MTCA cites several references to the WAC 173-304 and 173-351 codes for landfill closure and LFG control; however, because the Landfill was closed prior to adoption of these requirements, the regulations are not applicable, but serve as a guide to correct active LFG practices. This section stipulates requirements for monitoring and compliance with subsurface migration standards, excerpted below:

"(4) Explosive gases control

(a) Owners or operators of all MSWLF units must ensure that:

(i) The concentration of methane gas generated by the facility does not exceed twenty-five percent of the lower explosive limit for methane in facility structures (excluding gas control or recovery system components);

(ii) The concentration of methane gas does not exceed the lower explosive limit for methane at the facility property boundary or beyond; and

(iii) The concentration of methane gases does not exceed one hundred parts per million by volume of methane in off-site structures.

(b) Owners or operators of all MSWLF units must implement a routine methane monitoring program to ensure that the standards of (a)(i) and (ii) of this subsection are met.

(c) If methane gas levels exceeding the limits specified in subsection (4)(a)(i) or (ii) of this section are detected, the owner or operator must:

(i) Immediately take all necessary steps to ensure protection of human health including:

(A) Notifying the jurisdictional health department;

(B) Where subsection (4)(a)(ii) of this section is exceeded, monitoring of off-site structures for compliance with subsection (4)(a)(iii) of this section;

(C) Daily monitoring of methane gas levels unless otherwise authorized by the jurisdictional health department; and

(D) Evacuation of buildings affected by landfill gas shall be determined by the jurisdictional health department and fire department.

(ii) Within seven calendar days of detection, place in the operating record, the methane gas levels detected and a description of the steps taken to protect human health; and

(iii) Within sixty days of detection, implement a remediation plan for the methane gas releases, place a copy of the plan in the operating record, and notify the jurisdictional health department that the plan has been implemented. The plan shall describe the nature and extent of the problem and the remedy.

(iv) The jurisdictional health department may establish alternative schedules for demonstrating compliance with (c)(ii) and (iii) of this subsection."

The intrusion of VOCs from the subsurface, including from landfills, is regulated under MTCA. Emissions from a landfill must be controlled until indoor air CULs are met.

12.3 LANDFILL GAS CONTROL METHODS

Common LFG control technologies include means to collect, convey, and treat LFG to comply with government regulations, odors, or uncontrolled releases that may pose safety and health concerns. LFG control objectives are generally focused on off-site migration, on-site accumulation control, or both. LFG control systems addressing migration and accumulation can be categorized as active, passive, or a combination of both. The control objectives and strategies for this Landfill will focus on both off-site migration and on-site accumulation control, considering both active and passive systems.

Several potential LFG control systems appropriate to the Landfill are presented below.

12.3.1 Passive Venting

LFG off-site migration is driven by a pressure gradient that develops over time between the gas-producing waste and the atmosphere. Gas can migrate through surrounding soil that is permeable, including a cover above or native material to the side or bottom. The rate of migration is determined by the magnitude of the pressure gradient, the type and permeability of the native soils, the geometry of the solid waste/native soil interface, and barometric pumping. Landfill cover systems can contribute to the gradient by preventing LFG escape and causing lateral migration. If the gradient is interrupted by a vent to the atmosphere, the path of least resistance will be through the vent instead of the surrounding soils. Passive venting of LFG to control off-site migration and on-site accumulation that can infiltrate structures has been successfully demonstrated throughout the U.S. The type of passive vent system used is often dependent on the depth of solid waste and the type of cover system.

Shallow landfills less than approximately 20 feet deep, can be vented with a horizontal trench and perforated pipe system. A deeper landfill may require the installation of vertical wells, tightly spaced and vented to the atmosphere, to provide the necessary “break” in the LFG pressure gradient.

Landfills closed for a long period of time, or low volume and relatively shallow sites, can usually achieve effective on-site gas accumulation control with trenches or wells installed immediately below the landfill cover. Additionally, effective perimeter LFG migration control can usually be achieved with simple passive ventilation trenches buried within the edge of waste or native soil. Such passive vent systems consist of a slotted or perforated pipe buried within highly permeable backfill materials (e.g., drain rock). Trench depth is dependent on solid waste depth, such that the perforated pipe is placed at approximately one-half the solid waste depth unless deeper permeable strata exist that could cause LFG migration. Burial depth can vary, depending on native soil conditions or if changes in solid waste edge depth are required to accommodate landscaping or a landfill cover system. Based on Landfill soil boring data, depth to groundwater, and solid waste profiles, the average depth of a passive ventilation collector would be approximately 6 feet, with a trench depth averaging between 7 and 8 feet. Vent risers, typically spaced at 100-foot intervals, would be installed to allow LFG an unrestricted escape route. Also, widely spaced cleanout risers would be required for cleaning or flushing equipment access to reduce perforation fouling and debris accumulation.

LFG control trench systems can typically be excavated without specialized equipment. Trench spoils must be handled as municipal solid waste, requiring proper collection and disposal and/or reinterment. Landfill solid waste age, shallow solid waste depth, limited methane generation (i.e., small pressure gradient), and favorable groundwater and soil conditions all favor a passive trench system. Considering on-site accumulation and perimeter LFG control, a passive trench system may provide compliance at lower cost than a vertical well system, slurry walls, or active control systems.

For locations where waste extends beyond property lines, passive collection trenches installed at the property boundaries may not provide adequate control for gas accumulations or migration. In these instances, active collection using trenches or wells or off-property controls may be considered.

Additionally, proposed passive collection trenches at the perimeter and utility trench locations should be evaluated so that off-site preferential pathways are not created inadvertently, allowing off-site migration. Utility trench plugs or barriers can be installed to prevent migration from occurring within utility bedding.

Passive collection systems can be inexpensively installed as part of new site construction, as well as retrofitted on existing paved or covered sites. Passive venting of new buildings can be quite cost effective when coordinated with the foundation design. Typical passive building systems include an impermeable barrier to control intrusion protection. Passive venting is generally cost prohibitive at existing buildings, due to limited access and the limited radius of influence that can be expected from venting trenches and wells installed beyond the building footprint.

12.3.2 Active Control

Active LFG control systems are commonly used in newer landfills to extract LFG for destruction, cogeneration, and/or controlling off-site migration. Such systems typically include vertical wells or deep horizontal trenches installed throughout the solid waste, either while the landfill is being filled or, as with vertical wells, after final closure. These systems most commonly apply to large landfills that continue to receive municipal solid waste, or recently closed sites. The term “active” refers to the application of a vacuum to a gas ventilation system, usually by means of centrifugal blowers (i.e., exhausters) driven by electric motors. Instead of providing a passive “break” in the pressure gradient between the waste and the atmosphere, an active system “pulls” the gas out by applying a negative (vacuum) pressure at the collecting perforated pipelines. The gas is then conveyed to a treatment system for destruction (e.g., flare or thermal oxidizer), adsorption (e.g., granular activated carbon), or beneficial use (e.g., cogeneration), or it is vented to the atmosphere, depending on gas concentrations.

The effectiveness of an active LFG collection system depends greatly on the design and operation of the system, and on the methane generation capability of the landfill waste. An effective collection system should be designed and configured to do the following:

- Handle the maximum LFG generation rate
- Have sufficient radius of influence to effectively collect LFG to protect potential receptors
- Monitor and adjust the operation of individual extraction wells and trenches

Many configurations of wells and trenches, including perimeter systems and in-refuse network-type systems, have proven to be successful at controlling LFG and eliminating off-site migration at a wide variety of landfills. An active system, including a variety of interior collectors, may also be considered if future site development includes underground structures or foundations. Usually, landfill settlement is a concern for in-refuse horizontal collectors, but due to Landfill age and the fact that construction debris was dumped at the Landfill, significant settlement is not anticipated or could be mitigated with preloading.

Active control systems are balanced by adjusting the vacuum level applied to the perforated piping within the trench or well system. Typically, a radius of influence and appropriate vacuum level are estimated based on soil permeability, site geometry, and collector design. Monitoring probes located within the vicinity of LFG collectors can be used to adjust a control system until a proper radius of influence is achieved, without providing excessive vacuum. Usually, an active system's applied vacuum is balanced to evacuate LFG within a defined area without pulling in air from above the surface or surrounding soil.

Active LFG collection systems must address air intrusion that may naturally permeate through the landfill cover and at the margins of the waste into the solid waste, which can induce landfill fires if not monitored and controlled. Where excess atmospheric air (oxygen-rich air) is pulled into the solid waste, either inadvertently or by design, the collection system must be monitored and controlled to avoid potential fires.

12.3.3 Convertible Control Systems

At this time, it is difficult to determine the necessary system to control gas consistent with regulatory requirements in order to protect public safety. The design of cover installation and the potential development scenarios on each parcel will each play a role in determining the design of the final LFG management system. In general, both passive and active systems are viable strategies. Therefore, the final design decision needs to be made as part of site redevelopment.

A well-designed, integrated landfill control system should ensure that LFG does not migrate beyond the property boundary or accumulate on-site, potentially impacting on-site facilities. For portions of the Landfill where future development is unknown, it is generally recommended that passive collection systems be designed and constructed such that they can be converted to active collection systems without significant modification. This is generally achieved by providing discrete connections for individual trenches and wells from a non-perforated header initially, allowing location-specific vacuum or venting control. Additionally, impermeable barriers are generally installed in perimeter venting trenches (at the edge of waste) to allow them to be converted to active systems without inducing excess amounts of atmospheric air and creating a potential fire hazard. Barrier installation costs can be high when compared to gas venting trenches alone. The use of a membrane barrier or other low-permeability vertical cut-off trench at the Landfill's waste boundary may be both a technical- and cost-appropriate consideration, due to shallow solid waste depths and shallow groundwater. Additionally, barriers at the waste boundary such as along the SRDS property keyed to low permeable soil below groundwater can provide a greater degree of migration protection.

Based on the age and shallow solid waste depth at the Landfill, conversion of the passive collection system described above could readily be accomplished by the addition of a knockout vessel, an exhauster, and header piping to the previously discussed passive system configuration. Addition of an exhauster to the passive system might be based on insufficient methane reduction seen in perimeter gas probes (i.e., less than the LEL).

12.4 LANDFILL GAS CONTROL FEATURES

The installation of a landfill cover and potential development at the Landfill will change current LFG monitoring conditions and criteria for a LFG control system design. Design features generally used in a variety of passive venting or active collection scenarios are briefly described below.

12.4.1 Passive Collector Trench System

A full perimeter passive collector trench system may average approximately 6 feet in depth. A backhoe or small track hoe could excavate the trench to a minimum width of 2 feet. The geotextile, bedding/backfill, pipeline, and appurtenances could then be installed within the trench. It will be necessary to adhere to OSHA guidelines for work in hazardous locations (i.e., protective clothing and ambient air monitoring).

Riser vents for passive collection pipelines are typically 4-inch-diameter high density polyethylene (HDPE) pipes tied into main horizontal collectors. It is not necessary to include valves on risers because the system maintains near-atmospheric pressures. Depending on site conditions, the riser typically extends a minimum of 6 feet above grade and terminates in a bird screen or rain cap. Cleanouts are spaced at 300- to 500-foot intervals, depending on the horizontal trench layout. Cleanouts consist of a 4-inch HDPE angled (45-degree) riser for insertion of a vacuum or flushing wand and hose.

12.4.2 Active Collector Trench System

An active perimeter collector trench system would be similar to the passive trench; however, it may include an impermeable barrier to minimize air intrusion at the waste boundary. Active collection trenches not installed at the waste boundary would not include an impermeable barrier. The perimeter perforated piping would be connected to a solid header or manifold with valve stations to allow discrete control of trench segments. Active collection trenches would be installed to a depth of 6 feet. If an impermeable barrier were installed, the barrier would extend down to seasonal low groundwater elevation.

For an active collector system, a separate HDPE solid pipe header, buried below grade, would be installed to provide suction to key points in the perforated collector pipeline, depending on the perimeter collector length. Control valves with flow monitoring ports, installed in handholes on a lateral that connects the suction header to the perforated collector, would allow adjustment of suction pressure to various points in the system. The suction header, control valves, and laterals would also be necessary to balance the applied vacuum to the entire perimeter system, as required.

An active system requires vacuum pressure supplied by single-stage, explosion-proof centrifugal blowers/exhausters. Typically located on a concrete pad, the system includes the header piping, a condensate collector (i.e., water knockout), isolation valves, and the blower/vent pipes. A weatherproof control panel and power supply also would be included. To reduce noise and/or screen the exhauster equipment from view, a small, ventilated enclosure may be supplied.

12.4.3 Extraction Well System

An extraction well system is similar to an active collection trench system, except the trenches are replaced with a well grid. Extraction wells would average approximately 20 feet in depth. Wells would generally be constructed to extend down to seasonal low groundwater. Wells are typically

6-inch HDPE, with a deeper screened zone sized for collection (lower 5 to 10 feet bgs) when combined with a cover system with collector trenches. When a below-cover trench system is not used, wells are either screened throughout the solid waste depth or are partitioned to maximize radius of influence with a surface plug to minimize short-circuiting. Based on the age and type of waste, wells would be installed on a 100-foot grid depending on the type of cover system, extent of waste, proximity to buildings, and proximity to perimeter trenches.

12.4.4 Venting Well System

Venting wells would average approximately 20 feet in depth (constructed to extend down to seasonal low groundwater). Wells are typically 6-inch HDPE with a screened zone throughout the solid waste depth and vented to a manifold or directly to the atmosphere. Based on the age and type of waste, wells would be installed on a 50-foot grid, depending on the type of cover system, extent of waste, proximity to buildings, and proximity to perimeter trenches.

12.5 LANDFILL GAS CONTROL TECHNOLOGIES

12.5.1 Landfill Gas Control Technologies within Buildings

LFG control technologies for buildings and other development features rely on active and passive collection systems similar to landfill systems. Table 12.1 highlights technologies appropriate for the Landfill, depending on whether the building exists or is planned for development.

12.5.2 Landfill Gas Control Technologies

Table 12.2 highlights LFG control technologies appropriate for the Landfill. Implementation will depend on location of perimeter controls with regard to waste boundaries, existing or planned site development, cost, and site use.

12.6 LANDFILL GAS TREATMENT SYSTEMS

Based on LFG composition data as described in Section 6.0, it is unlikely that gas treatment will be necessary for planned site development. If emission estimates or later testing of gases emitted from an active or passive collection system are deemed a threat to public health, then a gas treatment system may be warranted.

LFG treatment systems generally require active gas collection. Vent-mounted flares and odor control canisters have been developed, but these require greater methane concentrations or volumetric flow rates than expected at this site. Treatment options are limited by the low concentration of methane and non-methane organic compounds (NMOCs; this term is commonly used in the LFG literature and includes the VOCs discussed in previous sections). Moreover, a perimeter active collection system may cause atmospheric air to be drawn in, further diluting the gas contaminants.

Treatment technologies currently used to reduce NMOC emissions from old landfills and other contaminated sites are selected primarily based on concentrations of the specific COCs and the expected volumetric flow of gas. Suitable technologies under these circumstances include catalytic oxidation and regenerative resin systems. Carbon adsorption systems have also been used for NMOC removal. A gas treatment system appropriate for greater volumetric flows and low NMOC concentrations might utilize large carbon adsorption canisters. Biofiltration, using specialized bacteria grown on enclosed porous media or well-aged compost media, is a new treatment technology with potential for application at the Landfill.

None of these technologies remove methane from LFG. Only flaring (or thermal oxidation) has been demonstrated as a proven, economical means of converting the methane to carbon dioxide and water.

Most active LFG control systems that do not recover energy terminate in a combustion flare. Flares have been shown to effectively combust all the methane while destroying at least 98 percent of the NMOCs and odorous sulfur compounds typically found in LFG; however, landfill sites closed for many years and exhibiting low gas generation and declining methane concentrations, frequently do not produce gas with sufficient energy content to sustain combustion. The minimum methane concentration required for continuous flaring is between 15 and 20 percent by volume, depending on atmospheric conditions. The use of an auxiliary fuel, such as natural gas or propane, can ensure continuous combustion with low energy LFG, but this practice is expensive and usually avoided. Typically, older landfills with minimal LFG generation also exhibit very low NMOC and sulfur compound concentrations. In these cases, it is often the practice to vent a LFG exhauster directly to the atmosphere. Periodic exhaust monitoring is then used to ensure that acceptable NMOC and methane emissions levels are maintained. Refer to Table 12.3 for a comparison of treatment options.

In the event that active collection is selected/required, it is unlikely that sufficient methane will be present to support combustion. In fact, methane, NMOC, and sulfur compound levels may be reduced beyond concern for public health or regulatory intervention, due to atmospheric air pulled into the collectors, diluting the LFG. In this case, air dispersion modeling may be necessary, based on gas composition and estimated emission rates, to obtain necessary approvals. Direct discharge to the atmosphere may be unacceptable in a populous area, due to low-level odors. A final odor polishing step may be required, such as discharge through compost media or carbon canisters. The need for odor control can usually be assessed once a discharge location of collected gas is established.

Table 12.3 lists potential gas treatment options appropriate for the discharge of collected gases.

Currently, LFG escaping from the Landfill is in the form of area-wide diffuse emissions, characterized by low methane and NMOC concentrations. Any control scenario using a blower or any type of point discharge must consider the potential for a concentration of odors and/or VOCs at concentrations greater than their ambient air CULs. In this context, air dispersion modeling may be recommended.

12.7 LANDFILL GAS CONTROL SYSTEM CONFIGURATION

Landfill development, including on-site structures, foundations, or other enclosed areas, will require gas control measures. Various venting, gas extraction, and structure isolation techniques can be implemented to guard against accumulation of dangerous concentrations of methane and NMOCs. Paved areas (i.e., parking lots, truck ramps, etc.) generally do not require protection, unless gas is forced to migrate toward more susceptible structures or boundaries. New building foundations can be sealed from beneath with bentonite or membranes to minimize gas intrusion. Building foundations or underground structures require more extensive measures, including, in some cases, active gas extraction and interior building monitoring systems. The particular design depends heavily on the type of development, the mix of buildings and pavement, depth of structure, and type of use.

Because of the uncertain timing of development and future use of the Landfill-impacted properties, each proposed development location should be looked at individually, as well as together, to ensure that the systems are compatible. Opportunities should be explored to coordinate venting or collection systems, avoid redundancies, and ensure intended performance. The following sections discuss viable LFG control systems appropriate for each of the properties on or adjacent to the Landfill.

12.7.1 South Park Property Development Parcel Proposed Landfill Gas Collection System

The proposed SPPD LFG control system has been designed as part of the interim action with an asphalt cap covering a majority of the parcel and geomembrane overlain with soil on side slopes not paved with asphalt. The asphalt cap or geomembrane terminate at the property boundary, at or just below existing grade.

The collection system is composed of the following:

- Shallow perimeter LFG collection trenches with perforated 6-inch HDPE pipe installed at the geomembrane or asphalt cover limits, along the northwest, west, south, and east perimeters
- Extraction wells along the SRDS property (north and northeast)
- Extraction wells located on a 100-foot grid across the parcel
- Extraction wells and trenches along the west side of 5th Avenue South

The vapor extraction wells and collection trenches are connected to solid HDPE header pipes, with individual valve controls at each well and trench. The HDPE headers convey LFG to a vacuum blower and carbon treatment system located at the northwest corner of the property.

The system is designed to be operated by monitoring residual nitrogen, rather than conventional parameters (oxygen, methane, carbon monoxide, temperature, and vacuum). This approach was based on anticipated high levels of oxygen (likely greater than 2 percent) pulled into the system due to short-circuiting along Landfill cover limits. Perimeter probe monitoring along the Landfill cover limits has not been conducted or proposed.

New buildings on the SPPD parcel will be constructed with impermeable liners below slabs and foundations, along with active collection trench systems under the buildings and membranes.

Additionally, it is planned that stormwater retention pipes currently crossing the parcel from east to west will be connected to the active collection system.

Condensate within the header pipes will be collected and pumped via force main to the sanitary sewer.

Operation of the interim LFG control system is compatible with appropriate control strategies and technologies identified for the adjacent parcels.

12.7.2 South Recycling and Disposal Station Parcel

The SRDS parcel is currently paved. The parcel includes the SRDS, Household Hazardous Waste Facility, and several other administrative and operational buildings. The parcel buildings are either naturally ventilated or screened (porous skirting) for methane mitigation. Occupied structures on grade are monitored quarterly for LFG; LFG has not been detected in 20 years of monitoring. Future development of the parcel will likely require fill material overlain by asphalt pavement and new buildings, with the exception of potential reuse of the existing transfer station foundation. Requirements for LFG control will likely be similar to existing conditions. As such, new building LFG control will likely include passive venting under buildings, with an impermeable under-slab barrier or vented skirted buildings to meet City Building Code. Based on the current parcel conditions, parcel-wide LFG control could likely be controlled with passive venting trenches under an operable cap, such as asphalt over permeable crushed rock, along with a passive venting perimeter trench at the waste boundary tied to the crushed rock layer under the pavement or cover system that vents to the atmosphere. It is highly recommended that if a passive system is installed, it be designed to be converted to an active system in the event that LFG migration is detected in perimeter LFG probes (GP-09, GP-26, GP-23, and, GP-07), or if odor control is required.

The above system would be compatible with the interim LFG control system designed on the SPPD property to the south and southwest.

12.7.3 Kenyon Industrial Park/7901 2nd Avenue South Parcels

The KIP/7901 parcels are currently developed with four buildings over the Landfill and one building located adjacent to the Landfill boundary. Any future development would be expected to be similar to the current site configuration. The parcel is predominately paved, with asphalt. The buildings are warehouse-type buildings with slabs on grade. The existing buildings and paved site areas have not had documented intrusion or LFG migration issues.

For existing structures and parcels that are above the Landfill that do not have any known redevelopment plans, two options may be acceptable. The first is that no further action other than monitoring is necessary if it can be demonstrated that there is no adverse risk to human health and the environment due to the presence of LFG, including methane and the VOCs (benzene and xylene). The second acceptable alternative is for the installation of controls such as passive or active LFG control systems. These systems are described below.

Passive venting of the paved areas and at the solid waste boundaries may provide adequate LFG accumulation control; however, it is recommended that, if passive venting is selected, it be designed to be converted to active control. LFG control for structures and buildings may be necessary because the building foundations have not been designed for methane mitigation (e.g., penetration seals, passive venting, and impermeable barriers). Potential building or structure mitigation alternatives include the following:

- An impressed air curtain under the building slabs within the crushed rock layer, which is vented, accessed at the perimeter footings
- Active vacuum collection using collection trenches at the building footings that are tied in to the crushed rock layer below the concrete slabs
- Perimeter building extraction wells

For the parcels, including the area to the west beyond the Landfill boundary, similar options and controls would be appropriate for protecting building occupants and minimizing off-site migration.

Utilities passing through waste areas or adjacent to waste areas should be assessed for preferential pathways and off-site LFG migration. This includes both utility bedding and conveyance piping and structures. Sealing of trenches and venting of structures and conveyance piping to prevent LFG accumulations should be included in design of the LFG control systems.

If passive venting is implemented, the system should be designed to be converted to active collection, allowing for adaptive management and potential migration issues associated with on-site or adjacent site development.

For any new development on these parcels, LFG mitigation will need to be addressed and may include under building membranes, passive venting, active venting, and/or monitoring.

12.7.4 5th Avenue South

For the public roads and ROWs, LFG has not been identified at levels of concern anywhere except for along 5th Avenue South. LFG has been monitored at levels greater than the explosive limit along 5th Avenue South at GP-27 and GP-29. The Landfill boundary along this area extends under 5th Avenue South within the ROW. Several utilities are located within this area, notably a 72-inch storm drain bedded through solid waste. LFG control in this area will need to address gas migration, utility corridors, confined spaces (i.e., manholes and vaults), extent of solid waste, and occupied buildings adjacent to the Landfill.

Appropriate LFG control strategies include active collection and passive venting. Passive venting to prevent migration may require construction within the ROW. Active collection systems will be similar to those identified for the KIP/7901 parcel. Active collection utilizing the existing 72-inch pipe bedding along 5th Avenue South may be possible to control migration under 5th Avenue South, which could be monitored at GP-27, GP-28, and GP-29. To provide increased influence along the pipe bedding, plugging the pipe trench with bentonite or injection grouting at the north and south edge of waste boundaries may be necessary. Additionally, extraction wells or trenches could be installed on the east side of 5th Avenue South to control migration and gas accumulations. Additional measures may need to be taken to prevent LFG migration through utilities within the ROW. This system may be tied-in to either the SPPD parcel or the SRDS LFG systems.

12.7.5 South Sullivan Street and 426 South Cloverdale Street

LFG has not been detected at levels greater than the LEL within Gas Probes GP-03, GP-05, GP-15, GP-31, or GP-32 along South Sullivan Street. The Landfill boundary along this area extends under South Sullivan Street within the ROW and extends onto the 426 South Cloverdale Street parcel to the south. Groundwater is very shallow in this area and likely limits the migration of LFG. LFG control in this area will need to address potential gas migration associated with any capping activities of the Landfill, which may increase the potential for lateral gas migration. Appropriate LFG control strategies may include active collection and passive venting at capping extents and/or continued monitoring of the perimeter gas probes post-Landfill development activities to ensure migration or gas accumulations are controlled.

12.7.6 Landscaped Area Northeast of South Recycling and Disposal Station

This area, located northeast of the SRDS, between 5th Avenue South and SR 99 will be addressed in conjunction with development of the SRDS property. The SRDS is currently paved and LFG control in this area will need to address potential gas migration associated with development modifications to the property. Appropriate LFG control strategies include active collection and passive venting. Continued monitoring or passive venting to prevent migration are options for addressing LFG in the landscaped areas. Passive venting may require construction within the landscaped area and ROW. Active collection systems will be similar to those identified for 5th Avenue South. Continued monitoring of Gas Probes GP-09, GP-07, GP-23, and GP-26 following development of the SRDS property will identify changes in LFG migration patterns.

12.8 COMPLIANCE WITH MTCA REQUIREMENTS

The LFG control component of the remedy described in this section complies with the MTCA requirements for a selected remedy. A description of how the MTCA requirements are met is included in Section 17.0.

13.0 Stormwater Control Alternatives

The Landfill contains operating facilities with stormwater requirements based on their business operations. These requirements fall under the jurisdiction of the Seattle Municipal Code and the codes and restrictions created under its authority. The City has established several goals for controlling flow and treatment of stormwater runoff designed to maximize the protection of life, property, and the environment as they relate to stormwater and potential pollutants carried within stormwater.

The primary goal of the stormwater controls relative to the Landfill is to maintain a separation between landfill contents and stormwater that is collected and conveyed in the stormwater system.

In conjunction with the City's goals, the stormwater controls located on the Landfill will need to be designed in coordination with the closed landfill site requirements. Such design considerations include the following:

- Compatibility with the landfill cap, including preventing stormwater that is collected and conveyed by the system from coming into contact with solid waste
- Minimizing depth of new improvements to limit disturbance of solid waste
- Providing physical barriers between new construction and solid waste
- Collecting and conveying stormwater off-site to limit infiltration into the landfill; elimination of infiltration is not required as discussed in Sections 10.0 and 11.0

This section provides a description of the existing site conditions in order to establish the current conditions of the property and understand how the selected alternatives will affect and be affected by the anticipated development of parcels on the Landfill. This section also provides guidance for the end land-user and helps identify feasible BMPs and new construction alternatives to satisfy both the City's requirements and those associated with the Landfill.

13.1 EXISTING STORMWATER INFRASTRUCTURE

The existing stormwater conditions were evaluated based on review of previous reports, as-built information, historical photos, the City's GIS database, and site visits. The existing stormwater systems are discussed in Section 2.4.5, and Figure 2.6 shows existing stormwater infrastructure for the properties associated with the Landfill.

13.2 PROPOSED STORMWATER CONTROLS

The City has established several tiers of goals for their stormwater flow and treatment control program established under Seattle Municipal Code Chapters 22.800 to 22.808. The first tier is focused on the protection of life, property, and the environment from stormwater and the potential pollutants carried within.

The second tier of goals is focused on BMPs to protect existing stormwater components, whether manmade or naturally occurring.

Proposed on-site stormwater controls for all parcels associated with the Landfill will also need to be developed to work in conjunction with the requirements of constructing on a closed landfill.

Interim stormwater controls necessary during construction and the permanent controls selected to comply with the City's requirements will need to comply with the closed landfill requirements. Section 10.2 of this FS discusses the cap and cover requirements for the Landfill.

13.2.1 Construction Practice Requirements

All construction sites that disturb more than an acre of land are required to submit a Notice of Intent (NOI) for coverage under the general National Pollutant Discharge Elimination System (NPDES) Construction Stormwater Discharge Permit. As part of the permit conditions, a SWPPP needs to be prepared and maintained for review by Ecology. The SWPPP includes selected BMPs necessary to protect downstream waters from silt-laden stormwater runoff during construction.

The installation of underground infrastructure creates the potential of stormwater entering excavations and coming into contract with solid waste. Additional BMPs, such as limiting the amount of open excavations and protecting excavations from stormwater run-on with earth berms or other diversion structures, will need to be included in the SWPPP.

Stormwater that enters any excavations will need to be managed the same as the water generated from the dewatering operations and covered in the BMPs selected for the SWPPP.

13.2.2 Stormwater Management Requirements

Design of the stormwater collection system and flow and treatment controls on the Landfill will need to factor into both the City's goals and the infiltration limitations associated with building on a closed landfill. Stormwater treatment BMPs that use infiltration as its primary mechanism will not be allowed within the limits of solid waste.

Stormwater infrastructure improvements should also be designed as shallow as possible to limit the amount of solid waste disturbance required for installation. Designing impervious surfaces to convey the stormwater (sheet flow) will help limit the amount of in-ground infrastructure required.

Stormwater infrastructure should be isolated from direct contact with solid waste and should be designed as tightline to prevent stormwater leaking into solid waste and LFG collecting in the stormwater system.

13.2.3 South Park Property Development Parcel

Stormwater infrastructure and facilities will need to be designed to meet the requirements of the City. These requirements include stormwater flow controls and water quality treatment. As discussed in Section 2.4.5, the current discharge point from the SPPD parcel is the privately-owned 30-inch KIP main stormwater line. This line connects to the existing City conveyance system in South Kenyon Street and discharges into the wetland system west of SR 509, ultimately discharging to the Duwamish Waterway.

After development of the SPPD parcel, it will be mostly covered with pavement and buildings, resulting in an increase in stormwater runoff and requiring the installation of a new stormwater system to collect the increased runoff. As part of SPPD's Interim Action, stormwater from the West Ditch will be rerouted through a new piped storm drain system in the Occidental Avenue South ROW (Figure 13.1). A separate drainage pipe will be installed in the ROW to collect surface water from the road. The system will tie into the existing City drainage system in the area of Occidental Avenue South and South Kenyon Street. The City will own and maintain

ROW infrastructure. SPPD will own and maintain drainage features in the West Ditch. The historical connection to the KIP stormwater line will be removed.

The proposed development of the SPPD parcel shows the continued use of the West Ditch to convey stormwater from the parcel to the outlet pipe located in the northeast corner of the parcel, either as an open conveyance system or a tightlined system. The bottom of the ditch is generally located outside of the Landfill boundary, but is below the elevation of the top of the waste. The proposed development includes a bioswale in a portion of the West Ditch and a bioswale in the northwest portion of the SPPD parcel for treatment of stormwater from the SPPD parcel.

Specific construction requirements for stormwater conveyance and treatment systems, including the West Ditch, are included in Section 10.3.2.3.

13.2.4 Developed Parcels within the Landfill Boundary

The stormwater management requirements established for this FS will also pertain to the future redevelopment of any of the parcels associated with the Landfill. Stormwater collection systems should be designed to meet the goals of the City as well as the limitations involved with developing on a closed landfill.

Because the existing developed sites are mostly covered in impervious surfacing, no additional stormwater flow controls may be necessary.

13.2.5 Roadway Improvements within the Landfill Boundary

Roadway improvements that are constructed to the current Seattle Department of Transportation standards will provide adequate stormwater controls to minimize infiltration into the Landfill. Road improvements should include the addition of curb, gutter, and storm drain collection systems to convey the stormwater away from the Landfill and into the surrounding public stormwater systems.

13.2.6 Adjacent Contributing Properties

As detailed in Section 2.2.6, several adjacent properties contribute stormwater runoff to the West Ditch on the SPPD parcel. The stormwater collection system will be required to continue to collect stormwater from these properties.

13.3 KENYON INDUSTRIAL PARK MAIN STORMWATER LINE

The KIP main stormwater line is a 30-inch private storm drain line located on private property and maintained by the owners of the KIP parcel. The KIP main stormwater line was installed when the KIP parcel was developed and is intended to convey stormwater from the KIP facility.

13.4 COMPLIANCE WITH MTCA REQUIREMENTS

The stormwater control component of the remedy described in this section complies with the MTCA requirements for a selected remedy. A description of how the MTCA requirements are met is included in Section 17.0.

14.0 Downgradient Groundwater Alternatives

Because the Landfill is an unlined landfill where leachate and on-site groundwater co-mingle, landfill constituents may have left the Landfill and migrated downgradient. This section of the RI/FS evaluates remedial action alternatives for groundwater that has already migrated or will migrate past the edge of waste.

14.1 OVERVIEW OF GROUNDWATER OCCURRENCE AND MIGRATION

The Landfill lies above and in the Shallow Aquifer. As discussed in Section 3.1, the Shallow Aquifer is part of the valley-wide Alluvial Aquifer. The uppermost zone of the aquifer at the Landfill is a thin layer of groundwater and infiltrating stormwater that is perched on the Silt Overbank Deposit and identified as the Perched Zone. The Silt Overbank Deposit is prevalent throughout the Duwamish Valley, but discontinuous due to both natural and man-made disturbances. Much of the Landfill sits on the Silt Overbank Deposit in contact with perched groundwater. Deeper sections of the Landfill, such as those on the KIP parcel, extend through the Silt Overbank Deposit deeper into the Shallow Aquifer. Three zones of the Shallow Aquifer were investigated at the Landfill:

- **The Perched Zone:** This zone is located just above the Silt Overbank Deposit.
- **The A-Zone of the Shallow Aquifer:** This zone is located beneath the Silt Overbank Deposit at depths of approximately 0 to -15 feet elevation NAVD 88.
- **The B-Zone of the Shallow Aquifer:** This zone is located deeper into the Shallow Aquifer at depths of approximately -15 to -35 feet elevation NAVD 88 above the estuarine/marine deposits.

Within the Shallow Aquifer, groundwater generally has a slight upward gradient from the A-Zone to the Perched Zone, due to the volume of groundwater recharge that enters the A-Zone from the adjacent hillside. The slight upward gradient and the presence of the Silt Overbank Deposit slow the transport of dissolved constituents from the Perched Zone into the A- and B-Zones. These deeper zones are the dominant groundwater pathway in the Shallow Aquifer. Contaminants from the Landfill have the potential to discharge directly into the lower Sand Aquifer where the Silt Overbank Deposit is missing. Once contaminants are in the A- and B-Zones, they will be transported toward the Duwamish Waterway. During this migration pathway, chemical and physical processes affect individual chemical compounds, allowing them to precipitate or adsorb onto soil or degrade into other chemicals. This process is called natural attenuation.

14.2 DOWNGRADIENT GROUNDWATER QUALITY

Groundwater quality at the Landfill was assessed with over 150 samples collected over the last 10 to 15 years. Figure 5.1 shows the location of groundwater wells and direct push probes and identifies those that were upgradient of the Landfill, beneath the Landfill, and downgradient of the Landfill. Information from those wells was compared in Table 5.3 with CULs for the Landfill. The only COC for groundwater is vinyl chloride. Three other organics will continue to be monitored for some time, even though they are in compliance and not COCs:

- TCE and *cis*-DCE because they are precursors of vinyl chloride, even though their concentrations have been less than the CULs for several years.

- Benzene because it has been detected frequently in one upgradient well (KMW-05) and one downgradient well (MW-25); although the concentrations at the Landfill, including MW-25, have been in compliance for several years.

As discussed in Sections 5.0 and 6.0, the remaining vinyl chloride exceedances of groundwater CUL at the edge of waste wells do not represent a traditional groundwater plume. Vinyl chloride is slowly diffusing from the Landfill area, likely from the biological degradation of molecules of TCE and *cis*-1,2-DCE entrained on the Silt Overbank Deposit. This same process is likely occurring at the former Glitsa property and contributing to the concentrations at MW-31. These same moderate reducing conditions that allow the organics to degrade, allow naturally occurring iron and manganese to leach from the soils in the formation.

14.2.1 Anaerobic Conditions and Biological Degradation

As discussed in Section 5.8, conditions at the Landfill, both historically and currently, support the natural reductive dechlorination of TCE to DCE isomers and then to vinyl chloride. Concentrations of TCE and the DCE isomers are now less than their respective CULs. Vinyl chloride, which has the lowest CUL (0.29 µg/L), still exceeds the CUL at some locations but not at all downgradient wells. The greatest vinyl chloride exceedance attributable to the Landfill is around 1 µg/L. Vinyl chloride is not detected at a detection limit of 0.1 µg/L along Riverside Drive near the Lower Duwamish Waterway, where the first potential exposure occurs.

Groundwater conditions at the Landfill are considered to be conducive to the natural attenuation of vinyl chloride to non-toxic chemical species (USEPA 1998). The degradation pathway may be by reductive dechlorination under methanogenic conditions as methane is still being formed at low concentrations at the Landfill, or it may occur as an oxidative pathway for vinyl chloride under anaerobic conditions. Geochemical conditions at the Landfill are appropriate for either pathway and consistent with the observation that vinyl chloride concentrations have been decreasing since at least 2006.

As groundwater moves further downgradient, infiltrating stormwater will introduce oxygen into the system, until it approaches the Duwamish Waterway. The increase in oxygen will increase the rate that vinyl chloride degrades through an anaerobic oxidative process (refer to Section 5.8.2). At the Duwamish Waterway, well-oxygenated surface water enters the formation during tidally influenced flow reversal along the Duwamish Waterway and creates aerobic groundwater conditions. The aerobic groundwater conditions will, therefore, further reduce the vinyl chloride concentrations because vinyl chloride biodegrades much more quickly under aerobic conditions than under anaerobic conditions (USEPA 1998). The applicable surface water criterion for vinyl chloride along the Duwamish Waterway is 2.4 µg/L. This standard is already met at the edge of the Landfill; however, it is exceeded at downgradient Well MW-31 across SR 99 from the Landfill.

The geochemical conditions most favorable to the continued degradation of chlorinated VOCs are less favorable for attenuating elevated concentrations of iron and manganese in groundwater. The iron and manganese are not released from the Landfill per se; rather they are leaching from native soils found within the aquifer as the anaerobic groundwater passes beneath the Landfill. The concentrations of iron and manganese in the aquifer are naturally high. The downgradient concentrations are currently between the background concentrations and 2 times the background concentrations and are expected to continue to decrease slowly to the background concentrations as the methane production continues to decrease as the Landfill ages.

14.2.2 Potential for Vapor Intrusion from Groundwater

Downgradient groundwater was also screened against Ecology screening levels for the potential to adversely affect structures downgradient of the Landfill. Because of the presence of the Silt Overbank Deposit, the groundwater of concern is that in the Perched Zone above the silt. The highest concentrations in this zone were measured near the Glitsa property in MW-30. TCE, *cis*-DCE, and vinyl chloride were detected but at concentrations less than the industrial screening levels in *Guidance for Evaluating Soil Vapor Intrusion in Washington State: Investigation and Remedial Action* (Ecology 2009c).

14.3 GROUNDWATER TRAVEL TIMES

Groundwater velocity calculations presented in Section 5.5.5 indicate that groundwater in the Shallow Aquifer in the vicinity of the Landfill moves relatively quickly, between 0.6 (southern region of the Landfill) and 2 ft/day (northern region of the Landfill). Based on these groundwater velocities, and a distance of approximately 1,600 feet between the downgradient boundary of the Landfill and the Duwamish Waterway, it would take approximately 2 to 7 years for groundwater at the downgradient edge of the Landfill to reach the Duwamish Waterway, where the first exposure occurs. Travel times from the POC wells to downgradient properties on the far side of SR 99 are around 6 months.

Vinyl chloride is mobile in groundwater, travelling at almost the same speed as groundwater (measured retardation factors are between 1.6 and 2.0 as discussed in Section 5.6.4.2); however, vinyl chloride will continue to degrade as it moves causing its concentrations to continue to decline as it migrates toward the waterway.

This means that the data collected at the Landfill since the late 1990s are predictive of the worst concentrations that could possibly exist downgradient of the Landfill today and that current data are predictive of the worst-case concentrations in the future. Natural degradation under either anaerobic conditions near the Landfill or aerobic conditions near the waterway will cause the actual downgradient concentrations to be even lower.

14.4 GROUNDWATER REMEDIATION ALTERNATIVES

There is no downgradient groundwater plume to remediate at the Landfill. However, there are low concentrations of vinyl chloride in several of the POC wells, where concentrations typically range between not detected at 0.02 µg/L and 1.4 µg/L versus a CUL of 0.29 µg/L. As discussed in Section 5.0, the concentrations are less than screening values for vapor intrusion; there are no current users of groundwater in the area; and there is no expected further use of groundwater. Current concentrations at the Landfill are less than the drinking water MCL of 2.0 µg/L.

The remaining "source" of vinyl chloride is likely diffusion from the Silt Overbank Deposit of vinyl chloride or its precursors followed by anaerobic degradation. Vinyl chloride will naturally attenuate through biological degradation to harmless constituents via both anaerobic and aerobic pathways.

There are two potential alternatives for remediation of the groundwater at the downgradient edge of the Landfill: (1) no further action and (2) MNA combined with source control of the anaerobic groundwater.

14.4.1 No Further Action

For this alternative, no additional actions would be taken to address the concentrations of vinyl chloride along the landfill boundary. They would continue to attenuate, but their concentrations would not be monitored and no changes would be made at the Landfill. This alternative is not consistent with the regulatory requirements for a landfill cap, stormwater control, and LFG controls and will not be considered further.

14.4.2 Monitored Natural Attenuation with Source Control

Because the downgradient vinyl chloride concentrations are only slightly greater than their respective CULs and because of the likelihood that these concentrations will be further reduced initially under anaerobic conditions and later under aerobic conditions, the recommended groundwater remediation alternative is MNA with source control via the presumptive remedy requirements. Note that the "source" that is being controlled is the source of anaerobic groundwater. In other words, by capping the Landfill and installing stormwater and LFG controls, less methane and oxygen-depleted leachate will enter the groundwater system, and the system will slowly return to more aerobic conditions.

MNA will confirm that trends in the concentrations either remain stable or further decrease, especially once the presumptive remedy requirements are implemented (landfill cap and LFG extraction). Source control will include (1) placement of a landfill cap and stormwater controls over the remaining unsurfaced areas (the SPPD parcel); and (2) installation of an LFG control system. The landfill cap will minimize infiltration of stormwater into the solid waste, and the LFG controls will reduce the amount of methane reaching groundwater. These should result in a slow transition of the groundwater from anaerobic to aerobic conditions, allowing the vinyl chloride to continue to degrade.

14.4.3 Proposed Groundwater Remedial Action

MNA has been proposed as the cleanup alternative for downgradient groundwater. The MNA alternative uses long-term groundwater monitoring and statistical trend analysis to track the residual vinyl chloride concentrations at the POC over time. The monitoring will confirm that trends in the concentrations either remain stable or decrease further over time, especially once the presumptive landfill remedial actions are implemented (landfill cap and LFG extraction). Continued groundwater monitoring will also further document that the geochemical conditions continue to support biodegradation of vinyl chloride.

Source control, as discussed in Section 14.4.2, will include: (1) placement of a landfill cap over the remaining unsurfaced areas (SPPD property), and (2) installation of an LFG extraction system. The landfill cap will minimize infiltration of stormwater into the solid waste, which could lead to further improvements in groundwater quality, while the gas extraction system will remove and treat any vinyl chloride within the Landfill that could potentially act as a source of further groundwater contamination. These components are part of the presumptive remedy and are discussed above.

A range of possible contingent groundwater actions has also been proposed as part of the MNA. Section 15.1 outlines the long-term monitoring approach for groundwater. The triggers and contingent actions will be defined in more detail in the CAP.

14.5 COMPLIANCE WITH MTCA REQUIREMENTS

The downgradient groundwater component of the remedy described in this section complies with the MTCA requirements for a selected remedy. A description of how the MTCA requirements are met is included in Section 17.0.

15.0 Operations, Maintenance, and Monitoring

This section addresses the required long-term monitoring that is part of the presumptive remedy for landfills. In order to ensure that the remedy is effective and provides long-term protection of human health and the environment, both LFG and groundwater must be monitored. In addition, as required by state and federal law, stormwater monitoring, if required, will be conducted on a parcel-by-parcel basis.

This section provides an overview of monitoring systems for each media. The final groundwater monitoring locations, sampling frequency, and analytes will be provided in a Compliance Monitoring Plan in the Draft CAP, and the LFG monitoring will be provided as an Operations, Maintenance, and Monitoring Plan in the design reports for the LFG systems to be implemented at the Landfill. Stormwater monitoring is not required as part of the Landfill remedial action because the stormwater that is conveyed off-site is blocked from contact with solid waste; however, operating facilities located at the Landfill may be required to monitor their stormwater consistent with NPDES permit requirements. The requirements are triggered by their operations and not by the present stage of the Landfill.

15.1 GROUNDWATER MONITORING

The goal of groundwater monitoring is to confirm that the landfill remedy is performing as expected and to determine when groundwater comes into compliance for vinyl chloride. The long-term monitoring plan will be further defined as part of the Draft CAP. The discussion below is designed to set expectations regarding the scope of the monitoring program.

15.1.1 Proposed Monitoring Well Network

The monitoring well network proposed for long-term compliance monitoring at the Landfill is presented in Table 15.1. The locations of the wells are shown on Figure 5.1. The network contains four upgradient locations to track groundwater quality entering the Landfill. Two of those locations, KMW-05 and MW-12, are contaminated; the other two locations are in compliance. All four locations monitor primarily the A-Zone of the Shallow Aquifer; the B-Zone does not exist upgradient of the Landfill because the aquifer becomes thinner near the valley wall. There are three edge of waste wells screened in the A-Zone. The unscreened sections of these wells extend through solid waste but are not screened in the solid waste.

15.1.2 Proposed Analytical Schedule

The Landfill was closed in 1966 under requirements in effect at that time, and groundwater at the Landfill has been monitored since approximately 1996. Vinyl chloride is the only COC for groundwater. The concentrations are low and trending downward, and MNA is the preferred remedial action. The analytical schedule presented in Table 15.2 is appropriate for the Landfill at this time in its history.

15.1.3 Reporting

During the first 5 years after the CAP implementation, reporting will occur annually. Further details are provided in the Draft CAP. Monitoring and reporting requirements beyond this period will be resolved as part of Ecology's ongoing site review process.

The final details, including the selected locations to be monitored, frequency of sampling, and chemicals to be analyzed for will be provided in the Long-Term Groundwater Monitoring section of the Draft CAP. The Draft CAP will also include a Sampling and Analysis Plan/Quality Assurance Project Plan, which will identify the sampling procedures and the steps that will be taken to ensure quality assurance/quality control, and a Health and Safety Plan to protect the staff performing the sampling.

15.2 LANDFILL GAS MONITORING

As described in Section 6.4.2.1, significant LFG monitoring occurred at the Landfill from February through the end of 2011 to collect baseline data from the newly installed gas probes. Continued gas probe monitoring will be contingent on development of the SPPD and SRDS parcels. Typically, LFG collection systems require two types of monitoring, operational and performance. The frequency and location of monitoring will be dependent on the design of the specific system.

Operational monitoring during system startup may be required to optimize the control system and to size the final blower(s). Ongoing monitoring will be required and will be developed based on system response following full build-out, and will ensure that the system is operational and that the LFG control systems, if several are active, are interacting positively.

Performance monitoring will likely be required for the entire Landfill and will be conducted at the Landfill perimeter using existing probes once development begins. Additional probes may be necessary for monitoring, contaminant testing, determination of volumetric flow, or verification of active system performance. The number of probes will be highly dependent on the final site development, extent of capping, and type of control system installed. Performance of the control systems will likely be based on concentrations of methane gas not exceeding the LEL for methane at the facility property boundary or beyond and the concentration of methane gases not exceeding 100 parts per million by volume (ppmv) of methane in off-site structures. Further details are presented in the Draft CAP.

The specific gas probe locations, frequency of monitoring, and specific monitoring requirements will be defined in an Operations, Maintenance, and Monitoring Plan that will be included as part of the design report for each LFG system.

15.3 STORMWATER MONITORING

Stormwater monitoring is not required as part of the MTCA process for the Landfill because the stormwater will not come into contact with the solid waste. Stormwater monitoring may be required at individual facilities operating on the Landfill surface depending on specific operations conducted at the facility. Ecology's Water Quality Program is delegated by USEPA as the state water pollution control agency responsible for implementing all federal and state laws and regulations related to stormwater runoff. This includes determining whether a specific facility needs a NPDES permit, and, if so, the type and terms of the permit. It is this permit that would specify monitoring requirements, if any, for the individual facilities.

In addition, during redevelopment, if more than 1 acre of area is disturbed, a Construction Stormwater General NPDES permit will be necessary to ensure that water leaving the parcels is not detrimental to downgradient water bodies. Each parcel that is to be redeveloped will be responsible for obtaining these permits and meeting the requirements.

16.0 Environmental Covenant

This section describes the institutional controls that will be required for owners of properties within the Landfill. The institutional controls will allow the preferred remedial alternative to function as intended and will provide a clear record of who is responsible for operation, maintenance, and monitoring of the selected remedial systems. The controls will also identify measures that will need to be taken to ensure that workers on and near the Landfill will conduct their work in a safe manner and not be exposed to any remaining contaminants. These controls will be documented in an Environmental Covenant[17] that will be attached to the properties themselves and will be transferred to the new owner in event of a property transfer.

16.1 MTCA REQUIREMENTS

In accordance with WAC 173-340-440, MTCA requires that institutional controls such as environmental covenants be imposed on contaminated property whenever the remedial action conducted will result in hazardous substances remaining in soil, groundwater, or other media at concentrations that exceed applicable CULs, or when Ecology determines that such controls "are required to assure the continued protection of human health and the environment or the integrity of the interim or cleanup action."

The purpose of an environmental covenant is to prohibit activities that may interfere with a cleanup action, operation and maintenance, or monitoring, or may result in the release of a hazardous substance that was contained as a part of the cleanup action. Environmental covenants must be recorded in order to give adjoining property owners, future purchasers, and tenants, as well as the general public, notice of the restrictions on use of the property. Property owners are also required to notify Ecology prior to any lease or sale of the restricted property.

The properties within the Landfill that will be subject to an Environmental Covenant are shown on Figure 16.1 and include the following:

- The SPPD property
- The SRDS property
- The KIP parcel
- The 7901 parcel
- 426 South Cloverdale Street (the Emerson Power Products property)
- Public roads and ROWs

16.2 MODEL ENVIRONMENTAL COVENANT

In order to provide a more consistent basis for the Environmental Covenant, the State of Washington has adopted the Uniform Environmental Covenants Act (UECA), which is the basis for a model environmental covenant that identifies the major components required for a legally

[17] The term "Environmental Covenant," as used in this document, is the same as the term "Restrictive Covenant". Restrictive Covenant is used in MTCA and Environmental Covenant is used in the Model Environmental Covenant prepared by Ecology.

binding covenant. The UECA also creates a system for maintaining a permanent record of the covenants so they can be easily identified during real estate transactions.

The model environmental covenant as provided by Ecology is included in Appendix K.

16.3 SOUTH PARK LANDFILL PROPOSED ENVIRONMENTAL COVENANT

Following the approval of this RI/FS, a Draft CAP and the Environmental Covenant will be developed. The Environmental Covenant will be finalized in the Final CAP and will be a requirement in the Consent Decree for the Landfill. Using the model environmental covenant as a template, a site-specific covenant will be developed that will address the conditions at the Landfill. The Environmental Covenant for the Landfill will likely include the following:

- Access of Ecology personnel for inspection and review of records, and to determine compliance with the selected remedial action.
- Compliance with the selected remedial action and schedule presented in this RI/FS and the subsequent Draft CAP.
- On-going operation and maintenance of the selected components of the remedial action. This will likely include the LFG collection and treatment systems, the cap/cover systems, long-term groundwater monitoring, and any other engineered controls. These requirements will be based on Operations, Maintenance, and Monitoring Plans, a Compliance Monitoring Plan, or remedial system design reports that will need to be prepared by the respective parties and submitted to Ecology.
- Requirements for worker safety for utility operation and maintenance and roadway improvements and maintenance.
- Requirements for construction practices to ensure that further construction continues to comply with the preferred remedial alternative. This may include foundation construction, pier and piling construction, and any subsurface construction.
- Notification requirements to Ecology if any conveyance of the parcels is desired. Adequate and complete provision for ongoing operation and maintenance of the remedial action components must be accounted for in any property conveyance.
- Land-use restrictions that will require the properties to remain as industrial or commercial sites and will prohibit any activity on the properties that may result in the release or exposure to the environment of a hazardous substance from the Landfill while allowing redevelopment and improvements of the properties. Additional uses, including recreation, may be allowed if it does not affect the components of the preferred remedial action.
- Restrictions of any groundwater use except for that of monitoring and remedial purposes as described in the Draft CAP or 5-year review process.
- Restrictions of water supply wells within 1,000 feet of the Landfill, consistent with existing state law.

The Environmental Covenant will be developed to ensure that the proposed remedial actions are properly implemented and maintained. The Environmental Covenant will also ensure that the remedial action remains protective of human health and the environment, and that the necessary maintenance and monitoring occur as necessary on the Landfill in coordination with Ecology.

17.0 Preferred Alternative

This section describes the preferred remedial alternative for the Landfill. It is based on the presumptive remedy for solid waste landfills, which is containment. It also includes provisions for long-term monitoring, institutional controls, and addressing downgradient groundwater.

Each component is summarized below and was described in more detail in Sections 10.0 through 16.0 of this RI/FS Report. The preferred alternative is designed to meet MTCA cleanup action requirements as described below.

This section also identifies the schedule and next steps for implementation of the selected remedial alternatives.

17.1 COMPREHENSIVE PREFERRED REMEDIAL ALTERNATIVE

As described in Sections 8.0 and 9.0, MTCA has defined specific requirements that must be met in order for a selected remedy to be protective of human health and the environment and identifies criteria that must be met by each alternative. In addition, MFS guide the selection of other requirements that must be met in order to allow a landfill to be closed in a fashion that reduces or eliminates the possibility of post-closure escape of solid waste constituents, leachate, LFG, and contaminated stormwater or waste decomposition products to the ground, groundwater, surface water, and the atmosphere. The regulations also ensure that a landfill must continue with operation and maintenance of the selected remedy and the on-going monitoring of the various media at the landfill.

17.1.1 Landfill Cap

The first component of the preferred alternative is the presence of a landfill cap above all areas containing solid waste. The goal of the landfill cap is to block access to the solid waste; secondary goals are to limit stormwater infiltration and to facilitate the performance of the LFG system.

The landfill cap requirements for areas of the Landfill that receive a new engineered surface are as follows:

1. A minimum of 12 inches of fill material over solid waste is required. Fill material does not need a low permeability standard. Existing fill shown to meet this depth will be considered acceptable.
2. A structural section of road base as required by the project geotechnical engineer is required.
3. An asphaltic concrete of 2 to 3 inches minimum thickness or 4 inches minimum thickness of concrete is required.
4. The design and inclusion of stormwater infrastructure to collect and convey the stormwater away from the Landfill is required. The stormwater controls were described further in Section 13.0.

This cap section should be applied to all future developments on the Landfill. The performance requirements listed in Section 10.0 have been met with the landfill caps already in place over the property that is part of the Landfill (i.e., KIP/7901 parcels, the SRDS, and portions of 5th Avenue South and Occidental Avenue South). All of these parcels have been developed with impervious surfaces (i.e., asphalt and concrete) over the maximum surface area practicable. Future activities at these parcels will need to maintain the landfill cap.

Other future developments, such as landscaped buffers, planter islands, or stormwater BMPs, that will not be paved or receive hardscape (i.e., concrete), will require a low permeability layer and a distinct barrier between the new improvements and the top of solid waste as specified by WAC 173-304 (described in Section 10.3). However, this is not intended to force the removal of large established trees; therefore, flexibility in the interpretation is allowed as long as there is a reasonable barrier between the surface and the waste.

Current areas such as road surfacing/hardscapes, medians and shoulder areas, landscaped areas, and building foundations that have been functioning adequately as a protective barrier for the solid waste in their current design do not require any additional work; however, if these areas undergo future development or maintenance there are specific requirements that must be met and are discussed in Section 10.3.

In addition to the requirements for the construction described above, there are also requirements for construction practices that will provide protection for the workers and ensure that construction at the Landfill is conducted in a manner that will minimize potential exposure or release of contaminants to the environment. These practices are described in Section 10.4 and will be referenced in the Environmental Covenant for the Landfill.

17.1.2 Leachate Control Preferred Alternative

No leachate treatment or control system is needed at the Landfill. Groundwater quality beneath the site and in edge of waste wells indicates the leachate production at the Landfill no longer contributes COCs greater than CULs to the Landfill. The remaining COC (vinyl chloride) are not leachate issues. Nevertheless, the addition of the landfill cap will reduce infiltration of rainwater across the site, reducing leachate production, particularly on the SPPD parcel, which is currently unpaved.

This alternative is consistent with the proposed development and use of the Landfill and is an acceptable alternative to address leachate at the Landfill.

17.1.3 Landfill Gas Controls

Section 12.0 describes the regulations regarding the collection and treatment of LFG at landfills and outlines the various alternatives that are appropriate at each facility on the Landfill. LFG controls must be sufficient to protect human health from toxic gases, to prevent explosion hazardous, and to demonstrate that LFG is not migrating off-site at unacceptable levels. As described in Section 6.0, monitoring of perimeter gas probes has shown that LFG is only present within the boundaries of the Landfill.

For existing parcels on the Landfill that have been shown to have LFG below them and that do not have any known redevelopment plans (KIP/7901 parcels), two options are acceptable. The first is that no further action is necessary, which is proven by demonstrating that there is no danger to human health and the environment due to the presence of LFG below the parcels. This can be accomplished by monitoring indoor air for LFG and other VOCs and the monitoring of on-site and perimeter gas probes. The second acceptable alternative is the installation of engineering controls such as a passive or active LFG control system. These systems are described in Section 12.0.

For parcels that have redevelopment plans, the preferred alternatives for each parcel are as follows:

- **SPPD:** As part of the redevelopment, SPPD has proposed to install and operate an active LFG collection and treatment system. The system has been designed in conjunction with the landfill cap and cover requirements described above, and new buildings and utilities on the parcel will be constructed to be compatible with the proposed system.
- **SRDS:** The buildings that are currently on the parcel are either naturally ventilated or are elevated and skirted with porous siding; both are appropriate methods of LFG mitigation. Future development of the parcel will require installation of LFG mitigation controls such as below-slab barriers, ventilated structures, or elevated structures, with passive venting being the primary method of controlling LFG. It is recommended that the system be convertible to an active system in the event that LFG migration is detected in perimeter LFG monitoring probes.

For the public roads and ROWs, LFG has not been identified at levels of concern anywhere except for along 5th Avenue South. Due to the presence of LFG at levels greater than the LEL at Gas Probes GP-27 and GP-29, LFG must be controlled in this area. Appropriate LFG control strategies include active collection and passive venting. Additional measures may need to be taken to prevent LFG migration through utilities within the ROW. This system may be tied in to either the SPPD or the SRDS LFG systems.

The final design of the systems described above will be included in design reports for each parcel, which will describe the LFG control system and will include Operations, Maintenance, and Monitoring Plans for each system, ensuring that the systems are working efficiently and that LFG migration is not occurring. Each design report will be submitted to Ecology for approval.

17.1.4 Stormwater Controls

The stormwater controls at a redeveloped landfill must meet two goals. The first goal is to capture the bulk of the stormwater before it has an opportunity to make contact with solid waste. At the Landfill, because the Landfill extends into the water table, this is not about limiting infiltration; rather, it is about preventing solid waste constituents from contaminating stormwater. The second goal of the system is to capture stormwater so that the operators of the facilities on top of the Landfill can meet their stormwater obligations with respect to quantity, flow, and quality.

The majority of the parcels in the vicinity of the site are paved and have stormwater infrastructure constructed that is consistent with the goals stated above; however, there are several parcels and related areas that will be redeveloped or will require new construction or upgrades of conveyance systems in order to meet the goals listed above. The work that is necessary to be done includes the following:

- **SPPD Parcel and the West Ditch:** As part of the IA, the majority of the parcel will be covered with a cap that is consistent with the preferred alternative. The design of this cap will include the construction of a new conveyance system and the filling of the East-West Channel that currently exists on the parcel. This will also include redevelopment of the West Ditch, including removal or stabilization of unusable material in the base of the ditch and a regrading and planting to use this area as a stormwater conveyance system and bioswale for stormwater treatment. The West

Ditch will be rerouted to a dedicated line that discharges to the City's system along Occidental Avenue South.

- **The KIP Main Stormwater Line:** This ditch will continue to serve the KIP parcel but will no longer serve the SPPD parcel and/or the West Ditch.

Additional BMPs for source control and stormwater improvements may be appropriate for all of the parcels, but are not required for purposes of the preferred alternative; however, each parcel must remain in compliance with the State of Washington's requirements for managing stormwater based on their own operations. In addition, any properties that will undergo redevelopment, such as the SRDS, must comply with the design considerations identified above.

17.1.5 Downgradient Groundwater Controls

MNA has been selected as the cleanup alternative for downgradient groundwater. The only COC for downgradient groundwater is vinyl chloride. Vinyl chloride is a degradation product of the solvent TCE. Due to the age of the landfill, TCE, and its other degradation products, the DCE isomers, have degraded to less than their CULs at the Landfill; only vinyl chloride remains at concentrations greater than the CUL. The geochemical conditions remain favorable for the continued degradation of vinyl chloride to non-toxic constituents. The vinyl chloride concentrations are decreasing and are now less than the drinking water standard for vinyl chloride of 2.0 µg/L but still above the cleanup level of 0.29 µg/L in some locations.[18] The downgradient concentrations are less than the screening levels for vapor intrusion into buildings, and there is no use of groundwater between the Landfill and its discharge location into the Lower Duwamish Waterway. Groundwater located just upgradient of the waterway has been tested for vinyl chloride, and it was not detected at a detection limit of 0.1 µg/L.

The MNA alternative uses long-term groundwater monitoring and statistical analysis of well-by-well trend plots. Long-term monitoring will confirm that trends in the concentrations either remain stable or decrease further, especially once the presumptive landfill remedial actions are implemented (landfill cap and LFG extraction). Continued groundwater monitoring will also further document that the geochemical conditions continue to support biodegradation of vinyl chloride.

Source control will include (1) placement of a landfill cap over the remaining unsurfaced areas (SPPD parcel), and (2) installation of an LFG extraction system. The landfill cap will minimize infiltration of stormwater into the solid waste, which could lead to further improvements in groundwater quality, while the gas extraction system will remove and treat any vinyl chloride within the landfill that could potentially act as a source of further groundwater contamination. These components are part of the presumptive remedy.

Finally, a range of possible contingent groundwater actions has also been proposed as part of the MNA. Section 15.1 outlines the long term monitoring approach for groundwater and includes specific groundwater conditions that would trigger additional groundwater actions. The triggers and contingent actions will be defined in more detail in the CAP.

[18] The MCL allowed by state and federal drinking water regulations is 2.0 µg/L for vinyl chloride; MTCA, the State's primary cleanup regulation uses a slightly different approach and its CUL for vinyl chloride for a drinking water scenario is 0.29 µg/L. Maximum concentrations of vinyl chloride at the Landfill are between the two standards.

17.1.6 Operations, Maintenance, and Monitoring Preferred Alternative

In order to ensure that the selected components of the presumptive remedy are implemented efficiently and are operating properly, long-term monitoring of the various components must be implemented. The following are the monitoring requirements for the affected media at the Landfill:

- **Groundwater:** Long-term groundwater monitoring and the use of trend plots for individual wells are part of the long-term monitoring requirements for this Landfill. Details are presented in Section 15.0 and the Draft CAP.

- **LFG:** Continued gas probe monitoring will be contingent on development of the SPPD and SRDS parcels. Typically, LFG collection systems require two types of monitoring, operational and performance. The frequency and location of monitoring will be dependent upon the design of the specific system. The specific gas probe locations, frequency of monitoring, and specific monitoring requirements will be defined in an Operations, Maintenance, and Monitoring Plan that will be included as part of the design report for each LFG system. The general approach to monitoring is discussed in further detail in the Draft CAP.

- **Stormwater:** No stormwater monitoring is required under MTCA because the remedial action prevents stormwater that enters the stormwater system from contacting solid waste. Stormwater monitoring may be required by facility-specific NPDES permits, which are based on the nature of activities conducted on each parcel, the discharge point, and the final destination of the conveyed stormwater.

17.1.7 Environmental Covenant

In order to ensure that the selected components of the presumptive remedy are operated efficiently and continue to be operated and maintained properly, even in lieu of a property transfer, a, environmental covenant will be used as a legal measure to provide a clear record of the responsibilities and restrictions for each parcel owner. The Environmental Covenant will be developed as part of the Draft CAP process and will be implemented for each parcel owner within the Landfill boundaries.

17.2 ATTAINMENT OF REMEDIAL ACTION OBJECTIVES

The presumptive remedy was evaluated for its compliance with MTCA cleanup goals, including those for containment remedies. As described below, the preferred alternative presented in this document meets the requirements of MTCA and attains the remedial action objectives set forth for this site.

17.2.1 Compliance with MTCA Requirements

As described in Section 8.0, there are minimum requirements that must be met in order for a selected remedy to comply with the requirements of MTCA. This section identifies how the alternative described above meet those requirements.

17.2.1.1 Threshold Requirements

The threshold criteria identified in WAC 173-340-360(2)(a) that must be met by the selected remedy, and the reasons that the remedy above meets them, are as follows:

1. **Protect human health and the environment:** The landfill cap described in Section 10.0 will prevent direct contact with solid waste by people, plants, and animals. It will also ensure that stormwater that leaves the Landfill through the stormwater conveyance systems will not have come into contact with solid waste.

   The cap will also decrease the amount of leachate produced by limiting infiltration of stormwater. As discussed in Section 11.0, because the Landfill is unlined and the contents are already in contact with groundwater, this decrease in stormwater is viewed as a minor benefit that may or may not produce measurable changes in groundwater quality.

   The LFG control described in Section 12.0 identifies system requirements that will prevent worker and visitor exposure to methane and carbon dioxide concentrations at levels that are dangerous to human health. Concentrations are already at acceptable levels outside the Landfill; therefore, this system will be limited to the footprint of the Landfill (footprint of solid waste). The LFG system will also collect any VOCs entrained in the LFG system and vent them in such a manner as to avoid the accumulation of VOCs in buildings (control vapor intrusion).

   The stormwater controls identified in Section 13.0 meet the MTCA requirements by effectively separating the stormwater from the Landfill solid waste and contaminated soil. The captured stormwater will be conveyed and discharged off-site in accordance with stormwater regulations and ordinances.

   As described in Section 14.0, MNA is an appropriate and protective remedy for downgradient groundwater because the only COC that is out of compliance in groundwater is vinyl chloride. Concentrations of vinyl chloride in the POC wells range from not detected at 0.02 µg/L to approximately 1.4 µg/L versus a MTCA CUL of 0.29 µg/L. Groundwater conditions are protective of the vapor intrusion pathway. There is no use of the downgradient groundwater for drinking, and existing regulations make it highly unlikely that any future drinking water well would be installed. Groundwater along Riverside Drive where the groundwater from the Landfill discharges to the Lower Duwamish Waterway has been tested and found to be free of vinyl chloride at a detection limit 0.1 µg/L.

   Monitoring and maintenance requirements combined with the Environmental Covenant will ensure that the cap is maintained over time. This protects human health and the environment and meets expectations contained in WAC 173-340-7491 for protection of terrestrial receptors.

2. **Comply with cleanup standards (WAC 173-340-700 through WAC 173-340-760):** The containment remedy is an effective MTCA remedy that complies with cleanup standards, and allows soil with concentrations greater than the CULs to be left in place as long as the requirements for a containment remedy are met. Soils outside of the contained Landfill will comply with MTCA Method C CULs for industrial land use. Groundwater concentrations will comply with Method B CULs at the conditional POC at the edge of waste. Groundwater concentrations are already in compliance for all historical contaminants except for vinyl chloride, iron, and manganese. As described in Section 14.0, the downgradient groundwater will meet the cleanup standards within a reasonable time frame and will be monitored routinely to ensure that the groundwater is achieving the desired conditions. The LFG controls comply with the standards developed to prevent levels greater than the permissible percentages of methane and

carbon dioxide and any applicable cleanup standards. The LFG controls will also control VOC emissions from the Landfill.

3. **Comply with applicable local, state, and federal laws (WAC 173-340-710):** The landfill cover section specified meets the alternative cap requirements for the landfill cap and cover allowed by WAC 173-340-710. The designed cap, in conjunction with the recommended stormwater infrastructure, ensures compliance with these requirements. The LFG control requirements apply to the specific landfill regulations as outlined in Section 11.0. The other components of the remedy are consistent with applicable regulations.
4. **Provide for compliance monitoring (WAC 173-340-410 and WAC 173-340-720 through WAC 173-340-760):** Compliance monitoring will be conducted for both gas and groundwater, as described in Section 15.0.

WAC 173-340-360(2)(b) specifies three other criteria that alternatives must achieve. The following shows how they are met:

1. **Use permanent solutions to the maximum extent practicable:** The selected remedy is permanent to the maximum extent practicable for a closed solid waste landfill contaminated by large volumes of hazardous substances present at low concentrations. Monitoring and maintenance requirements, along with Environmental Covenants, ensure that the containment remedy will remain protective over time.
2. **Provide for a reasonable restoration time frame:** The cap has been in place at several of the parcels already and the development of the SPPD parcel is currently in the permitting process and the cap for the SPPD parcel will be constructed within a reasonable time frame. The development of the LFG control systems will be implemented in conjunction with the development periods for the individual parcels and will be conducted in a reasonable time frame. The groundwater is anticipated to be in compliance within a reasonable time frame.
3. **Consider public concerns (WAC 173-340-600):** The selected remedy will be submitted to Ecology and eventually described in a CAP produced by Ecology, which will go out for public review.

17.2.1.2 Requirements for Containment Systems

There are several additional items listed in WAC 173-340-740(6)(f) that identify the requirements of a containment remedial action and allow soil and solid waste with concentrations greater than the soil CULs to remain in place. Those requirements are met in the following ways:

1. **Institutional controls are in place:** An Environmental Covenant will be established to ensure that the requirements of the remedy, including cap and LFG control systems maintenance and monitoring, and groundwater monitoring, will be established for the Landfill. This is described further in Section 16.0. There are currently no drinking water wells at or downgradient of the Landfill, and it is against Washington State law to install a future drinking water well within 1,000 feet of a landfill.
2. **Compliance monitoring and periodic reviews are designed to ensure long-term integrity of the system:** Monitoring for the LFG control systems will be implemented and will be included in the Operations, Maintenance, and Monitoring Plans for each LFG control system as described in Section 15.0 of this report. Likewise, groundwater will continue to be monitored until it is fully in compliance with CULs.

3. **Types, levels, and amounts of hazardous substances remaining on-site and the description of the measures used to prevent migration and contact are specified in the CAP:** The material remaining within the Landfill is municipal solid waste containing low levels of hazardous substances. A Final CAP will be produced by Ecology that acknowledges the Landfill as a previously closed solid waste landfill and will identify the components of the containment remedy.

17.3 ANTICIPATED SCHEDULE

The schedule for the revisions of the RI/FS and the deliverable of the Draft CAP is shown below. The schedule is consistent with the deliverables and schedule identified in the Work Plan and Exhibit C of the Agreed Order.

Document	Date
Submit Public Review Draft RI/FS Report incorporating Ecology's comments on Draft RI/FS Report	60 days from receipt of Ecology's final comments on the Draft RI/FS Report
Submit Draft CAP	60 days from the submission of the Public Review Draft RI/FS Report to Ecology
Submit Final RI/FS Report incorporating Ecology and public comments	60 days from the receipt of Ecology's comments (post-public comment period)

18.0 References

AMEC Earth and Environmental, Inc. (AMEC). 2009a. *Remedial Investigation Report, South Kenyon Street Bus Yard*. Bothell, Washington. 31 March.

———. 2009b. *Focused Feasibility Study, South Kenyon Street Bus Yard*. Bothell, Washington. 31 March.

———. 2009c. *Cleanup Action Plan, South Kenyon Street Bus Yard*. Bothell, Washington. 31 March.

Area-Wide Soil Contamination Task Force (Task Force). 2003. *Area-Wide Soil Contamination Task Force Report*. Prepared by Ross and Associates Environmental Consulting, Ltd., et al. 30 June.

Aspect Consulting, LLC (Aspect). 2006. *Shallow Groundwater Characterization Data Report – South Park Custodial Landfill.* Seattle, Washington. 14 March.

———. 2011. *South Park Custodial Landfill Monitoring Procedures*.

Associated Earth Sciences, Inc. (AESI). 1998. *South Park Custodial Landfill Environmental Site Investigation Data Gaps Memorandum*. Prepared by AESI for King County. Bainbridge Island, Washington. 27 July.

———. 1999a. *South Park Custodial Landfill Cover Soils Investigation*. Bainbridge Island, Washington. 22 March.

———. 1999b. *South Park Custodial Landfill Geotechnical Evaluation Memorandum*. Bainbridge Island, Washington. 13 July.

———. 1999c. Gas Data collected from 1999 to 2004.

———. 2000. *South Park Custodial Landfill Monitoring Well and Gas Probe Installation Technical Memorandum*. Bainbridge Island, Washington.

———. 2004. Gas Probe Measurements Collected from February 12, 1999, to September 10, 2004. Unpublished data.

Bison Environmental Northwest. 1992. *Untitled.*

Blasland, Bouck, and Lee, Inc. (BBL). 1995. *Extended Phase II Environmental Site Assessment—Seattle Kenyon Business Park, Seattle, Washington.* Irvine, California. November.

Bortleson, et al. 1980. *Historical Changes of Shoreline and Wetland at Eleven Major Deltas in the Puget Sound Region, Washington*. Hydrologic Investigations Atlas HA-617.

Bouwer, Herman. 1978. *Groundwater Hydrology*. McGraw-Hill Series in Water Resources and Environmental Engineering. McGraw-Hill Book Company. January.

Bradely, Paul M. and Francis H. Chapelle. 1996. "Anaerobic Mineralization of Vinyl Chloride in Fe(III)-Reducing, Aquifer Sediments." *Environmental Science Technology* 30 (6). 23 May.

Camp Dresser and McKee, Inc. (CDM). 2011. *Surface Soil Sampling Results—South Transfer Station, Seattle, Washington*. Bellevue, Washington. 14 July.

Calibre Systems, Inc. (Calibre). 2008. *Historical Data Summary Report—Final, EMF Site, Seattle, Washington*. 6 June.

Calibre Systems, Inc. (Calibre) and Floyd|Snider. 2009. *First Quarter Interim Action Enhanced Reductive Dechlorination for Groundwater Report*. 23 June.

Christiansen, Thomas H., Poul L. Bjerg, Steven A. Banwart, Rasmus Jakobsen, Gorm Heron, and Hans-Jorgen Albrechtsen. 2000. "Characterization of Redox Conditions in Groundwater Contaminant Plumes." *Journal of Contaminant Hydrology* 45:165–241.

City of Seattle Department of Engineering (City of Seattle DOE). 1965. *South Park Refuse Transfer Station Location Plan and Exiting Contours*. Sheet 1 of 7. 9 August.

City of Seattle Department of Planning and Development (City of Seattle). 2008. *Notification Regarding SMC 25.09 Wetland Determination, 8249 5th Avenue South.* 24 October.

Clearwater Group (Clearwater). 1999. *Site Assessment and Closure Report, Ryder Student Transportation Services, Inc.* Seattle, Washington. April.

Clement, T. Prabhakar, C.D. Johnson, Y. Sun, G.M. Klecka, and C. Bartlett. 1999. "Natural Attenuation of Chlorinated Ethene Compounds: Model Development and Field-scale Application at the Dover Site." *Journal of Contaminant Hydrology* 42 (2000) 113–140. Elsevier Science B.V. October.

David Evans and Associates. 2006. *South Park Bridge Hydrographic Survey, Seattle, Washington, Summary Report.* Prepared for King County Department of Transportation. 14 July.

Davis, J. Hal. 2003. *Fate and Transport Modeling of Selected Chlorinated Organic Compounds at Hanger 1000, U.S. Naval Air Station, Jacksonville, Florida*: U.S. Geological Survey Water Resources Investigations Report 03-4089.

Dawson, W.A. and Tilley, L.J. 1972. *Measurement of Salt-Wedge Excursion Distance in the Duwamish River Estuary, Seattle, Washington, by Means of the Dissolved-Oxygen Gradient*. U.S. Geological Survey Water Supply Paper 1873-D.

Diagnostic Engineering, Inc. (DEI). 1992. *Phase II Environmental Site Assessment, Liberty/Sammis – Seattle, Kenyon Industrial Park, Seattle, Washington*. Seattle, Washington. 13 July.

Eco Compliance Corporation. 2007. *Phase 1 Environmental Site Assessment and Hazardous Materials Survey*.

Ecology and Environment, Inc. 1988. *Site Inspection Report for South Park Landfill, Seattle, Washington [Only partial report available]*. Seattle, Washington. December.

Environmental Associates. 2009a. *Supplemental Exploration and Further Remediation Feasibility Study—Former Glitsa, Inc. Property, Seattle, Washington*. Bellevue, Washington. 11 June.

———. 2009b. *Underground Storage Tank Removal Report and Checklist—Former Glitsa Property, Seattle Washington.* Bellevue, Washington. 31 July.

———. 2010. *Independent Cleanup Action Status Report—Former Glitsa Property, Seattle, Washington.* Bellevue, Washington. 23 June.

Environmental Partners, Inc. and Golder Associates, Inc. 2009. *Boeing Plant 2 Seattle/Tukwila, Washington Uplands Corrective Measures Study Volume VIIIa: 2-31 Area Data Gap Investigation Work Plan*. Prepared for The Boeing Company. Seattle, Washington. April.

Environmental Toxicology International. 1986. *Quality Risk Assessment: King County Landfills.* Seattle, Washington. December.

Farallon Consulting, LLC (Farallon). 2007. *Letter Report Regarding Landfill Cover Soil Sampling and Analysis for Polychlorinated Biphenyls, South Park Property Development Site.* Issaquah, Washington. 11 June.

———. 2010a. *Remedial Investigation/Feasibility Study Work Plan, South Park Landfill Site*. Issaquah, Washington. 3 November.

———. 2010b. *Groundwater Monitoring and Sampling Results.* Issaquah, Washington. 19 July.

Farquhar, J. and F.A. Rovers. 1973. “Gas Production during Refuse Decomposition.” *Water Air Soil Pollut* 2:483–495.

Fetter, Charles W. 1994. *Applied Hydrogeology (Fourth Edition).* Upper Saddle River, New Jersey: Prentice Hall, Inc.

Floyd|Snider. 1998. *Duwamish Industrial Area Technical Memorandum—Shallow Groundwater Use Designation.* April.

———. 2008. *Cleanup Levels (TMCL) Technical Memorandum*. Prepared for The Boeing Company. Seattle, Washington. December.

———. 2011. *Target Media Cleanup Levels Technical Memorandum, Boeing Plant 2, Seattle, Washington.* Prepared for USEPA Region 10. 26 May.

———. 2012. *Interim Site-wide Groundwater Monitoring Plan*. Prepared for City of Seattle and South Park Property Development, LLC. 7 December.

Floyd|Snider and Aspect Consulting (Floyd|Snider and Aspect). 2012. *Interim Site-wide Groundwater Monitoring Plan.* 7 December.

———. 2013a. *April 2013 Interim Site-Wide Groundwater Monitoring Results*. September.

———. 2013b. *July 2013 Interim Site-wide Groundwater Monitoring Results*. October.

———. 2014. *March 2014 Interim Site-wide Groundwater Monitoring Results.* May.

Freeze, Allan and J. Cherry. 1979. *Groundwater*. Englewood Cliffs, New Jersey; Prentice Hall, Inc.

G-Logics. 2007. *Phase I Environmental Assessment Report, Bus Yard Properties*. Seattle, Washington. 18 May.

Golder Associates (Golder). 1989. *Monitor Well Installation and Soil, Groundwater, and Gas Sampling—The Sammis Company Industrial Parks, Seattle, Washington.* Redmond, Washington. 1 November.

———. 2011. *Management of Low Levels of Landfill Gas*. Prepared by Golder Associates Ireland Limited on behalf of the U.S. Environmental Protection Agency, Office of Environmental Enforcement). April.

Gossett, James M. 2010. "Sustained Aerobic Oxidation of Vinyl Chloride at Low Oxygen Concentrations." *Environment Science & Technology* 44(4): 1405–1411. 21 January.

Hart Crowser, Inc. (Hart Crowser). 1998. *Duwamish Industrial Area Hydrogeologic Pathways Project: Duwamish Basin Groundwater Pathways Conceptual Model Report*. Seattle, Washington. 1 April.

Herrera Environmental Consultants, Inc. (Herrera). 1999. *Underground Storage Tank Closure and Site Assessment, South Transfer Station, Seattle Washington*. Seattle, Washington. 14 September.

King County Parcel Viewer. Available at: http://www.kingcounty.gov/operations/gis/propresearch/parcelviewer.aspx. Accessed 3 March 2012.

Koll-Dove Venture I. 1996. *Kenyon Business Park Property Information Package*. Foster City, California. 1 October.

Pacific Groundwater Group (PGG). 2008. *Groundwater Investigation: 7th Avenue South and South Riverside Drive*. Prepared for Seattle Public Utilities. 27 February.

———. 2009. *Soil/Groundwater Characterization: South Park Pump Station & Water Quality Facility, Seattle, Washington*. Prepared for Seattle Public Utilities. 7 July.

Palmer, Stephen P. 1997. *Holocene Geologic History and Sedimentology of the Duwamish and Puyallup Valleys, Washington*. 29 September.

Professional Service Industries, Inc. (PSI). 1993. *Air Quality Investigation South Kenyon Street Property*. Seattle, Washington. 27 September.

Roberts, Paul V. G.D. Hopkins, D.M. Mackay, and L. Semprini. 1990. "A Field Evaluation of In-situ Biodegradation of Chlorinated Ethenes: Part I, Methodology and Field Site Characterization." *Ground Water* 28(4): 591–604. July/August.

R.W. Beck, Inc. 1999. *South Park Custodial Landfill Surface Water Evaluation.* Seattle, Washington. 16 September.

———. 2001. *South Park Custodial Landfill Conceptual Landfill Gas System Design.*

RZA Agra. 1992a. *Subsurface Exploration Geotechnical Engineering, and Environmental Assessment Report—South Park Detention Project, Seattle, Washington.* Kirkland, Washington. 16 March.

———. 1992b. *Subsurface Exploration Study—South Park Detention Project, Seattle, Washington.* Kirkland, Washington. 24 March.

Seattle Engineering Department. 1934. *Old Landfills in the City of Seattle—Untitled sketch dated 1934 from the Seattle Engineering Department archives indicating the placement of sawdust south of the current South Sullivan Street alignment.*

Seattle-King County Department of Public Health (SKCDPH). 1984. *Abandoned Landfill Study in the City of Seattle.* Seattle, Washington. 30 July.

———. 1986. *Seattle-King County Abandoned Landfill Toxicity/Hazard Assessment Project.* Seattle, Washington. 31 December.

Seattle Public Utilities (SPU). 1997. Letter of Transmittal from Philip Woodhouse, SPU to Deborah Labmert, P.E., WHPacific, re: Package of Materials on South Park Landfill. 28 April.

Seattle Public Utilities Materials Laboratory. 1998. *Geotechnical Summary of South Transfer Station Memorandum*. 1 June.

Stumm, W. and J. Morgan. 1996. *Aquatic Chemistry*. Wiley-Interscience. 15 January.

Sweet, Edwards and Associates. 1985. *Duwamish Groundwater Study*. Prepared for Municipality of Metropolitan Seattle. Seattle, Washington. 13 May.

Task Force. 2003. *Area-Wide Soil Contamination Task Force Report*. 30 June.

Tchobanoglous, Theisen, and Vigil. 1993. *Integrated Solid Waste Management: Engineering Principles and Management Issues*. McGraw Hill.

Thorson, R.M. 1980. “Ice-Sheet Glaciation of the Puget Lowland, Washington, during the Vashon Stade (late Pleistocene).” *Quaternary Research* 13: 303–321.

URS. 2009. *No Report Available. 90 pages of tables, figures, and lab reports were transmitted by Farallon Consulting to Floyd|Snider in 2012; these pages had previously been transmitted by URS to Farallon and represent work performed by URS for Harsch Investment Properties at the Kenyon Industrial Park. Dates on the materials indicate the work was performed in 2007 and 2008 and was “finalized” on April 17, 2009.*

U.S. Environmental Protection Agency (USEPA). 1981. *Presumptive Remedy for CERCLA Municipal Landfill Sites Directive.* OSWER Directive 9355.3–11.

U.S. Geological Survey (USGS). Seattle South, Washington 7.5 minute USGS Quadrangle. 1953, photo-revised 1981.

———. 1985. *Critical Review and Summary of Leachate and Gas Production from Landfills*. Office of Research and Development. Washington, DC. EPA/600-2-86-073. December.

———. 1994. Natural Background Soil Metals Concentrations in Washington State. Toxics Cleanup Program. October.

———. 1998. *Technical Protocol for Evaluating Natural Attenuation of Chlorinated Solvents in Ground Water, EPA 600-R-98-128*. September.

———. 2000. *Engineered Approaches to In-Situ Bioremediation of Chlorinated Solvents: Fundamentals and Field Applications, EPA 542-R-00-008*. July.

———. 2010. *Microbial Oxidation of Vinyl Chloride Under Iron-reducing Conditions*. http://www.toxics.usgs.gov/sites/solvents/oxidation_VC.html. Last accessed 2/28/2012. 2 July.

———. 2011. *Management of Low Levels of Landfill Gas*. Prepared by Golder Associates for USEPA. April.

Vanden Berg et al. 2006. *The 2005 World Health Organization Re-evaluation of Human and Mammalian Toxic Equivalency Factors for Dioxins and Dioxin-like Compounds*. Toxicological Sciences 93(2): 223-241.

Washington State Department of Ecology (Ecology). 1994. Natural Background Soil Metals Concentrations in Washington State. Toxics Cleanup Program. Publication #94-115. October.

———. 2005. *Focus on Developing Ground Water Cleanup Standards Under the Model Toxics Control Act*. Department of Ecology's Toxics Cleanup Program. April.

———. 2007. *Workbook Tools for Calculating Soil and Ground Water Cleanup Levels Under the Model Toxics Control Act Cleanup Regulation.* Olympia, Washington. December.

———. 2009a. *Public Participation Plan, South Park Landfill, Seattle, Washington.* Seattle, Washington. March.

———. 2009b. *Email Message Regarding South Park Landfill*. From Richard Robohm, Wetland Specialist to James H. Carsner, Senior Biologist, Grette Associates, LLC. 23 March.

———. 2009c. *Guidance for Evaluating Soil Vapor Intrusion in Washington State: Investigation and Remedial Action.* Appendix B. Review Draft. Publication No. 09-09-047. October.

———. 2011a. *Urban Seattle Area Soil Dioxin and PAH Concentrations Initial Summary Report*, Publication No. 11-09-049. Prepared for Ecology by Hart Crowser. September.

———. 2011b. *Washington Soil Dioxin Study Results.* Publication No. 11-09-219. September.

Washington State Department of Transportation (WSDOT). 1957. *Washington State Highway Commission SR 509 Burien to JCT. P.S.H. No. 1 Right-of-Way Plans*.

Wendlick, Joseph D. 1997. *Investigative Determination and Characterization of Intramural Aerial Methane Gas Concentrations at Various Businesses Comprising Kenyon Business Park* (South Park District of Seattle, Washington). Prepared for Jack B. Jacobson, Washington Federal Savings. 5 September.

WHPacific, Inc. 1997. *Draft Report South Park Landfill Development*. 1 June.

Williams, Paul T. 2005. *Waste Treatment and Disposal, Second Edition*. John Wiley & Sons, Ltd.; West Sussex, England.

WindWard Environmental. 2010. *Lower Duwamish Waterway Remedial Investigation Report*. Seattle, Washington. 9 July.

South Park Landfill Remedial Investigation/ Feasibility Study June 2014 Draft

Draft Document – Subject to Ecology Review and Revision

This draft document is being made available for information purposes only.

It does not constitute approval by the State of Washington Department of Ecology

South Park Landfill

Remedial Investigation/ Feasibility Study

Tables

Table 2.1
Owners and Tax Parcels

King County Tax Payer	King County Parcel Number	Land Area (acres)	Comments
Harsch Investment Properties, LLC	3224049007	6.49	Kenyon Industrial Park
7901 2nd Ave S, LLC	3224049077	0.72	Adjacent to Kenyon Industrial Park
Seattle, City of, SPU-SWU	7328400005	10.3	South Transfer Station
South Park Development	3224049005	21.0	South Park Property Development LLC
Lenci Frank Corporation	3224049045	2.77	South of South Sullivan Street

Abbreviation:
SPU-SWU Seattle Public Utility – Solid Waste Utility

Table 2.2
Summary of Regional Investigations

Title	Reference	Primary Scope and Contents	Report Findings[1]
Duwamish Groundwater Study	Sweet, Edwards and Associates (1985)	• Identified target investigations to address contaminant contribution to Duwamish Waterway. • Analyzed three groundwater monitoring programs to evaluate contaminant loading to Duwamish Waterway.	• Provided information regarding site hydrogeology. • Identified potential contamination from sites upgradient of the Duwamish Waterway.
Duwamish Industrial Area Hydrogeologic Pathways Project: Duwamish Basin Groundwater Pathways Conceptual Model Report	Hart Crowser, Inc. (1998)	• Improved understanding of regional hydrogeologic conditions within the Lower Duwamish River Basin. • Formulated beneficial use strategy for shallow groundwater; groundwater was identified as a potential impact to surface water.	• Further developed the understanding of hydrogeologic conditions that define groundwater, including: geologic history and framework, aquifer and aquitard occurrence, recharge and discharge factors, groundwater flow patterns, and groundwater quality.
Lower Duwamish Waterway Remedial Investigation Report	WindWard Environmental (2010)	• Identified extent and sources of contamination to the Lower Duwamish Waterway. • Provided baseline Risk Assessment to identify areas of cleanup. • Included data on tissue studies, organism surveys, and groundwater/porewater/sediment characterization. • Provided a list of CSCSs, RCRA and CERCLA properties, registered Brownfield properties, and LUSTs within the Lower Duwamish Waterway study area.	• Provided a summary of nearby CSCSs. • Looked at upland sources of contamination to the Lower Duwamish Waterway. • Identified the South Park Landfill as a potential upland source to the Lower Duwamish Waterway.

Note:
1 Report findings relevant to the South Park Landfill.

Abbreviations:
CERCLA Comprehensive Environmental Response, Compensation, and Liability Act
CSCS Confirmed or Suspected Contaminated Site
LUST Leaking underground storage tank
RCRA Resource Conservation and Recovery Act
RI/FS Remedial Investigation/Feasibility Study

Table 2.3
Summary of Previous Adjacent Investigations

Site	Title	Reference[1]	Primary Scope and Contents	Report Findings[2]
Former Glitsa Property	Not Available	Bison Environmental Northwest (1992)	• Advanced three exploratory soil borings through UST.	• Mineral spirits exceeded MTCA Method A CULs in soil surrounding a 7,500-gallon UST.
	Phase 1 Environmental Site Assessment and Hazardous Materials Survey	Eco Compliance Corporation (2007)	• Environmental review was conducted to identify recognized environmental conditions associated with the property.	• On-site soil and groundwater contamination, and possible methane gas were suspected. • Known contamination from a 6,000-gallon Stoddard-solvent UST.[3] • Suspect that a 7,500-gallon UST exists on the property.[3]
	Not Available	Environmental Associates (2008)	• Soil sampling and monitoring well installation at four locations (MW-1 to MW-4). • One boring (B-5) advanced.	• No report available.
	Underground Storage Tank Removal Report and Checklist—Former Glitsa Property, Seattle, Washington	Environmental Associates (2009b)	• Removal of 7,500-gallon Stoddard-solvent LUST and contaminated soils. • Confirmation sampling to assess removal of Stoddard-solvent impacted soil (N-6, S-6, E-6, W-4, B-12, B-12, and PSC 1). • Collected three follow-up soil samples (RE-W-6, RE-NW-6, and RE-SW-6).	• Removed LUST and 120 tons of contaminated soil. • Confirmation samples exceeded MTCA Method A CULs for Stoddard-solvent (W-4 and PSC-1), ethylbenzene (W-4) and xylenes (W-4 and PSC-1). • Removed an additional 58 tons of contaminated soil. • Follow-up confirmation samples contained Stoddard-solvent, ethylbenzene, and xylenes (RE-W-6 and RE-SW-6).
	Supplemental Exploration and Further Remediation Feasibility Study—Former Glitsa, Inc. Property, Seattle, Washington	Environmental Associates (2009a)	• Supplemental soil and groundwater investigation adjacent to the LUST. Installation of monitoring wells and soil sampling at two locations (MW-5 and MW-6). • Targeted soi sampling in potentially impacted areas related to a former auto-wrecking yard/maintenance area and within the Glitsa warehouse. Advanced two soil borings (LAR1 and AR2). • Developed remediation alternatives, including a vapor extraction system, and advanced six soil borings for further soil and groundwater contaminant delineation. Included soil and groundwater sampling for HVOCs. Completed vapor extraction wells (HA1/VES-1 to HA6/VES-6). • Sampled stockpile of topsoil located on the southern portion of the site (SS-1).	• Several soil samples exceeded MTCA Method A CULs for Stoddard-solvent (LAR2, HA1/VES-1, HA3/VES-3, and HA4/VES-4), ethylbenzene (HA4/VES-4) and total xylenes (LAR2, HA1/VES-1, and HA4/VES-4). • Groundwater samples from monitoring wells/soil borings exceeded MTCA Method A CULs for Stoddard-solvent (MW-1, MW-4, LAR2, VES-4, VES-5, and VES-6), benzene, (LAR2 and VES-4), and vinyl chloride (LAR2). Other HVOCs were detected. • Site Feasibility Study indicated remediation/site stabilization plan. It was mentioned that Soil Vapor Extraction and free-phase solvent recovery, should be effective.
	Independent Cleanup Action Status Report—Former Glitsa Property, Seattle, Washington	Environmental Associates (2010)	• Evaluated existing remediation system.	• Determined that the remediation system appears to be effectively removing the contaminated mass beneath the site.

Table 2.3
Summary of Previous Adjacent Investigations

Site	Title	Reference[1]	Primary Scope and Contents	Report Findings[2]
Former South Kenyon Street Bus Yard	Site Assessment and Closure Report, Ryder Student Transportation Services, Inc.	Clearwater Group (1999)	• Removed and closed three 12,000-gallon USTs (one gasoline UST and two diesel fuel USTs). • Soil borings were advanced at three locations and were converted to monitoring wells (MW-1 to MW-3). • Seven soil borings were advanced (SB-1 to SB-3, CD, ES, ESD, and WSD).	• Petroleum hydrocarbon-contaminated soil surrounding the removed USTs and fueling station was documented. • Determined releases of petroleum compounds and/or metals occurred on-site. Historical operations may have also impacted soil and groundwater, with potential releases of metals, petroleum compounds, and solvents.
	Phase I Environmental Assessment Report, Bus Yard Properties	G-Logics (2007)	• Phase I Environmental Site Assessment was conducted.	• No report available.
	Remedial Investigation Report, South Kenyon Street Bus Yard	AMEC Earth and Environmental, Inc. (2009a)	• Advanced 75 soil borings (SB1, B3 to B5, DB6, DB9, B10 to B46 and B49 to B80). • Soil and groundwater samples were collected at 17 locations, which were converted to groundwater monitoring wells (MW-4 to MW-20).	• Petroleum hydrocarbons were found to exceed MTCA Method A CULs in four of the primary soil samples where the former auto-wrecking facility was located. • Diesel-range hydrocarbons were found at one location and oil-range hydrocarbons and chromium were found at two locations. CPAHs were also identified. • Other chemicals (benzene, total xylenes, MTBE, methylene chloride, and naphthalene) were detected in soil at levels greater than the MTCA Method A CULs. • Areas of CKD fill contained elevated levels of arsenic, cadmium, and lead in soils at levels exceeding the MTCA Method A CULs. Other areas (non-CKD fill areas) also contained elevated metals. • Contaminants in groundwater exceeding MTCA Method A CULs include: gasoline-range hydrocarbons (MW-9); diesel-range hydrocarbons (MW-6); toluene, total xylenes, and MTBE (MW-9); and benzene (MW-6 and MW-9). • Concentrations of 1-methynaphthalene (MW-6), benzo(a)anthracene (MW-2, B-3, B-4, B-5, B-10, B-11, and B-12), benzo(b)fluoranthene (MW-2), and chrysene (B-10 and B-12) in groundwater exceed MTCA Method B CULs. • Arsenic and lead in groundwater exceed MTCA Method A CULs. • Pesticides and herbicides (alpha-BHC, beta-BHC, dieldrin, heptachlor, and heptachlor epoxide) and the herbicide MCPA in groundwater were detected at levels exceeding the MTCA Method B CULs at MW-9 and MW-6, respectively.

Table 2.3
Summary of Previous Adjacent Investigations

Site	Title	Reference[1]	Primary Scope and Contents	Report Findings[2]
Former South Kenyon Street Bus Yard (continued)	Focused Feasibility Study, South Kenyon Street Bus Yard	AMEC Earth and Environmental, Inc. (2009b)	• Focused Feasibility Study.	• Established remedial action objectives. • Developed and evaluated remedial alternatives. • Selected appropriate remedial alternative; removal, and off-site disposal of contaminated soil.
	Cleanup Action Plan, South Kenyon Street Bus Yard	AMEC Earth and Environmental, Inc. (2009c)	• Cleanup Action Plan.	• Presented approach for the removal of contaminated soil; included removal of 10–12 feet of CKD from existing swale.

Notes:
1 Documents cited in this column are referenced in Section 18.0 or this Ri/FS.
2 Report findings relevant to South Park Landfill.
3 Subsequent investigations by Environmental Associates (2009a, 2009b, and 2010) indicated the presence of a single 7,500-gallon Stoddard-solvent UST.

Abbreviations:
BHC Alpha-hexachlorocyclohexane
CKD Cement kiln dust
CPAH Carcinogenic polycyclic aromatic hydrocarbon
CUL Cleanup level
Glitsa Glitsa American, Inc.
HVOC Halogenated volatile organic compound
LUST Leaking underground storage tank
MCPA 2-methyl-4-chlorophenoxyacetic acid
MTBE Methyl tert-butyl ether
MTCA Model Toxics Control Act
RI/FS Remedial Investigation/Feasibility Study
UST Underground storage tank

Table 2.4
Summary of Prior Investigations

Title	Reference[1]	Primary Scope and Contents	Report Findings
• Abandoned Landfill Study in the City of Seattle	• Seattle-King County Department of Public Health (1984)	• Eleven bore holes to monitor landfill gases (1 to 11) were advanced. • One water sample was collected from the West Ditch (A).	• Two bore holes located within the north central portion of the Landfill had methane concentrations of 9 percent and 14 percent, which are within the explosive range. • Additional methane and non-specific organic/inorganic testing to evaluate the site was recommended. • A water sample from the West Ditch did not indicate impact from leachate.
• Abandoned Landfill Toxicity/Hazard Assessment Project	• Seattle-King County Department of Public Health (1986)	• Four water samples were collected from the East-West Channel and the West Ditch (W-01 to W-04). • Seven surface soil samples were collected from SRDS (SA-A to SA-G). • Three soil vapor locations were monitored for VOCs (OG-A to OG-C). • Twenty-one LFG probes (CG-1 to CG-21) were monitored for landfill gases.	• The detection of combustible gases led to the recommendation of monitoring during construction activities within 1,000 feet of the Landfill. • Water samples from W-1 and W-2 had greater levels of metals than other water samples. • Surface soil samples contained elevated concentrations of heavy metals and PAHs. • One significant combustible gas level was detected approximately 80 feet south of the KIP parcel.
• Quality Risk Assessment: King County Landfills	• Environmental Toxicology International (1986)	• Assessed if chemicals present at the Landfill created a toxic or hazardous environment.	• Indicated that although heavy metal concentrations in water and heavy metal and PAHs in surface soil were greater than background concentrations, elevated concentrations were likely due to the industrial nature of the area and did not pose a public health hazard.
• Site Inspection Report for South Park Landfill	• Ecology and Environment, Inc. (1988)	• Six water samples (SW-01 to SW-06) and six corresponding "sediment" samples (SS-01 to SS-06) were collected from the East-West Channel and the West Ditch.	• One water sample (SW-4) had pesticides/insecticides and PCBs at levels greater than background. • Report concluded that landfill waste, natural weathering of soils, and automobile emissions could be responsible for elevated concentrations. • Data did not indicate that contaminants were migrating off-site.
• Unknown	• Unknown (1989)	• Four soil borings were advanced.	• No information or report available (Farallon 2010b).
• Report to the Sammis Company on Monitoring Well Installation and Soil, Groundwater, and Gas Sampling—The Sammis Company Industrial Parks, Seattle, Washington	• Golder Associates, Inc. (1989)	• Four monitoring wells (KMW-01, KMW-02, KMW-02B, and KMW-03) were installed. • Advanced three soil borings that were converted to monitoring wells (KMW-01, KMW-02, KMW-02B). • Conducted a LFG survey and installed nine soil gas probes (SG-01 to SG-09), which were monitored for LFG. • Assessed indoor ambient air of four buildings on the KIP parcel for combustible LFG.	• Groundwater data indicated elevated concentrations of chlorobenzene, benzene, and methyl chloride in KMW-02B and also in soil samples collected at this location. • Low concentrations of chlorobenzene, benzene, and 1,2-dichloroethene were found in KMW-01. • Methane ranged from 0.001 percent to 30 percent for the nine samples.
• Subsurface Exploration Geotechnical Engineering, and Environmental Assessment Report—South Park Detention Project, Seattle, Washington	• RZA Agra (1992a)	• Ten soil borings (RB-01 to RB-10) were advanced and eight were converted to monitoring wells (RMW-01 to RMW-08). • Aquifer test conducted at Well RMW-08.	• Groundwater quality data indicated that concentrations of TPHs (RMW-06 to RMW-08) and chlorinated solvents (RMW-06 and RMW-08) exceeded the MTCA Method A CULs.

Table 2.4
Summary of Prior Investigations

Title	Reference[1]	Primary Scope and Contents	Report Findings
• Subsurface Exploration Study—South Park Detention Project, Seattle, Washington	• RZA Agra (1992b)	• Two soil borings (RB-9 and RB-10) completed on east side of the 5th Avenue South right-of-way. • Three soil borings (RB-11 to RB-13) were later advanced north of South Kenyon Street.	• 5th Avenue South soil samples collected from borings RB-9 indicated concentrations of diesel-range TPH at levels less than MTCA Method A CULs. • South Kenyon Street soil samples analyzed for TCLP metals and diesel-range TPH were reported either as non-detect or less than MTCA Method A CULs.
• Phase II Environmental Site Assessment, Liberty/Sammis—Kenyon Industrial Park, Seattle, Washington	• Diagnostic Engineering, Inc. (1992)	• Eight soil borings (KB-01 to KB-08) were advanced and five were completed as monitoring wells (KMW-04 to KMW-08).	• Soil samples indicated elevated concentrations of petroleum hydrocarbons. Concentrations exceeded MTCA Method A CULs at several locations (KB-02, KB-03, KMW-04, KMW-05, and KMW-06). • VOCs were also detected in soil samples, but at levels less than MTCA Method A CULs. • Analytical results from these and other monitoring wells on-site indicated that concentrations of TPHs and VOCs (benzene) exceeded the MTCA Method A CULs in KMW-02B. • Chlorobenzene, chloroform, 1,2-dichlorobenzene, and 1,4-dichlorobenzene were also detected.
• Air Quality Investigation South Kenyon Stree Property, Seattle, Washington	• Professional Service Industries, Inc. (1993)	• Ambient indoor air of four buildings on the KIP parcel was screened for combustible organic vapors using a flame ionization detector and combustible gas indicator.	• The concentration of total organic vapors indoors was comparable to ambient background levels (4 to 12 ppm). • Elevated concentrations of total organic vapors were found around a leaking gas meter and in three downspout catch basins (40 to greater than 1,000 ppm).
• Extended Phase II Environmental Site Assessment—Seattle Kenyon Business Park, Seattle, Washington	• Blasland, Bouck, and Lee, Inc. (1995)	• Sampled ambient indoor air from seven building suites on the KIP parcel for explosive gases and organic vapor. • Combustible LFG monitored at 27 locations (EG-01 to EG-27). • Twenty-six temporary soil vapor probe locations (BH-01 to BH-09 and BH-11 to BH-27) were advanced (26 were sampled for methane and organic vapors, 4 for VOCs). • Six soil borings locations (HP-01 to HP-06) plus groundwater grab samples were collected. • Two monitoring wells (KMW-01A and KMW-03A) were installed.	• No methane was detected in any of the seven building suites. • One of the 27 combustible LFG locations had methane concentrations at levels greater than the laboratory detection limit (EG-23). • Twenty of 26 soil vapor locations detected methane at levels greater than the detection limit (0.0063 percent to 74 percent, median value 12.4 percent). • Thirteen of 26 locations had methane concentrations greater than the 5 percent methane LEL. • Some soil samples collected from these soil boring and monitoring well locations (KMW-01A, KMW-03A, HP-02, HP-04, and HP-06) contained petroleum hydrocarbons that exceeded the MTCA Method A CULs. • Groundwater quality data from previously installed monitoring wells and groundwater samples collected during this investigation indicated exceedances of MTCA Method A CULs, including: TPHs (KMW-05, HP-03, and HP-05), VOCs (KMW-02B, KMW-03A, KMW-05, KMW-6, HP-01, and HP-02), and RCRA metals (KMW-01A, KMW-02B, KMW-03A, KMW-04 to KMW-06, and HP-01 to HP-06).
• Investigative Determination and Characterization of Intramural Aerial Methane Gas Concentrations at Various Businesses Comprising Kenyon Business Park	• Joseph D. Wendlick (1997)	• Ambient indoor air was sampled for combustible gas in four buildings on the KIP parcel.	• Methane concentrations detected between 2 and 4 ppm in each of the buildings.

Table 2.4
Summary of Prior Investigations

Title	Reference[1]	Primary Scope and Contents	Report Findings
• No Report Available	• Udaloy Environmental Services (1997)	• Fourteen test pits (TP-1 to TP-14) were excavated. • Three soil borings (SB-01, SB-02, and SB-02A) were advanced with two converted into soil gas probes (GP-01 and GP-02). • Three water samples were collected from standing water at three locations (SE, SW, and SP).	• Both gas probe locations (GP-01 and GP-02) had methane concentrations within the explosive range. • Surface water samples had detections of metals, but no pesticides or PCBs.
• No Report Available	• Olympus Environmental, Inc. (1997)	• Ten test pits (TP-15 to TP-24) were excavated for environmental sampling of landfill cover material.	• Elevated concentrations of PCB compounds (TP-20 and TP-22), metals (TP-20 and TP-24) and petroleum compounds (TP-21 and TP-22) were found in some of the test pits.
• Memorandum Regarding Geotechnical Summary of South Transfer Station	• Seattle Public Utilities Materials Laboratory (1998)	• Twenty-six soil borings (TB-01 to TB-06, TB-07A to TB-07C, TB-08A to TB-08C, TB-09A to TB-09B, TB-10 to TB-11, TB-12A to TB-12B, and TB-13 to TB-20) were advanced.	• Proposed the installation of several new monitoring wells and recommended a comprehensive quarterly groundwater monitoring program.
• South Park Custodial Landfill Environmental Site Investigation Data Gaps Memorandum	• Associated Earth Sciences, Inc. (1998)	• Compiled existing information and identified data gaps. • Collected quarterly water samples from the East-West Channel (SE, SW, and SP). • Fourteen additional soil gas probes were installed to monitor LFG.	• Results indicated elevated concentrations of copper, lead, and zinc in water samples, with the greatest concentrations at the southeastern end of the Landfill. • King County conducted periodic surface water sampling between 1999 and 2004. • Recommended that quarterly groundwater monitoring be completed at all wells.
• South Park Custodial Landfill Surface Water Evaluation	• R. W. Beck, Inc. (1999)	• Evaluated stormwater issues related to development.	• Determined on-site and off-site options for providing surface water management for the SPPD parcel.
• Underground Storage Tank Closure and Site Assessment, South Transfer Station, Seattle, Washington	• Herrera Environmental Consultants, Inc. (1999)	• Sixteen soil borings (DSB-1 to DSB-3, GSB-1 to GSB-3, GHA-1 to GHA-2, DHA-1 to DHA-7, and DHA-9) were advanced on the SRDS property. • One monitoring well (HMW-01) was installed.	• Low-level diesel-range hydrocarbon and lead concentrations were detected in several of the soil samples collected in the vicinity of the USTs. • Groundwater samples collected at HMW-01 indicate the presence of BTEX compounds at concentrations that exceeded the MTCA Method A CULs (as of April 1997), but decreased to levels less than the CULs as of October 1998.
• South Park Custodial Landfill Cover Soils Investigation	• Associated Earth Sciences, Inc. (1999a)	• Forty-three additional test pits (TP-25 to TP-67) were excavated to characterize cover soils. • Presented results for 24 previously sampled test pits (TP-01 to TP-24).	• Results indicated that concentrations of PCBs (TP-39) and lead (TP-25, TP-27, TP-34, TP-56, and TP-63) were at levels great than the MTCA Method C soil CULs.
• South Park Custodial Landfill Geotechnical Evaluation Memorandum	• Associated Earth Sciences, Inc. (1999b)	• Geotechnical issues for redevelopment were addressed.	• Deep pile-supported foundations appear to be feasible for development at the Landfill. • A large percentage of surface cover soils could be re-compacted for base material support.

Table 2.4
Summary of Prior Investigations

Title	Reference[1]	Primary Scope and Contents	Report Findings
• South Park Custodial Landfill Monitoring Well and Gas Probe Installation Technical Memorandum	• Associated Earth Sciences, Inc. (2000)	• Eight monitoring wells (MW-04, MW-06, MW-08, MW-10, MW-12, MW-14, MW-18, and MW-24) were installed. • Fourteen soil gas probes (GP-03, GP-05, GP-07, GP-09, GP-11, GP-13, GP-15 to GP-17, and GP-19 to GP-23) were installed to monitor LFG. • Samples were collected from the soil gas probes and analyzed by USEPA Method TO-14 (October–November 2000). • Two geotechnical borings (SB-26 and SB-27) were advanced.	• Low levels of VOCs and petroleum hydrocarbons were detected upgradient of the Landfill. • Arsenic and vinyl chloride were the only groundwater constituents that exceeded the MTCA Method C CULs downgradient of the Landfill. • LFG was detected in gas probes completed in refuse within the landfill boundary. • Methane concentrations exceeded the 5 percent LEL along the eastern landfill boundary (GP-17). • Subsurface methane gas levels did not exceed regulatory limits between the landfill boundary and adjacent residential neighborhoods. • Geotechnical soil borings indicated competent bearing capacity between 40 and 45 feet bgs, but it was suggested that special pile design considerations might be necessary to prevent drag-down of impacted soil/groundwater or refuse material.
• No Report Available	• Associated Earth Sciences, Inc. and Aspect Consulting LLC (1999c)	• Conducted periodic groundwater, surface water, and LFG monitoring events (no report).	• No report available.
• South Park Custodial Landfill Conceptual Landfill Gas System Design	• R.W. Beck, Inc. (2001)	• Evaluated LFG collection and treatment options based on fieldwork and investigations conducted between 1997 and 2000.	• Concluded that soil gas monitoring probes located within the Landfill, or near the edge, contained subsurface methane at low, but variable levels. Concentrations appeared to vary with barometric pressure, rainfall, temperature, and time of day. • Hydrogen sulfide gas was detected in concentrations that would be dangerous if encountered within confined spaces at GP-21. • Concluded that the Landfill was similar in comparison to other municipal landfills closed since 1966.
• Shallow Groundwater Characterization Data Report—South Park Custodial Landfill	• Aspect Consulting, LLC (2006)	• Shallow groundwater was characterized in three monitoring wells (MW-25 to MW-27). • A groundwater monitoring sampling event (new Wells MW-25 to MW-27 and upgradient Wells MW-4, MW-12, and MW-14) occurred. • Site-wide groundwater levels were measured.	• These wells were paired with previously installed deeper monitoring wells (MW-8, MW-10, and MW-24) in order to compare groundwater quality in upper and lower groundwater bearing zones. • Select soil samples were submitted for physical testing of fractional organic carbon, bulk density, and effective porosity. • Groundwater was analyzed for HVOCs, vinyl chloride, ethene, and total and dissolved arsenic.
• Letter Report Regarding Landfill Cover Soil Sampling and Analysis for Polychlorinated Biphenyls, South Park Property Development Site	• Farallon Consulting, LLC (2007)	• Twenty-five test pits (C-01 to C-25) were excavated to investigate elevated PCB levels previously discovered.	• Elevated PCB levels were not detected and all samples were non-detections except one with a concentration of 90 µg/kg.

Table 2.4
Summary of Prior Investigations

Title	Reference[1]	Primary Scope and Contents	Report Findings
• No Report Available	• URS Corporation (2007)	• Results are summarized in tables (no report).	• No report available.
• Groundwater Monitoring and Sampling Results	• Farallon Consulting, LLC (2010b)	• Reported on the site-wide semi-annual groundwater monitoring program (2007 through 2009). • Installed six temporary groundwater sampling locations (FB-01 to FB-06).	• Summary of semi-annual groundwater and reconnaissance groundwater sampling.

Note:
1 Documents cited in this column are referenced in Section 18.0 of this RI/FS.

Abbreviations:
bgs Below ground surface
BTEX Benzene, toluene, ethylbenzene, and xylene
CUL Cleanup level
HVOC Halogenated volatile organic compound
KIP Kenyon Industrial Park
Landfill South Park Landfill
LEL Lower explosive limit
LFG Landfill gas
µg/kg Micrograms per kilogram
MTCA Model Toxics Control Act
PAH Polycyclic aromatic hydrocarbon
PCB Polychlorinated biphenyl
ppm Parts per million
RCRA Resource Conservation and Recovery Act
RI/FS Remedial Investigation/Feasibility Study
SPPD South Park Property Development, LLC
SRDS South Recycling and Disposal Station
TCLP Toxicity Characteristic Leaching Procedure
TPH Total petroleum hydrocarbons
USEPA U.S. Environmental Protection Agency
UST Underground storage tank
VOC Volatile organic compound

Table 3.1
Geologic Description of Regional Deposits

Imported Fill	
Historical Duwamish Valley development included the use of bulk fill to raise land elevations. Unclassified fill (non-solid waste) has been encountered immediately outside of the South Park Landfill boundary. The South Park Landfill boundary soil conditions will be discussed in Section 4.2. Fill depths are variable and may be more than 20 feet in the vicinity of the South Park Landfill. The composition and texture of the fill varies significantly, but generally consists of silt and/or sand with some gravel and organics. In addition, the fill can often contain brick fragments and woody debris, as observed in soil borings completed near the South Park Landfill (MW-01, MW-03, MW-04, and MW-14). The valley-wide unclassified fill is distinct from the solid waste material deposited into the South Park Landfill.	
Alluvial Channel and Flood Deposits	
• Younger Alluvium (Q_{yal}) • Alluvium (Q_{al})	Include both alluvial channel and overbank flood deposits. Alluvial channel deposits consist of interbedded sand, silty sand, and silt. Overbank flood deposits generally consist of interbedded sand and silt with abundant organic matter.
Estuarine Sediment Deposits	
Estuarine deposits can extend to depths of more than 100 feet in the center of the Duwamish Valley, but are usually present at shallower depths (40 to 50 feet) and are thinner near the edge of the valley. The estuarine deposits typically consist of sand and silty sand in the upper portion of the sequence and transition to a sandy silt toward the base of the sequence (Hart Crowser 1998). Estuarine deposits are often characterized by the presence of shell fragments	
Glacial Sediment Deposits	
The maximum depth of the glacial deposits in the center of the Duwamish Valley is unknown. Glacial deposits are exposed at the surface along the edges of the valley and the uplands (Figure 3.1).	
• Vashon Recessional Outwash (Q_{vr})	Deposited by rivers and streams emerging from the base of the retreating ice sheet; generally consists of fine- to coarse-grained sand with gravel and occasional silt lenses.
• Vashon Subglacial Till (Q_{vt})	Formed from the melt-out of debris at the base of the ice sheet; generally consists of a gravelly, silty to very silty sand. Glacially consolidated.
• Vashon Advance Outwash (Q_{va})	Deposited by rivers and streams during the advance of the ice sheet; generally consists of sand with some gravel and silts. Glacially consolidated.
• Lawton Clay Member, Vashon Drift (Q_{vlc})	Accumulated in lakes formed by the impoundment of drainages by the advancing ice sheet; generally consists of silt and clay. Glacially consolidated.

Table 4.1
Historical Operations and Owners

Date	Current Parcels	Owner	Activity	Aerial Photograph[1]
1936 and Earlier				
1922	SRDS	King County	First Addition River Park (South Recycling and Disposal Station [SRDS]) added to King County Tax Rolls via foreclosure (SPU 1997).	
1927	SPPD	King County	Tax Lot 5 (South Park Property Development [SPPD]) added to King County Tax Rolls via foreclosure (SPU 1997).	
1934	KIP, SPPD	King County	Reported dumping of garbage and rubbish on Kenyon Industrial Park (KIP) and SPPD parcels and sawdust fill on southern portion of SPPD parcel (Seattle Engineering Department 1934).	
1936 to 1941				
1936	KIP, SPPD	King County	Active dumping of rubbish on KIP and SPPD parcels.	X
1941	KIP, SPPD	King County	Continued active dumping of rubbish on KIP and SPPD parcels. Open burning of refuse was occurring.	X
1941 to 1956				
1946	SRDS	King County	Active dumping of rubbish expanded onto SRDS parcel. Open burning of refuse was occurring.	X
1948	SRDS, KIP, SPPD	King County	Open burning of rubbish was documented (AESI 1998).	
1951	SRDS, KIP	City of Seattle	First Addition River Park (SRDS) and Tax Lot 7 (KIP) were purchased by the City of Seattle out of Tax Title Status (SPU 1997).	
1955	KIP	John Farrell	John Farrell purchased the northwest corner of Tax Lot 7 (KIP); waived right to file claims related to burning of rubbish (SPU 1997).	
1956	SRDS, KIP, SPPD	City of Seattle and King County	Auto-wrecking yards developed on KIP and SPPD parcels. Aerial photograph evidence of active burning of rubbish on SRDS parcel.	X
1956 to 1960				
1957	SPPD	King County	King County (Health Department) purchased Tax Lot 5 (SPPD) out of Tax Title Status (SPU 1997).	
1958	SPPD	King County	King County leased SPPD property to City of Seattle for rubbish disposal (10-year period). Deeded southwest portion of Tax Lot 5 (SPPD) to the State of Washington for SR 509 (SPU 1997).	
1960	SRDS, SPPD	City of Seattle and King County	Expansion of active dumping of rubbish on SRDS and SPPD parcels. Aerial photograph evidence of active burning of rubbish.	X
1960 to 1969				
1961	SRDS, SPPD	City of Seattle and King County	Reported end of rubbish burning (Farallon 2010b).	
1963	SRDS, KIP, SPPD	City of Seattle and King County	Filling and grading activities on SRDS, KIP, and SPPD parcels.	X
1965 to 1966	SPPD	King County	King County deeded eastern portions of SPPD parcel to the City of Seattle for streets (SPU 1997).	
1966	SRDS	City of Seattle	SRDS parcel stopped receiving rubbish (SPU 1997; Ecology and Environment, Inc. 1988).	
1967	SRDS	City of Seattle	SRDS completed and opened.	X
1967	KIP	City of Seattle	Initial development of KIP (two buildings).	X
1967	SPPD	King County	East-West Channel constructed.	X
1967	KIP, SPPD	City of Seattle and King County	Continued filling and grading activities on KIP and SPPD parcels.	X
1968	SPPD	King County	City of Seattle renewed its lease from King County for clean fill and earthen material disposal for 10-year period (SPU 1997).	
1969	SPPD	King County	Continued filling and grading activities on SPPD parcel. Re-alignment of South Sullivan Street.	X
1969 to 1980				
1974	KIP	City of Seattle	Completion of development of KIP (total of four buildings, as well as paved surfaces across entire parcel). Completion of KIP main stormwater line.	X

Table 4.1
Historical Operations and Owners

Date	Current Parcels	Owner	Activity	Aerial Photograph[1]
1969 to 1980 (continued)				
1974	SPPD	King County	Grading activities continue on SPPD parcel.	X
1976	SPPD	King County	City of Seattle submitted request to purchase the SPPD parcel (SPU 1997).	
1977	SPPD	King County	A portion of the SPPD parcel was used for storage. Filling and grading was occurring on the property.	X
1978	SPPD	King County	City of Seattle's lease of SPPD parcel expired (SPU 1997).	
1979 to 1984	SPPD	King County	Negotiations between King County and City of Seattle for purchase of SPPD parcel (SPU 1997).	
1980	SPPD	King County	Continued storage on SPPD parcel.	X
1980 to 1997				
1982	SPPD	King County	Continued storage on SPPD parcel.	X
1984	SPPD	King County	King County leased the SPPD parcel to multiple entities (AESI 1998).	
1985	SPPD	King County	Continued leased storage on SPPD parcel.	X
1986	KIP	Liberty Service Corporation	Northwest corner of Tax Lot 7 (KIP) purchased by Liberty Service Corporation from John Farrell (King County Parcel Viewer).[2]	
1990	SPPD	King County	Continued leased storage on SPPD parcel.	X
1992	SPPD	King County	Continued leased storage on SPPD parcel.	X
1995	SPPD	King County	Continued leased storage on SPPD parcel.	X
1996	SPPD	King County	Continued leased storage on SPPD parcel.	X
1997	SPPD	King County	Continued leased storage on SPPD parcel.	X
1997	KIP	Statewide Mortgage Service Corporation	Northwest corner of KIP parcel purchased by Statewide Mortgage Service Corporation from Liberty Service Corporation via foreclosure (King County Parcel Viewer).[2]	X
1997 to Present				
2000	SPPD	King County	SPPD parcel no longer leased for storage; King County actively pursued sale of parcel.	X
2002	SPPD	King County	No activity.	X
2004	SPPD	King County	No activity.	X
2005	KIP	John Hill	Northeast corner of KIP parcel purchased by John Hill from Janice Farrell (King County Parcel Viewer).[2]	
2005	KIP	7910 2nd Avenue South, LLC	Northeast corner of KIP parcel purchased by 7901 2nd Avenue South, LLC from John Hill (King County Parcel Viewer).[2]	
2006	SPPD	SPPD	SPPD parcel sold to SPPD in June 2006 (Farallon 2010b). Parcel was cleared of vegetation and crushed concrete was added to amend the grade.	
2008	KIP	Harsch Investment Properties, LLC	Northwest corner of KIP parcel purchased by Harsch Investment Properties, LLC from Statewide Mortgage Service Corporation (King County Parcel Viewer).[2]	

Notes:
1 Aerial photographs are presented in Appendix A.
2 Information taken from the King County Parcel Viewer (http://www.kingcounty.gov/operations/gis/propresearch/parcelviewer.aspx) in October 2011.

Abbreviations:
KIP Kenyon Industrial Park
SPPD South Park Property Development, LLC
SRDS South Recycling and Disposal Station

Table 4.2
Frequency of Detections and Exceedances in Historical Soil/Landfill Samples on the SPPD Parcel

Chemical	Unit	Number of Results	Number of Detected Results	Percent of Detected Results	Minimum Detected Value	Maximum Detected Value	MTCA Method C Cleanup Level	Exceeds MTCA Method C
Volatile Organic Compounds								
Acetone	µg/kg	71	8	11%	33	270	Not toxic	No
Methylene Chloride	µg/kg	71	45	63%	17	53	18,000,000	No
Semivolatile Organic Compounds: PAHs and Phthalates								
CPAHs as BaP TEQ using half RL	µg/kg	78	28	36%	55	3,100	18,000	No
CPAHs as BaP TEQ using zero as RL	µg/kg	78	27	35%	0.52	3,100	18,000	No
Benzo(a)anthracene	µg/kg	78	13	17%	140	2,900	Evaluated as total CPAHs calculated as a BaP toxicity equivalent quotient (refer to CPAHs as BaP TEQ above)	
Benzo(a)pyrene	µg/kg	78	8	10%	79	2,200		
Benzo(b)fluoranthene	µg/kg	78	13	17%	79	2,800		
Benzo(g,h,i)perylene	µg/kg	78	4	5%	200	750		
Benzo(j)fluoranthene	µg/kg	78	5	6%	150	1,800		
Chrysene	µg/kg	78	27	35%	52	3,200		
2-Methylnaphthalene	µg/kg	78	4	5%	110	380	14,000,000	No
Acenaphthene	µg/kg	78	5	6%	45	290	210,000,000	No
Fluoranthene	µg/kg	78	30	38%	43	3,400	140,000,000	No
Fluorene	µg/kg	78	4	5%	110	350	140,000,000	No
Naphthalene	µg/kg	78	5	6%	41	1,000	70,000,000	No
Phenanthrene	µg/kg	78	15	19%	120	2,000	R-ND	No
Pyrene	µg/kg	78	23	29%	83	3,200	110,000,000	No
bis(2-ethylhexyl)phthalate	µg/kg	78	27	35%	86	27,000	9,400,000	No
Di-n-octyl phthalate	µg/kg	78	4	5%	190	710	R-ND	No
Polychlorinated Biphenyls[1]								
PCB Aroclor 1254	µg/kg	71	13	18%	130	4,300	10,000	No
PCB Aroclor 1260	µg/kg	71	17	24%	79	18,000	10,000	No, refer to text
Total PCBs	µg/kg	71	22	31%	79	18,000	10,000	No, refer to text
Herbicides and Pesticides								
Dieldrin	µg/kg	71	9	13%	8.2	500	380000	No
p,p'-DDD	µg/kg	71	8	11%	8.2	2,600	550,000	No
p,p'-DDE	µg/kg	71	4	6%	12	51	390,000	No
p,p'-DDT	µg/kg	71	7	10%	7.6	78	390,000	No
Petroleum Hydrocarbons								
Diesel-range Hydrocarbons	mg/kg	76	9	12%	32.1	2,580	7,000 [2]	No
Motor Oil-range Hydrocarbons	mg/kg	92	37	40%	37.1	5,940	7,000 [2]	No
Metals[3]								
Antimony	mg/kg	73	18	25%	6.1	110	1,400	No
Arsenic	mg/kg	73	73	100%	2	180	88	**Yes**
Cadmium	mg/kg	73	30	41%	1	34	3,500	No
Chromium	mg/kg	73	73	100%	12	260	5,250,000	No
Copper	mg/kg	73	73	100%	9	4,300	130,000	No
Lead	mg/kg	73	70	96%	9.6	6,800	1,000 [4]	**Yes**
Mercury	mg/kg	73	31	42%	0.1	5	1,050	No
Nickel	mg/kg	73	73	100%	8	770	70,000	No
Silver	mg/kg	73	12	16%	1.3	80	17,500	No
Zinc	mg/kg	73	73	100%	29	7,900	1,100,000	No

Notes:

(grey shading) Mixture of CPAHs considered for toxicity equivalency quotient calculations.

Lead Highlighted chemical is a chemical of concern for this media.

PCB Chemical was considered for inclusion as a chemical of concern but not retained. Refer to Section 4.3.1.1 in the text for details.

1 The MTCA Method A value for industrial soil has been used in place of MTCA Method C value that conflicts with a Federal ARAR. The following is a footnote from MTCA for the Method A value: "Cleanup level based on applicable federal law (40 C.F.R. 761.61). This is a total value for all PCBs. This value may be used only if the PCB contaminated soils are capped and the cap maintained as required by 40 C.F.R. 761.61. If this condition cannot be met, the

2 A site-specific MTCA Method C Cleanup Value was calculated using Washington State Department of Ecology's MTCATPH11.1 worksheets.

3 Natural Background Soil Metals Concentrations in Washington State (Ecology 1994), Statewide 90th Percentile Values are as follows: arsenic—7 mg/kg, cadmium—1 mg/kg, chromium—42 mg/kg, copper—36 mg/kg, lead—17 mg/kg, mercury—0.07 mg/kg, nickel—38 mg/kg, and zinc—86 mg/kg; however, the arsenic value was reevaluated and a value of 20 mg/kg replaced the 1994 Ecology value (Task Force 2003)

4 MTCA Method A value was used for industrial soils for lead, as no Method B or C values exist.

Abbreviations:

ARAR Applicable or Relevant and Appropriate Requirement
BaP Benzo(a)pyrene
CPAH Carcinogenic polycyclic aromatic hydrocarbon
DDD Dichlorodiphenyldichloroethane
DDE Dichlorodiphenyldichloroethylene
DDT Dichlorodiphenyltrichloroethane
FOD Frequency of detection
FOE Frequency of exceedance
µg/kg Micrograms per kilogram
mg/kg Milligrams per kilogram
MTCA Model Toxics Control Act
PAH Polycyclic aromatic hydrocarbon
PCB Polychlorinated biphenyl
RL Reporting limit
R-ND The chemical was researched by the Washington State Department of Ecology, and no toxicity data of acceptable quality was found
SPPD South Park Property Development, LLC
TEQ Toxic equivalency quotient

Table 4.3

Chemicals Detected in West Ditch Solids Samples[1]

Location		SS-01	SS-01	SS-01	SS-02	SS-02	SS-02[2]	SS-02	SS-03	SS-03	SS-03	SS-P
Sample Date		12/6/2010	12/6/2010	12/6/2010	12/6/2010	12/6/2010	12/6/2010	12/6/2010	12/6/2010	12/6/2010	12/6/2010	12/8/2010
Depths (ft bgs)		0–2	2–4	4–6	0–2	2–4	2–4	6–8	0–2	2–4	4–6	0–0.5
Chemical	**Unit**											
Semivolatile Organic Compounds (USEPA Method 8270D/8041[3])												
CPAHs as BaP TEQ using Half RL	µg/kg	**200**	**120** J	24 U	**170** J	**230** J	**270** J	**240** J	**600** J	**38** J	**1,100** J	**53**
CPAHs as BaP TEQ using zero as RL	µg/kg	**200**	**110** J	34 U	**170** J	**220** J	**260** J	**230** J	**600** J	**34** J	**1,100** J	**51**
Benzo(a)anthracene	µg/kg	**120**	**110**	34 U	**230**	**130**	**220**	**110** J	**370** J	**34** J	**710**	**34**
Benzo(a)pyrene	µg/kg	**150**	**80**	34 U	**120**	**170**	**190**	**180**	**430**	**26** J	**870**	**39**
Benzo(g,h,i)perylene	µg/kg	**87**	**68** J	34 U	**59** J	**130**	**120**	**110** J	**400**	**22** J	**470**	**24**
Benzofluoranthenes (Total)	µg/kg	**260**	**140**	34 U	**210**	**290**	**370**	**300**	**1,000**	**41**	**1,200**	**81**
Chrysene	µg/kg	**120**	**220**	34 U	**180**	**300**	**400**	**300**	**570** J	**48**	**1,000**	**65**
Indeno(1,2,3-cd)pyrene	µg/kg	**72**	**46** J	34 U	**50** J	**99** J	**97** J	**85** J	**250**	38 U	**380**	23 U
1-Methylnaphthalene	µg/kg	**48** J	74 U	34 U	76 U	110 U	110 U	110 U	180 U	38 U	**99**	23 U
2-Methylnaphthalene	µg/kg	**140**	74 U	34 U	76 U	110 U	110 U	110 U	180 U	38 U	**160**	23 U
Acenaphthene	µg/kg	**110**	**170**	34 U	**230**	**210**	**250**	**200**	**120** J	**25** J	**200**	23 U
Acenaphthylene	µg/kg	59 U	74 U	34 U	76 U	110 U	110 U	110 U	180 U	38 U	**36**	23 U
Anthracene	µg/kg	**53** J	74 U	34 U	**62** J	**120**	**180**	**97** J	180 U	38 U	**350**	**12** J
Fluoranthene	µg/kg	**430**	**430**	**73**	**520**	**640**	**1,300**	660	**810**	**89**	**2,000**	**80**
Fluorene	µg/kg	**90**	**130**	34 U	**74** J	110 U	**160**	**63** J	180 U	**32** J	**200**	23 U
Naphthalene	µg/kg	59 U	74 U	34 U	76 U	110 U	110 U	110 U	180 U	38 U	**210**	23 U
Phenanthrene	µg/kg	**210**	**1,400**	**98**	**66** J	**160**	**580**	**170**	**240**	**91**	**1,900**	**43** J
Pyrene	µg/kg	**400**	**530**	**56**	**480**	**710**	**1,100**	**690**	**1,100**	**93**	**1,900**	**100**
bis(2-ethylhexyl)phthalate	µg/kg	330 U	5,700 U	280 U	**850**	520 U	**920**	**900**	**8,400**	220 U	230 U	**370**
Butyl benzyl phthalate	µg/kg	59 U	74 U	34 U	76 U	110 U	110 U	110 U	180 U	38 U	36 U	**71**
Diethylphthalate	µg/kg	59 U	74 U	34 U	76 U	110 U	**160**	110 U	180 U	**24** J	36 U	**13** J
Dimethyl phthalate	µg/kg	59 U	74 U	34 U	76 U	110 U	110 U	110 U	180 U	38 U	**60**	**24**
Di-n-butyl phthalate	µg/kg	59 U	74 U	**21** J	76 U	110 U	110 U	110 U	180 U	38 U	36 U	23 U
1,4-Dichlorobenzene	µg/kg	59 U	74 U	34 U	76 U	110 U	110 U	110 U	**240**	38 U	36 U	52 U
4-Methylphenol	µg/kg	59 U	74 U	34 U	76 U	110 U	110 U	110 U	180 U	38 U	**25** J	23 U
Carbazole	µg/kg	59 U	74 U	34 U	76 U	110 U	110 U	110 U	180 U	38 U	**140**	23 U
Dibenzofuran	µg/kg	**57** J	74 U	34 U	76 U	110 U	**79** J	110 U	180 U	38 U	**130**	23 U
Pentachlorophenol (by USEPA 8041)	µg/kg	**50** J	19 UJ	15 UJ	31 UJ	33 UJ	31 UJ	30 UJ	38 UJ	16 UJ	13 UJ	11 UJ
Pentachlorophenol (by USEPA 8270D)	µg/kg	300 U	370 U	170 U	380 U	550 U	540 U	550 U	900 U	190 U	180 U	110 U
Polychlorinated Biphenyls (USEPA 8082)												
PCB Aroclor 1242	µg/kg	32 U	32 U	33 U	**540**	130 U	120 U	120 U	**430**	**180**	**2,800**	32 U
PCB Aroclor 1248	µg/kg	**670**	**430**	**580**	74 U	**1,300**	**1,700**	**1,500**	92 U	32 U	160 U	240 U
PCB Aroclor 1254	µg/kg	**730**	**630**	330 U	**400**	**2,200**	**2,300**	**2,000**	**240**	**150**	**510**	**630**
PCB Aroclor 1260	µg/kg	**380**	**520**	**90**	**260**	**1,300**	**1,200**	**1,200**	**170**	**96**	160 U	96 U
Total PCBs	µg/kg	**1,780**	**1,580**	**670**	**1,200**	**4,800**	**5,200**	**4,700**	**840**	**426**	**3,310**	**630**
Herbicides and Pesticides (USEPA 8081B)												
alpha-Chlordane	µg/kg	8.1 U	**31** JN	**8.2** J	**14** J	**300** J	**480** J	**250** J	**28** J	**14** J	**180**	**3.6** J
gamma-Chlordane	µg/kg	8.1 U	**23**	**7.9**	**20** JN	**290**	**440**	**270**	**47** JN	**17**	**130**	**7.1** JN
p,p'-DDD	µg/kg	**24** JN	**1,800**	**770**	**240**	**3,900**	**5,100**	**2,800**	**40** JN	**39** JN	**120** JN	3.1 U
p,p'-DDE	µg/kg	**85** JN	**330**	**82** J	**84** JN	**630**	**680**	**580** J	**20** JN	**17** JN	**18** JN	3.1 U
p,p'-DDT[4]	µg/kg	16 R	**66** JN	**6.3** J	7.6 R	**450**	**120** JN	**92** JN	9.3 R	3.2 R	16 R	3.1 UJ

Table 4.3
Chemicals Detected in West Ditch Solids Samples[1]

Chemical	Unit	SS-01	SS-01	SS-01	SS-02	SS-02	SS-02[2]	SS-02	SS-03	SS-03	SS-03	SS-P
	Sample Date	12/6/2010	12/6/2010	12/6/2010	12/6/2010	12/6/2010	12/6/2010	12/6/2010	12/6/2010	12/6/2010	12/6/2010	12/8/2010
	Depths (ft bgs)	0–2	2–4	4–6	0–2	2–4	2–4	6–8	0–2	2–4	4–6	0–0.5
Petroleum Hydrocarbons (NWTPH-Dx)												
Diesel-range Hydrocarbons	mg/kg	**310**	**640**	**49**	**310**	**750**	**930**	**610**	**780** J	**130**	**260**	**120**
Motor Oil-range Hydrocarbons	mg/kg	**860**	**2,100**	**76**	**750**	**2,400**	**2,700**	**2100**	**3,200**	**360**	**750**	**480**
Metals (USEPA Method 6010B)[5]												
Aluminum	mg/kg	**16,600**	**28,100**	**15,100**	**17,400**	**18,500**	**14,000**	**19,000**	**26,800**	**15,700**	**7,050**	**7,400** J
Arsenic	mg/kg	**40**	**20**	8 U	**30**	**20**	**20**	**20**	**60**	**10**	6 U	**7** J
Barium	mg/kg	**325**	**251**	**46.8**	**198**	**238**	**121**	**237**	**152**	**106**	**32.6**	**26.3**
Cadmium	mg/kg	**5.2**	**3.2**	0.3 U	**3.8**	**9.4**	**7.5**	**9.7**	**5**	**0.9**	0.2 U	**0.6**
Chromium	mg/kg	**54**	**68**	**14.3**	**41**	**71**	**54**	**73**	**101**	**36.7**	**23.4**	**18.1**
Copper	mg/kg	**277**	**144**	**25.5**	**130**	**304**	**229**	**324**	**245**	**44.2**	**14.1**	**24.5** J
Iron	mg/kg	**49,700**	**49,200**	**14,700**	**66,300**	**29,700**	**31,200**	**31,200**	**92,800**	**28,300**	**11,100**	**12,300**
Lead	mg/kg	**461**	**239**	**6**	**280**	**600**	**440**	**620**	**380**	**83**	**63**	**29** J
Manganese	mg/kg	**474**	**535**	**120**	**319**	**304**	**226**	**312**	**470**	**211**	**120**	**148** J
Mercury	mg/kg	**0.59**	**0.52**	**0.08**	**0.5**	**0.7**	**0.88**	**0.8**	**1.2**	**0.17**	0.02 U	**0.04**
Nickel	mg/kg	**48**	**73**	**10**	**45**	**64**	**46**	**90**	**73**	**43**	**20**	**24**
Silver	mg/kg	**2**	**0.8**	0.5 U	1 U	**4**	**3**	**3**	2 U	0.5 U	0.3 U	0.4 U
Zinc	mg/kg	**1,070**	**667**	**45**	**701**	**1,750**	**1,650**	**1760**	**999**	**190**	**49**	**392**

Notes:

(grey shading) Mixture of CPAHs considered for toxicity equivalency quotient calculations.

BOLD Indicates was detected (or detected and estimated).

1 A single chemical has a frequency of detection greater than zero and less han 5 percent; therefore, it is included on this table that presents all detected data.

2 Blind field duplicate of SS-02 from 2 to 4 ft; labeled on the Chain of Custody as SS-02-6 8-120610.

3 Only pentachlorophenol was measured by USEPA Meth ds 8270D and 8041.

4 During analysis DDT can break down to form DDE and DDD. The anal tical method (USEPA 8081B) includes a check sample to monitor this process. During analyses of these samples, DDT was found to be breaking down and could not be accurately quantified. This re l s in DDT flagged as rejected and DDD and DDE concentrations flagged as estimated. The sum of DDT+DDE+DDD is not affected and is acceptable for use, as any DDT that breaks down is converted into DDD and DDE.

5 Natural Background Soil Metals Concentrations in Washington State (Ecology 1994) Statewide 90th Percentile Values are as follows: arsenic—7 mg/kg, cadmium—1 mg/kg, chromium—42 mg/kg, copper—36 mg/kg, lead—17 mg/kg, mercury—0.07 mg/kg, nickel—38 mg/kg, and zinc—86 mg/kg; however, the arsenic value was reevaluated and a value of 20 mg/kg replaced the 1994 Washington State Department of Ecology vaule (Task Force 2003).

Abbreviations:

BaP Benzo(a)pyrene
bgs Below ground surface
CPAH Carcinogenic polycyclic aromatic hydrocarbon
DDD Dichlorodiphenyldichloroethane
DDE Dichlorodiphenyldichloroethylene
DDT Dichlorodiphenyltrichloroethane
ft Feet
µg/kg Micrograms per kilogram
mg/kg Milligrams per kilogram
PCB Polychlorinated biphenyl
RL Reporting limit
TEQ Toxic equivalency quotient
USEPA U.S. Environmental Protection Agency

Qualifiiers:

J Estimated value
JN Estimated due to tentative identification
R Rejected as bad data, detect
UJ Not detected, estimated detection limit
U Not detected

Table 4.4
Frequency of Detections and Exceedances in Solids Samples from the West Ditch

Potential Chemical of Concern	Unit	Number of Samples	Number of Detected Results	Percent of Detected Results	Minimum Detected Value	Maximum Detected Value	MTCA Method C Cleanup Level	Exceeds MTCA Criteria?
Semivolatile Organic Compounds								
CPAHs as BaP TEQ using half RL	µg/kg	11	10	91%	24	1,100	18,000	No
CPAHs as BaP TEQ using zero as RL	µg/kg	11	10	91%	34	1,100	18,000	No
Benzo(a)anthracene	µg/kg	11	10	91%	34	710	Evaluated as total CPAHs calculated as a BaP toxicity equivalent quotient (refer to CPAHs as BaP TEQ above)	
Benzo(a)pyrene	µg/kg	11	10	91%	26	870		
Benzo(g,h,i)perylene	µg/kg	11	10	91%	22	470		
Benzofluoranthenes (Total)	µg/kg	11	10	91%	41	1,200		
Chrysene	µg/kg	11	10	91%	48	1,000		
Indeno(1,2,3-cd)pyrene	µg/kg	11	8	73%	46	380		
1-Methylnaphthalene	µg/kg	11	2	18%	48	99	NR	No
2-Methylnaphthalene	µg/kg	11	2	18%	140	160	14,000,000	No
Acenaphthene	µg/kg	11	9	82%	25	250	210,000,000	No
Acenaphthylene	µg/kg	11	1	9%	36	36	210,000,000	No
Anthracene	µg/kg	11	7	64%	12	350	1,100,000,000	No
Fluoranthene	µg/kg	11	11	100%	73	2,000	140,000,000	No
Fluorene	µg/kg	11	7	64%	32	200	140,000,000	No
Naphthalene	µg/kg	11	1	9%	210	210	70,000,000	No
Phenanthrene	µg/kg	11	11	100%	43	1,900	R-ND	No
Pyrene	µg/kg	11	11	100%	56	1,900	110,000,000	No
bis(2-ethylhexyl)phthalate	µg/kg	11	5	50%	370	8,400	9,400,000	No
Butyl benzyl phthalate	µg/kg	11	1	9%	71	71	69,000,000	No
Diethylphthalate	µg/kg	11	3	27%	13	160	--	No
Dimethyl phthalate	µg/kg	11	2	18%	24	60	R-ND	No
Di-n-butyl phthalate	µg/kg	11	1	9%	21	21	--	No
1,4-Dichlorobenzene	µg/kg	11	1	9%	240	240	R-ND	No
4-Methylphenol	µg/kg	11	1	9%	25	25	18,000,000	No
Carbazole	µg/kg	11	1	9%	140	140	R-ND	No
Dibenzofuran	µg/kg	11	3	27%	57	130	3,500,000	No
Pentachlorophenol (by USEPA 8041)	µg/kg	11	0	0%	0	0	330,000	No
Pentachlorophenol (by USEPA 8270D)	µg/kg	11	1	9%	50	50	330,000	No
Polychlorinated Biphenyls [1]								
PCB Aroclor 1242	µg/kg	11	4	36%	180	2,800	10,000	No
PCB Aroclor 1248	µg/kg	11	6	55%	430	1,700	10,000	No
PCB Aroclor 1254	µg/kg	11	10	91%	150	2,300	10,000	No
PCB Aroclor 1260	µg/kg	11	9	82%	90	1,300	10,000	No
Total PCBs	µg/kg	11	10	91%	426	5,200	10,000	No
Herbicides and Pesticides								
alpha-Chlordane	µg/kg	11	10	91%	3.6	480	350,000	No
gamma-Chlordane	µg/kg	11	10	91%	7.1	440	350,000	No
p,p'-DDD	µg/kg	11	10	91%	24	5,100	550,000	No
p,p'-DDE	µg/kg	11	10	91%	17	680	390,000	No
p,p'-DDT	µg/kg	6	5	83%	6.3	450	390,000	No

Table 4.4
Frequency of Detections and Exceedances in Solids Samples from the West Ditch

Potential Chemical of Concern	Unit	Number of Samples	Number of Detected Results	Percent of Detected Results	Minimum Detected Value	Maximum Detected Value	MTCA Method C Cleanup Level	Exceeds MTCA Criteria?
Petroleum Hydrocarbons								
Motor Oil-range Hyrdocarbons	mg/kg	11	11	100%	76	3,200	7,000 [2]	No
Diesel-range Hydrocarbons	mg/kg	11	11	100%	49	930	7,000 [2]	No
Metals[3]								
Aluminum	mg/kg	11	11	100%	7,050	28,100	NR	No
Arsenic	mg/kg	11	9	82%	7	60	88	No
Barium	mg/kg	11	11	100%	26	325	700,000	No
Cadmium	mg/kg	11	9	82%	0.6	10	3,500	No
Chromium	mg/kg	11	11	100%	14	101	5,250,000	No
Copper	mg/kg	11	11	100%	14	324	130,000	No
Iron	mg/kg	11	11	100%	11,100	92,800	NR	No
Lead	mg/kg	11	11	100%	6.0	620	1,000	No
Manganese	mg/kg	11	11	100%	120	535	490,000	No
Mercury	mg/kg	11	10	91%	0.04	1	1,050	No
Nickel	mg/kg	11	11	100%	10	90	70,000	No
Silver	mg/kg	11	5	45%	0.8	4	17,500	No
Zinc	mg/kg	11	11	100%	45	1,760	1,100,000	No

Notes:

(grey shading) Mixture of CPAHs considered for toxicity equivalency quotient calculation.

-- No value.

1 The MTCA Method A value for industrial soil has been used in place of MTCA Method C value which conflicts with a Federal ARAR. The following is a footnote from MTCA for the Method A value: "Cleanup level based on applicable federal law (40 C.F.R. 761.61). This is a total value for all PCBs. This value may be used only if the PCB contaminated soils are capped and the cap maintained as required by 40 C.F.R. 761.61. If this condition cannot be met the value in Table 740 1 must be used."

2 A site-specific MTCA Method C Cleanup Value was calculated using Washington State Department of Ecology's MTCATPH11.1 worksheets.

3 Natural Background Soil Metals Concentrations in Washington State (Ecology 1994), Statewide 90th Percentile Values are as follows: arsenic—7 mg/kg, cadmium—1 mg/kg, chromium—42 mg/kg, copper—36 mg/kg, lead—17 mg/kg, mercury—0.07 mg/kg, nickel—38 mg/kg and zinc—86 mg/kg; however, the arsenic value was reevaluated and a value of 20 mg/kg replaced the 1994 Washington State Department of Ecology value (Task Force 2003).

Abbreviations:

- ARAR Applicable or Relevant and Appropriate Requirement
- BaP Benzo(a)pyrene
- CPAH Carcinogenic polycyclic aromatic hydrocarbon
- DDD Dichlorodiphenyldichloroethane
- DDE Dichlorodiphenyldichloroethylene
- DDT Dichlorodiphenyltrichloroethane
- FOD Frequency of detection
- FOE Frequency of exceedance
- µg/kg Micrograms per kilogram
- mg/kg Milligrams per kilogram
- MTCA Model Toxics Control Act
- NR The chemical was not researched by the Washington State Department of Ecology
- PAH Polycyclic aromatic hydrocarbon
- PCB Polychlorinated biphenyl
- RL Reporting limit
- R-ND The chemical was researched by the Washington State Department of Ecology and no toxicity data of acceptable quality was found
- TEQ Toxic equivalency quotient
- USEPA U.S. Environmental Protection Agency

Table 4.5
Chlorinated Dioxins and Furans Detected in Multi-Increment Soil Samples for Semivolatile Organic Compounds

Chemical	Unit	TEF	DU-1 (West Ditch) Sample Results	DU-1 (West Ditch) TEQ	DU-2 (Transfer Station) Sample Results	DU-2 (Transfer Station) TEQ	DU-3 (SPPD) Sample Results	DU-3 (SPPD) TEQ
Semivolatile Organic Compounds								
Dioxins								
2,3,7,8-Tetrachloro dibenzo-p-dioxin (2,3,7,8-TCDD)	ng/kg	1	1.82	1.82	113	113	4.57	4.57
1,2,3,7,8-Pentachloro dibenzo-p-dioxin (1,2,3,7,8-PeCDD)	ng/kg	1	4.72	4.72	72.9	72.9	9.87	9.87
1,2,3,4,7,8-Hexachloro dibenzo-p-dioxin (1,2,3,4,7,8-HxCDD)	ng/kg	0.1	8.68	0.868	71.9	7.19	18.7	1.87
1,2,3,6,7,8-Hexachloro dibenzo-p-dioxin (1,2,3,6,7,8-HxCDD)	ng/kg	0.1	35.1	3.51	169	16.9	51.2	5.12
1,2,3,7,8,9-Hexachloro dibenzo-p-dioxin (1,2,3,7,8,9-HxCDD)	ng/kg	0.1	18.8	1.88	154	15.4	37.4	3.74
1,2,3,4,6,7,8-Heptachloro dibenzo-p-dioxin (1,2,3,4,6,7,8-HpCDD)	ng/kg	0.01	551	5.51	2430	24.3	1,230	12.3
1,2,3,4,6,7,8,9-Octachloro dibenzo-p-dioxin (1,2,3,4,6,7,8,9-OCDD)	ng/kg	0.0003	4,990	1.497	18,100	5.43	15,500	4.65
Furans								
2,3,7,8-Tetrachloro dibenzofuran (2,3,7,8-TCDF)	ng/kg	0.1	8.17	0.817	48.20	4.82	15.60	1.56
1,2,3,7,8-Pentachloro dibenzofuran (1,2,3,7,8-PeCDF)	ng/kg	0.03	5.87	0.176	49.70	1.491	13.70	0.411
2,3,4,7,8-Pentachloro dibenzofuran (2,3,4,7,8- PeCDF)	ng/kg	0.3	5.42	1.626	80.70	24.21	17.00	5.1
1,2,3,4,7,8-Hexachloro dibenzofuran (1,2,3,4,7,8-HxCDF)	ng/kg	0.1	17.2	1.72	178.0	17.8	79.6	7.96
1,2,3,6,7,8-Hexachloro dibenzofuran (1,2,3,6,7,8- HxCDF)	ng/kg	0.1	9.51	0.951	102.00 J	10.2	26.40 J	2.64
2,3,4,6,7,8-Hexachloro dibenzofuran (2,3,4,6,7,8-HxCDF)	ng/kg	0.1	11.1	1.11	107.0	10.7	28.5	2.85
1,2,3,7,8,9-Hexachloro dibenzofuran (1,2,3,7,8,9- HxCDF)	ng/kg	0.1	2.90 J	0.29	18.60	1.86	10.70	1.07
1,2,3,4,6,7,8-Heptachloro dibenzofuran (1,2,3,4,6,7,8-HpCDF)	ng/kg	0.01	123	1.23	650	6.5	223	2.23
1,2,3,4,7,8,9-Heptachloro dibenzofuran (1,2,3,4,7,8,9-HpCDF)	ng/kg	0.01	7.67	0.077	44.50	0.445	23.10	0.231
1,2,3,4,6,7,8,9-Octachloro dibenzofuran (1,2,3,4,6,7,8,9-OCDF)	ng/kg	0.0003	190	0.057	1,170	0.351	480	0.144
Summary								
Total dioxin/furan TEQ	ng/kg			28		333		66
2,3,7,8-TCDD	ng/kg			1.82		113		5
MTCA Method C for dioxin/furan TEQ	ng/kg			1,500		1,500		1,500
MTCA Method B for dioxin/furan TEQ	ng/kg			11		11		11

Abbreviations:
- CUL Cleanup level
- MTCA Model Toxics Control Act
- ng/kg Nanograms per kilogram
- ppt Parts per trillion
- SPPD South Park Property Development, LLC
- SVOC Semivolatile organic compound
- TEF Toxicity equivalency factor
- TEQ Toxicity equivalency quotient

Qualifier:
- J Estimated value

Table 5.1
Slug Test Results[1]

Well ID[2]	Date	Aquifer Zone	Screen Elevation[3] (ft bgs)	Screen Length (ft)	Aquifer Thickness (ft)	Aquifer Condition	Aquifer Response	Analytic Method	Hydraulic Conductivity ft/min	Hydraulic Conductivity ft/day	Hydraulic Conductivity cm/sec
Well Pair MW-25/MW-10											
MW-25	1/19/2011	A	22–27	5	25.5	Confined	Underdamped	Butler-Zahn	0.102	150	5.2E-02
MW-10	1/19/2011	B	35–45	10	33.5	Confined	Underdamped	Butler-Zahn	0.045	65	2.3E-02
60 min Pumping Test/ Cooper-Jacob Pumping Analysis (Aquifer Thickness 35 ft)									**0.120**	**170**	**6.0E-02**
Well Pair MW-26/MW-24											
MW-26	1/20/2011	A	15–25	10	≥37.5	Confined	Underdamped	Butler-Zahn	0.072	100	3.7E-02
MW-24	1/20/2011	B	35–45	10	≥38	Confined	Overdamped	Hvorslev	0.018	26	9.1E-03
60 min Pumping Test/Cooper-Jacob Pumping Analysis (Aquifer Thickness 56 ft)									**0.048**	**69**	**2.4E-02**
Well Pair MW-27/MW-08											
MW-27	1/20/2011	A	10–20	10	≥49	Unconfined	Overdamped	Bouwer & Rice	0.029	42	1.5E-02
MW-08	1/20/2011	B	35.5–45.5	10	≥49	Unconfined	Overdamped	Bouwer & Rice	0.025	36	1.3E-02
60 min Pumping Test/Cooper-Jacob Pumping Analysis (Aquifer Thickness 56 ft)									**0.049**	**71**	**2.5E-02**
								Slug Test Geometric Mean	**0.04**	**60**	**2E-02**
								Slug Test Range	**0.02 to 0.10**	**26 to 150**	**9E-03 to 5E-02**
								Pumping Test Geometric Mean	**0.07**	**90**	**3E-02**
								Pumping Test Range	**0.05 to 0.12**	**70 to 170**	**2E-02 to 6E-02**

Notes:

1 Pumping test data are from AESI (2000).

2 Well pairs are listed top down from northwest to southeast, and include the following: MW-25 and MW-10; MW-26 and MW-24; and MW-27 and MW-8.

3 All well screens are partially penetrating and fully submerged.

Abbreviations:

A A-Zone portion of the Shallow Aquifer
AESI Associated Earth Sciences, Inc.
B B-Zone portion of the Shallow Aquifer
bgs Below ground surface
cm Centimeter
ft Feet
min Minute
sec Second

Table 5.2
Vertical Groundwater Gradients

Monitoring Well	Groundwater Measurement Date[1]	Aquifer Zone	Well Screen Interval (ft bgs)	Ground Surface Elevation (ft, NAVD 88)	Top of Well Casing Elevation (ft, NAVD 88)	Screen Midpoint Elevation (ft, NAVD 88)	Groundwater Level (ft bTOC)	Groundater Elevation (ft, NAVD 88)	Vertical Gradient Upward (-) Downward (+)	Gradient Direction
MW-08	1/27/2011	B	35.5–45.5	12.88	14.76	-27.62	6.70	8.06	-0.0063	Up
MW-27	1/27/2011	A	10–20	12.72	14.76	-2.28	6.86	7.90		
MW-08	7/16/2013	B	35.5–45.5	12.88	14.76	-27.62	8.82	5.94	Not Observed[2]	
MW-27	7/16/2013	A	10–20	12.72	14.76	-2.28	8.78	5.98		
MW-08	3/19/2014	B	35.5–45.5	12.88	14.76	-27.62	6.70	8.06	Not Observed[2]	
MW-27	3/19/2014	A	10–20	12.72	14.76	-2.28	6.70	8.06		
MW-10	1/28/2011	B	35–45	17.70	19.35	-22.30	11.60	7.75	Not Observed[2]	
MW-25	1/27/2011	A	22–27	17.30	20.09	-7.20	12.35	7.74		
MW-10	4/2/2013	B	35–45	17.70	19.35	-22.30	12.78	6.57	0.0079	Down
MW-25	4/1/2013	A	22–27	17.30	20.09	-7.20	13.40	6.69		
MW-10	7/15/2013	B	35–45	17.70	19.35	-22.30	13.63	5.72	Not Observed[2]	
MW-25	7/15/2013	A	22–27	17.30	20.09	-7.20	14.30	5.79		
MW-10	3/17/2014	B	35–45	17.70	19.35	-22.30	11.60	7.75	Not Observed[2]	
MW-25	3/17/2014	A	22–27	17.30	20.09	-7.20	12.32	7.77		
MW-24	1/27/2011	B	35–45	13.57	15.13	-26.43	7.23	7.90	Not Observed[2]	
MW-26	1/27/2011	A	15–25	13.55	15.94	-6.45	8.05	7.89		
MW-24	4/2/2013	B	35–45	13.57	15.13	-26.43	8.47	6.66	Not Observed[2]	
MW-26	4/2/2013	A	15–25	13.55	15.94	-6.45	9.25	6.69		
MW-24	7/16/2013	B	35–45	13.57	15.13	-26.43	9.29	5.84	Not Observed[2]	
MW-26	7/16/2013	A	15–25	13.55	15.94	-6.45	10.06	5.88		
MW-24	3/19/2014	B	35–45	13.57	15.13	-26.43	7.21	7.92	Not Observed[2]	
MW-26	3/19/2014	A	15–25	13.55	15.94	-6.45	7.99	7.95		
MW-30	6/20/2011	PZ	8–13	17.37	17.07	6.87	10.25	6.82	0.0573	Down
MW-31	6/20/2011	A	18–23	17.42	17.12	-3.08	10.87	6.25		
MW-30	7/8/2011	PZ	8–13	17.37	17.07	6.87	10.48	6.59	0.0754	Down
MW-31	7/8/2011	A	18–23	17.42	17.12	-3.08	11.28	5.84		
MW-30	4/2/2013	PZ	8–13	17.37	17.07	6.87	9.80	7.27	0.0824	Down
MW-31	4/2/2013	A	18–23	17.42	17.12	-3.08	10.67	6.45		
MW-30	7/16/2013	PZ	8–13	17.37	17.07	6.87	10.67	6.40	0.0704	Down
MW-31	7/16/2013	A	18–23	17.42	17.12	-3.08	11.42	5.70		
MW-30	3/19/2014	PZ	8–13	17.37	17.07	6.87	8.37	8.70	0.1025	Down
MW-31	3/18/2014	A	18–23	17.42	17.12	-3.08	9.44	7.68		

Notes:

1 MW-08/MW-27 well pair gradient not calculated during April 2013 due to a suspected erroneous waterlevel measurment.

2 Difference in head between measurement points was either 0, or within measurement error inherent in waterlevel measurement method, and so no vertical gradient was observed.

Abbeviations:

A A-Zone portion of the Shallow Aquifer
B B-Zone portion of the Shallow Aquifer
bgs Below ground surface
bTOC Below top of casing
ft Feet
NAVD 88 North American Vertical Datum of 1988
PZ Perched Zone

Table 5.3
Frequency of Detections and Exceedances in On-Site and Downgradient Groundwater

Potential Chemicals of Concern	Cleanup Level			Detections (since 1998)					Exceedances (since 2005)		Retained as a Groundwater COC?	
	Unit	Proposed Cleanup Level	Source of Cleanup Level	Number of Results	Percentage of Detections	Maximum Detected Value	Location of Maximum Detection	Date of Maximum Detection	Number of Detections Exceeding Criterion	Percentage of Samples Exceeding Criterion	Retained as COC?	Comment
Volatile Organic Compounds												
1,1-Dichloroethane	µg/L	1,600	MCTA B	160	16%	0.68	MW-26	2/27/2006	None	--	No	
1,2-Dichlorobenzene	µg/L	720	MCTA B	162	6%	0.68	MW-25	3/31/2009	None	--	No	
1,2-Dichloropropane	µg/L	NA	MCTA B	160	6%	0.32	MW-10	12/17/2002	None	--	No	
Benzene	µg/L	5.0	MCL/MTCA	150	26%	5.8	MW-25	1/27/2011	1	0.7%	No	Monitor MW-25
Chlorobenzene	µg/L	160	MCTA B	160	53%	46	MW-25	3/31/2009	None	--	No	
***cis* -1,2-Dichloroethene**	µg/L	16	MCTA B	221	57%	23	FB-14	3/11/2011	1	0.5%	No	Monitor as precursor to vinyl chloride
trans-1,2-Dichloroethene	µg/L	160	MCTA B	182	28%	3.2	FB-14	3/11/2011	None	--	No	
Trichloroethene	µg/L	5.0	MCL/MTCA	221	10%	3.5	FB-14	3/11/2011	None	--	No	
Vinyl chloride	µg/L	0.29	MCL/MTCA	221	76%	11	MW-[illegible]4	12/27/1999	25	11%	Yes	Maximum at MW-31 (9 µg/L)
Semivolatile Organic Compounds												
Naphthalene	µg/L	160	MTCA B	99	2%	0.3	KMW-03A	1/27/2011	None	--	No	
Pesticides and Herbicides												
No pesticides or herbicides associated with the Landfill have been detected; refer to Appendix C for full listing of data												
Polychlorinated Biphenyls												
No PCBs associated with the Landfill have been detected; refer to Appendix C for full listing of data.												
Petroleum Hydrocarbons												
TPH-G	mg/L	0.8	MTCA A	129	18%	0.56	MW-10	5/6/1999	None	--	No	
TPH-D	mg/L	0.5	MTCA A	149	52%	0.97	MW-24	12/18/2002	1	0.7%	No	MW-24 in 2006 (0.53 µg/L)
TPH-Oil	mg/L	0.5	MTCA A	145	1%	0.46	MW-24	3/24/2000	None	--	No	
Metals, Dissolved (Filtered)												
Aluminum	mg/L	1.6	MCTA B	78	21%	0.1	MW-08	12/22/2000	None	--	No	
Arsenic	mg/L	0.005	MTCA A	176	43%	0.025	MW-27	3/31/2009	11	6%	No	Not related to Landfill; see text
Barium	mg/L	2.0	MCL/MTCA	157	78%	6	KMW--034	12/18/2007	4	3%	No	In compliance at POC
Cadmium	mg/L	0.005	MCL/MTCA	160	9%	0.009	MW-10	10/26/1999	None	--	No	
Copper	mg/L	0.64	MCTA B	114	28%	0.00716	MW-08	9/21/2005	None	--	No	
Lead	mg/L	0.015	MCL/MTCA	169	5%	0.0024	MW-27	10/23/2008	None	--	No	
Selenium	mg/L	0.05	MCL/MTCA	157	69%	0.055	MW-08	9/13/2001	None	--	No	
Vanadium	mg/L	0.14	MCTA B	114	50%	0.013	MW-25	2/27/2006	None	--	No	
Zinc	mg/L	5.0	MCL/MTCA	114	24%	0.2	MW-24	12/27/1999	None	--	No	

Table 5.3
Frequency of Detections and Exceedances in On-Site and Downgradient Groundwater

Potential Chemicals of Concern	Cleanup Level			Detections (since 1998)					Exceedances (since 2005)		Retained as a Groundwater COC?	
	Unit	Proposed Cleanup Level	Source of Cleanup Level	Number of Results	Percentage of Detections	Maximum Detected Value	Location of Maximum Detection	Date of Maximum Detection	Number of Detections Exceeding Criterion	Percentage of Samples Exceeding Criterion	Retained as COC?	Comment
Metals, Total (Unfiltered)												
Aluminum	mg/L	1.6	MCTA B	81	58%	0.55	MW-10	3/19/1999	None	--	No	
Arsenic	mg/L	0.005	MTCA A	137	38%	0.055	MW-27	3/27/2007	8	6%	No	Not related to Landfill; see text
Barium	mg/L	2.0	MCL	120	71%	0.086	MW-18	10/28/1999	0	--	No	
Copper	mg/L	0.64	MCTA B	85	25%	0.013	MW-08	8/3/2000	0	--	No	
Lead	mg/L	0.015	MCL	132	8%	0.023	KMW-01A	1/28/2011	1	0.8%	No	In compliance at POC
Selenium	mg/L	0.05	MCL	120	68%	0.062	MW-08	3/26/2002	0	--	No	
Vanadium	mg/L	0.14	MCTA B	85	46%	0.016	MW-25	2/27/2006	0	--	No	
Zinc	mg/L	5.0	MCL	85	14%	0.011	MW-10	3/19/1999	0	--	No	

Notes:
-- No value.
Red type Chemical is a COC for this medium.
Red type Chemical was considered for inclusion as a COC but not retained. Refer to text for details.

Abbreviations:
COC Chemical of concern
CUL Cleanup level
Landfill South Park Landfill
MCL Maximum Contaminant Level (drinking water)
MCL/MTCA MCL modified to comply with MTCA risk levels
µg/L Micrograms per liter
mg/L Milligrams per liter
MTCA A Model Toxics Control Act Method A cleanup level
MTCA B Model Toxics Control Act Method B cleanup level
NA Not applicable
PCB Polychlorinated biphenyl
POC Point of compliance
TPH Total petroleum hydrocarbons
TPH-G TPH gasoline range
TPH-D TPH diesel range
TPH-G TPH oil range

Table 5.4
Water Wells Downgradient of the South Park Landfill

Well Log ID	Depth (feet)	Diameter (inches)	Well Owner Name	Township (N)	Range (E)	Section	Quarter Section	Quarter-Quarter Section	Completion Date	Comments
102798	--	--	Dewatering Observation Wells	24	4	29	SE	SW	Unknown	Resource Protection Well
105311	--	8	Markey Bachinary	24	4	29	SW	NE	Unknown	Resource Protection Well
105282	--	--	Marine Lumber Service	24	4	29	SW	NW	7/5/1995	Resource Protection Well
107477	--	--	Sternco Metal	24	4	29	SW	SE	3/11/1991	Resource Protection Well
103766	--	8	Gerguson Construction	24	4	29	SW	SW	Unknown	Resource Protection Well
103836	--	--	Great Western Chemical	24	4	29	SW	SW	5/24/1989	Resource Protection Well
661318	23	5	City of Seattle	24	4	29	SW	SW	7/9/2010	Dewatering Well 130 South Kenyon Street
661320	23	5	City of Seattle	24	4	29	SW	SW	7/9/2010	Dewatering Well 130 South Kenyon Street
661322	23	5	City of Seattle	24	4	29	SW	SW	7/9/2010	Dewatering Well 130 South Kenyon Street
661324	23	5	City of Seattle	24	4	29	SW	SW	7/9/2010	Dewatering Well 130 South Kenyon Street
661326	23	5	City of Seattle	24	4	29	SW	SW	7/9/2010	Dewatering Well 130 South Kenyon Street
661327	23	5	City of Seattle	24	4	29	SW	SW	7/9/2010	Dewatering Well 130 South Kenyon Street
661329	23	5	City of Seattle	24	4	29	SW	SW	7/9/2010	Dewatering Well 130 South Kenyon Street
661331	23	5	City of Seattle	24	4	29	SW	SW	7/9/2010	Dewatering Well 130 South Kenyon Street
661333	20	5	City of Seattle	24	4	29	SW	SW	7/9/2010	Dewatering Well 130 South Kenyon Street
661335	20	5	City of Seattle	24	4	29	SW	SW	7/9/2010	Dewatering Well 130 South Kenyon Street
661337	20	5	City of Seattle	24	4	29	SW	SW	7/9/2010	Dewatering Well 130 South Kenyon Street
661339	20	5	City of Seattle	2	4	29	SW	SW	7/9/2010	Dewatering Well 130 South Kenyon Street
661341	20	5	City of Seattle	24	4	29	SW	SW	7/9/2010	Dewatering Well 130 South Kenyon Street
661342	20	5	City of Seattle	24	4	29	SW	SW	7/9/2010	Dewatering Well 130 South Kenyon Street
661344	20	5	City of Seattle	24	4	29	SW	SW	7/9/2010	Dewatering Well 130 South Kenyon Street
661346	20	5	City of Seattle	24	4	29	SW	SW	7/9/2010	Dewatering Well 130 South Kenyon Street
661348	20	5	City of Seattle	24	4	29	SW	SW	7/9/2010	Dewatering Well 130 South Kenyon Street
661350	20	5	City of Seattle	24	4	29	SW	SW	7/9/2010	Dewatering Well 130 South Kenyon Street
661352	20	5	City of Seattle	24	4	29	SW	SW	7/9/2010	Dewatering Well 130 South Kenyon Street
661354	20	5	City of Seattle	24	4	29	SW	SW	7/9/2010	Dewatering Well 130 South Kenyon Street
661355	20	5	City of Seattle	24	4	29	SW	SW	7/9/2010	Dewatering Well 130 South Kenyon Street
661357	20	5	City of Seattle	24	4	29	SW	SW	7/9/2010	Dewatering Well 130 South Kenyon Street
661359	20	5	City of Seattle	24	4	29	SW	SW	7/9/2010	Dewatering Well 130 South Kenyon Street
661361	20	5	City of Seattle	24	4	29	SW	SW	7/9/2010	Dewatering Well 130 South Kenyon Street
661363	20	5	City of Seattle	24	4	29	SW	SW	7/9/2010	Dewatering Well 130 South Kenyon Street

Table 5.4
Water Wells Downgradient of the South Park Landfill

Well Log ID	Depth (feet)	Diameter (inches)	Well Owner Name	Township (N)	Range (E)	Section	Quarter Section	Quarter-Quarter Section	Completion Date	Comments
661365	20	5	City of Seattle	24	4	29	SW	SW	7/9/2010	Dewatering Well 130 South Kenyon Street
661367	20	5	City of Seattle	24	4	29	SW	SW	7/9/2010	Dewatering Well 130 South Kenyon Street
661369	20	5	City of Seattle	24	4	29	SW	SW	7/9/2010	Dewatering Well 130 South Kenyon Street
661371	20	5	City of Seattle	24	4	29	SW	SW	7/9/2010	Dewatering Well 130 South Kenyon Street
661373	20	5	City of Seattle	24	4	29	SW	SW	7/9/2010	Dewatering Well 130 South Kenyon Street
661375	20	5	City of Seattle	24	4	29	SW	SW	7/9/2010	Dewatering Well 130 South Kenyon Street
661377	20	5	City of Seattle	24	4	29	SW	SW	7/9/2010	Dewatering Well 130 South Kenyon Street
661379	20	5	City of Seattle	24	4	29	SW	SW	7/9/2010	Dewatering Well 130 South Kenyon Street
661381	20	5	City of Seattle	24	4	29	SW	SW	7/9/2010	Dewatering Well 130 South Kenyon Street
661383	20	5	City of Seattle	24	4	29	SW	SW	7/9/2010	Dewatering Well 130 South Kenyon Street
661384	20	5	City of Seattle	24	4	29	SW	SW	7/9/2010	Dewatering Well 130 South Kenyon Street
661386	20	5	City of Seattle	24	4	29	SW	SW	7/9/2010	Dewatering Well 130 South Kenyon Street
661388	20	5	City of Seattle	24	4	29	SW	SW	7/9/2010	Dewatering Well 130 South Kenyon Street
661390	20	5	City of Seattle	24	4	29	SW	SW	7/9/2010	Dewatering Well 130 South Kenyon Street
661392	20	5	City of Seattle	24	4	29	SW	SW	7/9/2010	Dewatering Well 130 South Kenyon Street
661394	20	5	City of Seattle	24	4	29	SW	SW	7/9/2010	Dewatering Well 130 South Kenyon Street
661395	20	5	City of Seattle	24	4	29	SW	SW	7/9/2010	Dewatering Well 130 South Kenyon Street
661396	20	5	City of Seattle	24	4	29	SW	SW	7/9/2010	Dewatering Well 130 South Kenyon Street
661398	20	5	City of Seattle	24	4	29	SW	SW	7/9/2010	Dewatering Well 130 South Kenyon Street
661400	20	5	City of Seattle	24	4	29	SW	SW	7/9/2010	Dewatering Well 130 South Kenyon Street
661401	20	5	City of Seattle	24	4	29	SW	SW	7/9/2010	Dewatering Well 130 South Kenyon Street
661403	20	5	City of Seattle	24	4	29	SW	SW	7/9/2010	Dewatering Well 130 South Kenyon Street
661405	20	5	City of Seattle	24	4	29	SW	SW	7/9/2010	Dewatering Well 130 South Kenyon Street
661407	20	5	City of Seattle	24	4	29	SW	SW	7/9/2010	Dewatering Well 130 South Kenyon Street
661409	20	5	City of Seattle	24	4	29	SW	SW	7/9/2010	Dewatering Well 130 South Kenyon Street
661411	20	5	City of Seattle	24	4	29	SW	SW	7/9/2010	Dewatering Well 130 South Kenyon Street
661412	20	5	City of Seattle	24	4	29	SW	SW	7/9/2010	Dewatering Well 130 South Kenyon Street
661414	20	5	City of Seattle	24	4	29	SW	SW	7/9/2010	Dewatering Well 130 South Kenyon Street
661416	20	5	City of Seattle	24	4	29	SW	SW	7/9/2010	Dewatering Well 130 South Kenyon Street
661418	20	5	City of Seattle	24	4	29	SW	SW	7/9/2010	Dewatering Well 130 South Kenyon Street
661420	20	5	City of Seattle	24	4	29	SW	SW	7/9/2010	Dewatering Well 130 South Kenyon Street

Table 5.4
Water Wells Downgradient of the South Park Landfill

Well Log ID	Depth (feet)	Diameter (inches)	Well Owner Name	Township (N)	Range (E)	Section	Quarter Section	Quarter-Quarter Section	Completion Date	Comments
661422	20	5	City of Seattle	24	4	29	SW	SW	7/9/2010	Dewatering Well 130 South Kenyon Street
661424	20	5	City of Seattle	24	4	29	SW	SW	7/9/2010	Dewatering Well 130 South Kenyon Street
661426	20	5	City of Seattle	24	4	29	SW	SW	7/9/2010	Dewatering Well 130 South Kenyon Street
661428	20	5	City of Seattle	24	4	29	SW	SW	7/9/2010	Dewatering Well 130 South Kenyon Street
661430	20	5	City of Seattle	24	4	29	SW	SW	7/9/2010	Dewatering Well 130 South Kenyon Street
661432	20	5	City of Seattle	24	4	29	SW	SW	7/9/2010	Dewatering Well 130 South Kenyon Street
661434	20	5	City of Seattle	24	4	29	SW	SW	7/9/2010	Dewatering Well 130 South Kenyon Street
661436	20	5	City of Seattle	24	4	29	SW	SW	7/9/2010	Dewatering Well 130 South Kenyon Street
661438	20	5	City of Seattle	24	4	29	SW	SW	7/9/2010	Dewatering Well 130 South Kenyon Street
661440	20	5	City of Seattle	24	4	29	SW	SW	7/9/2010	Dewatering Well 130 South Kenyon Street
661442	20	5	City of Seattle	24	4	29	SW	SW	7/9/2010	Dewatering Well 130 South Kenyon Street
661444	20	5	City of Seattle	24	4	29	SW	SW	7/9/2010	Dewatering Well 130 South Kenyon Street
661446	20	5	City of Seattle	24	4	29	SW	SW	7/9/2010	Dewatering Well 130 South Kenyon Street
661448	20	5	City of Seattle	24	4	29	SW	SW	7/9/2010	Dewatering Well 130 South Kenyon Street
661450	20	5	City of Seattle	24	4	29	SW	SW	7/9/2010	Dewatering Well 130 South Kenyon Street
102797	--	--	Dewatering Observation Wells	24	4	29	--	--	Unknown	Dewatering and Observation Well
352097	104	--	Hemrick Brewing Co.	24	4	29	--	--	Unknown	Located on east side of Duwamish Waterway
100885	--	--	16th Ave Bridge	2	4	32	NE	NE	Unknown	Resource Protection Well
103430	--	8	Fence Site # 8484	24	4	32	NE	SE	Unknown	Resource Protection Well
106316	--	--	Precision Engineering	24	4	32	NW	NE	3/7/1989	Resource Protection Well
106318	22	2	Precision Engineering	24	4	32	NW	NE	4/6/1989	Resource Protection Well
105169	--	--	Long Painting Co.	24	4	32	NW	--	8/25/1997	Resource Protection Well

Note:
-- No value.

Table 5.5
Ranges of Benzene and Chlorinated Ethenes in Groundwater
from January 2011 through March 2014[1]

Well	Trichloroethene (µg/L) Criteria (MCL-mod) = 5		cis-1,2-Dichloroethene (µg/L) Criteria (MTCA B) = 16		Vinyl chloride (µg/L) Criteria (MCL-mod) = 0.29		Benzene (µg/L) Criteria (MCL) = 5	
	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum
KMW-01A	0.2 U	0.2 U	0.2 U	0.2 U	0.091	0.091	0.2 U	0.2 U
KMW-03A	0.2 U	0.2 U	0.2 U	0.2 U	**0.3**	**0.39**	0.2 U	0.2 U
KMW-04	0.2 U	0.2 U	0.2 U	0.2 U	0.22	0.22	0.2 U	0.2 U
KMW-05	2 U	4 U	2 U	4 U	0.2 U	0.4 U	**5.6**	**8.2**
KMW-06	0.2 U	0.2 U	0.2 U	0.2 U	**0.31**	**0.31**	0.2 U	0.2 U
KMW-07	0.2 U	0.2 U	0.2 U	0.2 U	0.02 U	0.02 U	0.2 U	0.2 U
KMW-08	0.2 U	0.2 U	0.2 U	0.2 U	0.02 U	0.02 U	0.2 U	0.2 U
MW-01	0.2 U	0.2 U	0.2 U	0.2 U	0.02 U	0.02 U	0.2 U	0.2 U
MW-03	0.2 U	0.2 U	0.2 U	0.2 U	0.02 U	0.02 U	0.2 U	0.2 U
MW-04	0.2 U	0.2 U	0.2 U	0.2 U	0.02 U	0.02 U	0.2 U	0.2 U
MW-08	0.2 U	0.2 U	0.2 U	0.3	0.063	0.15	0.2 U	0.2 U
MW-10	0.2 U	0.2 U	1.1	1.9	0.26	**1.2**	0.2 U	0.2 U
MW-12	0.15	0.6	3.1	5.7	0.1	0.26	0.2 U	0.2 U
MW-14	0.02 U	0.2 U	0.02 U	0.2 U	0.02 U	0.02 U	0.2 U	0.2 U
MW-18	0.02 U	0.2 U	0.2 U	0.044	0.02 U	0.075	0.2 U	0.2 U
MW-24	0.2 U	0.2 U	0.2 U	0.2 U	0.02 U	0.051	0.2 U	0.2 U
MW-25	0.2 U	0.2 U	0.48	0.8	**0.79**	**1.4**	0.2 U	**5.8**
MW-26	0.31	0.42	0.2	0.43	0.02 U	0.053	0.2 U	0.2 U
MW-27	0.2 U	0.2 U	0.2 U	0.41	0.11	**0.31**	0.2 U	0.2 U
MW-29	0.02 U	0.2 U	0.2 U	0.034	0.02 U	0.02 U	0.2 U	0.2 U
MW-30	0.49	0.75	0.64	3.2	0.12	**2.2**	NS	NS
MW-31	0.2 U	0.2 U	3.9	6.3	**4.3**	**9.0**	NS	NS
MW-32	0.2 U	0.2 U	1.5	2	0.2	**0.36**	NS	NS
MW-33	0.2 U	0.2 U	0.2 U	0.7	**0.3**	**1.1**	NS	NS

Notes:

Bold Exceeds critera.

1 Data are from 2011 through 2014.

Abbreviations:

MCL Maximum contaminant level

MCL-mod Maximum contaminant level modified

MTCA Model Toxics Control Act

µg/L Micrograms per liter

NS Not sampled

Qualifer:

U Not detected

Table 6.1
Landfill Gas Monitoring Results[1]

Gas Probe	Date	Barometric Pressure (inches Hg)	Well Head Pressure (inches H_2O)	Methane (percent volume)	Carbon Dioxide (percent volume)	Oxygen (percent volume)	Volatiles by PID Final Reading (ppmv)	Volatiles by PID Maximum Reading (ppmv)
GP-01	2/9/2011	30.46	0.10	**11**	22.3	0.0	1.4	1.4
GP-02	2/9/2011	30.44	-0.04	**21**	15.5	0.0	0.7	0.7
GP-03	2/9/2011	30.41	0.00	0.2	5.8	9.5	2.3	2.5
GP-03	5/25/2011	29.69	-0.01	0.1	3.5	14.9	1.0	1.2
GP-03	9/23/2011	29.86	0.14	0.0	11.0	6.4	0.0	0.0
GP-03	12/28/2011	29.66	-0.20	0.0	1.0	2.2	--	--
GP-05	2/9/2011	30.41	-0.05	0.2	8.6	0.0	2.9	7.9
GP-05	5/25/2011	29.69	-0.08	0.1	4.0	11.5	4.4	8.7
GP-05	6/27/2011	29.65	0.10	0.0	9.2	1.4	1.8	2.3
GP-05	9/23/2011	29.98	0.27	0.0	11.9	3.6	0.0	0.0
GP-05	11/17/2011	29.55	-0.28	0.0	13.9	0.4	--	--
GP-05	12/28/2011	29.51	-0.18	0.0	11.8	0.0	--	--
GP-07	2/9/2011	30.42	0.00	0.2	1.3	18.3	2.5	4.1
GP-07	5/25/2011	29.70	-0.08	0.1	1.4	18.5	2.8	19.5
GP-07	9/23/2011	29.86	0.09	0.0	3.2	17.0	0.1	0.2
GP-07	12/28/2011	29.74	-0.18	0.0	3.1	16.3		
GP-09	2/7/2011	30.11	0.00	0.0	5.0	14.2	0.1	0.8
GP-09	5/25/2011	29.72	-0.04	0.0	2.0	18.1	0.0	0.0
GP-09	9/23/2011	29.91	0.22	0.0	3.1	17.4	0.0	0.0
GP-09	12/28/2011	29.76	-0.17	0.0	3.9	15.2	1.1	1.6
GP-11	2/8/2011	30.34	-0.01	0.0	3.8	10.5	1.6	1.6
GP-11	5/25/2011	29.68	-0.08	0.1	0.1	20.0	0.0	0.0
GP-11	9/23/2011	29.88	0.17	0.0	4.9	9.3	9.7	10.2
GP-11	12/28/2011	29.70	-0.18	0.0	4.7	4.9	--	--
GP-15	9/23/2011	29.99	0.28	0.0	11.8	7.7	16.0	16.0
GP-15	11/17/2011	29.61	**3.35**	0.0	0.2	19.4	0.9	1.3
GP-16	2/8/2011	30.29	0.00	0.0	19.0	19.0	7.3	7.7
GP-16	5/25/2011	29.69	-0.06	0.0	0.1	20.2	0.0	0.0
GP-16	6/27/2011	29.68	0.12	0.0	20.1	0.8	1.0	1.4
GP-16	9/23/2011	29.91	0.25	0.0	17.6	2.9	0.0	0.0
GP-16	11/17/2011	29.61	-0.29	0.0	21.4	0.0	3.6	4.1
GP-16	12/28/2011	29.96	-0.18	0.0	19.9	0.0	--	--
GP-17	2/8/2011	30.29	0.00	**10.1**	19.1	0.0	7.9	7.9
GP-17	5/25/2011	29.70	-0.06	**5.8**	18.9	0.0	0.0	0.0
GP-17	6/27/2011	29.67	0.11	**8.3**	17.9	0.0	0.0	0.7
GP-17	9/23/2011	29.97	0.31	1.0	18.5	0.0	0.1	0.1
GP-17	11/17/2011	29.56	0.30	2.1	22.9	0.0	--	--
GP-17	12/28/2011	29.96	-0.18	7.4	21.4	0.0	--	--
GP-19	2/8/2011	30.37	-0.02	1.9	14.3	0.0	8.4	8.4
GP-20	2/9/2011	30.45	0.06	3.3	8.9	0.0	2.1	2.2
GP-21	2/9/2011	30.44	-0.07	**20.0**	17.6	0.0	7.1	7.2
GP-22	2/9/2011	30.44	0.01	**7.1**	11.3	0.0	10.7	10.7
GP-23	2/8/2011	30.36	0.01	0.0	1.1	19.7	0.0	0.5
GP-23	5/25/2011	29.71	-0.08	0.1	0.4	19.8	20.2	39.2
GP-23	9/23/2011	29.86	-0.23	0.0	4.6	15.7	0.0	0.7
GP-23	12/28/2011	29.75	-0.18	0.0	5.0	6.9	--	--
GP-24	2/7/2011	30.12	NA	**15.4**	0.0	6.1	3.7	3.7
GP-24	2/9/2011	30.45	0.00	**14.4**	0.0	5.4	2.0	3.1
GP-24	2/18/2011	29.81	0.14	4.6	0.0	17.4	0.0	0.0
GP-24	2/21/2011	29.93	0.11	4.7	0.0	16.1	0.0	0.0
GP-24	5/25/2011	29.71	0.02	**8.5**	0.0	15.1	0.0	0.0
GP-24	6/27/2011	29.65	0.13	**35**	0.0	0.0	0.2	0.2
GP-24	9/23/2011	29.97	0.02	**48**	0.0	0.0	0.0	0.0
GP-24	11/17/2011	29.72	-0.02	**29**	0.1	5.5	1.0	1.0
GP-24	12/28/2011	29.78	-0.15	**19**	0.0	4.2	0.0	0.0
GP-25	2/7/2011	30.11	NA	**62**	0.1	0.0	1.0	2.2
GP-25	2/9/2011	30.43	-0.03	**56**	0.1	0.4	0.7	1.9
GP-25	2/18/2011	29.77	-3.22	**30**	0.0	9.7	0.0	0.0
GP-25	2/21/2011	29.93	0.07	**33**	0.1	9.0	0.0	0.0
GP-25	5/11/2011	29.75	0.02	**73**	0.1	0.1	0.0	0.0
GP-25	5/25/2011	29.71	0.00	**26**	0.1	12.4	0.0	0.0
GP-25	6/27/2011	29.65	0.13	**76**	0.0	0.0	0.0	0.0
GP-25	9/23/2011	29.95	0.02	**85**	0.1	0.0	0.0	0.0
GP-25	11/17/2011	29.74	-0.33	**62**	0.1	4.8	0.5	0.7
GP-25	12/28/2011	29.76	-0.13	**51**	0.1	2.0	6.9	19.5
GP-26	3/8/2011	29.86	0.14	0.0	0.8	18.8	0.0	0.0
GP-26	3/10/2011	29.53	0.05	0.0	1.7	18.4	0.0	0.0
GP-26	5/25/2011	29.71	-0.10	0.1	1.5	18.7	18.5	34.8
GP-26	6/27/2011	29.66	0.12	0.0	3.1	16.6	2.4	3.1
GP-26	9/23/2011	30.02	0.24	0.0	2.4	17.6	0.0	0.0
GP-26	11/17/2011	29.67	-0.28	0.0	2.6	17.5	5.7	7.1
GP-26	12/28/2011	29.76	-0.48	0.0	2.9	16.4	--	--

Table 6.1
Landfill Gas Monitoring Results[1]

Gas Probe	Date	Barometric Pressure (inches Hg)	Well Head Pressure (inches H_2O)	Methane (percent volume)	Carbon Dioxide (percent volume)	Oxygen (percent volume)	Volatiles by PID Final Reading (ppmv)	Volatiles by PID Maximum Reading (ppmv)
GP-27	2/7/2011	30.09	-0.01	**6.1**	7.8	0.9	0.5	0.6
GP-27	2/17/2011	29.73	0.13	2.9	4.7	9.1	0.0	0.0
GP-27	2/21/2011	29.90	0.10	3.1	4.8	9.1	0.0	0.0
GP-27	5/11/2011	29.73	0.05	**6.5**	8.3	0.1	0.0	0.0
GP-27	5/25/2011	29.68	-0.08	2.6	4.0	11.1	0.3	1.4
GP-27	6/27/2011	29.69	0.12	**6.3**	8.9	0.0	1.9	1.9
GP-27	9/23/2011	29.98	0.10	4.3	11.4	0.0	0.0	0.0
GP-27	11/17/2011	29.76	-0.17	3.3	8.4	5.2	0.3	0.4
GP-27	12/28/2011	29.92	0.00	6.0	11.9	0.0	--	--
GP-28	2/7/2011	30.11	0.01	0.0	3.1	8.1	0.3	1.2
GP-28	2/21/2011	29.89	0.10	0.0	2.0	15.3	0.0	0.0
GP-28	5/11/2011	29.73	0.05	0.5	5.4	0.4	0.0	0.0
GP-28	5/25/2011	29.70	-0.05	0.6	3.1	11.7	0.0	0.0
GP-28	6/27/2011	29.70	0.06	2.8	7.7	0.0	0.0	0.0
GP-28	9/23/2011	29.99	0.06	0.2	8.9	2.8	0.0	3.5
GP-28	11/17/2011	29.73	-0.19	0.1	8.9	4.2	0.0	0.1
GP-28	12/28/2011	29.94	-0.01	0.0	6.2	4.9	--	--
GP-29	2/7/2011	30.10	0.06	**7.1**	12.5	0.0	1.6	1.6
GP-29	2/21/2011	29.89	0.09	3.6	6.9	9.0	0.0	0.0
GP-29	5/11/2011	29.73	-0.03	**6.9**	12.2	0.3	0.0	0.0
GP-29	5/25/2011	29.70	-0.06	2.4	4.1	12.6	0.0	0.0
GP-29	6/27/2011	29.68	0.11	**8.5**	13.1	0.0	0.1	1.8
GP-29	9/23/2011	29.99	0.03	**7.2**	14.2	0.0	--	--
GP-29	11/17/2011	29.73	-0.22	**7.1**	12.2	3.7	0.5	0.5
GP-29	12/28/2011	29.95	-0.11	**8.1**	15.1	0.0	--	--
GP-30	5/11/2011	29.74	0.02	0.0	0.1	20.2	0.0	0.0
GP-31	5/11/2011	29.75	0.02	0.0	0.1	19.9	0.1	0.1
GP-31	5/25/2011	29.72	-0.05	0.0	0.1	20.3	0.0	0.0
GP-31	6/27/2011	29.72	0.08	0.0	9.6	6.6	0.0	0.0
GP-31	9/23/2011	29.97	0.05	0.0	14.7	4.4	--	--
GP-31	11/17/2011	29.61	-0.42	0.0	10.4	7.5	4.9	6.0
GP-31	12/28/2011	29.56	-0.22	0.0	8.0	3.7	--	--
BH-30	3/10/2011	29.54	-0.03	0.0	0.7	15.2	0.0	0.0
BH-30	5/25/2011	29.68	-0.04	0.0	0.2	19.8	0.0	0.0
BH-30	6/28/2011	29.61	0.05	0.0	1.6	18.5	0.4	0.6
BH-30	9/23/2011	29.93	0.27	0.0	0.8	19.1	0.0	0.0
BH-30	12/28/2011	29.59	0.21	0.0	1.5	17.7	--	--
BH-32	3/10/2011	29.54	0.00	0.0	1.4	17.5	0.0	0.0
BH-32	5/25/2011	29.70	-0.08	0.1	0.3	19.9	0.0	0.0
BH-32	5/25/2011	29.70	0.08	0.1	0.3	19.9	0.0	0.0
BH-32	6/28/2011	29.63	0.03	0.0	5.9	13.7	0.3	0.5
BH-32	9/23/2011	29.99	0.31	0.0	3.4	16.7	0.0	0.0
BH-32	11/17/2011	29.62	-0.29	0.0	1.2	18.8	1.3	1.6
BH-32	12/28/2011	29.64	-0.20	0.0	4.2	15.3	--	--
NP	5/12/2011	30.09	0.02	0.0	0.1	20.3	0.5	0.6
NP	5/26/2011	29.88	-0.04	0.0	0.1	20.4	0.0	0.2
SP	5/11/2011	29.76	0.00	**21**	5.5	10.3	0.0	0.0
KMW-04	5/12/2011	30.11	0.06	0.0	0.1	20.2	0.0	0.2
KMW-04	5/26/2011	29.88	-0.06	0.0	0.1	20.3	0.0	0.0
KMW-05	5/11/2011	29.84	0.00	**50**	0.0	2.0	0.0	1.0
KMW-06	11/17/2011	29.66	-0.24	**12**	1.7	0.0	13.6	13.6
KMW-07	11/17/2011	29.69	-0.26	0.0	5.4	12.0	24.7	24.7
KMW-08	11/17/2011	29.71	-0.26	0.2	0.1	8.3	0.3	0.4

Notes:

Highlighted results are greater than the LEL of 5.1 percent at 20°C.

-- No value.

1 Periodic results for probes GP-13, GP-15, GP-30, GP-31, and GP-32 were not collected due to high water levels.

Abbreviations:

C Celsius

H_2O Water

Hg Mercury

LEL Lower explosion level

NA Not applicable

PID Photoionization detector

ppmv Parts per million by volume

Table 6.2
Chemicals Detected in Soil Vapor Samples for Volatile Organic Compounds[1]

Chemicals	Unit	MTCA Soil Gas Screening Levels (Industrial)	GP-25	GP-27	KMW-04	KMW-05	N Piez TS	S Piez TS
		Sample ID	GP-25	GP-27	KMW-04	KMW-05	N. Piezo Transfer Station	S. Piezo Transfer Station
		Sample Date	5/11/2011	5/11/2011	5/12/2011	5/11/2011	5/12/2011	5/11/2011
		Screen Interval	5–10 ft	9–14 ft	9–19.5 ft	8.5–18.5 ft	Unknown	Unknown
Chlorinated Volatile Organic Compounds								
1,1-Dichloroethene	µg/m³	20,000	6.4 U	19	13 U	12 U	3.2 U	4.6 U
cis-1,2-Dichloroethene	µg/m³	3,500	6.4 U	99	13 U	12 U	3.2 U	4.6 U
Chlorobenzene	µg/m³	1,800	9.9	20	15 U	14 U	3.7 U	5.3 U
Methylene chloride	µg/m³	5,300	5.6 U	3 U	11 U	11 U	7.4	4 U
Tetrachloroethene	µg/m³	420	11 U	13	22 U	27	5.5 U	7.8 U
trans-1,2-Dichloroethene	µg/m³	7,000	6.4 U	45	13 U	12 U	3.2 U	4.6 U
Trichloroethene	µg/m³	100	8.7 U	80	17 U	17 U	4.3 U	6.2 U
Vinyl chloride	µg/m³	280	4.1 U	270	100	18	2 U	2.9 U
Benzene, Toluene, Ethylbenzene, and Xylene (BTEX) Constituents								
Benzene	µg/m³	320	190	22	16	460	8.9	3.7 U
Ethylbenzene	µg/m³	100,000	160	9.7	15	260	37	5 U
Toluene	µg/m³	490,000	190	61	66	790	110	4.3 U
Xylene (meta and para)	µg/m³	10,000	360	16	46	690	97	5 U
Xylene (ortho)	µg/m³	10,000	110	7.9	16	210	32	5 U
Other Volatile Organic Compounds Associated with Total Petroleum Hydrocarbons								
1,2,4-Trimethylbenzene	µg/m³	600	24	16	16 U	46	11	5.6 U
1,3,5-Trimethylbenzene	µg/m³	600	17	7.3	16 U	35	6.4	5.6 U
2,2,4-Trimethylpentane	µg/m³	--	7.6 U	310	110	8,800 J	24	5.4 U
4-Ethyltoluene	µg/m³	--	17	10	16 U	62	16	5.6 U
Cyclohexane	µg/m³	--	3,600 J	130	220	1,600	14	22
iso-Propanol	µg/m³	--	16 U	8.6 U	32 U	54	23	11 U
iso-Propylbenzene	µg/m³	--	11	4.3 U	16 U	39	5.1	5.6 U
n-Heptane	µg/m³	--	1,800	30	72	1,400	17	4.7 U
n-Hexane	µg/m³	70,000	4,500 J	300	540	1,700	11	5.7
n-Propylbenzene	µg/m³	--	8 U	7	16 U	17	4 U	5.6 U
Styrene	µg/m³	4,400	6.9 U	3.7 U	14 U	86	13	4.9 U
Miscellaneous Volatile Organic Compounds								
Acetone	µg/m³	--	28	9.8	32	420	110	130
Carbon disulfide	µg/m³	70,000	27	11 U	40 U	38 J	10 U	14 U
Dichlorodifluoromethane	µg/m³	18,000	8 U	16	16 U	15 U	4 U	5.7 U
Ethanol	µg/m³	--	12 U	6.6 U	32	73	45	8.7 U
Methyl ethyl ketone	µg/m³	100,000	19 U	10 U	38 U	76	9.5 U	40

Notes:
Exceeds MTCA Soil Gas Screening Levels for Industrial Sites.
-- No screening level value calculated or available through Washington State Department of Ecology CLARC Database.
1 Volatile organic compounds analyzed by USEPA Method TO-15.

Abbreviations:
CLARC Cleanup Levels and Risk Calculation
ft Feet
µg/m³ Micrograms per cubic meter
MTCA Model Toxics Control Act
TO-15 USEPA Method for determining volatile organic compounds in air
VOC Volatile organic compound

Qualifiers:
J Estimated value
U Not detected

Table 6.3

Frequency of Detections and Exceedances in Soil Vapor Samples for Volatile Organic Compounds[1]

Chemical	Unit	Number of Results	Number of Detect Results	Percent of Detect Results	Minimum Detect Value	Maximum Detect Value	Site Specific Soil Vapor Screening Levels	Detected and Exceeds?	WA Method C Soil Vapor Screening Levels (greater than 15 feet bgs)	Detected and Exceeds?
Chlorinated Volatile Organic Compounds										
Tetrachloroethene	µg/m³	6	2	33%	13	27	231	No	420	No
Trichloroethene	µg/m³	6	1	17%	80	80	55	Yes	100	No
cis-1,2-Dichloroethene	µg/m³	6	1	17%	99	99	1,925	No	3,500	No
1,1-Dichloroethene	µg/m³	6	1	17%	19	19	11,000	No	20,000	No
trans-1,2-Dichloroethene	µg/m³	6	1	17%	45	45	3,850	No	7,000	No
Vinyl chloride	µg/m³	6	3	50%	18	270	154	Yes	280	No
Dichloromethane	µg/m³	6	1	17%	7.4	7.4	2,915	No	5,300	No
Benzene, Toluene, Ethylbenzene, and Xylene (BTEX) Constituents										
Benzene	µg/m³	6	5	83%	8.9	460	176	Yes	320	Yes
Ethylbenzene	µg/m³	6	5	83%	9.7	260	55,000	No	100,000	No
Toluene	µg/m³	6	5	83%	61	790	269,500	No	490,000	No
Xylene (meta & para)	µg/m³	6	5	83%	16	690	5,500	No	10,000	No
Xylene (ortho)	µg/m³	6	5	83%	7.9	210	5,500	No	10,000	No
Other Volatile Organic Compounds Associated with Total Petroleum Hydrocarbons										
1,2,4-Trimethylbenzene	µg/m³	6	4	67%	11	46	11,000	No	20,000	No
1,3,5-Trimethylbenzene	µg/m³	6	4	67%	6.4	35	330	No	600	No
2,2,4-Trimethylpentane	µg/m³	6	4	67%	24	8,800	--	NA	--	NA
4-Ethyltoluene	µg/m³	6	4	67%	10	62	--	NA	--	NA
iso-Propanol	µg/m³	6	2	33%	23	54	--	NA	--	NA
iso-Propylbenzene	µg/m³	6	3	50%	5.1	39	--	NA	--	NA
n-Heptane	µg/m³	6	5	83%	17	1,800	--	NA	--	NA
n-Hexane	µg/m³	6	6	100%	5.7	4,500	38,500	No	70,000	No
n-Propylbenzene	µg/m³	6	2	33%	7	17	--	NA	--	NA
Styrene	µg/m³	6	2	33%	13	86	2,420	No	4,400	No
Miscellaneous Volatile Organic Compounds										
Acetone	µg/m³	6	6	100%	9.8	420	--	NA	--	NA
Carbon disulfide	µg/m³	6	2	33%	27	38	38,500	No	70,000	No
Chlorobenzene	µg/m³	6	2	33%	9.9	20	9,900	No	1,800	No
Cyclohexane	µg/m³	6	6	100%	14	3,600	--	NA	--	NA
Dichlorodifluoromethane	µg/m³	6	1	17%	16	16	--	NA	--	NA
Ethanol	µg/m³	6	3	50%	32	73	--	NA	--	NA
Methyl ethyl ketone	µg/m³	6	2	33%	40	76	55,000	No	100,000	No

Notes:

Yes Chemical both detected and exceeds either site-specific or Washington State Department of Ecology Method C Soil Vapor Screening Levels for depths greater than 15 feet.

-- No screening level calculated or available for this chemical.

1 Volatile organic compounds analyzed by USEPA Method TO-15.

Abbreviations:

bgs Below ground surface
FOD Frequency of detection
FOE Frequency of exceedance
µg/m³ Micrograms per cubic meter
NA Not applicable
VOC Volatile organic comound
WA Washington

Table 6.4

Volatile Organic Compounds Detected in Indoor Air at Kenyon Industrial Park[1, 2]

Sample ID		B-2	B-4	C-1	D-2	Background-2
KIP Building		B	B	C	D	South of D
Collection Date		12/19/2007	12/19/2007	12/19/2007	12/19/2007	12/19/2007
Chemical	**Unit**					
Chlorinated Volatile Organic Chemicals						
Tetrachloroethene	$\mu g/m^3$	**1.1**	**1.9**	**2.0**	**0.44**	0.25 U
Trichloroethene	$\mu g/m^3$	**0.27**	**0.28**	0.51 U	0.2 U	0.2 U
1,1-Dichloroethene	$\mu g/m^3$	0.069 U	**0.11**	0.19 U	0.074 U	0.072 U
cis-1,2-Dichloroethene	$\mu g/m^3$	0.14 U	0.14 U	0.38 U	0.15 U	0.14 U
trans-1,2-Dichloroethene	$\mu g/m^3$	0.69 U	0.72 U	1.9 U	0.74 U	0.72 U
Vinyl chloride	$\mu g/m^3$	0.045 U	0.04 U	0.12 U	0.048 U	0.047 U
Benzene, Toluene, Ethylbenzene, and Xylene (BTEX) Constituents						
Benzene	$\mu g/m^3$	**2.4**	**14**	**7.7**	**2.0**	**1.0**
Ethylbenzene	$\mu g/m^3$	**2.4**	**6.7**	**120**	**0.18**	**0.48**
Toluene	$\mu g/m^3$	**7.7**	**22**	**28**	**2.4**	**3.3**
Xylene (m- and p-)	$\mu g/m^3$	**8.9**	**24**	**360**	**0.42**	**1.5**
Xylene (o-)	$\mu g/m^3$	**2.4**	**6.7**	**74**	0.16 U	**0.44**

Notes:

BOLD Detected at levels greater than the reporting limit

1 Data from URS (2007).

2 Volatile organic compounds analyzed by USEPA Method TO-15.

Abbreviations:

KIP Kenyon Industrial Park

$\mu g/m^3$ Micrograms per cubic meter

VOC Volatile organic compound

USEPA U.S. Environmental Protection Agency

Qualifier:

U Not detected

Table 6.5
Frequency of Detections and Exceedances in Indoor Air for Volatile Organic Compounds[1]

Chemical	Unit	Number of Results	Number of Detected Results	Percent of Detect Results	Minimum Detect Value	Maximum Detect Value	MTCA Method C Industrial Worker CUL	Exceeds CUL?	Comment
Chlorinated Volatile Organic Compounds									
Tetrachloroethene	µg/m³	5	4	80%	0.44	2.0	3.5	No	
Trichloroethene	µg/m³	5	2	40%	0.27	0.28	1.0	No	
1,1-Dichloroethene	µg/m³	5	1	20%	0.11	0.11	200	No	
cis-1,2-Dichloroethene	µg/m³	5	0	0%	ND (0.038)	ND (0.38)	R-ND	No	
trans-1,2-Dichloroethene	µg/m³	5	0	0%	ND (0.69)	ND (1.9)	60	No	
Vinyl chloride	µg/m³	5	0	0%	ND (0.035)	ND (0.12)	2.8	No	
Benzene, Toluene, Ethylbenzene, and Xylene (BTEX) Constituents									
Benzene	µg/m³	5	5	100%	1	14	3.2	Yes	COC for indoor air NE corner of Building B at KIP
Ethylbenzene	µg/m³	5	5	100%	0.18	120	1,000	No	
Toluene	µg/m³	5	5	100%	2.4	28	5,000	No	
Xylene (meta & para)	µg/m³	5	5	100%	0.42	360	100	Yes	COC for indoor air NE corner of Building C at KIP
Xylene (ortho)	µg/m³	5	4	80%	0.44	74	100	No	

Notes:
Yes Chemical detected and exceeds Washington State Department of Ecology MTCA Method C Indoor Air Cleanup Levels for Industrial Workers.
1 Volatile organic compounds analyzed by USEPA Method TO-15.

Abbreviations:
COC Chemical of concern
CUL Cleanup level
FOD Frequency of detection
FOE Frequency of exceedance
KIP Kenyon Industrial Park
µg/m³ Micrograms per cubic meter
MTCA Model Toxics Control Act
ND Not detected
R-ND The chemical was researched by the Washington State Department of Ecology and no toxicity data of acceptable quality was founc
VOC Volatile organic compound
USEPA U.S. Environmental Protection Agency

Table 12.1
Landfill Gas Building Control Technologies

LFG Building Control Technology	Advantages	Disadvantages	Applicability to South Park Landfill
Impermeable floor/slab barriers	• Simple • Low maintenance • Low cost • Positive barrier • Easy to construct in new construction	• Not applicable for existing slab on grade • Expansion joints, penetrations, interfaces, or cracks may allow gas access without careful design	High
Passive venting	• Simple • Low maintenance • Easily combined with impermeable barriers • Low cost	• Not applicable for existing slab on grade • Limited to perimeter trenching	Moderate/High
Active perimeter collection below buildings (trench or wells)	• Applicable for existing buildings • Moderate operation cost • Moderate construction cost • Can be tied into existing below-slab aggregate layer	• Less effective than vents and barriers • Methane and possible odors • Requires routine O&M	Moderate/Low
Impressed air curtain	• Easy to monitor discharge air • Applicable for existing buildings • Moderate operation cost • Moderate construction cost • Can be tied into existing below-slab aggregate layer • Easy to retrofit • Vents LFG from below existing buildings	• May need odor treatment • Requires routine O&M	Moderate

Table 12.1
Landfill Gas Building Control Technologies

LFG Building Control Technology	Advantages	Disadvantages	Applicability to South Park Landfill
Interior building monitoring	• Provides emergency alarm	• Requires routine O&M • Moderate/expensive cost • Not always compatible with building use • Coverage area is small • False-positive alarms	Moderate/Low

Abbreviations:
LFG Landfill gas
O&M Operation and Maintenance

Table 12.2
Landfill Gas Control Technologies

LFG Control Technology	Advantages	Disadvantages	Applicability to South Park Landfill
Cap/Cover systems	• Simple • Low maintenance	• Moderate cost • Needs to work in concert with LFG system	Moderate/High
Passive trench venting	• Low cost • Minimal O&M • Convertible to active • Compatible with multiple systems • Effective at waste extents • Works well with impermeable cover systems • Works well with semi-permeable covers over subsurface collection layers (i.e., crushed rock under asphalt pavement)	• Limited radius of influence within landfill	Moderate
Perimeter barriers	• Controls migration at waste extents	• Moderate to high cost • Utility conflicts	Moderate
Extraction wells	• Discrete zone control • Shallow depth makes affordable • Compatible with multiple systems	• Moderate maintenance required • Moderate cost • Limited influence radius • Requires blower and possible treatment	Moderate

Table 12.2
Landfill Gas Control Technologies

LFG Control Technology	Advantages	Disadvantages	Applicability to South Park Landfill
Active collection trenches	• Discrete zone control • Compatible with multiple systems	• Moderate maintenance required • Moderate cost • Limited influence radius • Requires blower and possible treatment	Moderate

Abbreviations:
LFG Landfill gas
O&M Operation and Maintenance

Table 12.3
Landfill Gas Treatment Technologies

LFG Treatment Technology	Advantages	Disadvantages	Applicability to South Park Landfill
Flare	• Simple • Low maintenance • Complete destruction of NMOC, methane, and odors	• Requires high auxiliary fuel use • Requires enclosed flame—large footprint • Moderate cost	Low
Thermal oxidizer	• Complete destruction of NMOCs, methane, and odors	• Requires auxiliary fuel • Moderate maintenance required • High cost	Moderate/Low
Regenerative catalytic resin membrane	• Destroys NMOCs	• Moderate maintenance required • Vents methane and possible odors • High cost	Low
Carbon filter	• Simple • Controls some NMOCs and odors • Low cost	• Vents methane • Requires frequent carbon replacement • Selective control	Moderate
Compost filter	• Simple • Effective on odors • Low cost	• Vents methane • Large footprint • Maintenance of compost media	Moderate/Low

Abbreviations:
LFG Landfill gas
NMOC Non-methane organic compound

Table 15.1
Proposed Monitoring Well Network

Well	Location	Zone	Comments
Upgradient Wells (Quality of Groundwater Entering the Site)			
KMW-05	Upgradient	Perched Zone and A-Zone	Known source of contamination, including benzene
MW-12	Upgradient	A-Zone	Low levels of vinyl chloride; currently less than CULs
MW-14	Upgradient	A-Zone	Non-detect for vinyl chloride
MW-29	Upgradient	A-Zone	Non-detect for vinyl chloride
Downgradient Wells Representing Conditions at the Edge of Waste			
MW-18	Edge of waste	A-Zone	In compliance
MW-25	Edge of waste	A-Zone	Maximum Site-related VC (0.5 to 1.4 µg/L)
MW-32	Edge of waste	A-Zone	Installed below refuse on near edge of SR 99
MW-33	Edge of waste	A-Zone	Installed below refuse on near edge of SR 99
MW-26	Downgradient	A-Zone	Downgradient; far edge of SR 99
MW-27	Downgradient	A-Zone	Downgradient; far edge of SR 99
MW-10	Downgradient	B-Zone	Downgradient; pair with MW-25
MW-24	Downgradient	B-Zone	Downgradient; far edge of SR 99; pair with MW-26
MW-08	Downgradient	B-Zone	Downgradient; far edge of SR 99; pair with MW-27
Downgradient Wells Representing Conditions Near Former Glitsa Property			
MW-30	Downgradient	Perched Zone	Vinyl chloride; monitors Perched Zone at former Glitsa property
MW-31	Downgradient	A-Zone	Vinyl chloride; downgradient of both Perched Zone at former Glitsa property and A-Zone at the Landfill

Abbreviations:

CUL	Cleanup level
Glitsa	Glitsa American, Inc.
Landfill	South Park Landfill
µg/L	Micrograms per liter
Site	MTCA-regulated site
SR	State Route

Table 15.2
Proposed Analytical Schedule[1]

Chemical	Analytical Method	Location	Comment
Chemicals of Concern			
Benzene	SW846 – 8260 Short List	KMW-05 & MW-25 only	In compliance in all other wells
TCE	SW846 – 8260 Short List	All wells	Precursor to vinyl chloride
cis-1,2-DCE	SW846 – 8260 Short List	All wells	Precursor to vinyl chloride
Vinyl chloride	SW846 – 8260 Short List	All wells	COC
Iron	SW846 – 6010 Short List	All wells	COC
Manganese	SW846 – 6010 Short List	All wells	COC
Monitored Natural Attenuation and General Landfill Parameters			
Specific conductance	Field parameter	All wells	--
pH	Field parameter	All wells	--
Redox	Field parameter	All wells	--
Dissolved oxygen	Field and lab parameters	All wells	Critical geochemical parameter
Dissolved methane	RSK 175	All wells	Critical geochemical parameter
Dissolved hydrogen gas	RSK 175	All wells	Geochemical parameter
Sulfate	EPA 375.2	All wells	Geochemical parameter
Sulfide	EPA 376.2	All wells	Geochemical parameter

Note:

1 Only a limited suite of natural attenuation and landfill parameters have been included because of the age of the Landfill and the current groundwater conditions.

Abbreviations:

COC Chemical of concern
DCE Dichloroethene
Landfill South Park Landfill
TCE Trichloroethene