Feasibility Study Bridging Document

Gas Works Park Site
Seattle, Washington

for
Puget Sound Energy

October 11, 2013

GeoEngineers
Earth Science + Technology

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ACRONYM LIST

AB	Area Boundary
ALU	ambient Lake Union
AOI	area of investigation
ARARs	applicable or relevant and appropriate requirements
ATCO	American Tar Company
BaP	benzo(a)pyrene
bgs	below ground surface
BTEX	benzene, toluene, ethylbenzene, and xylenes
BTU	British thermal unit
CAP	cleanup action plan
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
cPAH	carcinogenic polycyclic aromatic hydrocarbons
COC	contaminant of concern
CRM	Candidate Remedial Measures
CSEM	conceptual site exposure model
CSL	cleanup screening level
CT	central tendency
CUL	cleanup level
DNAPL	dense nonaqueous phase liquid
DNR	Washington State Department of Natural Resources
EPA	US Environmental Protection Agency
ESA	Eastern Sediment Area
FFS	focused feasibility study
FS	feasibility study
GWPS	Gas Works Park Site
GWPSS	Gas Works Park Sediment Site
HPAH	high molecular weight polycyclic aromatic hydrocarbon
L	liter
LNAPL	light nonaqueous phase liquid
MGP	manufactured gas plant
µg	microgram
MTCA	Model Toxics Control Act
ng	nanogram
NAPL	nonaqueous phase liquid

PAHs	polycyclic aromatic hydrocarbons
PCBs	polychlorinated biphenyls
PSE	Puget Sound Energy
RAO	remedial action objective
RCW	Revised Code of Washington
RI	remedial investigation
RME	reasonable maximum exposure
SCSD	Supplement to the Cleanup Standard Document
SCSL	Site-specific cleanup screening level
SMA	sediment management area
SMS	Sediment Management Standards
SQS	sediment quality standard
SSQL	site-specific sediment quality level
TarGOST®	Tar-specific Green Optical Screening Tool
TBT	tributyltin
TEE	terrestrial ecological evaluation
TPAH	total polycyclic aromatic hydrocarbons
TSWP	Treatability Study Work Plan
USC	United States Code
UV	ultraviolet
WAC	Washington Administrative Code
WNG	Washington Natural Gas
WSA	Western Sediment Area

EXECUTIVE SUMMARY

The site (hereafter referred to as the Gas Works Park Site or GWPS), was recently redefined by modifying Agreed Order DE 2008 to include the upland (i.e., Gas Works Park and Harbor Patrol) and adjacent sediments. The expanded area of investigation ensures upland to sediment pathways are adequately characterized and facilitates completion of a site-wide remedial investigation and feasibility study (RI/FS) that encompasses both upland and offshore sediment areas. This Feasibility Study (FS) Bridging Document has been prepared to "bridge" from previous work performed to a site-wide FS. As such, this document summarizes previous remedial investigations, feasibility studies, and cleanup actions conducted to date for upland and in-water portions of the site and describes the approach that will be followed to complete the site-wide FS.

Numerous environmental investigations have been conducted in the upland and sediments to characterize the nature and extent of contamination. Earlier work identified the chemicals of concern (COCs) associated with historical operations conducted at the GWPS. Existing site data were reviewed to identify additional data needs and develop the scope of a supplemental investigation. The purpose of the supplemental investigation is to provide additional data to characterize potential upland sources and migration pathways to sediments to allow completion of the site-wide RI/FS. The scope of the supplemental investigation is presented in the March 2013 Supplemental Investigation Work Plan.

A number of studies have been completed to evaluate remedial alternatives for the GWPS. One of these, the 1998 focused feasibility study, culminated in a Cleanup Action Plan (CAP) for the upland. The CAP describes remedial actions which have since been implemented in the upland. Prior to this, several remedial actions focused on source removal were completed. The 1999 consent decree required implementation of several cleanup actions; these actions have reduced risk to park users associated with soil and groundwater. An additional remedial action to address contaminated soil in the Kite Hill area is planned for fall 2014.

The primary GWPS COCs are polycyclic aromatic hydrocarbons; volatile aromatic hydrocarbons and arsenic are additional COCs for specific media in the uplands. A preliminary conceptual site exposure model (CSEM) has been prepared to identify sources, transport mechanisms, and exposure media of potential concern as well as exposure pathways and potential receptors for COCs to be addressed in the site-wide FS. Supplemental investigation data will be integrated into the preliminary CSEM to address entire pathways from source to receptor for use in the site-wide FS.

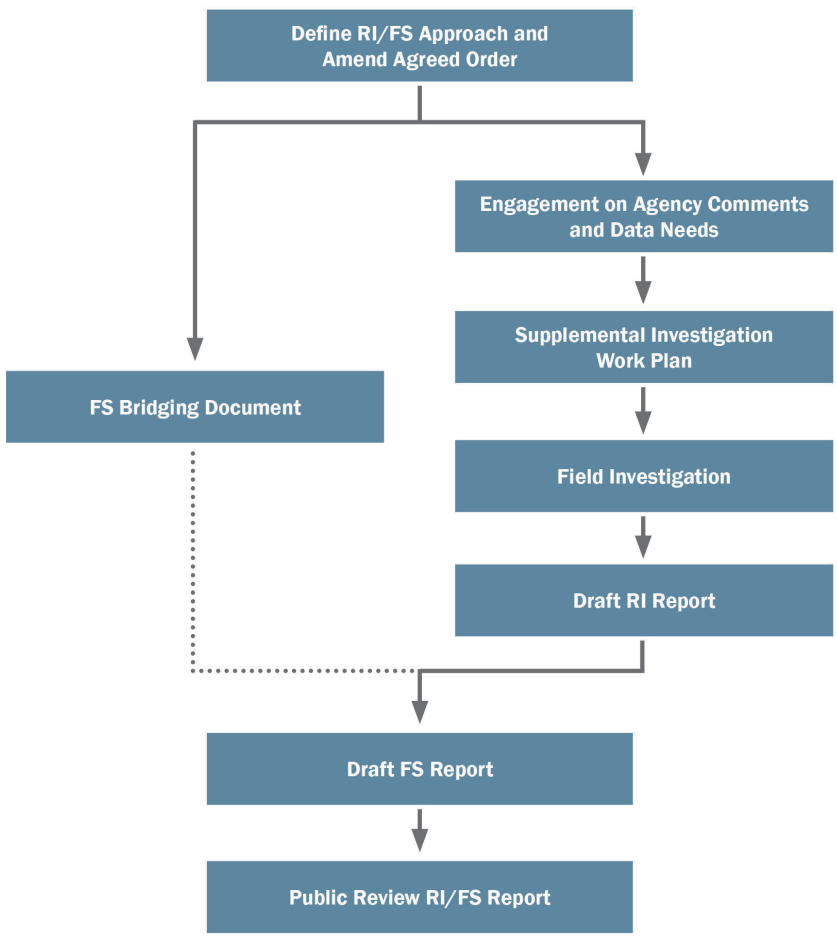
The site-wide FS, outlined in this FS Bridging Document, will incorporate a significant amount of work performed during previous feasibility study analyses for the GWPS, where applicable. However, the site-wide FS will also be based on updated site characterization data, data resulting from previous completed cleanup actions, and updated regulatory requirements. Compliance with all applicable or relevant and appropriate requirements will form the basis for remedial action goals, cleanup levels, points of compliance, and ultimately a remedy for a site. The CSEM will be used to develop site-specific remedial action objectives (RAOs) that address each complete pathway for the site. RAOs will also be used to evaluate remedial alternatives in the site-wide FS.

The remedial alternatives developed in the site-wide FS will represent site-wide actions using mutually compatible technologies for upland soil and groundwater as well as sediment. Transport pathways between soil, groundwater, and sediment representing significant risk to human and ecological receptors will be addressed holistically in the FS. The alternatives will be evaluated in accordance with Model Toxics Control Act (MTCA) to identify a preferred alternative.

The path forward for the project is shown graphically below. The primary workflow generally consists of completing the supplemental investigation followed by completion of a site-wide RI/FS report. Although not part of the primary workflow, this document summarizes previous work and describes the approach for completing the site-wide FS.

GAS WORKS PARK SITE

Conceptual Workflow



1.0 INTRODUCTION

This Feasibility Study Bridging Document has been prepared for Puget Sound Energy (PSE) and the City of Seattle (City) to describe the process associated with completion of a site-wide feasibility study (FS) for City of Seattle (City) Gas Works Park and Harbor Patrol properties and adjacent in-water areas in Lake Union, Seattle, WA (Figure 1). Previous investigations (including remedial investigations and feasibility studies) and remedial action planning have been completed for portions of the site; however, no site-wide evaluation has been conducted to support previously performed remedial actions and final cleanup planning for the site in its entirety, including pathways between the upland and in-water portions of the site.

In order to "bridge" from previous work to a site-wide FS, this document:

- Summarizes the previous remedial investigations, feasibility studies, and cleanup actions conducted to date for upland and in-water portions of the site;
- Identifies subsequent data needs and currently ongoing supplemental investigation efforts to collect additional data;
- Concludes with a description of the process for preparing a site-wide FS for the combined upland and sediment areas that will form the basis of the final cleanup action plan for the whole site.

The Gas Works Park Site (GWPS) was originally defined in a 1999 Consent Decree as the upland areas of Gas Works Park and the adjacent Harbor Patrol property to the west of the park (Ecology 1999). The Gas Works Park Sediment Site (GWPSS) was initially defined in a 2005 Agreed Order (Ecology 2005a) to be the adjacent 56 acres of impacted sediment that are submerged or seasonally submerged by the waters of Lake Union. The GWPSS was recently modified to include the GWPS as defined in the 1999 Consent Decree. This change was made to ensure the upland to sediment pathway is adequately characterized and facilitate completion of a site-wide remedial investigation and feasibility study (RI/FS) that encompasses both upland (original GWPS) and offshore sediment (original GWPSS) areas. For simplicity, the combined upland and in-water portions of the site will be referred to as the GWPS (Figure 2). For the purposes of this report, "the uplands" or "the upland portion of the GWPS" refers to the original GWPS, consisting of Gas Works Park and the Harbor Patrol property, as shown on Figure 2 and Figure 3.

2.0 BACKGROUND INFORMATION

The upland portion of the GWPS is located on a 20.5-acre peninsula (formerly known as Brown's Point), at the northern edge of Lake Union (Figure 2). The GWPS includes several properties owned by the City of Seattle: Gas Works Park and the Harbor Patrol property adjacent to the west boundary of the park. The present shoreline is the result of placement of fill material primarily between 1907 and 1929 to expand the peninsula over time for industrial use (Washington State Board of Appraisers of Tide and Shore Lands and Commissioner of Public Lands 1907, Sanborn Fire Insurance 1919, Seattle Gas Company 1949).

Gas Works Park consists of open grassy areas and landscaping in addition to historic industrial structures and a bulk-headed shoreline known as the Prow. As a city-wide destination known for sponsoring summertime public events, the park is accessed by car, bus, bicycles, and by foot (the Burke-Gilman bike trail runs along the north border of the park).

Industrial or commercial properties, including offices and warehouses, are adjacent to the GWPS. The Chevron/Metro industrial site, leased, in part, by the Center for Wooden Boats, and the North Lake Union Shipyard are located west of the Harbor Patrol property. The Gas Works Park Marina is located to the east. Residences and commercial facilities are located immediately north of the park boundary and within the Gas Works Park Marina adjacent to the northeastern boundary of the park.

Historical operations and activities at the GWPS have resulted in contamination of soil, groundwater, and sediment. The upland portion of the GWPS has been investigated, remedial actions have been implemented, and monitoring is ongoing. The nature and extent of contamination in sediment areas has also been investigated. The following documents contain more complete descriptions of background information or more detailed descriptions of site conditions:

- Supplemental Investigation Work Plan prepared for the Gas Works Park Site (GeoEngineers 2013).
- Remedial Investigation prepared for the Gas Works Park Site (Hart Crowser 2012).
- Gas Works Park Eastern Shoreline Investigation Data Report (AECOM 2008).
- Gas Works Sediment Area Supplement to the Cleanup Standards Document (AECOM et al. 2012).
- Hydrogeologic Testing Report for Gas Works Sediment Area (GWSA) (Aspect 2012).
- Draft Groundwater Flow Model Construction and Calibration Memorandum for Gas Works Sediment Area (Aspect et al. 2012).
- Gas Works Park Northeast Corner Investigation Data Report (Floyd|Snider 2008b).
- Monitoring Well Installation Report for Gas Works Sediment Area (GeoEngineers 2010).
- Work in Progress Geologic and Interpreted NAPL Cross Sections for Gas Works Sediment Area (GWSA 2010b).
- Draft Revised Geologic CSM Memorandum - Maps and Cross-Sections for Gas Works Sediment Area (GWSA) (GWSA Technical Team 2011a).
- Preliminary Revised Hydrogeologic Conceptual Site Model Memorandum for Gas Works Sediment Area (GWSA Technical Team 2011b).
- Regional Geologic Setting Memorandum for Gas Works Sediment Area (GWSA Technical Team 2011c).
- Gas Works Sediment Western Study Area (WSA) Remedial Investigation/Feasibility Study (RI/FS) (Floyd|Snider 2007a).
- Gas Works Sediment Eastern Study Area (ESA) Draft RI/FS (RETEC 2006).

2.1. Site History

Site history reflects the evolution of the Puget Sound region. Once the home of the Duwamish Tribe, it was later the site of small homesteads and farms. This area of Seattle was originally settled by non-natives in the mid- to late 1800s. The first industries were associated with sawmills and forest products. Lake Union was a major barge route for coal mined in eastern King County, timber, and other materials. In 1891, Wallingford and other communities on the north side of Lake Union were annexed by the City of Seattle. In 1907, a manufactured gas plant (MGP) was constructed on the north shore of Lake Union to service the growing communities around Seattle. The following sections discuss site history from 1907 onwards.

2.1.1. The Manufactured Gas Plant

The MGP, constructed by the Seattle Gas Light Company on the eastern side of Brown's Point, operated until 1956. Three gas manufacturing processes were used at the plant (Progressive Age, multiple dates):

- Coal carbonization from 1907 to 1937;
- Carbureted water gas from 1907 to 1952; and
- Oil gas (Pacific Coast Low BTU Oil Gas--500 BTU) from 1937 to 1956.

The Cracking Towers (gas production towers) currently located on the GWPS were associated with the oil gas process—the third manufacturing process used at the facility. Historical MGP features, including overwater structures, are shown on Figure 4. In 1954, the Trans Mountain Pipeline began providing natural gas to the Seattle area. This decreased demand for manufactured gas, and led to the plant closing in 1956 (Sabol et al. 1988). The MGP was in stand-by mode from 1956 to approximately 1966; it was subsequently used for gas storage until the property was transferred to the City in 1973.

2.1.2. The Tar Refinery

West of the MGP, a tar refinery began operating sometime between 1907 and 1912. The tar refinery operated until the mid-1950s under the name American Tar Company (ATCO) (Figure 4) and continued with storage operations into the mid-1960s (USEPA 1995). According to a 1924 Seattle Times article, the tar refinery obtained tar from the adjacent gas plant and from other gas plants throughout the Pacific Northwest. These materials were refined using steam distillation to produce various grades of tar and tar derivatives (Seattle Times 1924).

2.1.3. Municipal Landfill/Incinerator

The City operated a landfill at Lake Union at the foot of Wallingford Avenue N (western portion of the GWPS) (City of Seattle 1914). Municipal landfill operations ended in this area by the early 1920s. Earlier, the City also operated a refuse incinerator at the junction of Wallingford Avenue N and N Northlake Way from 1912 to 1914.

2.1.4. Park Construction

From 1962 to 1973, MGP decommissioning and demolition were conducted by Washington Natural Gas (WNG). In 1971, a master plan for what would become Gas Works Park was completed (Richard Haag and Associates 1971). By this time, the MGP had been decommissioned, some MGP facilities had been demolished, and fill material had been imported and stockpiled in the Kite Hill area. Between 1972 and 1976, park development activities were conducted by the landscape architecture firm Richard Haag Associates.

In 1973, the City completed limited improvements to the Great Mound (Kite Hill) so that it could be temporarily opened for public use during development of the remainder of the park. The Great Mound primarily consisted of imported excavation material generated from construction at Interstate 5, the Safeco Building, and possibly other off-site sources (Sabol et al. 1988). Earlier in 1973, the City authorized targeted excavation of contaminated soil and demolition throughout the remainder of the park. Targeted excavation depths extended up to 8 feet below grade and to "water level" near shore. Substantial cutting and stockpiling of impacted soil occurred during these excavation activities. A minimum of 20,000 cubic yards of impacted soil were excavated and temporarily stockpiled on site; however, exact quantities of what was excavated and removed from the park are unknown. By early 1974, most of the demolition of former MGP structures, excavation, and regrading of the majority of the park had occurred. In 1975, the focus was on renovating the former MGP structures to become the Picnic Shelter and Play Barn.

In 1976, another phase of regrading occurred as the uplands were sculpted into their current topographic form. Between 1973 and 1976, substantial soil was cut from shoreline areas and areas away from the shoreline were filled. Near the end of the redevelopment, a layer of soil, sawdust, and dewatered biosolids (as fertilizer) was tilled into the soil to encourage the breakdown of pollutants and control dust (Richard 1983). Two inches of hydroseeded topsoil was used for cover. The property was opened as a public park in 1976.

2.2. Environmental Setting

Lake Union is a glacially carved water body that drained to Salmon Bay via a small stream. Originally hydraulically isolated from Lake Washington, it now forms a major component of the Lake Washington Ship Canal system. The lake serves as the receiving water for outflow from Lake Washington, stormwater from a variety of private and municipal sources, and combined sewer overflows from the City and King County. In addition, various industries (e.g., boat yards and shipyards) discharge to the lake. Much of the shoreline is developed, with a high percentage of overwater cover from docks, piers, and house boats. Naturalized shoreline features exist as part of small pocket parks that have been constructed around the lake; Gas Works Park represents the largest section of public shoreline on the lake.

The GWPS is underlain by low-permeability pre-Vashon glacial till. Higher permeability glacial outwash deposits, including Vashon recessional outwash and Vashon advance outwash, are on top of the till along the eastern and western shorelines and adjacent upland areas (GWSA Technical Team 2011a). Additional detail on site geology is provided in Appendix A.

Direct recharge to fill and outwash deposits is the main source of groundwater from the uplands to the lake. Total groundwater discharge to north Lake Union from the uplands is estimated to range from 1,100 to 1,920 cubic feet per day for the entire area of the Park, or approximately 6 to 10 gallons per minute. Greater than 98 percent of the groundwater discharge is estimated to originate from direct recharge, primarily from precipitation and irrigation at the park (Aspect et. al. 2012).

Groundwater generally flows radially across the uplands before discharging to Lake Union (Figure 4). The average horizontal gradient observed in the uplands during five recent groundwater monitoring events ranges from approximately 0.01 to 0.02 feet per foot. Groundwater elevations in the glacial till appear to be controlled by seasonal recharge due to infiltration and tend to be higher during wet weather and subsequent months (i.e., winter and spring) and lower in the summer when the weather is drier. Groundwater elevations in monitoring wells near the shoreline tend to be governed by the elevation of Lake Union, which is maintained by the US Army Corps of Engineers[1] at a higher elevation in the summer.

2.3. Regulatory Framework

The U.S. Environmental Protection Agency (EPA) became interested in the park in 1981 and conducted a survey of off-shore sediments in 1983. Based on the results of this survey, EPA notified WNG (PSE's predecessor) that they may be a responsible party under the Comprehensive Environmental Response Compensation and Liability Act (CERCLA or Superfund). Ecology conducted a Site Hazard Assessment in 1990 and notified the City and PSE of their "potentially liable persons" status. In 1996, Ecology and EPA signed a Deferral Agreement formally deferring regulatory authority to Ecology to oversee response actions on the GWPS. Since then, environmental investigations, studies, and remedial actions have been overseen by Ecology. The following legal instruments govern response actions on the GWPS:

- Deferral Agreement between EPA Region 10, dated July 17, 1996 (EPA 1996). This document formally defers site regulatory authority to Ecology (Ecology 1996).
- Agreed Order number 97TC-148, dated August 1, 1997. The 1997 Agreed Order executed by the City and PSE develops procedures and a schedule for preparation of cleanup action planning documents related to contaminated media in the uplands (Ecology 1997).
- Consent Decree 99-2-52532-9SEA, dated December 22, 1999. This document establishes the framework for remedial actions on the uplands (Ecology 1999).
- Amendment 1 to Consent Decree 99-2-52532-9SEA, dated May 12, 2005. This document incorporated an updated Cleanup Action Plan (CAP) for the uplands (Ecology 2005b).
- Agreed Order DE 2008, dated March 18, 2005. This document establishes the framework for sediment investigation within the area of investigation (AOI) in Lake Union (Ecology 2005a).
- Modification of Agreed Order DE 2008, dated March 15, 2013. The agreed order was modified to expand the AOI defined in the 2005 Agreed Order to include the uplands (Figure 2). The AOI was expanded to ensure that upland-to-sediment pathways are adequately characterized. The modified Agreed Order requires preparation of a site-wide RI/FS that will address sediments,

[1] The Corps maintains the water level in Lake Union by regulating flow through the Hiram M. Chittenden Locks on the western end of Salmon Bay. Lake Union water levels vary approximately 2 feet on a yearly basis, from approximately 20 feet during the winter months to approximately 22 feet during the summer months.

inclusive of the shoreline area, and upland areas that are part of upland-to-sediment pathways (Ecology 2013).

2.4. Summary of Existing Remedial Investigation Data

The nature and distribution of hazardous materials at the park have been investigated and monitored by the City, PSE, EPA, and Ecology since 1971. Early environmental assessments of the subsurface conditions began in that year. In the 1970s, several soil investigations took place during planning and development of the park. In the 1980s, multiple soil and groundwater quality investigations were conducted, as concerns regarding potential contamination of the park were explored. Further investigations took place in the 1990s, 2000s, and 2010s.

Sediment investigations date back to EPA's initial survey in 1983. EPA conducted a second investigation in 1994. PSE began their investigation in 1999 and conducted a second phase of investigation in 2002. Ecology, with Texas A&M University, also conducted an investigation in 2002. The City began their investigation in 2004. The final phase of the sediment RI/FS investigation was completed by the City and PSE in 2004 and 2005.

Descriptions of the major investigations are provided in Table 1; full details can be found in the investigation documents listed in the reference section. Exploration/sample locations associated with previous investigations are shown on Figures 5 (upland) and 6 (sediments). A supplemental investigation, being conducted in 2013, will refine our understanding of the nature, extent, fate, and transport of site-related chemicals; this information will be interpreted in the site-wide RI/FS.

2.4.1. Chemicals of Concern

The chemicals produced by the industrial processes conducted on site—manufacture of gas from coal and petroleum and tar refining—are well established and consist primarily of polycyclic aromatic hydrocarbons (PAHs). Additional chemicals associated with these historical industrial processes include benzene, toluene, ethylbenzene, xylene, arsenic, sulfur, and cyanide. Cleanup levels (CULs) for contaminants in soil and groundwater with the broadest distribution representing the greatest risk for the upland area were established in the upland CAP (Parametrix 1999) and incorporated into the 1999 Consent Decree (Ecology 1999). The contaminants for which cleanup values were specified were volatile organic compounds (VOCs) (specifically benzene, toluene, and ethylbenzene), seven carcinogenic PAHs (cPAHs), selected non-carcinogenic PAHs, and arsenic.

CLEANUP LEVELS ESTABLISHED IN THE 1999 CONSENT DECREE

Analytes	Groundwater Cleanup Level[1] (µg/L)	Soil Cleanup Level[1] (mg/kg)
Metals		
Arsenic	NE	20
Carcinogenic PAHs		
Benzo(a)anthracene	0.0296	0.137
Benzo(b)fluoranthene	0.0296	0.137
Benzo(k)fluoranthene	0.0296	0.137

Analytes	Groundwater Cleanup Level[1] (µg/L)	Soil Cleanup Level[1] (mg/kg)
Benzo(a)pyrene	0.0296	0.137
Chrysene	0.0296	0.137
Dibenzo(a,h)anthracene	0.0296	0.137
Indeno(1 ,2,3-cd)pyrene	0.0296	0.137
Other PAHs		
Fluoranthene	90.2	3,200
Fluorene	3,460	NE
Naphthalene	9,880	3,200
Pyrene	2,590	2,400
Volatile Organic Compounds		
Benzene	43	NE
Ethylbenzene	6,910	NE
Toluene	48,500	NE

Note:

[1]Cleanup levels established in Cleanup Action Plan based on MTCA Method B.

µg/L = micrograms per liter PAH = Polycyclic aromatic hydrocarbon

mg/kg = milligrams per kilogram NE = not established; is not a risk driver in this medium

PAHs and VOCs are present at the highest concentrations in non-aqueous phase liquid (NAPL) and NAPL-impacted media. The highest concentrations of VOCs were associated with light non-aqueous phase liquid (LNAPL) in the southeast area of the upland (Hart Crowser 2012); this area was subsequently remediated. PAHs, and to a lesser extent VOCs are associated with tars—namely coal tar, carbureted water gas tar, and oil gas tar. These tars are typically manifested as dense non-aqueous phase liquid (DNAPL) and as residual impacts to soil and sediment. Where the MGP and tar refinery tars are weathered and/or present in a semi-solid or solid form, they are considered to be a “tar” in the generic sense. Further usage of the term “tar” in this document will refer to the generic semi-solid to solid tar and is not intended to imply the particular type (e.g., coal tar) or source (e.g., MGP) of the tar.

A separate screening process was conducted for the sediments that identified PAHs, selected metals, polychlorinated biphenyls (PCBs), pentachlorophenol, bis(2-ethylhexyl)phthalate, chlordane, and tributyltin (TBT) as the contaminants most likely posing risks associated with direct or indirect exposure to sediment (AECOM et.al., 2012). Because there are multiple sources of almost all of these chemicals to an urban waterway such as Lake Union, an evaluation of area background concentrations was conducted. PAHs were the only contaminants that were significantly higher in sediments adjacent to the park relative to the remainder of Lake Union. Total PAH (TPAH) was selected to represent this group of related compounds and a preliminary cleanup level of 170 mg/kg dry weight was calculated for protection of benthic organisms based on site-specific bioassay responses and an evaluation of the spatial distribution of bioassay failures relative to site-specific chemistry. Details of this evaluation are provided in the Cleanup

Standard Determination document (RETEC 2005). As a companion to the Cleanup Standard Determination document, the Supplement to the Cleanup Standards Document (AECOM et.al., 2012) was prepared to further evaluate site-wide chemicals of potential concern and determine indicator COCs that drive risk at the GWPS. This evaluation determined that TPAH, benzo(a)pyrene, and high molecular weight PAH (HPAH) are the indicator COCs that drive risk.

A summary of the occurrence and distribution of contaminants representing significant potential risks at the GWPS based on existing information is provided in the following sections. Additional data being collected as part of a supplemental investigation will be evaluated in the site-wide RI. Discussion and graphical presentation of existing data focuses on the following contaminants:

- Total PAHs, (TPAH) as a surrogate for PAHs as a whole, in sediment;
- Naphthalene, as the most mobile PAH, in soil, sediment, and groundwater;
- Benzo(a)pyrene (BaP), as the most toxic PAH, in soil, sediment, and groundwater;
- Benzene, as the most toxic of the VOCs, in soil and groundwater;
- Arsenic in soil; and
- LNAPL and DNAPL.

2.4.2. Soil

Shallow surface soil samples have been collected throughout the upland area. Concentrations of BaP, naphthalene, benzene, and arsenic in soil samples are presented on Figures B-1 through B-8 in Appendix B of this FS Bridging Document. Shallow soil (depth of 0 to 3 feet below ground surface [bgs]) sample locations and analytical results are presented on Figures B-1 through B-4. Subsurface soil sample locations and analytical results (deeper than 3 feet bgs) are presented on Figures B-5 through B-8.

The majority of the upland area is covered by structures, impervious surfaces, and vegetated soil covers. The primary exception is the Kite Hill/Cracking Tower area although localized areas in the northeast corner of the park also remain uncovered. Areas of previous cleanup actions, including installation of soil caps, are shown on Figure 7, and discussed further in Section 5.0. Shallow soil samples in areas subsequently covered by soil caps are not representative of current surface soil conditions.

BaP was detected in shallow and subsurface soil samples collected from numerous locations across the uplands at concentrations exceeding the CUL of 0.137 mg/kg. Figures B-1 and B-5 in Appendix B show the location and concentrations of BaP detected in soil samples. The highest concentrations of BaP were detected in soil samples from north of the Prow, in the northeast corner, Harbor Patrol, and the southeast area.

Concentrations of naphthalene were detected in shallow and subsurface soil samples collected from numerous locations across the upland area at concentrations below the CUL. Figures B-2 and B-6 in Appendix B show the location and concentrations of naphthalene detections in soil. Concentrations of naphthalene exceeded its CUL of 3,200 mg/kg in two samples. One soil sample collected from 16.5 feet bgs from a boring located in the Harbor Patrol area, contained

6,695 mg/kg naphthalene. This exceedance occurs below a depth considered to represent a potential risk to humans through direct contact. Another soil sample from 9 feet bgs from a boring located in the northeast corner, contained 8,200 mg/kg naphthalene.

Benzene was not detected at concentrations greater than the reporting limit in shallow samples from the Kite Hill area, with the exception of one soil sample from an area where soil was later removed (see Section 5.0). Benzene exceeded the Model Toxics Control Act (MTCA) Method B cleanup level (18 mg/kg) in subsurface soil samples primarily from the southeast area in the former location of the light oil plant, and in one sample in the northeast corner. Figures B-3 and B-7 in Appendix B present benzene concentrations in surface and subsurface soils.

Concentrations of arsenic were detected in surface and subsurface soil samples throughout the park. Arsenic concentrations exceeding the CUL of 20 mg/kg were limited to five shallow soil samples (collected from 0 to 3 feet bgs) on the east side of the park in the Play Barn area, and one shallow soil sample collected near the Cracking Towers (Hart Crowser 2012, AMEC 2012). Arsenic concentrations are depicted in Appendix B—Figures B-4 (surface soil) and B-8 (subsurface soil).

Recoverable LNAPL was removed and an air sparging/soil vapor extraction system operated in the southeast area (shown on Figure 7) from 2001 to 2006 (ThermoRETEC 2001, Hart Crowser 2012). Analytical soil sample results from the southeast area that were collected before 2006 (i.e., when air sparging/soil vapor extraction was discontinued) are not considered representative of current subsurface conditions in this area.

2.4.3. Groundwater

Concentrations of BaP, naphthalene, and benzene in groundwater from selected monitoring events are presented in figures included in Appendix C (Figures C-1 through C-3). Arsenic was not selected as a site-specific groundwater contaminant because arsenic was detected in upgradient monitoring well MW-3D at a concentration of 4.9 µg/L indicating the presence of arsenic in area-wide groundwater (Parametrix and Key 1998).

BaP exceeded the CUL at a number of locations throughout the uplands. Similar to naphthalene, it was also detected at the greatest concentrations in groundwater samples collected from the Harbor Patrol/former ATCO area.

Naphthalene was detected in most groundwater samples reported, but only exceeded the CUL in a limited number of locations. Concentrations of naphthalene were greatest in groundwater samples collected from Harbor Patrol/former ATCO area.

Benzene was detected at concentrations greater than the CUL of 43 µg/L in groundwater samples collected from monitoring wells located in the Harbor Patrol area, central meadow, near the Cracking Towers/Kite Hill, and in the air sparging/soil vapor extraction area in the southeast area. Concentrations of benzene were greatest in groundwater samples collected from the southeast area, Harbor Patrol, and the former ATCO property. Benzene was remediated in the southeast area. Concentrations in groundwater samples collected in February 2011 from OBS-1, OBS-2, and OBS-3, are more than 100 times lower than the concentrations of benzene collected from those monitoring wells in July 2000 and comply with the remediation level established to meet the cleanup level at the groundwater conditional point of compliance located within the surface water of Lake Union as close to the groundwater - surface water interface as possible, as specified in the upland CAP (Parametrix 1999).

2.4.4. Sediment

Three comprehensive sediment investigations were conducted between 1999 and 2005 in Lake Union adjacent to the park. Collectively, these three phases of investigation comprise the sediment RI. The first two phases of investigation, conducted in 1999 and 2002, evaluated nature and extent of sediment contamination, identified contaminants most likely posing unacceptable risks, and were used to establish the AOI for completion of the remedial investigation. The third and final phase of the sediment RI consisted of two separate investigations for the east and west portions of the sediment area in 2004 and 2005.

As discussed above, TPAH was the contaminant encompassing the greatest distribution and bioassay effects associated with site-related releases. Surface sediment TPAH concentrations ranged from 5 to 18,015 mg/kg; however, impacts decreased offshore to below the preliminary cleanup level within ~300 feet of the shoreline. Appendix D includes figures presenting TPAH concentrations in sediment excerpted from the 2007 WSA RI/FS (Floyd|Snider et al. 2007a) and the 2006 ESA RI/FS (RETEC 2006). The original AOI line shown on the Appendix D figures was drawn based on evaluation of historic sediment investigation data to delineate chemical concentrations associated with GWPS and ambient Lake Union sources. The following considerations were made to delineate the AOI:

- Based upon historical activities at the GWPS, PAHs were primarily used as a basis for defining the AOI.
- GWPS area PAH patterns are generally distinguishable from ambient Lake Union sediments.
- Based upon the evaluation of sediment investigation data collected between 1994 and 2002, the extent of sediments containing elevated PAHs could be clearly delineated as a narrow band wrapping around the shoreline.
- The distribution of metals and other non-GWPS contaminants in sediments in the vicinity of the GWPS indicates the presence of non-GWPS sources that further help to delineate the extent of GWPS-related impacts.

TPAH concentrations generally increased with depth in the sediment column (Appendix D). Subsurface TPAH concentrations ranged from non-detect to 64,000 mg/kg.

2.4.5. Dense and Light Nonaqueous Phase Liquids (DNAPL and LNAPL) and Tar

Numerous subsurface explorations have been performed to evaluate the presence of visible DNAPL and LNAPL and tar throughout the GWPS. The estimated lateral extent and locations of known NAPL are presented on Figure 8. Upland areas where substantial subsurface NAPL has been encountered include Harbor Patrol/ATCO, the northeast corner of the park, and the Play Barn area. Recoverable LNAPL was removed and an air sparging/soil vapor extraction system was installed in the light oil plant area in 1999 and 2000 (Hart Crowser 2012). As a result of the LNAPL removal and system operation, LNAPL measurements made in this area before 2006 are likely not representative of current conditions. Visual observations of LNAPL were made during investigations performed east of the Play Barn in 2007. This area is outside the extent of the air sparging /soil vapor extraction system and will be incorporated into supplemental RI investigation activities.

DNAPL has been encountered in the Harbor Patrol/ATCO area and in the northeast corner of the park and at multiple locations in sediment. The high TPAH concentrations correlate with the presence of DNAPL at depth. In the lower lake slope and lake bottom regions of the east side of the park, DNAPL-impacted sediments are overlain by cleaner sediments providing evidence that DNAPL is not impacting surface sediments in these areas.

3.0 CONCEPTUAL SITE EXPOSURE MODEL

A conceptual site exposure model (CSEM), as used in this document, is a depiction of the potential primary and secondary chemical sources, transport mechanisms, pathways, and receptors at the GWPS. The CSEM identifies potential human and ecological receptors that could be affected by contaminants from MGP and other historical releases. A preliminary CSEM, graphically represented on Figure 9, has been developed for the GWPS based on existing information. It is considered a dynamic model and will be refined, as needed, based on the results of the supplemental investigation conducted in spring 2013. Institutional controls have been established for the uplands that address potential pathways for human receptors identified in this preliminary CSEM.

The CSEM does not quantify potential risks to human health or the environment posed by site-related chemical impacts. Instead, it is intended to focus on those pathways that may warrant further consideration (i.e., investigation, monitoring, or cleanup), because of the likelihood that there is a complete pathway from a source to a receptor. This section summarizes the main elements of the preliminary CSEM for the GWPS.

3.1. Primary and Secondary Sources of Potential Concern

Primary sources of contaminants at the GWPS generally consist of gas manufacturing and tar refining processes that released hazardous materials to the environment. Other primary sources of chemicals may exist at the GWPS, based on past site activities. Primary sources are often used to identify areas of likely affected media (e.g., soil, groundwater) that become secondary sources. However, the location of primary sources at the GWPS may not reflect the current location of all affected media and associated contaminants for the following reasons:

- Primary sources have been removed from the GWPS upland area during facility demolition and remedial actions.
- Natural transport mechanisms have distributed contaminants beyond the original source areas.
- Substantial cutting and filling occurred during park construction resulted in removal and/or relocation of COCs from primary source areas to other areas of the uplands.

Secondary sources at the GWPS include contaminated surface and subsurface soil, groundwater, surface and subsurface sediment, and NAPL.

3.2. Transport Mechanisms and Exposure Media of Potential Concern

Principle transport mechanisms and exposure media at the GWPS include:

- Erosion of soil (and weathered tar) and stormwater transport to surface water and sediment;
- Mobile NAPL migration to soil, surface water, and sediment;
- Erosion of bank/shoreline materials by wave action;
- Current transport of fine-grained sediments from nearshore to offshore, or along shore;
- Discharge of contaminated groundwater to surface water and sediment; and
- Uptake by benthic biota, crayfish and finfish from surface water and sediment.

Transport of contaminated surface water and infiltrated groundwater through storm drain to surface water and sediment is also considered a transport mechanism of concern for the GWPS. Storm drain transport will be addressed separately under the source control phase of the project.

3.3. Exposure Pathways and Potential Receptors for Chemicals of Concern

The following sections describe potential exposure pathways based on a preliminary CSEM. These exposure pathways are labeled as "complete or potentially complete" or "incomplete or minor pathway" in Figure 9. The preliminary CSEM is based on the preliminary evaluation of data from previous investigations. The CSEM will continue to be refined as existing data are further evaluated and new data are incorporated.

3.3.1. Outdoor and Indoor Air

The preliminary CSEM for the GWPS (Figure 9) includes evaluation of potential outdoor and indoor air pathways. Based on previous investigation findings, the exposure pathways and receptors associated with outdoor and indoor air determined to be potentially applicable for the GWPS included:

- Inhalation of potential vapors in indoor air, and
- Inhalation of vapors and particulate-bound contaminants in outdoor air.

The City conducted a study within the park to evaluate impacts to indoor and ambient air quality. During the late summer and early fall of 2006, mothball-like odors were noted in several sections of the park, particularly near the Play Barn, former MGP structures, and at the eastern shoreline where there were visible tar seeps. To evaluate the source and potential impacts of the odors, the City conducted an air quality-monitoring program consisting of collecting three rounds of ambient and indoor air samples in various areas of the park and at the Harbor Patrol. The monitoring program consisted of the following:

- Ambient air samples were collected from three locations including the Cracking Tower area, East Shoreline, and the Prow (upwind background sample).

- Air samples were collected inside the Harbor Patrol office building and below the Play Barn.
- Samples were collected in the spring (April) and summer (August/September) of 2007 and in the winter (January) of 2008.

Detailed descriptions of the air monitoring events and analytical results are presented in Quarterly Air Sampling Data Reports (Floyd|Snider 2007b, 2007c, and 2008a). A June 13, 2008, memorandum from Floyd|Snider summarizing the results of the air quality evaluation program is provided in Appendix E.

Aromatic hydrocarbons likely associated with material released from historical MGP operations were detected in most of the samples collected, along with low concentrations (less than 2 nanograms per liter [ng/L]) of several chlorinated VOCs that appear to be associated with background sources (e.g., personal hygiene and cleaning products). According to the analysis provided in the Floyd|Snider summary memorandum (Appendix E), concentrations of these aromatic compounds (excluding benzene) generally did not exceed MTCA Method B unrestricted (residential) air cleanup levels (Floyd|Snider 2008c). Although benzene concentrations typically exceeded the Method B air cleanup level of 0.32 ng/L, they generally fell within the range of Seattle ambient air background concentrations. Excluding an apparently anomalous Spring 2007 result obtained from one of two replicate samples collected in the Cracking Tower area, benzene concentrations in the air samples were also below a calculated modified Method B cleanup level applicable to a park recreational visitor exposure scenario (four hours per week of exposure versus continuous residential occupation).

Floyd|Snider concluded that the mothball-like odor noted during the summer of 2006 was primarily associated with surface tar on the eastern shoreline. Seattle Parks subsequently excavated the tar and covered the areas with clean gravel. Following these maintenance activities, no odors were noted during the spring and summer of 2007.

Based on the results of indoor and outdoor air monitoring in 2007 and 2008, concentrations of VOCs in outdoor and indoor air at the park and Harbor Patrol property are below levels of concern (Floyd|Snider 2008a). Therefore, volatilization to indoor and outdoor air, although complete, is considered a minor pathway and does not pose a significant risk to people or ecological receptors (Hart Crowser 2012).

Inhalation of particulate-bound contaminants in outdoor air was considered an incomplete or minor pathway because most surface soil at the GWPS is covered by vegetation, buildings, or pavement. Engineered, vegetated soil caps have been installed in most areas of the Park and additional capping is proposed to be completed in 2014/2015 in the Kite Hill area, as described in Section 5.1.3.

3.3.2. Soil

HUMAN HEALTH

Based on previous investigation findings, the potential exposure pathways and receptors for impacted soil in the upland portion of the GWPS include:

- Dermal contact with contaminated soil by park visitors and site workers;

- Incidental ingestion of contaminated soil by park visitors and site workers; and
- Direct contact with contaminated soil by terrestrial plants, soil biota, and wildlife.

Environ evaluated human health risk for uncapped areas of the uplands for the City. Hart Crowser incorporated Environ's work into the Uplands RI Report prepared for Ecology (Hart Crowser 2012). A summary of Environ's findings are provided below.

Surface soil contaminant concentrations were compared to MTCA Method B direct contact cleanup levels under a residential exposure scenario (i.e., assumed to be continuously exposed over 30 years). Contaminants (primarily cPAHs) exceeding Method B direct contact cleanup levels for soil are present across most of the uplands. However, buildings, paved areas, and clean vegetated soil caps installed on most of the uplands prevent park visitors from directly contacting these contaminated soils. Exposure to contaminated soils in the Cracking Tower area is prevented by a tall, locked chain-link fence that surrounds it. There does appear to be some potential for human exposure to cPAH-impacted soil in the Kite Hill area of the park and to a lesser extent, in uncapped areas in the northeast corner. Although a topsoil and grass cover were placed over the Gas Works fill deposit in the Kite Hill area, it was not covered by an engineered cap as in other portions of the park.

Exposure to contaminated dust at the GWPS is likely minimal given the presence of an extensive and well-maintained vegetated soil cap, as well as an active irrigation program. During the dry season, the computerized irrigation system is used to water the park approximately every other day, but is adjusted to daily watering if abnormally hot weather occurs. Although the Cracking Tower area is not watered, much of this area is covered by pavement or other hard surfaces and is heavily vegetated.

ECOLOGICAL

A simplified terrestrial ecological evaluation (TEE) was conducted on the upland portion of the GWPS compliant with MTCA (WAC 173-340-7492) (Hart Crowser 2012) and is summarized here. A significant portion of the uplands is covered by concrete, asphalt, or compacted gravel that prohibits ecological exposures to underlying soil. Most areas of the park including the northwest corner, northeast corner, southeast area, and central meadow have been covered with vegetated soil cap that limit ecological exposure. Other areas have received some soil bioremediation, but residual contaminants remain in the surface soils.

Exposure to residual contaminants in subsurface soil is limited because the dominant plants and animals found on the uplands are exposed only to surface soil. The dominant vegetation is turfgrass, which has a root system that is limited to the upper 1 foot of soil. Most soil invertebrates found at the GWPS (e.g., earthworms and crane flies) inhabit this same zone. No burrowing animals were observed, so direct wildlife contact with soil is likely restricted to shallow soil. However, limited ecological exposure to chemicals in subsurface soil is possible. One species of deep burrowing soil invertebrate (night crawler) and several species of shrubs and trees (e.g., Himalayan blackberry, beech tree) that have deeper root systems and are a food source to wildlife are present at the GWPS.

Two contaminants that may pose a risk to ecological receptors were identified in soil at the GWPS: arsenic and BaP. As part of the TEE, applicable toxicity values and bioaccumulation factors were identified and used to derive protective ecological soil screening values (SSVs). The SSVs were then compared to reasonable maximum exposure (RME) concentrations in soil in ecological exposure areas. The RME concentrations were all below the SSVs indicating these contaminants do not pose an ecological hazard.

3.3.3. Groundwater

Potential receptors and exposure pathways for groundwater are limited at the GWPS. Shallow groundwater beneath the GWPS is not a drinking water source. Based on the results of pumping tests conducted at the GWPS, the shallow groundwater zone beneath the GWPS is not capable of producing water of sufficient quantity to support use as a future water supply. Specifically, groundwater does not yield greater than 0.5 gallon per minute on a sustainable basis (per WAC 173-340-720[2]); therefore, ingestion of groundwater is not considered a complete exposure pathway at the GWPS (Hart Crowser 2012, Parametrix 1999). Seeps, where direct contact could occur, are limited to the shoreline directly east of the Prow during periods of lake drawdown (late fall/early winter). PAHs have not been detected in seep water samples collected from this location (ARI 2001).

The transport/exposure pathway that may pose a potential risk to people or ecological receptors is groundwater discharge to Lake Union sediment and surface water and subsequent contact with impacted sediment and surface water by wildlife, fish, and benthic organisms; or consumption of contaminated aquatic organisms. This pathway has not been fully evaluated in previous investigations but will be addressed as part of the site-wide RI/FS. The supplemental investigation described in Section 7.0 includes activities specifically intended to provide information related to this pathway.

3.3.4. Sediment

Potential receptors and exposure pathways associated with contaminated sediment include:

- Ingestion of or dermal contact with potentially impacted surface water by beach users, recreational fishers, Tribal fishers, or wildlife, fish, and benthic invertebrates;
- Ingestion of or dermal contact with potentially impacted sediment by beach users, recreational fishers, Tribal fishers, or wildlife, fish, and benthic invertebrates;
- Bioaccumulation of water- or sediment-borne contaminants in benthic invertebrates and fish; and
- Ingestion of contaminated biota (fish, crayfish) by park visitors, Tribal fishers, site workers, fish and wildlife.

Multiple lines of evidence were evaluated in the human health and ecological risk evaluations to determine the contaminants that likely drive risks in sediment (AECOM et al. 2012). Potential risk drivers included: BaP, high molecular weight PAHs (HPAHs), and total PAHs. The selection of sediment risk drivers within the study area, in accordance with Ecology and EPA guidance, will focus the FS by identifying the chemicals that have the largest contribution to estimated overall site risk, based on the reasonable maximum exposure.

3.3.5. Potentially Mobile NAPL and Tar

Studies performed on the uplands indicate that NAPL identified are not substantially mobile (Floyd|Snider 2007a, ENSR 2008). Potential receptors and exposure pathways for potentially mobile NAPL on the GWPS include:

- Direct contact (through upwelling to surface soil) with tar by humans and wildlife;
- Contact (through mobile NAPL transport to sediment and surface water) with impacted sediment by humans, wildlife, fish, and benthic organisms; and
- Ingestion of contaminated benthic organisms by humans, fish, and wildlife.

The supplemental investigation described in Section 7.0 will include activities specifically intended to evaluate the nature, extent, and mobility of NAPL at the GWPS focusing on the upland and shoreline areas.

4.0 PREVIOUS REMEDIAL ACTION PLANNING AND FEASIBILITY STUDIES

Remedial action planning and feasibility studies have been conducted for the upland and sediment areas of the GWPS. The previous studies are described chronologically by area in the following sections.

4.1. Previous Upland Feasibility Studies

Planning for upland remedial action in the GWPS has been performed in several stages since the 1980s, including feasibility study analyses performed under formal agreement between Ecology, the City, and PSE. The proposed site-wide feasibility study described in Section 8.0 of this FS Bridging Document will build on these previous analyses while developing cleanup alternatives based on updated remedial technologies and a more comprehensive CSEM that integrates upland and in-water portions of the site. The integrated CSEM will incorporate supplemental investigation data and address entire pathways from source to exposure point. Reports documenting previous remedial action planning are listed below:

- Focused Field Investigation and Irrigation Feasibility Study, Gas Works Park, Seattle, Washington (HDR, 1988).
- Treatability Study Work Plan, Gas Works Park (HDR, 1989a).
- Groundwater Containment Migration Control System Conceptual Design Report (HDR, 1989b).
- Gas Works Park Environmental Cleanup, Phase 1—Candidate Remedial Measures (Parametrix, 1996).
- Agreed Order No. DE 97TC-148, Attachment 1—Focused Feasibility Study and Cleanup Action Plan Work Scope, Gas Works Park Environmental Cleanup (Ecology, 1997).

- Gas Works Park Environmental Cleanup, Focused Feasibility Study (Parametrix and Key Environmental, 1998).
- Extremely Hazardous Waste Memorandum (ThermoRETEC, 1999).

The primary phases of remedial action planning for the uplands are presented in the sections that follow.

4.1.1. HDR Remedial Action Planning, 1988-1989

Groundwater contamination and treatment methods were the focus of the FS work conducted by HDR. The Focused Field Investigation and Irrigation Feasibility Study (HDR, 1988) was intended to determine the extent and magnitude of contamination of groundwater, present a preliminary feasibility analysis of alternatives for the control of contaminants, and assess the feasibility of irrigating the park without further mobilizing contaminants.

Thirty-two groundwater samples were collected from existing, newly-installed or temporary wells located throughout the uplands to provide a "snapshot" of groundwater conditions. The groundwater samples were analyzed for VOCs, with selected samples also analyzed for PAHs and/or metals. The field investigation concluded that three plumes of contaminated groundwater existed, two located in the southeast portion of the park near the Play Barn structures, and the third in the northwest portion of the park near the former ATCO facility.

The Focused Field Investigation and Irrigation Feasibility Study considered four alternatives to control contaminants in each of the three plume areas.

- Alternative 1—Excavating contaminated materials
- Alternative 2—Capping contaminated areas
- Alternative 3—Capturing and treating contaminated groundwater
- Alternative 4—No action

These alternatives were evaluated based on compatibility with park use, water quality, waste, the ability to implement with respect to irrigation, and life-cycle cost estimates. Based on the results of the comparative evaluation, the recommended alternative for control of contaminants was Alternative 3 in all areas and Alternative 1 (excavate contaminated materials) in the vicinity of the former ATCO facility. Four groundwater treatment technologies were presented as part of Alternative 3 including: 1) air stripping with and without air pollution control, 2) evaporation, 3) ultraviolet light oxidation, and 4) activated carbon adsorption. The report stated that these treatment processes appeared to have promise in treating the contaminated groundwater but recommended additional studies to evaluate these and other groundwater treatment technologies.

In assessing the feasibility of irrigating the park, the primary considerations were the potential for excavating contaminated soil during installation of the irrigation system and mobilizing contaminants during operation. To prevent or reduce the mobilization of contaminants, irrigation sensors and controllers were recommended to limit water from leaching below the plant root zone.

Based on the recommendations from their irrigation FS, HDR prepared the Treatability Study Work Plan (TSWP) (HDR,1989a) to compare groundwater treatment technologies and select three alternatives for bench scale analysis. The TSWP documented the initial screening process for potential soil and groundwater remediation technologies, developed and screened a set of remedial alternatives, and developed cost estimates for implementation. Groundwater treatment technologies utilizing chemical, biological, and physical removal and/or degradation processes were evaluated.

The technology screening performed in the TSWP retained five alternative treatment technologies:

- Technology 1—Ultraviolet (UV)/Peroxide
- Technology 2—Biological—(*in situ*)
- Technology 3—Biological (bioreactor)
- Technology 4—Biological (carbon)
- Technology 5—Physical (carbon with oil/water separator)

These alternative technologies were evaluated based on performance, ability to implement, regulatory acceptability, and cost. Based on the results of the comparative evaluation, three groundwater treatment technologies including carbon with oil/water separator, UV/peroxide, and *in situ* biological treatment, were recommended for bench scale studies and a treatability evaluation.

Following the bench scale studies and treatability evaluation, only UV/peroxide with pretreatment proved to be successful in removing and destroying all the contaminants. Although the results of the treatability studies indicate UV/peroxide had the best treatment performance, additional criteria including short- and long-term effectiveness, reduction of toxicity, mobility, and volume, public and environmental considerations, institutional acceptability, implementability, and cost were considered in determining the preferred treatment technologies. Two treatment alternatives were further evaluated using the expanded criteria.

- Alternative 1—Flow equalization, polymer/alum pretreatment, sludge handling, UV/peroxide treatment, and standby carbon
- Alternative 2—Flow equalization, dual fixed-film bioreactors, a filtration system, and standby carbon

When compared and evaluated, Alternative 1 (UV/peroxide treatment process) ranked higher and was used in the conceptual design for the treatment facility. Design elements presented included discharge requirements, residual handling, chemical usage, safety considerations, spill containment and monitoring. After pilot scale testing of the UV/peroxide treatment system, a final design of the treatment system was recommended.

HDR prepared the Groundwater Containment Migration Control System Conceptual Design Report in June of 1989 (HDR, 1989b) to present the results of a subsurface geophysical survey, hydrogeological modeling, groundwater treatability studies, and conceptual design of a groundwater control and treatment facility.

Additional hydrogeological data were collected from the existing wells to develop a groundwater model that simulated aquifer responses to imposed groundwater pumping. The preliminary results indicated that 10 extraction wells (four wells placed along the western perimeter near Kite Hill, three wells west of the Play Barn area, and three wells south of the Play Barn area) would be sufficient to slow or stop the migration of the contaminant plumes. To determine the actual location of wells for a well extraction system, HDR recommended a full-scale aquifer test and further modeling. The efficacy of pumping groundwater was further evaluated by Parametrix as described below.

4.1.2. Parametrix Remedial Action Planning, 1996-1998

The 1996 Candidate Remedial Measures report (CRM) prepared by Parametrix (1996) was the first phase of the GWPS focused FS (FFS). The CRM documented the initial screening process for potential upland soil and groundwater remediation technologies, developed and screened a set of remedial alternatives, and developed preliminary cost estimates. Soil cleanup technologies ranging from capping to excavation and disposal were evaluated for appropriateness for site conditions and effectiveness. Several groundwater technologies were also evaluated, ranging from natural attenuation to pump and treat. The 1996 CRM is included as Appendix F of this FS Bridging Document.

The technology screening performed in the CRM resulted in five alternatives being retained:

- Alternative 1—Geotextile and topsoil surficial soil cover
- Alternative 2—Geotextile and topsoil surficial soil cover with low-permeability surficial cap
- Alternative 3—Upgradient cutoff wall combined with surficial soil cover and/or low-permeability cap
- Alternative 4—Partial downgradient cutoff wall with funnel and gate treatment cells combined with surficial soil cover and/or low-permeability cap
- Alternative 5—Enhanced biodegradation (biosparging) combined with surficial soil cover and/or low-permeability cap

The alternative screening process in the CRM eliminated several soil and groundwater alternatives from further consideration. Soil alternatives involving *in situ* biodegradation, *in situ* fixation, and use of excavated soil for asphaltic road base were evaluated and eliminated due to limited expected effectiveness and high cost relative to other alternatives. One groundwater alternative, groundwater pump and treat, was also eliminated from further consideration. Pump and treat was determined to not provide effective source reduction for the expected cost.

Much of the technology evaluation documented in the 1996 CRM remains valid and will be referenced for the future site-wide FS document outlined in this FS Bridging Document. However, advancements in soil and groundwater remediation technologies and additional site data collected since 1996 warrants performing an updated technology screening process as part of the site-wide FS.

Following preparation of the CRM, the City and PSE entered into an Agreed Order with Ecology for the uplands (Ecology 1997). The Agreed Order, dated August 1, 1997, outlined requirements for cleanup action planning following the CRM. The CAP Work Scope, included as an attachment the Agreed Order, outlined the plan for preparation of the cleanup action planning documents.

Parametrix and Key Environmental prepared a Draft FFS Report (Draft FFS) in October 1998 (Parametrix and Key 1998) based on the scope of work outlined in the Agreed Order. In addition to a description of general site information and known conditions, the Draft FFS included a summary of work performed since the CRM was prepared in 1996. This included several phases of additional investigation and treatability evaluation, including the following:

- Inspection and sampling of monitoring wells installed during early (approximately 1986 to 1989) investigation phases to determine current groundwater conditions and evaluate the need to repair or reconstruct monitoring wells.
- Collection of surficial soil samples to characterize current park conditions relative to those during the initial investigation periods.
- Characterization and removal of upwelling tar.
- Assessment of the potential for the Cracking Tower area to act as a source of contamination to surrounding soil and groundwater.
- Completion of an ecological survey to evaluate risks to threatened or endangered species, on-site ecological habitat, and off-site ecological resources that may be affected by on-site impacts.
- Characterization of contaminant fate and transport in the western upland area of the GWPS.
- Implementation of an interim action to remove LNAPL in the southeastern upland portion of the GWPS.

Based on existing data and the results of the additional characterization and work listed above, Parametrix selected soil CULs for contaminants posing the greatest risk in the uplands area of the GWPS and groundwater CULs for contaminants posing the greatest risk to surface water. Proposed CULs were based on MTCA Method B values for direct contact with soil and MTCA Method B surface water values for groundwater. Additional potential groundwater COCs (arsenic, cyanide, and selected non-carcinogenic PAHs) were predicted not to exceed standards at the agreed upon point of compliance and were not retained as COCs. COCs and associated CULs are listed in Section 2.4.1.

As a result of the significant amount of additional work performed following the 1996 CRM, the 1998 Draft FFS included a revised conceptual site model, remedial technology screening, and development and evaluation of five cleanup action alternatives:

- Alternative 1, No Action—This alternative includes no cleanup action activities for soil and groundwater
- Alternative 2, Soil Cover—This alternative consists of placement of vegetated soil cover over the north central and southeast portions of the uplands

- Alternative 3, Air sparging and soil cover—This alternative combines air sparging and soil vapor extraction to treat the benzene contamination south of the Play Barn, with vegetated soil cover in the north central and southeast portions of the uplands
- Alternative 4, Containment—Downgradient groundwater cutoff wall with soil cover in the north central and southeast portions of the uplands
- Alternative 5, Excavation and Fill—Removal of vadose zone soil across 8.8 acres of the GWPS, and backfilling to original grade

Detailed life-cycle cost estimates were developed for each alternative and a comparative evaluation of the alternatives was performed in accordance with MTCA requirements. Appendix G of this FS Bridging Document includes Table 14-1 from the Parametrix Draft FFS, which outlines the results of the comparative evaluation of the five cleanup action alternatives proposed for the GWPS. Based on the results of the comparative evaluation, Alternative 3, which included air sparging and soil vapor extraction and vegetated soil cover, was recommended as the cleanup action for the uplands.

A CAP, documenting the selection of Alternative 3, was prepared and approved by Ecology on June 18, 1999. The CAP summarized the selected cleanup actions, presented cleanup standards for the planned cleanup, identified the points of compliance and outlined cleanup implementation details including construction activities, monitoring requirements and institutional controls needed following completion of the cleanup. The selected cleanup actions described in the CAP include:

- Removal and treatment of residual tar seeps as necessary;
- Placement of a vegetated soil cap in unpaved open areas in the north-central and southeastern portions of the Park;
- Treatment of groundwater using air sparging and soil vapor extraction for volatile organic compound-impacted groundwater;
- Treatment of groundwater by natural attenuation for PAH-impacted groundwater in the western portion of the uplands; and
- Implementation of institutional controls designed to limit or prohibit activities that may result in exposure to hazardous substances.

The soil cleanup levels selected for the upland portion of the GWPS were based upon a future residential exposure scenario. The selected cleanup levels for hydrocarbons in GWPS soil (carcinogenic and non-carcinogenic PAHs) were based on MTCA Method B levels, and the cleanup level for arsenic was the MTCA Method A value of 20 mg/kg. Groundwater cleanup levels presented in the 1999 CAP were based on the protection of surface water and correspond to the MTCA Method B Surface Water Cleanup Levels. The selection of this cleanup level is based on the determination of non-potability of groundwater at the GWPS, in accordance with WAC 173-340-720(1)(c), and the known connection between groundwater at the GWPS and Lake Union surface water.

The standard MTCA point of compliance for contaminants in soil above cleanup levels based on human exposure due to direct contact is 15 feet bgs. However, in the CAP Ecology acknowledged that the proposed vegetated soil cap complied with cleanup standards when combined with long-term monitoring and institutional controls, in accordance with WAC 173-340-740(6)(f). The conditional point of compliance for GWPS groundwater selected in the CAP was within adjacent surface water, as close as possible to points where groundwater discharges into the surface water in accordance with WAC 173-340-720(8)(d)(i).

In December 1999, PSE and the City entered into a Consent Decree with Ecology (Ecology 1999) to implement the remedial actions described in the CAP. Section 5.1.2 of this FS Bridging Document describes the remedial actions completed in accordance with the 1999 Consent Decree.

The upcoming site-wide RI/FS will update the identification of risk drivers, cleanup levels, and points of compliance for potential pathways, exposures, and media not addressed in the Consent Decree (e.g., sediment, groundwater to sediment, sediment bioaccumulation). Past studies of the sediment portion of the GWPS, not addressed by the Consent Decree, are discussed in the next section.

4.2. Previous Sediment Feasibility Studies

Evaluation of sediment remedial actions has been performed by the City and PSE in several stages since the 1980s, with several major efforts conducted between 2004 and 2008 under the 2005 Agreed Order DE 2008. The 2013 amendment to Agreed Order DE 2008 now provides for a site-wide feasibility study, combining the uplands and sediments. The proposed site-wide feasibility study described in this FS Bridging Document is expected to build on these previous analyses while updating cleanup action alternatives for sediment. The site-wide FS will combine information from all previous studies, while providing a holistic assessment of the linkages between the upland and in-water portions of the GWPS and remedies that address complete pathways and exposures representing significant risk to human and ecological receptors.

Remedial action evaluation performed to date is documented in the following reports and discussed in the following sections:

- Lake Union Capping Feasibility Study (Parametrix, Inc., 1992).
- Gas Works Sediment Area Cleanup Standard Determination, Gas Works Sediment Area, Seattle, Washington (RETEC, 2005b).
- Draft Remedial Investigation and Feasibility Study. Gas Works Sediment Eastern Study Area. Seattle, Washington (RETEC, 2006).
- Gas Works Sediment Western Study Area. Remedial Investigation/Feasibility Study, Ecology Review Draft (Floyd|Snider, 2007a).
- Gas Works Sediment Area Supplement to the Cleanup Standards Document, Draft Final (AECOM et al. 2012).

4.2.1. Parametrix Capping Feasibility Study (1992)

Prior to any MTCA-imposed cleanup planning for contaminated sediments associated with Gas Works Park, Ecology sponsored an evaluation of sediment capping technologies for potential use at the GWPS. Parametrix documented this evaluation in the June 1992 Lake Union Capping

Feasibility Study (Parametrix 1992). For this report, the term "feasibility study" was used to define the process of determining if capping in place, a known remedy for contaminated sediment sites, would be feasible under the conditions in Lake Union adjacent to Gas Works Park. This study was not an evaluation of a full range of cleanup alternatives that would typically be completed for an FS under MTCA and CERCLA. The capping feasibility study involved four separate steps: 1) completing a siting evaluation to identify the most appropriate site for a pilot capping project; 2) performing a cap material evaluation to determine the most likely sources of cap material for a capping remedy; 3) evaluating permit requirements for completing a capping remedy; and 4) performing sediment cap modeling to evaluate the potential for recontamination of cap materials following cap construction.

The results of the evaluation indicated that sediment capping was feasible and that suitable cap material would be available. Modeling completed during this study indicated that groundwater discharge through the cap would not jeopardize the cap effectiveness, thus allowing capping of contaminated sediments prior to completing upland groundwater remediation.

4.2.2. RETEC Gas Works Sediment Area Cleanup Standard Determination (2005)

In accordance with Agreed Order No. DE 2008 for RI/FS activities to evaluate cleanup actions for contaminated sediment at the GWPS, RETEC conducted a study to determine site-specific sediment cleanup standards for the sediments prior to completing the RI/FS process (RETEC 2005b). CULs, as well as points of compliance, were evaluated for sediment. The approach to determining sediment CULs focused on chemicals associated with upland sources (i.e., PAHs, selected metals, volatile compounds) and biological responses of site-specific sediment toxicity tests.

The data evaluated for this effort supported the use of TPAH as a surrogate for organic contaminants, as it is representative of impacts from GWPS upland sources. Two cleanup levels were derived for use during subsequent RI/FS activities for the sediment to be functionally equivalent to the Washington State Sediment Management Standards (SMS) sediment quality standard (SQS) and the cleanup screening level (CSL). The lower site-specific sediment quality value (SSQL) defined a threshold below which no adverse effects would be expected (170 mg/kg TPAH [dry weight]); the higher site-specific cleanup screening level (SCSL) was equivalent to a lowest adverse effects value (290 mg/kg TPAH [dry weight]). The SCSL was intended to define the sediment areas requiring active remediation and the SSQL defined the long-term goal for the GWPS.

The second component of the cleanup standards determination evaluated bioassay effects to identify a boundary for sediment remediation. The results of the evaluation indicated that the area of investigation (AOI) proposed in Agreed Order DE 2008 encompassed sediment contaminated by sources from the GWPS, as well as areas affected by non-GWPS sources. Subsequently, an area within the AOI was further defined to represent the primary area impacted by GWPS sources that would be evaluated in the FS. Appendix I presents the subarea identified for further evaluation (termed the Area Boundary or AB line in the Cleanup Standards Determination document).

The cleanup standard determination process was revisited in 2011 and is discussed below in Section 4.2.4.

4.2.3. GWPS Eastern and Western Study Area RI/FS Process (2006-2007)

Remedies for the sediments were evaluated independently for portions of the GWPS delineated as the Eastern Study Area (ESA) and the Western Study Area (WSA). As described in Agreed Order DE 2008, the ESA RI/FS was PSE's responsibility and the WSA RI/FS was the responsibility of the City. The remedial action technologies proposed in the subsequent draft RI/FS reports evaluated numerous remediation alternatives to identify preferred sediment cleanup alternatives for the two study areas. Both documents presented the initial screening process for potential sediment remediation technologies, developed and screened a set of remedial alternatives, and developed cost estimates for the assembled alternatives.

The 2006 ESA Draft RI/FS (RETEC 2006) evaluated the use of monitored natural recovery, enhanced natural recovery, containment, and removal technologies, as well as institutional controls. To develop and evaluate cleanup alternatives, the ESA was subdivided into five sediment management areas (SMAs) based on site characteristics. The preferred remedial alternative includes several technologies specifically to account for the variation in site conditions such as bathymetry, contaminant concentrations, erosive forces, and sediment strengths. The preferred alternative included a combination of capping and natural recovery in the entire ESA. Remedial technologies that were proposed, by SMA, are described below. Appendix J (Figure 14-1 from the ESA Draft RI/FS) illustrates the preferred remedy, which is summarized below:

- SMA 1 (Gas Works Park Marina)—Monitored natural recovery and institutional controls to minimize disruptions to an active marina with residents.
- SMA 2 (Waterway 19)—A composite (grout mat plus sand) capping at the head of the waterway to protect boaters that may wade into the water during launching of hand-carried craft; a 2-ft cap of clean material in the remainder of the waterway that exceeded the TPAH criterion in surface sediments.
- SMA 3 (Southeast Nearshore)—Placement of a thick (> 6 ft of sand and rock) cap over the entire SMA to confine tar and surficial DNAPL. The toe of the cap will extend into portions of SMA 2 (Waterway 19) and SMA 4 (offshore of SMA 3) to achieve a 4.5:1 slope.
- SMA 4 (Southeast Offshore) —The toe of the cap from SMA 3 will extend into SMA 4 providing a 2-ft cap of the portion of this SMA that exceeded the TPAH criterion in surface sediments.
- SMA 5 (Seawall and South Offshore)—Placement of a 2-ft cap in areas of higher (>700 mg/kg) TPAH concentrations; thin-layer placement (6 inches) in the majority of the remaining area. One outer lobe of the SMA would be allowed to naturally recover.

Long-term monitoring of remedy performance is a component of the action in each SMA. No action would be implemented in the area offshore of the SMAs but within the AOI (Figure 14.1 in Appendix J).

The 2007 WSA Draft RI/FS (Floyd|Snider 2007a) evaluated the same technologies considered for the ESA for nine SMAs. The preferred alternative accounted for variations in site condition and proposed the following cleanup actions (see Appendix J, Figure 12.4 from the WSA Draft RI/FS for a depiction of the recommended remedy):

- SMA 1 (Gas Works Park)—Construction of a retaining wall and dredging to allow placement of a 2-ft sand cap along the shoreline. The remaining slope area would be capped with 2-ft of sand or a low permeability barrier.
- SMA 2 (Harbor Patrol property)—Carbon-amended sand cap along the shoreline with a rock buttress at the bulkhead. Underpier area would be capped with amended sand (no rock). A low permeability or impermeable barrier would be placed on the remaining slope below the shoreline.
- SMA 3 (Washington State Department of Natural Resources [DNR] and King County properties)—Placement of a sand cap with a rock buttress (for bulkhead stability) at the King County property shoreline; habitat material would be included in the cap design. Placement of an impermeable barrier at the DNR shoreline and low permeability barrier or 2-ft sand cap on the remaining slope of the entire SMA.
- SMA 4 (offshore of SMA 3)—Cap with 2 ft of sand (will be a continuation of the sand cap or overlap with the low permeability barrier in SMA 3).
- SMA 5 (offshore of SMA 2)—Cap with 2 ft of sand (will overlap with impermeable or low permeability barrier in SMA 2).
- SMA 6 (offshore of SMA 1)—Cap with 2 ft of sand (will be a continuation of the sand cap or overlap with the low permeability barrier in SMA 1).
- SMA 7 (offshore of SMA 1)—Cap with 2 ft of sand.
- SMA 8 (outer portion of SMAs 4, 5 and 6)—Placement of 6 inches of clean material to enhance natural recovery.
- SMA 9 (between all other SMAs and the site boundary)—No action.

All SMAs include debris removal in the shoreline area and long-term monitoring of the remedy performance.

The preferred remedial alternatives and recommendations for the ESA and WSA utilized similar technologies and evaluation techniques, but differed in their recommended preferred alternatives, in part, because of assumptions regarding the groundwater-to-sediments pathway and resulting impacts on the remedy. The ESA FS deferred evaluating a near-shore remedy in light of the data gaps subsequently evaluated during the 2007 Eastern Shoreline Investigation (ENSR 2008). Both documents were reviewed by Ecology, with subsequent responses from the City and PSE that addressed Ecology's concerns. The site-wide FS will reconcile the recommendations for the eastern and western portions of the sediment area, account for the linkages between the upland and sediments, and develop site-wide alternatives and remedial alternative recommendations.

4.2.4. Gas Works Sediment Area Supplement to the Cleanup Standards Document (2012)

In response to agency and stakeholder comments on the 2005 Cleanup Standard Determination document (RETEC 2005b) and the 2006 and 2007 draft RI/FS documents for the ESA and WSA, additional risk evaluation work was initiated to supplement the Cleanup Standards Determination work and provide a basis for evaluating remedial action for sediments when the site-wide FS is prepared. The Draft Final Gas Works Sediment Area Supplement to the Cleanup Standards

Document (SCSD) (AECOM et al. 2012) was designed to be a companion document to the 2005 Cleanup Standard Determination document and addressed agency and stakeholder concerns about the screening process for identification of contaminants of potential concern and the evaluation of risks to human health and ecological receptors. The SCSD utilized existing data to perform additional contaminant screening and evaluate site-specific ecological risks and human health risks from additional exposure pathways, specifically beach play/wading at Gas Works Park, Tribal net fishing, recreational fishing, and consumption of Lake Union fish and shellfish resources. Previous work, presented in the Cleanup Standard Determination document, evaluated the benthic pathway through site-specific bioassay testing.

Comparison of sediment data to an extensive list of screening criteria resulted in 59 constituents being identified as contaminants of potential concern; these contaminants were subsequently included in the human and ecological risk evaluations.

Human health exposure pathways identified for contaminated sediments were direct contact (dermal absorption) and incidental ingestion by children and adults through beach play/wading and net fishing (Tribal population) and fish and shellfish ingestion by both recreational and Tribal fishers. In order to evaluate a range of risks, both a reasonable maximum exposure (RME) and a central tendency (CT) scenario were developed. Estimated potential risks for the CT scenarios were about one to two orders of magnitude less than the estimated risks for the RME scenarios. For CT scenarios, three contaminants, arsenic, HPAHs, and PCBs exceeded the threshold for acceptable cancer risks.

Several ecological receptors were evaluated in the SCSD, including the great blue heron, the American mallard, the northern river otter, and juvenile Chinook salmon. Incidental ingestion of sediments and potentially contaminated fish prey were considered, with incidental sediment ingestion being the primary source of potential risk for wildlife receptors. The ecological risk assessment determined that TBT represented the greatest potential risk for juvenile salmonids, while BaP and HPAHs slightly exceeded the risk thresholds for the American mallard and Northern river otter, respectively.

Based on the evaluation of contaminants and risk scenarios and in accordance with MTCA guidance, specific risk drivers were selected for identifying areas requiring remedial action. Risk drivers included TPAH (including BaP and HPAH), arsenic, and PCBs for human health exposure and TBT for juvenile salmonid exposure. Risk drivers were not identified for the blue heron, mallard, or otter.

Concentrations of contaminants that exceeded risk thresholds were compared to ambient Lake Union (ALU) concentrations to identify those contaminants that were most closely associated with GWPS sources and, if cleaned up, would contribute to the greatest reduction in risks to people and ecological receptors. Risk drivers that also exceeded ALU values were considered COCs in sediments and were intended to be carried forward in the evaluation of site-specific sediment remedies. HPAH, TPAH, and BaP were identified as indicator COCs as a result of this process. Additional chemicals representing a potential risk (TBT, PCBs, antimony, arsenic, chromium, lead, bis(2-ethylhexyl)phthalate, pentachlorophenol, and chlordane) are also present in GWPS sediment, but at similar or lower concentrations than ALU conditions. These additional chemicals are more likely due to diffusive sources throughout Lake Union and are considered ALU COCs.

The SCSD also re-evaluated the lateral extent of contamination to determine where offshore surface sediment concentrations were no longer distinguishable from ambient conditions in Lake Union. The AOI was divided into five bands representing increasing distance from the shoreline (see Figure 6-2 from the SCSD document, reproduced in Appendix K). Different cleanup scenarios were assumed, remediating all sediment within each band, beginning with only the nearshore band in the first scenario and adding another band with each additional cleanup scenario. Bands not included in remediation scenarios were considered No Action areas. With each scenario, the No Action area "mean" (90^{th} upper confidence limit of the mean or four times the 50^{th} percentile) was calculated for COCs and compared to the ambient condition. The results indicated that cleanup of the first three bands closest to shore would reduce the average concentration of the No Action area (i.e., bands 4 and 5) to ambient conditions for HPAH, TPH, and BaP. The outer boundary of the third band was proposed as the limit of active remediation for evaluation in the FS and as an alternative to the area boundary (AB) line proposed in the 2005 Cleanup Standard Determination document.

The SCSD was intended to build upon the original 2005 Cleanup Standard Determination document that was the basis for the RI/FS documents prepared for the ESA and WSA. The conclusions and recommendations regarding COCs and limits of cleanup will serve as the basis for developing and evaluating cleanup action alternatives for sediment in the site-wide feasibility study described in this FS Bridging Document.

5.0 PREVIOUS REMEDIAL ACTIONS

Several remedial actions have been performed to date in upland areas of the GWPS. Ongoing maintenance of the upland remedy and source control work in anticipation of the sediment remedy are planned prior to completing cleanup action planning. A list of previous remedial actions performed in the uplands is presented in Table 2. Areas where significant remediation has been conducted are shown on Figure 7. The sections below discuss the scope of previous and planned remedial actions, and the resulting change in conditions in the upland areas at the GWPS. These previous actions will be considered during preparation of the site-wide FS.

5.1. Summary of Previous Remedial Actions

Several remedial actions have been performed in the upland portion of the GWPS, beginning with plant demolition and park development. As part of plant demolition, facilities were decommissioned and the majority of the primary sources were demolished and removed. Since 1999, remedial actions have been completed at the GWPS to comply with the Consent Decree and more recently maintenance and source control work to address immediate concerns. A discussion of the significant phases of remedial action conducted to date and additional planned work is provided in the sections below.

5.1.1. Remedial Actions Prior to 1999 Consent Decree

Several remedial actions took place prior to enacting the 1999 Consent Decree for upland remediation at the GWPS. As described above in Section 2.1.4, development of Gas Works Park involved addressing contaminated media, although not as a formal remedial action. Demolition of a significant amount the facility was completed between 1962 and 1973. As the City constructed

Gas Works Park, extensive re-grading and redistribution of surface materials, including contaminated media, was performed. The scope of the excavations included excavation of between 2 and 8 feet of contaminated soil from several areas of the former gas works facility. Some of the excavated soil was stockpiled in the north portion of the property for reuse as fill and some of the excavated soil was transported off-site for disposal.

In 1973, the City authorized targeted excavation and demolition throughout the remainder of the park. Targeted excavation depths extended up to 8 feet below grade and to "water level" near the shore. This phase of park construction included excavation and grading of the southeast shoreline to remove contaminated surface soil and to grade the final surface down to the lake level. The excavation commenced 30 feet or more inland from the water's edge. The upper 2-feet of the regraded shoreline area was filled with cleaner fill generated from other areas of the park construction. Substantial cutting and stockpiling of impacted soil occurred during these excavation activities. A minimum of 20,000 cubic yards of impacted soil were excavated and temporarily stockpiled on site; however, exact quantities of what was excavated and removed from the park are unknown. By early 1974, most of the demolition of former MGP structures, excavation, and regrading of the majority of the park had occurred.

In 1976, another phase of regrading occurred as the park was sculpted into its current topographic form. During this period of regrading, substantial soil was cut from shoreline areas and areas away from the shoreline were filled. Near the end of the redevelopment, a layer of soil, sawdust, and dewatered biosolids was tilled into the soil to encourage the breakdown of pollutants and control dust (EPA 1995). Two inches of hydroseeded topsoil was used for cover.

Additional remediation was performed in the upland portion of the GWPS in the 1980s prior to completing RI/FS activities and development of the Consent Decree for the upland area. As a result of soil and sediment sampling conducted by EPA and the University of Washington in 1983 and 1984, the park was temporarily closed while health risks were evaluated. This work resulted in a 1-foot-thick clean soil cover being placed over the most impacted areas of the park to reduce risks to park visitors. The Park was reopened in August 1984 after this remedial action was completed (Hart Crowser 2012).

In 1985, a tar seep was discovered in the northwest section of the park, south of the railroad right-of-way and in the vicinity of the original tar refinery. The tar seeps emerging from asphalt sidewalks were paved to seal the seeps, but the seeps continued to penetrate the asphalt, particularly during warmer months (Hart Crowser 2012).

Between the 1997 Agreed Order and the 1999 Consent Decree, additional interim actions were completed in the uplands. In 1997, tar and tar-contaminated soil was characterized at 12 test pit locations across the park (TP-1 through TP-12) (Parametrix and Key 1998). The test pits were dug in October 1997 to characterize tar seeps. During the characterization, additional tar was removed from the areas surrounding test pits TP-6 and TP-10 through TP-12. Twenty-two drums of tar (1 drum from TP-6 and 21 drums from TP-10, TP-11, and TP-12) were removed as well as 24 cubic yards of tar-contaminated soil from the area of TP-10. The locations of the 1997 tar removal are shown on Figure 7.

In 1997, during investigation activities in the Cracking Tower area, a partially buried tank containing approximately 2,500 gallons of viscous tarry liquid was discovered. The liquid was sampled and analyzed to determine appropriate disposal or recycling methods. In June 1998, the liquid was removed and transported off-site to be burned at an energy recovery facility (Parametrix and Key 1998).

Prior to completing groundwater treatment outlined in the 1999 Consent Decree, an interim action was conducted to remove LNAPL. In 1998, recovery wells were installed in the southeastern corner of the GWPS. LNAPL was removed from the wells using mobile high-vacuum extraction through a contracted vac-truck service.

5.1.2. Remedial Actions Following 1999 Consent Decree

A complete list of individual cleanup actions performed under the Agreed Order and Consent Decree for the GWPS is presented in Table 2. Areas where significant or larger scale remedial action has been completed is presented on Figure 7. The 1999 Consent Decree and CAP required several cleanup actions (Parametrix 1999). Additional details regarding the proposed implementation of the selected cleanup action is contained in the 1999 CAP attached as Appendix H to this FS Bridging Document. The City of Seattle and PSE entered into a Consent Decree in 1999 for cleanup of the uplands, based on the approved CAP. Remediation activities that were implemented in accordance with the Consent Decree included:

- Removal and treatment of tar seeps;
- Placement of additional vegetated soil cap over unpaved open areas of the park;
- Installation of an *in situ* groundwater treatment system involving air sparging and soil vapor extraction in the southeastern corner of the park, and operating the system for six years at which point benzene concentrations had decreased to below remediation levels;
- Monitoring of natural attenuation of PAHs in groundwater in the western portion of the park;
- Maintenance of engineering and administrative controls within the Park designed to limit exposure to contaminants by park users, including fencing, signage, and irrigation; and
- Implementation of restrictive covenants preventing actions that disturb contaminated soil or groundwater.

Further discussion of how the cleanup actions called for in the 1999 CAP were completed is provided in the 2012 Draft Gas Works Park Uplands Remedial Investigation document (Hart Crowser 2012).

In 2005, the Consent Decree and CAP were amended to allow barriers to the northwestern corner of the GWPS to be removed and make the area accessible to the public. The amended CAP provided for regrading the area, placement of a geotextile barrier and a 1-foot vegetated topsoil cover.

In 2006 and 2007, additional tar was observed along the eastern shoreline—in sediments near the ordinary highwater mark and in the northeastern area of the uplands. The tar was removed and the areas covered with geotextile and clean fill (Hart Crowser 2012). In 2008, four additional tar seeps were observed in the eastern shoreline area and near the Cracking Towers. The Parks Department removed or partially removed three tar seep areas and backfilled the excavated areas and covered one tar seep area with gravel.

In 2012, Ecology conducted maintenance of the upland remedy, to reduce the potential for exposure to contaminated surface soil, and source control work, in anticipation of the sediment remedy, in the northeast corner of the uplands portion of the GWPS. Placement of an approximately 1- to 2-foot thick soil cap across an area of approximately 3/4 of an acre was completed in the fall of 2012.

5.1.3. Planned Additional Actions

Currently, maintenance of the upland remedy and source control work in anticipation of the sediment remedy is planned to begin in the Kite Hill area in summer 2014. Kite Hill area work is expected to consist of constructing a vegetated soil cap to cover exposed contaminated soil. Implementation would be similar to previous vegetated cap projects conducted at the GWPS, including the 2012 northeast corner capping project described above. The Kite Hill area capping project is not expected to alter the use of Kite Hill or the surrounding area.

5.2. Effect of Previous Remedial Actions on Current Site Conditions

Current conditions at the GWPS will be established based on the existing data from previous investigations and the ongoing supplemental investigation. However, site conditions have changed since previous investigations as a result of remedial actions, including soil capping, groundwater treatment, and tar removal. The potential effect of previous remedial actions on the use and interpretation of data will be accounted for in the site-wide RI/FS.

A significant portion of the park has been capped with a vegetated soil cap (including a subsurface geotextile layer) to prevent direct exposure to surface soil. As a result of these remedial actions, the soil direct contact pathway was eliminated in these areas. These actions will affect the interpretation of current conditions and risks; the existing surface and shallow soil data for the cap areas are not representative of surface soil and the associated exposure pathways that were documented in previous investigations. During the site-wide RI, the existing data will be presented and evaluated with consideration for the respective cap thickness.

The Kite Hill area has not been capped, but placement of a soil cap is currently being planned as described above in Section 5.1.3. This work is expected to be completed concurrently with preparation of the site-wide FS, and the resulting conditions relative to the current data will be considered during the evaluation of cleanup action alternatives in the site-wide FS.

Groundwater and LNAPL conditions have also changed as a result of previous remedial action at the GWPS. As a result of operation of the air sparging/soil vapor extraction system for six years, concentrations of benzene (and other contaminants) in groundwater in the southeast portion of the uplands have decreased significantly. In addition, the LNAPL recovery performed in 1999 and 2000 has resulted in a reduction of LNAPL mass relative to data collected during early RI phases.

COC concentrations in groundwater and NAPL extent and mobility data collected during the supplemental investigation, including data from new well locations, will be used to update the understanding of NAPL and groundwater conditions. The updated data will be used to evaluate potential cleanup action alternatives in the site-wide FS based on current conditions.

6.0 DATA GAPS ANALYSIS

This section summarizes the work completed to identify data gaps and how the data gaps are being addressed prior to completion of the site-wide feasibility study. Ecology identified upland data gaps following preparation of the February 2012 Gas Works Park Upland Remedial Investigation Report (Hart Crowser 2012). Ecology documented the data gaps in a March 22, 2012 letter, which is included in Appendix L of this FS Bridging Document.

More recently, the City and PSE worked with Ecology to compile EPA and Ecology comments submitted from 2004 through 2012 regarding the cleanup planning process at the GWPS. The compilation of comments, and respective responses to those comments, focused on data gaps identified for the GWPS and outlined general plans for addressing those data gaps. The comments and responses were documented in a January 23, 2013 letter from Ecology to EPA, which is included in Appendix M of this document.

In order to resolve the site data gaps, a supplemental investigation is being conducted, and is described below. The purpose of this supplemental upland investigation is to provide additional data regarding upland areas that may impact sediments and characterize potential sources and migration pathways to sediments to allow completion of a site-wide RI/FS. Objectives of the supplemental investigation included the following:

- Perform an evaluation of primary sources of impacts on the uplands.
- Characterize upland soil in targeted areas to assess potential ongoing sources of groundwater impacts.
- Characterize upland groundwater to address the groundwater to sediment pathway.
- Assess light and dense non-aqueous phase liquid (LNAPL and DNAPL) occurrence and mobility on the uplands, relative to migration to sediment.

The methods used to obtain the data outlined above during the supplemental investigation are described more completely in the Supplemental Investigation Work Plan (GeoEngineers 2013).

An expedited schedule to fill the primary data gaps and collect other necessary data to complete a site-wide RI/FS is being implemented for the supplemental investigation. The majority of the field investigation was conducted in March and April 2013 during the park's low-use season, which generally extends from November through April. A second round of groundwater sampling will be completed in late summer 2013. The expected schedule for the supplemental investigation, including data evaluation and reporting, is presented as Figure 13.

7.0 SUPPLEMENTAL INVESTIGATION

The Supplemental Investigation Work Plan was prepared to collect supplemental data necessary to complete a site-wide RI/FS focusing on further characterization of upland to sediment transport pathways and potential risks to human health and the environment.

The primary transport mechanisms and pathways of concern that will be refined as a result of the supplemental investigation activities include:

- Leaching of contaminants from impacted soil to groundwater;
- Transport of impacted groundwater to surface water and sediment; and
- Migration of mobile NAPL to surface water and sediment.

The results of the supplemental investigation are expected to facilitate refining the conceptual site model to evaluate site-wide cleanup actions as part of the FS. The transport pathways expected to be retained following completion of the supplemental investigation include:

- Wind erosion and dispersion of impacted soil to outdoor air;
- Volatilization of COCs from impacted media indoor and outdoor air;
- Erosion of impacted soil and subsequent storm water or surface water transport to sediment and surface water;
- Leaching of COCs from impacted soil and dissolved groundwater transport to surface water and sediment; and
- Mobile NAPL transport to surface water and sediment.

7.1. Supplemental Investigation Elements

The supplemental investigation included the following general work elements:

- **Geophysical Surveys**. Non-intrusive magnetic/gradiometer and electromagnetic conductivity surveys were performed to provide information regarding the presence and location of potential buried MGP structures that may be primary sources. Ground penetrating radar was used in selected areas of the GWPS, where magnetic methods did not yield usable data, including the NE Corner (Figure 10). This information was used to focus subsequent TarGOST® investigation in areas of potential concern.
- **Monitoring Well Survey**. Existing monitoring wells were located and inspected to determine their usability for groundwater monitoring. A total of 40 existing monitoring wells were surveyed, multi-level-sampler wells were not included in the survey. Groundwater levels and NAPL measurements were documented. NAPL samples were collected from wells with measurable NAPL thickness. The samples were shipped to Dakota Technologies for pre-mobilization purposes to determine if the TarGOST® technology would respond to the NAPL characteristic of that found at the GWPS. TarGOST® did respond to NAPL samples provided. Monitoring wells were repaired as necessary before including them in the monitoring well network.

- **"TarGOST®" Laser Induced Fluorescence Screening**. TarGOST® was used in selected areas of the site were tar or NAPL has been identified, or other areas where semi-quantitative data could be used to provide a rapid method of identifying the potential presence and further delineating the extent of known occurrences of tar or NAPL. TarGOST® was used to evaluate potential primary sources identified through historical research or anomalies identified by the geophysical survey. Forty-five TarGOST® explorations plus two replicate explorations were completed. The location of the TarGOST® explorations are shown on Figure 11.
- **Soil Investigation**. Soil borings were drilled in selected locations based on the results of the geophysical surveys and TarGOST® screening. Twenty-six soil borings were completed; depths extended from approximately 15 feet bgs to 40 feet bgs. The location of the soil borings are shown on Figure 11. Soil samples were selected for chemical analysis of benzene, toluene, ethylbenzene, and xylenes (BTEX), PAHs, and arsenic. Select split soil samples from borings were submitted to Dakota to correlate the TarGOST® responses to chemical analytical results.
- **Geotechnical Evaluation of Kite Hill**. The geotechnical stability of Kite Hill was evaluated in anticipation of placing an engineered, vegetated soil cap in that area. Three geotechnical borings were completed (Figure 11): depths ranged from approximately 30 feet bgs to 50 feet bgs. One location was converted to a monitoring well. Soil samples were collected for geotechnical soil properties analysis. Additionally split soil samples were collected from several borings for chemical analysis.
- **Monitoring Well Installation**. Twelve new monitoring wells were installed near the shoreline to evaluate the concentrations of COCs in groundwater discharging to sediments and surface water. The location of the new monitoring wells are shown on Figure 12. Three well pairs were installed to target groundwater in different geologic units.
- **Baseline Groundwater Monitoring**. Usable monitoring wells were sampled to provide a snapshot of groundwater quality across the uplands and baseline data to select wells for future groundwater monitoring. Groundwater samples from the wells without NAPL presence were collected, including existing and newly installed wells. Fifty-three wells were sampled. Groundwater samples were submitted for chemical analysis of BTEX and PAHs. Conductivity, turbidity, dissolved oxygen, oxidation reduction potential, total dissolved solids, salinity, pH and temperature were documented during groundwater sampling. Additionally, water levels were measured in all monitoring wells on site and METRO wells located northwest of the site over a two-day period to provide a snapshot of groundwater elevations. The monitoring wells sampled for baseline data are highlighted on Figure 12.
- **NAPL Testing**. NAPL samples were collected from six wells and were submitted for viscosity and density testing. Additionally three petrophysical borings were completed near the shoreline. Petrophysical testing of selected soil samples were collected for core photography and potential follow-up testing. Data will be used to evaluate potential NAPL mobility.
- **Slug Testing**. Hydraulic conductivity of the water bearing zones was estimated based on slug tests of eight (8) newly installed monitoring wells.
- **Groundwater Monitoring**. An additional round of groundwater monitoring will be conducted in late summer. Groundwater sampling will provide data to evaluate groundwater quality, focusing on the GWPS shoreline.

8.0 SCOPE OF SITE-WIDE FEASIBILITY STUDY

The most recent FSs prepared for the sediment area of the GWPS are part of the 2006 Remedial Investigation and Feasibility Study for the Gas Works Sediment Eastern Study Area prepared by RETEC (RETEC 2006) and the 2007 Remedial Investigation/Feasibility Study for the Gas Works Sediment Western Study Area prepared by Floyd|Snider (Floyd|Snider 2007a). The most recent feasibility study addressing the uplands portion of the GWPS is the 1998 Focused Feasibility Study Report prepared by Parametrix (Parametrix and Key 1998). In addition to the supplemental investigation described above, several investigation phases have been performed at GWPS since the most recent feasibility study was prepared. The Eastern Shoreline Investigation performed by ENSR (ENSR 2008) and the Northeast Corner Investigation performed by Floyd|Snider in 2007 (Floyd|Snider 2008b) addressed a significant data gap concerning the shoreline and adjacent upland area of the eastern portion of the GWPS. In addition, upland groundwater investigation activities were conducted in 2010 to evaluate hydrogeologic conditions at the GWPS and develop revised geologic and hydrogeologic conceptual site models. The results of the 2010 investigation activities resulted in refining the understanding of the site geology and the hydrostratigraphic units and were summarized in memoranda to Ecology that presented the Draft Revised Geologic CSM and Hydrogeologic CSM prepared by the Gas Works Sediment Area Technical Team (GWSA Technical Team 2011a and 2011b).

The previous feasibility studies prepared for the sediment area of the GWPS were conducted independently for the east and west portions of the sediment area, resulting in different recommended cleanup actions. The site-wide FS will identify cleanup alternatives for the entire sediment area. In addition, groundwater and potential DNAPL migration from upland impacted media to sediment needs to be addressed holistically. Identifying upland and sediment cleanup alternatives separately could lead to potentially incompatible and/or inefficient remedial actions. The site-wide FS outlined in this FS Bridging Document will address all of these issues by developing and evaluating cleanup action alternatives for the entire GWPS.

The site-wide FS will incorporate a significant amount of work performed during previous FS analyses for the GWPS, where applicable. However, the site-wide FS will also be based on updated site characterization data, data resulting from previous completed cleanup actions, and updated regulatory requirements. The site-wide FS will also be prepared with primary consideration for cleanup actions at adjacent upland and sediment areas to be compatible and protective. The site-wide FS will include the following components:

- Identify all applicable or relevant, and appropriate requirements (ARARs) for cleanup of site media;
- Develop remedial action objectives based on ARARs and the revised CSEM;
- Develop cleanup levels and points of compliance and, as necessary, establish remediation levels;
- Delineate affected media where evaluation of remedial actions are appropriate;
- Screen and evaluate potential remediation technologies and assemble a set of cleanup alternatives;

- Evaluate cleanup alternatives using MTCA criteria for selection of cleanup actions, in accordance with WAC 173-340-360; and
- Recommend a preferred alternative.

The following sections provide the details of the FS process that will be completed for the GWPS.

8.1. Identify Applicable or Relevant and Appropriate Requirements

Compliance with ARARs forms the basis of selection of remedial action goals, cleanup levels, points of compliance, and ultimately a remedy for a site. These requirements may be by statute (federal or state) or as guidance and are defined by MTCA. The primary ARARs for the GWPS will be the applicable MTCA and Sediment Management Standards (SMS) cleanup levels and regulations that address implementation of a cleanup under MTCA. CERCLA and RCRA requirements governing cleanup actions will also be considered primary ARARs. Other potential ARARs may include the following:

- Washington Pollution Control Act and the implementing regulations: Water Quality Standards for Surface Waters of the State of Washington (Chapter 173-201A WAC).
- Washington Hazardous Waste Management Act and the implementing regulations: Dangerous Waste Regulations (Chapter 173-303 WAC), to the extent that any dangerous wastes are discovered or generated during the cleanup action.
- Washington's Shoreline Management Act with respect to construction cleanup activities conducted within 200 feet of the shoreline.
- Archeological and Historical Preservation—The Archeological and Historical Preservation Act (16 USC 469a-1) would be applicable if any culturally significant materials are discovered during site grading and excavation activities. Additional historic preservation requirements, if any, related to the recent listing of Gas Works Park on the National Register of Historic Places will be identified.
- Health and Safety—Site cleanup-related construction activities would need to be performed in accordance with the requirements of the Washington Industrial Safety and Health Act (RCW 49.17) and the federal Occupational Safety and Health Act (29 CFR 1910, 1926). These applicable regulations include requirements that workers are to be protected from exposure to contaminants and that excavations are to be properly shored.

ARARs may be chemical-, location-, or action-specific. Chemical-specific ARARs are usually risk-based; location-specific ARARs address considerations such as the presence of wetlands, sensitive habitats or historic site-specific features that would pose additional requirements; action-specific ARARs typically address concerns regarding the implementation of the remedy (e.g., types of treatment and disposal). The site-wide FS will identify the complete set of ARARs that are applicable to the site cleanup.

8.2. Development of Remedial Action Objectives

Remedial action objectives (RAOs) define the overall goals that the cleanup must achieve. The RAOs will specify the goals for site-specific COCs, the potential exposure pathways, and receptors (human or ecological). The CSEM will be used to develop site-specific RAOs, which are typically narrative statements that address each complete pathway for the GWPS. They will also be used to compare remedial alternatives that will be evaluated in the site-wide FS.

8.3. Development of Cleanup Levels, Points of Compliance and Remediation Levels

Cleanup levels for the uplands were established in the CAP (Parametrix 1999) and incorporated into the 1999 Consent Decree (Ecology 1999). The Consent Decree also specified institutional controls and site use restrictions for overall protection of human health and the environment. The CULs included in the Consent Decree for soil were based on risks associated with direct exposure to soil. The selection of CULs included consideration of a risk assessment performed by the University of Washington (Ongerth 1985) that evaluated risks to park users from exposure to PAHs in soil. However, the MTCA Method B cleanup levels for soil were determined to be more conservative than the site-specific risk-based values and were selected as the CULs for soil.

Use of TPAH to define sediment areas requiring cleanup and a CUL of 170 mg/kg TPAH was proposed for the sediment area in the Gas Works Sediment Area Cleanup Standard Determination (RETEC 2005b) document. This value was determined to be protective of the benthic community inhabiting Lake Union sediments from acute and chronic toxicity from exposure to PAHs. Recently, Washington State proposed new freshwater sediment standards, which will be promulgated as part of the revised SMS in September 2013. The GWPS sediments will be re-evaluated for compliance with the revised standards. Additional pathways will also be evaluated in the site-wide RI to address bioaccumulative effects and the potential migration of contaminated groundwater or NAPL to sediment and surface water.

The preliminary CSEM, described above and depicted in Figure 9, may be further revised in the RI based on the results of the supplemental site investigation conducted in 2013. Transport pathways in the CSEM involving migration of contaminants from upland media to Lake Union surface water and sediments will be considered during development of CULs and points of compliance. Migration of contaminants as a result of direct groundwater flow into Lake Union, as well as through stormwater discharge and erosion will be evaluated. As needed, remediation levels may also be established for specific cleanup alternatives.

Cleanup levels for groundwater, established in the 1999 Consent Decree, are based on protection of Lake Union surface water. Attenuation factors for COCs will be evaluated to ensure the groundwater to sediment pathway is protective. Uplands groundwater is not a current or reasonable future source of drinking water. It is expected that information developed during the site-wide RI will confirm previous findings that groundwater at the property meets the requirements of WAC 173-340-720 for non-potable groundwater. A groundwater point of compliance will be developed, which may include a proposed conditional point of compliance located at or near the groundwater/surface water interface.

8.4. Delineation of Media Requiring Remedial Action

The results of the Supplemental Site Investigation will be used to update the delineation of upland media requiring remedial action. Sediment data from previous GWPS RI/FS documents will be used to delineate sediment remediation areas. The site-wide FS will include figures representing the limits of media exceeding cleanup levels or remediation levels in the GWPS. The figures will present the limits of contaminated media in plan and cross-section view, which will be used to quantify distances, areas, and volumes of contaminated media for use in estimating cleanup costs.

8.5. Screening of Cleanup Alternatives

Cleanup alternatives will be developed for each medium of concern. Initially, general remediation technologies will be identified for the purpose of meeting RAOs. General remediation technologies consist of specific remedial action technologies and process options and will be considered and evaluated based on the media type and the properties of any contaminant(s). These may include no action, institutional controls, containment or other engineering controls, removal, *in situ* treatment and natural attenuation. Remedial action technologies appropriate for all COCs, media, and other site constraints will be evaluated during the screening process, and the compatibility of the technologies between upland and sediment media will be considered.

Specific remedial action technologies are the engineering components of a general remediation technology. Several specific technologies may be identified for each general remediation technology and multiple process options may exist within each specific technology. Specific remedial action technologies and representative process options will be selected for evaluation based on documented development or documented successful use for the particular medium and contaminants. Cleanup alternatives will be developed from the general and specific remedial technologies and process options consistent with Ecology expectations identified in WAC 173-340-370 using best professional judgment and guidance, as appropriate. The cleanup alternatives developed in the FS will represent site-wide actions using mutually compatible technologies for upland soil and groundwater as well as sediment. Transport pathways between soil, groundwater, and sediment will be addressed in the site-wide cleanup action alternatives evaluated in the FS.

Conceptual level designs will be prepared for each of the cleanup alternatives developed for comparative evaluation. The design for each alternative will include figures showing the layout of any treatment systems, locations for barriers or other permanent installations, etc. to provide a conceptual representation of the proposed elements of the alternative and allow for estimating quantities and costs of capital expenses. The design will also specify post-construction requirements including: operation durations; labor, equipment, and products required during operation; maintenance or replacement assumptions; and, compliance monitoring requirements. The cost of these short-term or long-term operation and maintenance elements will be estimated using MTCA guidance and the EPA guidance document "A Guide to Developing and Documenting Cost Estimates during the Feasibility Study" (EPA 2000).

8.6. Evaluation of Cleanup Alternatives

MTCA requires that cleanup alternatives be compared to a number of criteria as set forth in WAC 173-340-360 to evaluate the adequacy of each alternative in achieving the intent of the regulations, and as a basis for comparing the relative merits of the developed cleanup alternatives. Consistent with MTCA, the alternatives will be evaluated with respect to compliance with threshold requirements, permanence, and restoration timeframe, and the results of the evaluation will be documented in the FS. The estimated costs for each alternative will be evaluated relative to benefit using the MTCA disproportionate cost analysis procedures to determine a preferred cleanup action alternative.

9.0 PATH FORWARD

The path forward following completion of this FS Bridging Document will generally consist of completing the scope of the supplemental investigation followed by completion of a site-wide RI/FS report. A request to amend Agreed Order Number DE 2008 was submitted to Ecology by the City of Seattle and PSE to expand the AOI to include the Gas Works Park and Harbor Patrol properties to evaluate upland areas that may impact sediments. In a letter dated March 15, 2013, Ecology approved the requested Agreed Order amendment. The proposed Revised Schedule of Deliverables as presented in the request to amend the Agreed Order is presented below.

PROJECT DELIVERABLES	COMPLETION SCHEDULE
Agency Review Draft – Site-Wide RI Report Report will encompass all sediments data, data collected as part of the supplemental uplands investigation, and existing uplands data necessary to address uplands to sediments pathways.	Not later than the later of 120 days after completion of field investigation activities or 300 days after Ecology's approval of the Final Work Plan for Supplemental Investigation[2].
Agency Review Draft – Site-wide FS Report The FS will address sediments, inclusive of the shoreline area, and uplands areas that are part of uplands to sediments pathways	Not later than 120 days after resolution of Ecology's comments on the Agency Review Draft – Site-wide RI Report.
Final Draft – Site-wide RI/FS delivered to Ecology The RI/FS report will package the revised drafts of the RI and FS reports, incorporating agency comments.	Not later than 60 days after Ecology orders production of the Final Draft Site-wide RI/FS report.
Public Comment Period	Not later than 45 days after the receipt of the Final Draft Site-wide RI/FS report.

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TABLES

Table 1

Previous Upland Investigations

Gas Works Park Site

Seattle, Washington

Year	Investigation Description	Location	Location IDs	Type of Exploration	Analytical Collected
1971	Cole and Machno summarized the subsurface conditions at the park for the City. They found oil in the water table and oil-soaked ground in the southeast corner of the park and several other areas. Hydrocarbon wastes, ashes, cinders, and oil were found in the majority of the 20 soil borings.	site-wide	#1 to #20	soil borings	--
1972	In 1972, two surface soil samples were collected and analyzed for arsenic. Results showed levels of arsenic from "under the old filter" and from "15 feet around the periphery." There are no maps showing the locations of the soil arsenic samples. "Under the old filter" could be interpreted to mean underneath the former Kelly filter area to the south of the playbarn.	unknown - Kelly filter?	A and B	surface soil samples	soil
1973	Thirty-one backhoe test pits (referred to as "borings") were dug; encountered foundations, pipes, gas plant waste materials, and native soils.	site-wide	A, A-A, A-1, B, B-B, C, D, E, Trench F, G, H, I, J, K, L, M, N, O, P, Q, R, S, T, T-1, T-2, U, V, W, X, Y, Z	test pits	--
1973	Five test pits and three borings were installed along a proposed sewer line in December 1973; noted fill and some oily wastes.	site-wide	MH1 to MH5; A, B, C	test pits and borings	--
1984	In April 1984, Ecology and Environment conducted a soil sampling investigation of the Site, collecting and analyzing 72 composite samples from 0 to 0.5 feet and 0 to 3 feet depths at 24 locations. Seven additional soil samples were collected from apparent "hotspots" on the east side of the park and under the pier.	site-wide	84EPA... series; EPA1 to EPA24	soil sampling	soil
1984	Surface soil samples (upper inch) were collected from the Site in May 1984 and evaluated for PAHs.	site-wide	UW... series	surface soil samples	soil
1984	Air and soil samples were collected in June 1984 to evaluate off-site release of volatile organic compounds and determine PAH compounds in dust.	site-wide	P1 to P5; S1 to S5; V1 to V9	air and soil sampling	air and soil (NOT IN DATABASE)
1985	Additional testing was conducted in 1985, which included surface soil, tar samples, and groundwater samples. This investigation consisted of collecting 21 surface soil samples (upper 2 inches) and six tar samples; 34 soil samples and associated field replicates were analyzed for PAHs and one location was analyzed for cyanide.	site-wide	B.., C..., D..., E..., F..., G..., H..., I..., J..., K..., L..., M..., N..., P... series	surface soil, tar, and groundwater samples	soil
1986-1987	The Seattle Parks Department and US Geological Survey conducted an investigation in 1986 and 1987 to evaluate groundwater quality under the park and potential discharge of contaminants to Lake Union. This included the installation of 16 groundwater monitoring wells, borehole sampling (10 soil samples), groundwater sampling and testing, investigation of subsurface stratigraphy, soil gas sampling (28 samples), groundwater elevation, and hydraulic transmissivity testing. Soil cores were obtained from the well borings and analytical testing for organic compounds was conducted on ten soil samples. Groundwater samples were collected and analyzed for PAHs, VOCs, metals, cyanide, polychlorinated biphenyls, and pesticides. Results from the groundwater analyses indicated that the southeast corner had elevated levels of VOCs. The northwest corner had elevated levels of oil and tar wastes. Soil results indicated the presence of a number of PAH compounds associated with coal tar wastes. Several volatile organic compounds were detected in soil gas including benzene, toluene, ethylbenzene, xylene, and naphthalene.	site-wide	MW-01 to MW-16	monitoring wells, groundwater, soil, and soil gas sampling	groundwater, soil, and soil gas
1988	In February 1988, air, soil, and asbestos testing from the Play Barn area were conducted for protection of workers prior to renovation. Results from this testing showed low levels of PAHs in the soils, low levels of VOCs in the air, and the presence of friable asbestos in pipe lagging, though no airborne asbestos fibers were detected above the reporting limit.	Playbarn	PB-S-1 to PB-S-4	air, soil, and asbestos testing	air and soil
1988	A focused field investigation was conducted in June and July 1988 to continue ongoing monitoring of the park and assess plans for an irrigation system. Collected groundwater samples from 15 temporary monitoring wells and tested for VOCs; installed one permanent monitoring well (MW-17) and tested for VOCs, PAHs, and metals; tested six soil samples for cyanide.	NE Corner	MW-1 to MW-17; TMS1 to TMS15; S23 to S29	monitoring well, groundwater, and surface soil sampling	groundwater and soil
1989	Installation of four permanent monitoring wells and groundwater sampling for VOCs and PAHs; geophysics study in former tar refinery area.	site-wide	MW-18 to MW-21	monitoring wells and groundwater sampling	groundwater
1995	In 1995, EPA conducted an Expanded Site Inspection, where two samples from the shoreline, one upland soil sample, and two surface water samples were collected. Evaluation of the results indicated elevated levels of PAHs and other contaminants existed in the shoreline, soil, and water samples collected.	NE Corner; SE Corner shoreline	95EPA... series	soil and surface water sampling	soil and surface water
1997	In 1997, in response to the Agreed Order work scope, groundwater monitoring wells were sampled and ten surficial soil samples were collected as part of the Focused Feasibility Study/Cleanup Action Plan. Known and suspected tar seeps were characterized. Twelve test pits were excavated and three tar samples were collected.	site-wide	MW-1 to MW-21; S-1 to S-10; TP-1 toTP-12	test pits, groundwater, surface soil, and tar sampling	groundwater, soil, and tar

Year	Investigation Description	Location	Location IDs	Type of Exploration	Analytical Collected
1997 -1998	Also as part of the Agreed Order, soil and groundwater quality was investigated at the Harbor Patrol area and the area directly east of Kite Hill. Data generated from soil borings, monitoring wells, and piezometers were used to develop cross-sections of the Site, measure groundwater flow gradients, and evaluate the nature and extent of NAPL occurrences. Fate and transport modeling was used to predict downgradient attenuation of dissolved PAHs as part of the conceptual site model. A total of two soil boring were completed and nineteen wells/piezometers were installed.	Harbor Patrol area	B-1-EPRI; B-2- EPRI; DW-4 to DW-7; PZ-1 to PZ-10; RW-01; MLS-1 to MLS-7; MW-13; MW-14, MW-22 to MW-25	soil borings, monitoring wells, piezometers, pump test, soil and groundwater sampling	groundwater and soil
1998	Field investigations of the southeastern area were conducted in 1998 to evaluate the feasibility of an air sparging system. Thirty-four geoprobe borings were advanced and soil and groundwater samples were collected. Elevated benzene concentrations were detected in soil and groundwater samples, and were delineated as two separate plumes, one near the shoreline and one further upgradient. Analytical results from LNAPL samples collected indicated that light oil was the source of the benzene in the shoreline plume.	southeastern area mostly; one location NW corner	B-1 to B-34	soil borings, groundwater, soil and LNAPL sampling	groundwater, soil, and LNAPL
2000	Installation of four monitoring wells: OBS-1 to OBS-3 were installed as part of benzene cleanup action as performance monitoring wells; CMP-1 was installed as part of groundwater monitoring compliance.	SE Corner; Harbor Patrol	CMP-1; OBS-1 to OBS-3	monitoring wells	--
2004	In 2004, the northwest corner of the park was investigated in order to allow the City to remove the existing physical barriers and allow public access to that area. Thirteen test pits were excavated and sixteen surficial soil samples collected and analyzed.	northwest area	NWSS-... series	test pits and surface soil sampling	surface soil
2005	A soil quality investigation was conducted within the fenced Cracking Towers area in July 2005. Six soil samples were collected at depths of 0.5 to 1.5 feet below ground surface. The samples were analyzed for PAHs, VOCs, PCBs, and metals (including arsenic, lead, and mercury). Elevated concentrations of PAHs were detected in all six soil samples. No PCBs or VOCs were detected in the samples. Metals concentrations were generally not detected or were well below MTCA Method A unrestricted cleanup levels.	cracking towers	GWP-TP1 to GWP-TP6	test pits and soil sampling	soil
2006	In September 2006, an investigation of the western shoreline was conducted to delineate the presence and assess the mobility of DNAPL in the subsurface. Nine soil borings were advanced, and permanent and temporary monitoring wells installed. Soil samples were collected and analyzed for petrophysical properties, and slug tests were performed to determine hydrogeologic properties.	western shoreline	TDW-1 to TDW-3; TSW-1 to TSW-3; TSB-1 to TSB-3	soil borings and monitoring wells	soil (petrophysical and geotechnical)
2007	In August 2007, a soil gas survey was conducted in the northeastern portion of the park to identify locations for further exploration.	northeast corner	SG-01 to SG-54	soil gas survey	soil gas
2007	In 2007, two separate but complementary investigations of the northeastern meadow and eastern shoreline area were conducted by PSE, the City of Seattle, and Ecology. In September 2007, 34 soil borings were advanced, and soil samples were collected and analyzed. LNAPL and DNAPL were observed most frequently in the southern section of the investigation area. Chemical tests were conducted on selected samples for SVOCs, VOCs, total petroleum hydrocarbons, and Synthetic Precipitation Leaching Procedure analysis for SVOCs.	northeast corner/eastern shoreline	GP1 to GP14; HA1 to HA9; SB 1 to SB 13	soil borings and soil sampling	soil
2007	In October 2007, a NAPL sample was collected from monitoring well MW-9, and was found to contain elevated concentrations of PAHs.	MW-9	MW-9	MW Sampling	NAPL
2007-2008	Air quality was evaluated using three quarterly monitoring events conducted from spring 2007 to winter 2008. Air samples were collected from five locations within the Park (Cracking Towers, Prow Upwind, Weather Station Location, East Shore, and Play Barn Basement) and Harbor Patrol facility. The quarterly results showed that the detected concentrations of VOCs, benzene and naphthalene in particular do not exceed the park user scenario; and do not exceed OSHA occupational standards that would be applicable to Park and Harbor Patrol employees.	site-wide	HP, CT, PUP, WSL, ES, PBB	air sampling	air
2008-2011	Annual groundwater sampling.	SE Corner; Harbor Patrol; W Kite Hill	CMP-1; OBS-1 to OBS-3; MLS-5; MLS-6; MW-17; MW-19	groundwater sampling	groundwater
2010	In June 2010, six surface soil samples were collected from the WW No.19 storm drain ditch as part of storm drain source control evaluation.	NE Corner	WW19-01 to WW19-06	surface soil sampling	surface soil
2010	In September 2010, a hydrogeologic investigation was conducted to collect additional hydrogeological data in support of a site-wide, three-dimensional numerical groundwater flow model. This investigation included a survey of groundwater levels from existing monitoring wells, advancing soil borings to provide stratigraphic information, completion of monitoring wells slug and pump tests. Ecology obtained split soil samples from the well borings and submitted 19 of the samples for chemical analysis of metals and SVOCs.	site-wide	MW-26 to MW-31	monitoring wells and soil sampling	soil
2011	Ecology sampled surface soil on Kite Hill.	Kite Hill	KH-1 to KH-7	surface soil grab sampling	soil
2011	For Seattle Structural and Seattle Police Department, HartCrowser sampled geotechnical boring B-1 and sinkhole location for environmental COCs as part of bulkhead structural review and assessment.	Harbor Patrol area	B-1; sinkhole	soil sampling	soil
2012	Proposed play area soil sampling, and asbestos and lead paint sampling of playbarn structure.	Playbarn	GWP-PA-01 to GWP-PA-04	hand auger and soil sampling	soil

Note:

Storm drain and sediment investigations and associated sampling not included.

Table 2

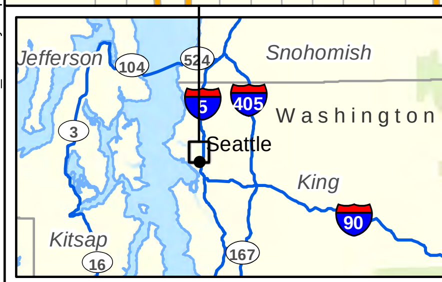
Previous Remedial Actions

Gas Works Park Site

Seattle, Washington

Year	Remedial Action Description	Who Remediated	Location
1971 / 1972	SOIL COVER. In 1971 or 1972, the City learned about a large oil spill that occurred over approximately one-third of the Site in January 1969. Washington Natural Gas covered it with a thin layer of fill. Test holes 7, 8 and 10 were located within the spill and cover area.	WNG	South Central Area
1973	EXCAVATION. Targeted areas were identified for removal to depths ranging from 1.5- to 8-feet below grade or to water level during plant demolition and initial regrading for park development.	City	South Central; Central; Southeast; Northwest; Northeast Area
1976	"CLEAN" SOIL COVER. Park regraded with net removal near shoreline and net fill away from shoreline. A cover layer of biosolids mixed with sawdust and other organic materials was placed over the Site. This material was mixed with imported fill and/or excavated soil and graded and/or tilled into the upper surface soil layer. Kite Hill was created by mounding 20,000 cubic yards of excavation materials and covering the mound with thousands of yards of imported fill. Excavated material and debris was covered with as much as 6 feet of clean soil during the construction of Kite Hill.	City	Site-Wide
1984	CLEAN SOIL COVER. Approximately 1-foot-thick clean soil cover was placed over the most impacted areas of the park.	City	Site-Wide
1985	ASPHALT CAPPING OF TAR. In 1985, tar was observed seeping up through the asphalt sidewalk in the northwest section of the park, south of the railroad right-of-way. This area is in the general vicinity of the old tar refinery originally located on the Site. The City attempted to pave (seal) some of the larger seeps (5 or 6 inches in diameter). However, the seeps continued to penetrate the asphalt, particularly during the warmer months.	City	Northwest Area
1997	REMOVAL AND TREATMENT OF RESIDUAL UPWELLING TAR. Characterization of known and suspected tar seeps was conducted in October 1997 using backhoe test pits. With concurrence from Ecology, the City and Puget Sound Energy made the decision during the tar characterization work to define the extent of the shallow tar with the backhoe, remove as much tar as practicable, and backfill the excavations with clean fill. Tar was removed from the Site. Twenty-two drums of semi-solid tar were removed in October 1997; one drum from TP-6 and 21 drums from TP-10, TP-11, and TP-12. Also, approximately 24 cubic yards of tar-contaminated soil were removed from the TP-1 excavation.	City/PSE	North of Kite Hill; Southeast Corner
1997	PRODUCT REMOVAL FROM TANK. As part of an assessment of soil quality within the Cracking Tower area, HWA Geosciences discovered a partially buried tank beneath the two relief-holder scrubbers. Approximately 2,500 gallons of viscous tarry liquid was present in the tank. Most of the product was removed. The remaining non-pumpable product was left in the tank. The tank access covers were replaced and secured.	Seattle Parks Department	Cracking Tower Area
1998	FENCING, BARRIERS, SIGNAGE. Maintenance of fencing around the cracking towers, barriers to public access in the northwest corner, and signs warning park users not to eat dirt, or drink from, wade, or swim in Lake Union. The fence is inspected weekly.	City/PSE	Cracking Towers; Northwest Corner
1998	LNAPL RECOVERY. Prior to installation of the AS/ SVE system, an Interim Remedial Action was conducted in 1998. This action included installation of a network of recovery wells in the southeastern corner of the park. A vacuum truck was used to recover oil and groundwater from the wells.	City/PSE	Southeast Corner
1999	RESTRICTIVE COVENANTS. A restrictive covenant was recorded that restricts actions that disturb contaminated soil or groundwater.	Seattle Parks Department	Site-Wide
1998-2000	CLEAN SOIL COVER. 1500 to 2000 cubic yards of clean fill from another City of Seattle project was moved to NW Corner and later spread to create a level surface. The thickness of this fill layer was estimated to be approximately 1 foot.	City	Northwest Corner
1999-Present	TAR REMOVAL/COVERING. Seattle Parks Department does periodic inspections for upwelling tar. Recent communications with Seattle Parks Department personnel indicate that surface seepage of tar is infrequent and generally involves covering “button-sized” or “thread-like” occurrences with clean soil. Residual upwelling tar is removed when discovered.	Seattle Parks Department	Site-Wide
2000-2001	CLEAN SOIL COVER. A 12- to 18-inch-thick vegetative soil cover was placed on approximately 5.7 acres of the Site in the north-central and southeastern portions of the park. These areas were scarified and rough graded to a depth of 4-6 inches below ground surface. Soil cover consists of grass turf layer, 12 inches of sandy loose soil, and a geogrid identifier layer. The soil cover is inspected weekly.	City/PSE	North Central; Southeast Area
2001-2006	AIR SPARGE/SOIL VAPOR EXTRACTION. Installation of an in situ groundwater air sparging and soil vapor extraction treatment system of the southeastern corner of the park. The AS/ SVE treatment system operated in the southeast corner of the park, from 2001 until December 2006.	City/PSE	Southeast Corner
2001-2010	MONITORED NATURAL ATTENUATION. Monitored natural attenuation of PAHs in groundwater in the western portion of the park. A detailed study conducted by EPRI of the tar-impacted area near the Seattle Harbor Patrol facility confirmed that tar impacts extended from the former ATCO plant toward Lake Union. Monitored natural attenuation was selected as the remedy for this area. Portions of this remedial action were further described and implemented in the Construction Completion Report.	City/PSE	Harbor Patrol; Southwest Corner
2005	SOIL COVER. In 2005, the Consent Decree and Cleanup Action Plan were amended to allow installation of a vegetated soil cover in the northwestern corner of the Site. This area was recontoured and geotextile fabric and 1 foot of topsoil were added following the installation of an irrigation system.	City	Northwest Corner
2007	TAR REMOVAL/COVERING. Two tar occurrences were removed by the Seattle Parks Department from the seasonally submerged areas along the eastern shoreline in January 2007. An additional occurrence was observed in May 2007 in the northeastern area of the uplands. This tar occurrence was partially removed, covered with geotextile fabric, and covered with clean fill.	Seattle Parks Department	Eastern Shoreline; Northeast Corner
2008	TAR REMOVAL/COVERING. In August 2008, Seattle Parks Department partially removed tar seeps observed in the eastern shoreline and in the valley west of the cracking towers. A total of four seeps were identified. Excavated areas were backfilled.	Seattle Parks Department	Eastern Shoreline; Cracking tower
2012	SOIL COVER. In November 2012, the Northeast corner was capped with clean soil by Ecology.	Ecology	NE Corner

FIGURES



N
W E
S

0 2,000 4,000
Feet

Notes:
1. Gas Works Park Site boundary is equivalent to the Gas Works Park Sediment Site boundary documented in the 2013 Amendment of Agreed Order DE2008.
2. Reference: basemap provided by Esri.
3. The locations of all features shown are approximate.
4. This drawing is for information purposes. It is intended to assist in showing features discussed in an attached document. GeoEngineers, Inc. cannot guarantee the accuracy and content of electronic files. The master file is stored by GeoEngineers, Inc. and will serve as the official record of this communication.

Vicinity Map

Gas Works Park Site
Seattle, Washington
Feasibility Study Bridging Document

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Figure 1

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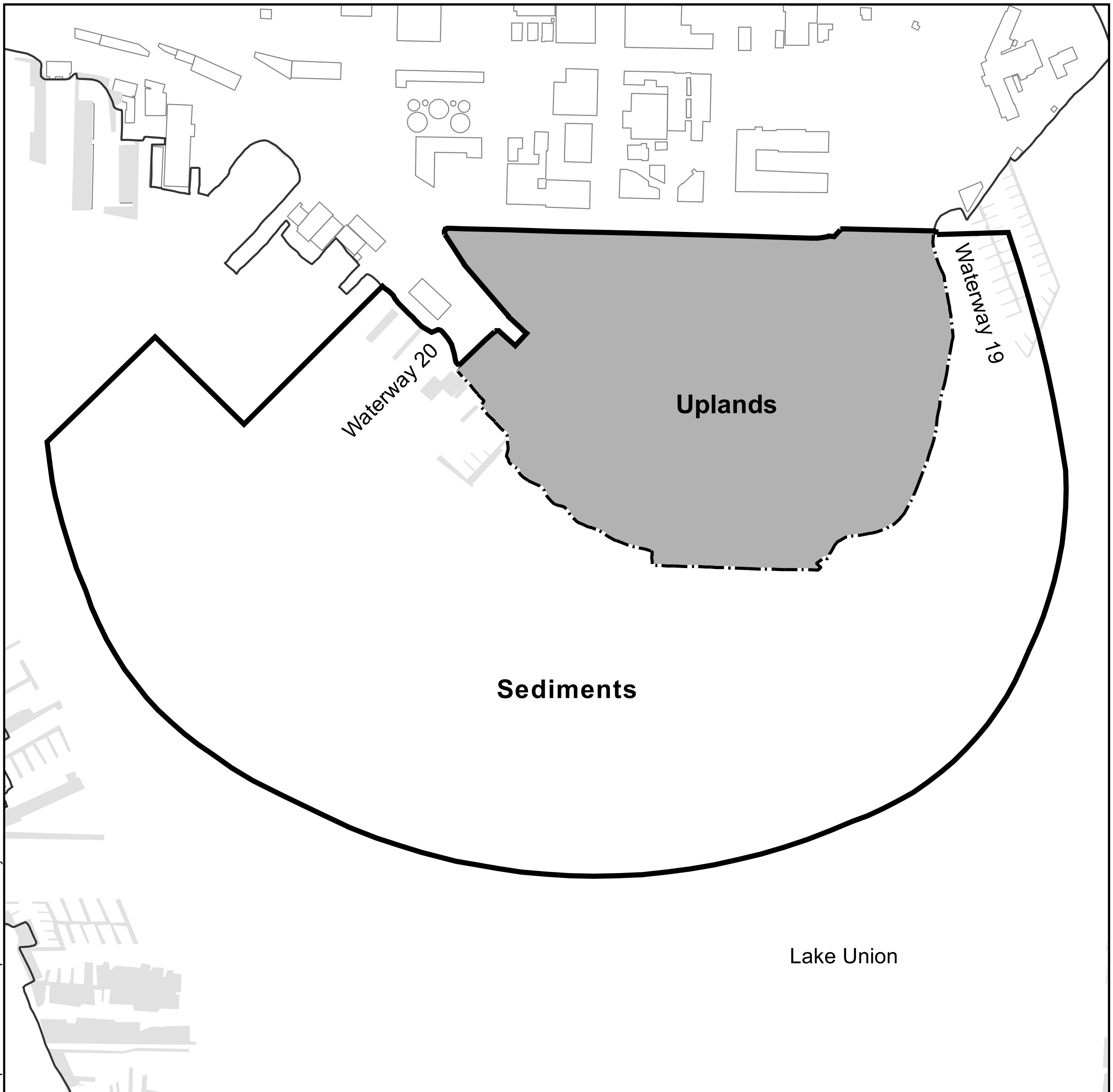

Legend

- Area of Investigation
- Consent Decree Area

N W E S

400 0 400

Feet

Gas Works Park Site Components

Gas Works Park Site
Seattle, Washington
Feasibility Study Bridging Document

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Figure 2

Notes:
1. Gas Works Park Site boundary is equivalent to the Gas Works Park Sediment Site boundary documented in the 2013 Amendment of Agreed Order DE2008.
2. Reference: basemap provided by Esri.
3. The locations of all features shown are approximate.
4. This drawing is for information purposes. It is intended to assist in showing features discussed in an attached document. GeoEngineers, Inc. cannot guarantee the accuracy and content of electronic files. The master file is stored by GeoEngineers, Inc. and will serve as the official record of this communication.

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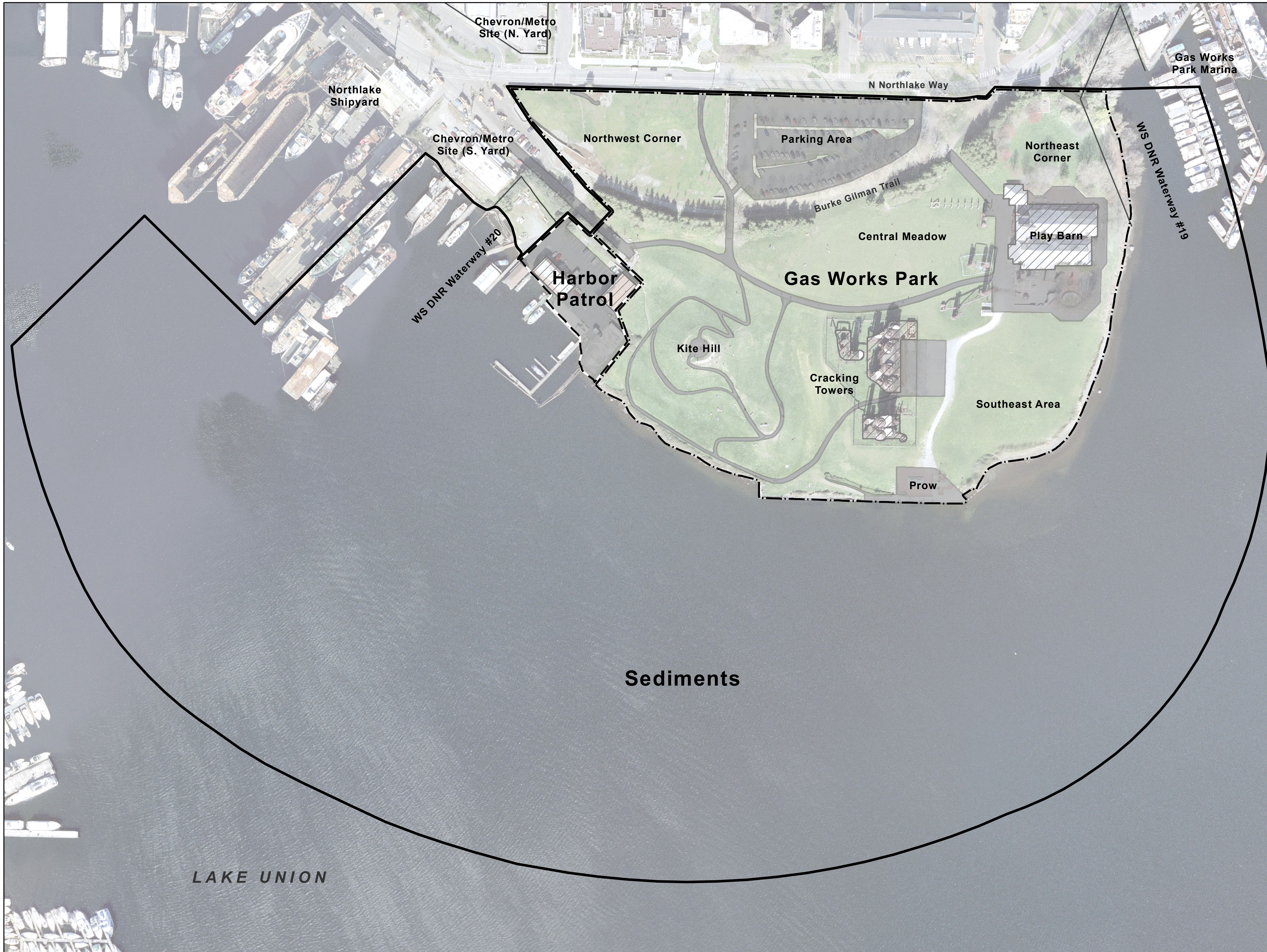

Legend

- Gas Works Park Site Boundary
- Gas Works Park
- Harbor Patrol Property
- Building or Structure
- Impervious Surface

Notes:
1. Gas Works Park Site Boundary is equivalent to the Gas Works Park Sediment Site Boundary documented in the 2013 Amendment of Agreed Order DE2008.
2. The locations of all features shown are approximate.
3. This drawing is for information purposes. It is intended to assist in showing features discussed in an attached document. GeoEngineers, Inc. cannot guarantee the accuracy and content of electronic files. The master file is stored by GeoEngineers, Inc. and will serve as the official record of this communication.

Site Layout

Gas Works Park Site
Seattle, Washington
Feasibility Study Bridging Document

GeoEngineers

3

Path: P:\0\0186846\GIS\MXD\Phase01\T800\018684601_FSBD_SiteLayout.mxd Map Revised: 17 May 2013 tward

Legend

- Historical Railroad Features
- Current Shoreline
- Former MGP Structure
- Former Tar Refinery Footprint

Notes:
1. Reference: Historical structures provided by Floyd|Snider, 2012.
2. Site structures delineated as shown in the General Plan, Lake Station, Seattle Gas Company, April 1949, revised in June 1953, the 1950 Oil Lines, Seattle Gas Co. Map, and a 1956 aerial photograph.
3. Historical railroad features shown as delineated in General Plan, Lake Station, Seattle Gas Co., June 1938.
4. Structure labels shown in *( ) indicate previous MGP operational uses (pre-1946).
5. The locations of all features shown are approximate.
6. This drawing is for information purposes. It is intended to assist in showing features discussed in an attached document. GeoEngineers, Inc. cannot guarantee the accuracy and content of electronic files. The master file is stored by GeoEngineers, Inc. and will serve as the official record of this communication.

Historical Structures

Gas Works Park Site
Seattle, Washington
Feasibility Study Bridging Document

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4

Path: \\sea\projects\0\0186846\GIS\MXD\Phase01\T800\018684601_WorkPlan_HistoricalStructures.mxd Map Revised: 15 May 2013 amanza

Legend

- Shallow Exploration
- Exploration Partially Penetrates Fill
- Exploration Fully Penetrates Fill
- Exploration Fully Penetrates Fill and Terminates in Till (Qpgt)

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

Previous Upland Sampling Locations

Gas Works Park Site
Seattle, Washington
Feasibility Study Bridging Document

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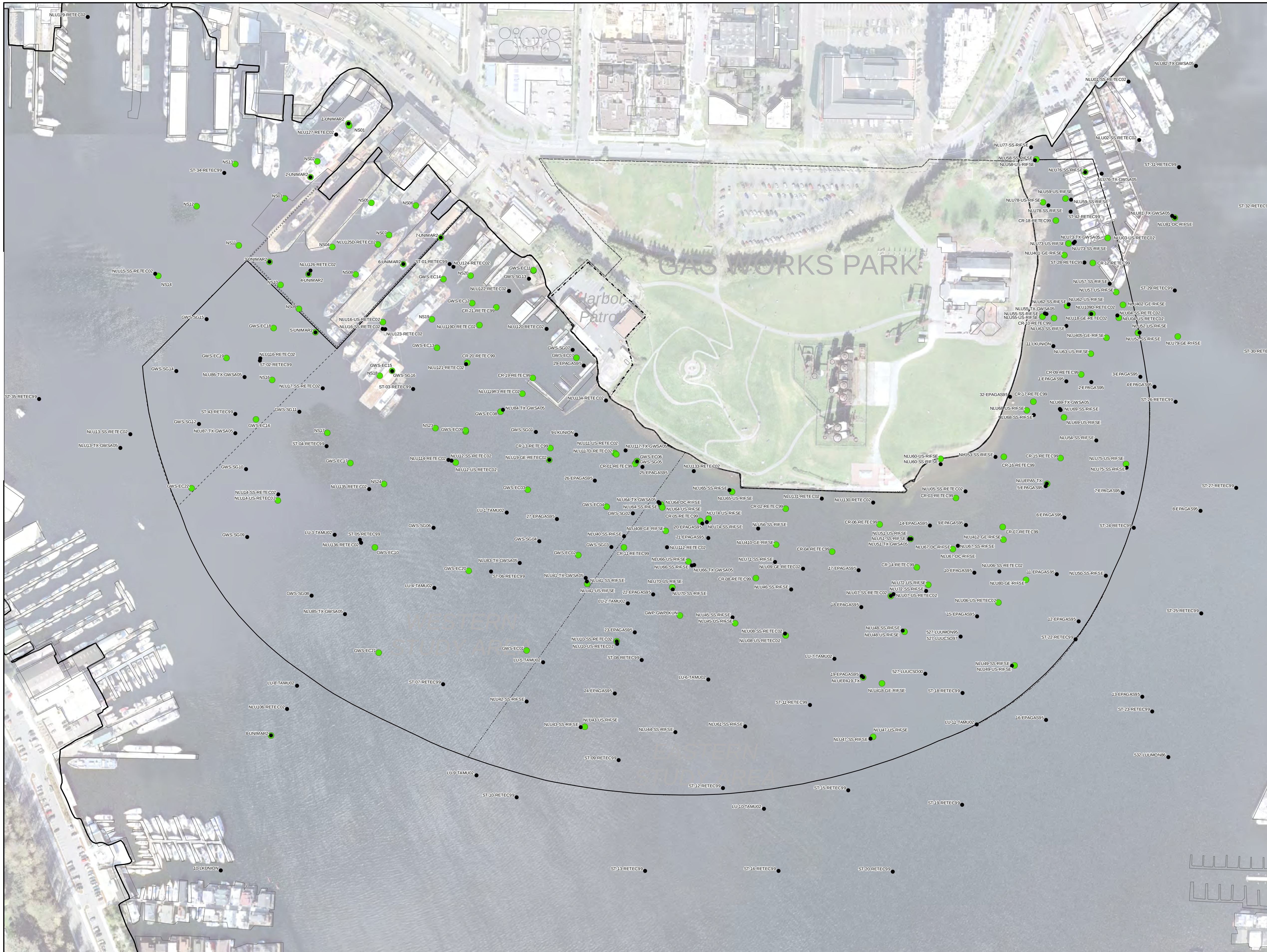
5

Path: \\sea\projects\0\0186846\GIS\MXD\Phase01\T800\018684601_WorkPlan_PreviousInvestigations.mxd Map Revised: 30 April 2013 amanza



Legend

- Surface Sample
- Subsurface Sample

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

N W E S

0 250 500
Feet

Sediment Sample Locations

Gas Works Park Site
Seattle, Washington
Feasibility Study Bridging Document

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6

Path: \\sea\Projects\0\0186846\GIS\MXD\Phase01\T800\018684601_SedimentSamples.mxd Map Revised: 01 May 2013 amanza

Legend

- 1984: Approximate area of tar removal.
- 1997: Approximate location of tar removal test pit.
- 2006-2011: Approximate location of tar removal.
- 2001: Vegetative soil cap and geotextile layer was placed over the unpaved areas.
- 2005: Soil cap consisting of grass turf, 1 foot of topsoil, and a geotextile layer.
- 2012: Area covered with a 1-foot thick vegetated soil cap consisting of grass turf, 1 foot of topsoil, and a geotextile layer.
- Air Sparging Area

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

N W E S

0 100 200
Feet

Previous Remedial Action Areas

Gas Works Park Site
Seattle, Washington
Feasibility Study Bridging Document

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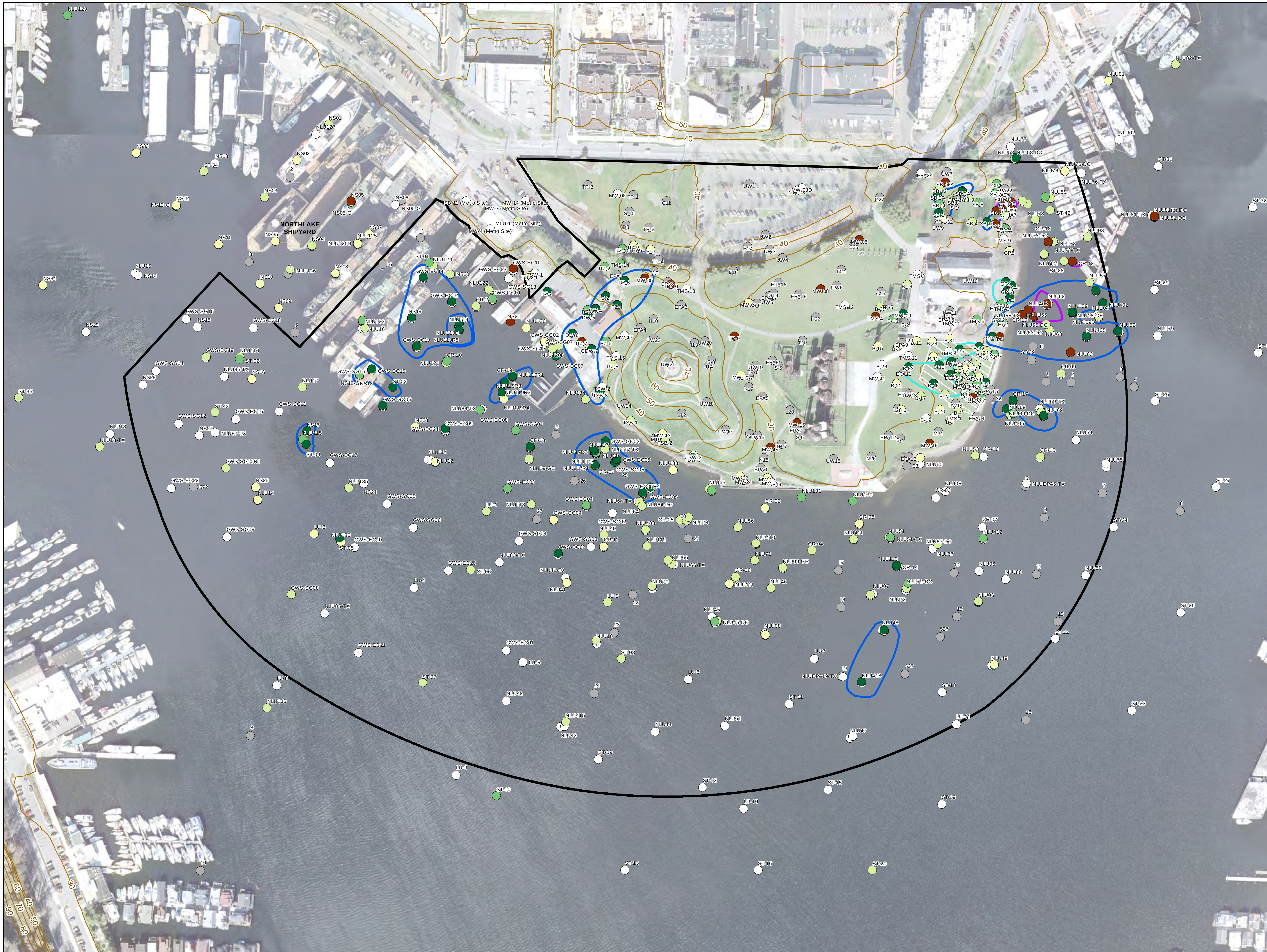
7

Path: \\SEA\projects\0\0186846\GIS\MXD\Phase01\T8000\018684601_WorkPlan_RemedialActionAreas.mxd Map Revised: 10 October 2013 tward



Legend

- Site Boundary
- Air Sparging System

NAPL Occurrence

- Tar
- Heavy sheen with NAPL
- Heavy sheen and/or trace NAPL
- Slight to moderate sheen
- Staining and/or odor
- No impacts
- Location not used for NAPL mapping

Estimated Lateral Extent of Multiple-Location NAPL or Tar

- LNAPL
- DNAPL
- Tar

Mapping Rationale:

1. Where both Tar and Heavy Sheen with NAPL were observed in an exploration, the exploration is shown as Tar-impacted.
2. Mapping intends to show areas where Tar or NAPL have been interpreted to exist at multiple adjacent sample locations.

Notes:

1. Modified from figure provided by Floyd|Snider, 2012.
2. NAPL data presented in this figure was sourced from a table jointly produced by Floyd|Snider and GeoEngineers.
3. Observations of contiguous near-surface tar in the offshore delineated by diver probe.
4. The locations of all features shown are approximate.
5. This drawing is for information purposes. It is intended to assist in showing features discussed in an attached document. GeoEngineers, Inc. cannot guarantee the accuracy and content of electronic files. The master file is stored by GeoEngineers, Inc. and will serve as the official record of this communication.

N W E S

0 250 500
Feet

Estimated Extent of NAPL and Tar

Gas Works Park Site
Seattle, Washington
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8

Path: \\seal\projects\0\0186846\GIS\MXD\Phase01\T800\0186846601_ConceptualExtent_NAPL_Tar.mxd   Map Revised: 08 May 2013   amanza

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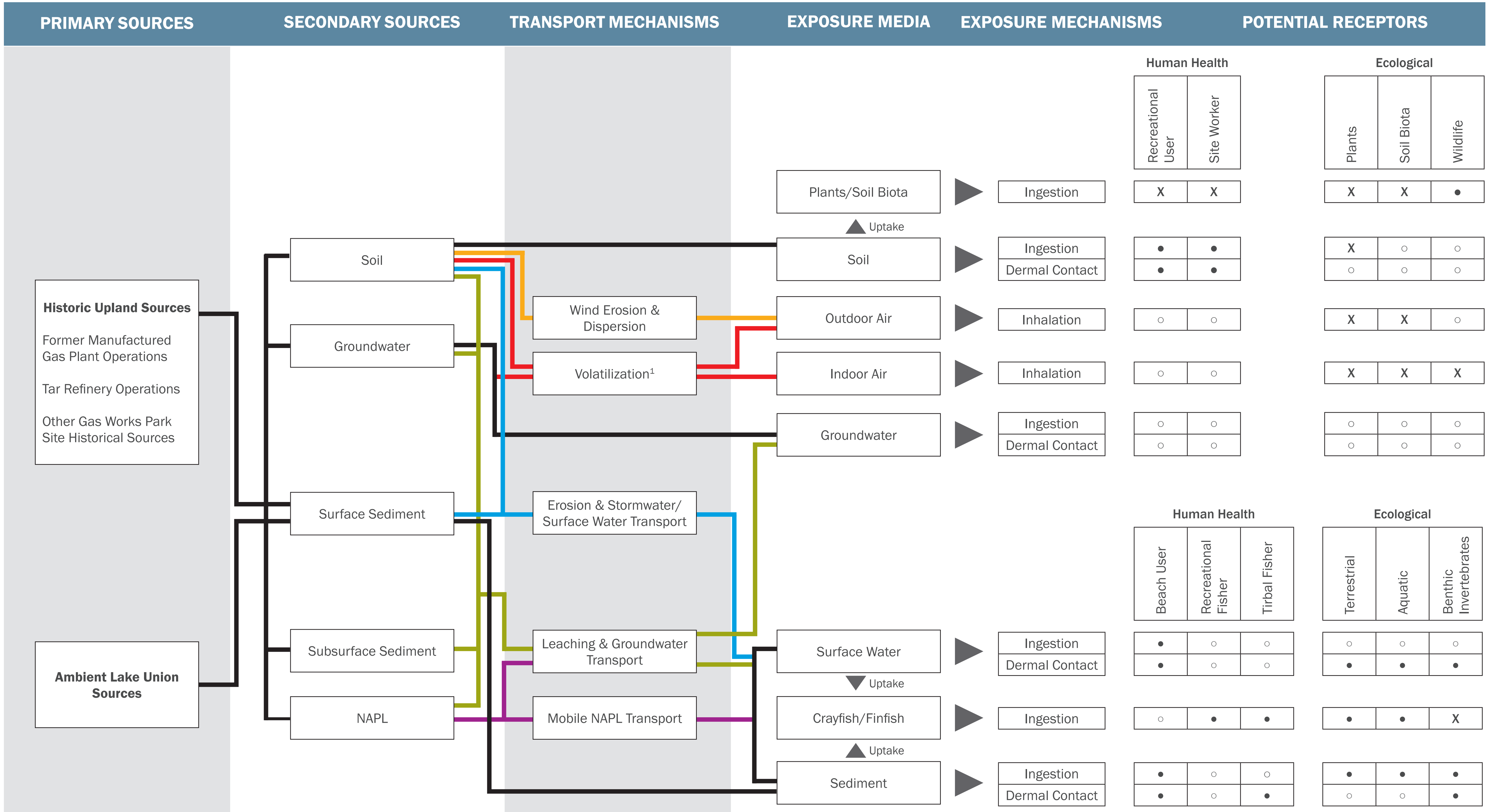
Earth Science + Technology



LEGEND
- Volatilization
- Wind Erosion & Dispersion
- Leaching & Groundwater Transport
- Mobile NAPL Transport
- Erosion & Storm/Surface Water Transport

NOTES
1. Upland NAPL also potential source for volatilization to indoor and outdoor air

KEY
- ● Complete or Potentially Complete
- ○ Incomplete or Minor Pathway
- X Not Applicable

Figure 9
PRELIMINARY CONCEPTUAL SITE EXPOSURE MODEL
Gas Works Park Site | Seattle, WA

Legend

- Building or Structure
- Impervious Surface
- AS/SVE Impervious Cover
- Area of Magnetic and Electromagnetic Survey
- Former MGP Structure
- Former Tar Refinery Footprint

Notes:
1. Reference: Historical structures provided by Floyd|Snider, 2012.
2. Site structures delineated as shown in the General Plan, Lake Station, Seattle Gas Company, April 1949, revised in June 1953, the 1950 Oil Lines, Seattle Gas Co. Map, and a 1956 aerial photograph.
3. Historical railroad features shown as delineated in General Plan, Lake Station, Seattle Gas Co., June 1938.
3. The locations of all features shown are approximate.
4. This drawing is for information purposes. It is intended to assist in showing features discussed in an attached document. GeoEngineers, Inc. cannot guarantee the accuracy and content of electronic files. The master file is stored by GeoEngineers, Inc. and will serve as the official record of this communication.

Supplemental Investigation Geophysical Survey Area

Gas Works Park Site
Seattle, Washington
Feasibility Study Bridging Document

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10

Path: \\sea\Projects\0\0186846\GIS\MXD\Phase01\T800\018684601_WorkPlan_GeophysicalSurvey.mxd   Map Revised: 01 May 2013   amanza

Legend

AS/SVE Impervious Cover

2013 Exploration Locations

Soil Boring

Geotechnical Boring

TarGOST Exploration

Previous Deep Explorations

Deep Exploration: Exploration Fully Penetrates Fill

Deep Exploration: Exploration Fully Penetrates Fill and Terminates in Till (Qpgt)

Notes:

1. MLS = multi-level sampler.
2. * Soil boring will be completed following approval from Washington State Department of Archaeology and Historical Preservation.
3. The locations of all features shown are approximate.
4. This drawing is for information purposes. It is intended to assist in showing features discussed in an attached document. GeoEngineers, Inc. cannot guarantee the accuracy and content of electronic files. The master file is stored by GeoEngineers, Inc. and will serve as the official record of this communication.

Supplemental Investigation Soil Borings and TarGOST Exploration Locations

Gas Works Park Site
Seattle, Washington
Feasibility Study Bridging Document

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11

Path: \\sea\projects\0\0186846\GIS\MXD\Phase01\T800\0186846 01_WorkPlan_ProposedSoilBoring_TarGOST.mxd   Map Revised: 16 May 2013   amanza

Legend

AS/SVE Impervious Cover

Monitoring Well Locations

Existing Monitoring Well

2013 Monitoring Well

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

N W E S

0 100 200
Feet

Supplemental Investigation Monitoring Wells

Gas Works Park Site
Seattle, Washington
Feasibility Study Bridging Document

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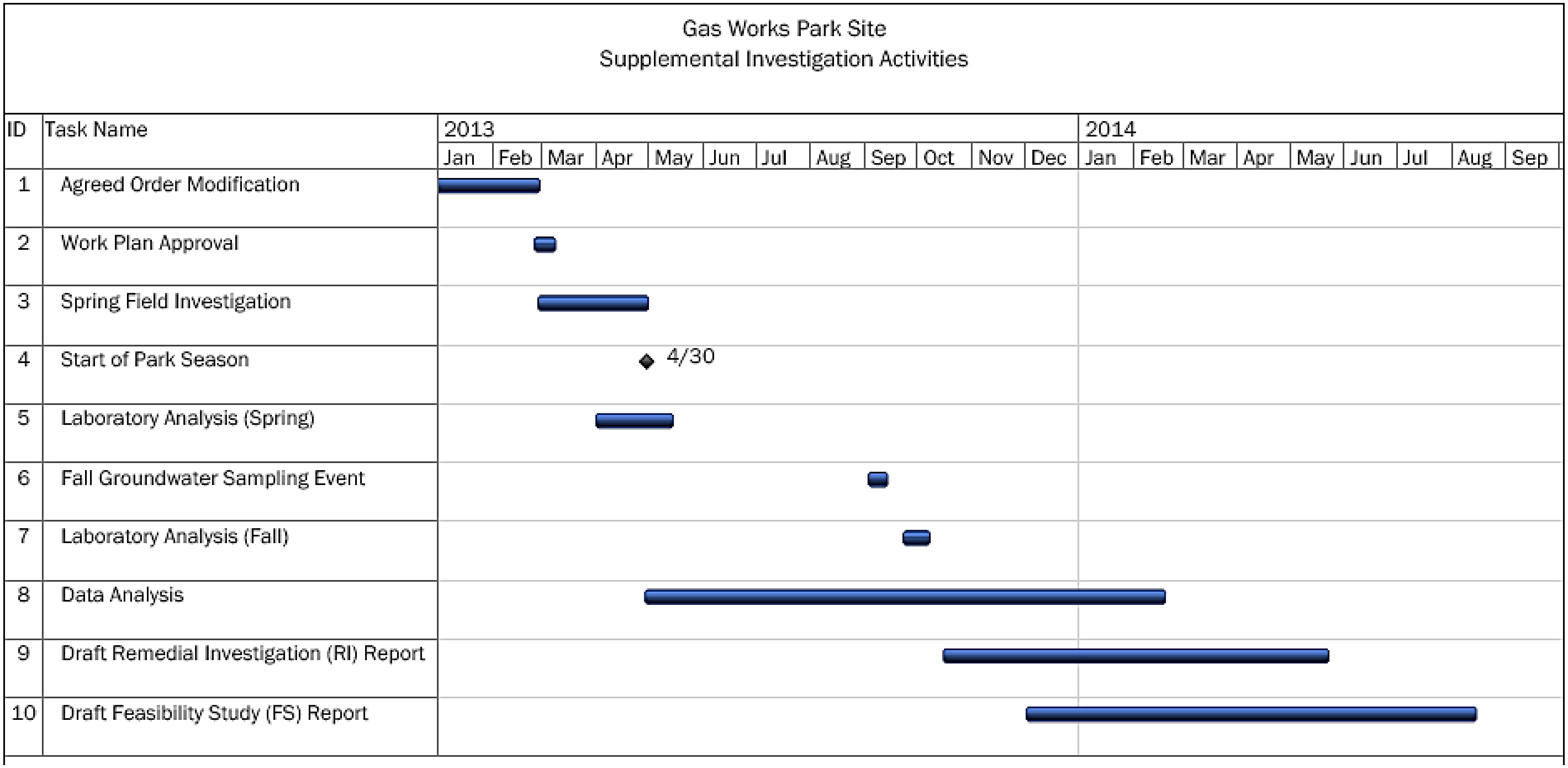
12

Path: \\seal\projects\0\0186846\GIS\MXD\Phase01\T800\018684601_WorkPlan_ProposedMonitoringWells.mxd Map Revised: 15 May 2013 amanza



Notes:

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

Schedule

Gas Works Park Site
Seattle, Washington
Feasibility Study Bridging Document

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Figure 13

APPENDICES

APPENDIX A
Geologic Cross Sections

Legend

- Current Monitoring Well
- Impervious Surface
- Buildings and Structures
- DNR Property (Waterway 19)
- Surface Runoff Extent
- Cross Section Locations (See Figures 4-8 for cross sections)

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

Site Layout and Cross Section Areas

Gas Works Park Site
Seattle, Washington
Feasibility Study Bridging Document

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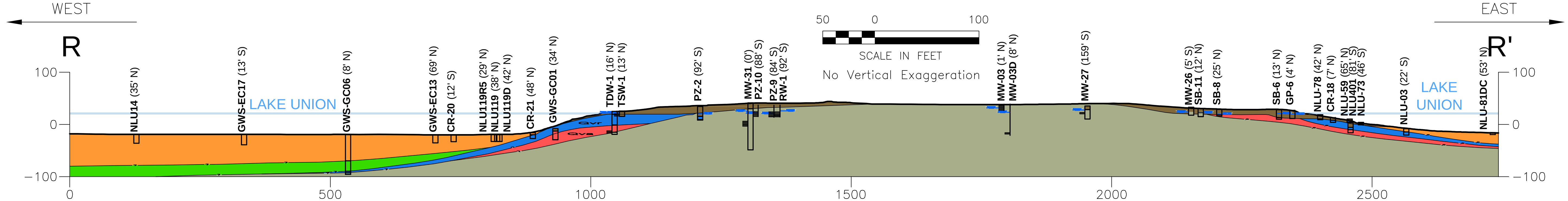
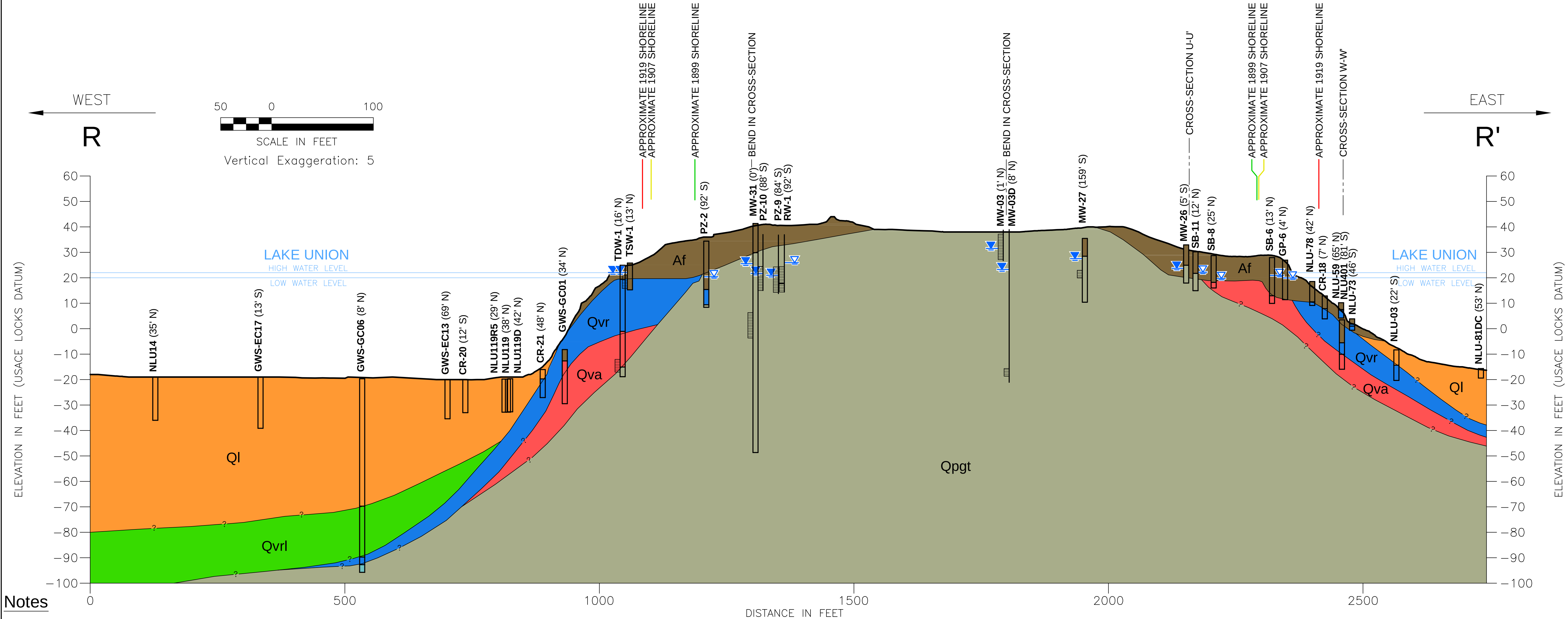
A-1

Path: \\sea\Projects\0\0186846\GIS\MXD\Phase01\0186846 01_WorkPlan_SiteLayout_CrossSections.mxd Map Revised: 03 January 2013 amanza





Notes

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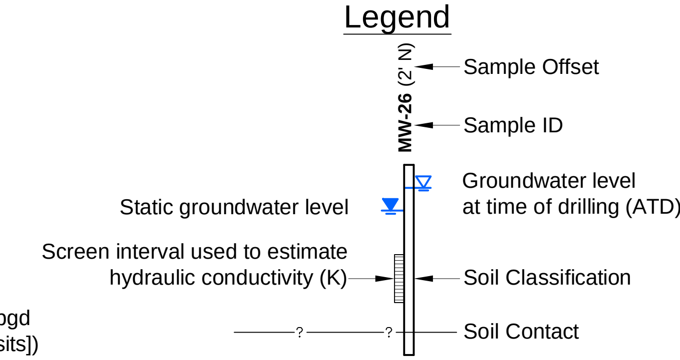
3. MW-03 and MW-03D were not used to interpret lithology.

Source: GWSA Tech Team 2011a (Revised Geologic CSM)

Geologic Units

- Af - Fill
- Ql - Recent Lacustrine Deposits
- Qvrl - Vashon Recessional Glaciolacustrine Deposits
- Qvr - Vashon Recessional Outwash (includes Qb)
- Qva - Vashon Advance Outwash
- Qpgt - Pre-Fraser Till (includes Qpgtm [Pre-Fraser Meltout Till], Qpgd [Pre-Fraser Diamict], and Qpgl [Pre-Fraser Glaciolacustrine Deposits])

Legend



K Value Summary:

Well	Screen Elev (ft.)	K(cm/sec)
TDW-1	-12.2 to -17.2	$4x10^{-3}$
TSW-1	20.6 to 15.6	$2x10^{-2}$
MW-31	6.3 to -3.7	$1x10^{-5}$
PZ-10	22.3 to 12.3	$2x10^{-3}$
PZ-9	23.1 to 13.1	$2x10^{-3}$
RW-1	23.4 to 13.4	$1x10^{-3}$
MW-03	39.1 to 30.1	$2x10^{-4}$
MW-03D	-13.9 to -16.9	$4x10^{-5}$
MW-27	22.9 to 19.9	$3x10^{-4}$
MW-26	23.9 to 20.4	$1x10^{-4}$

Geologic Cross-Section R-R'

Gas Works Park Site
Seattle, Washington
Feasibility Study Bridging Document

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Figure A-2

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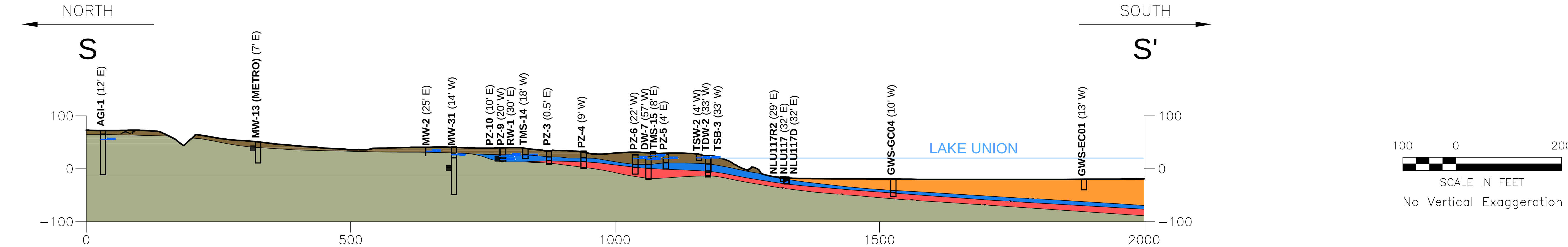

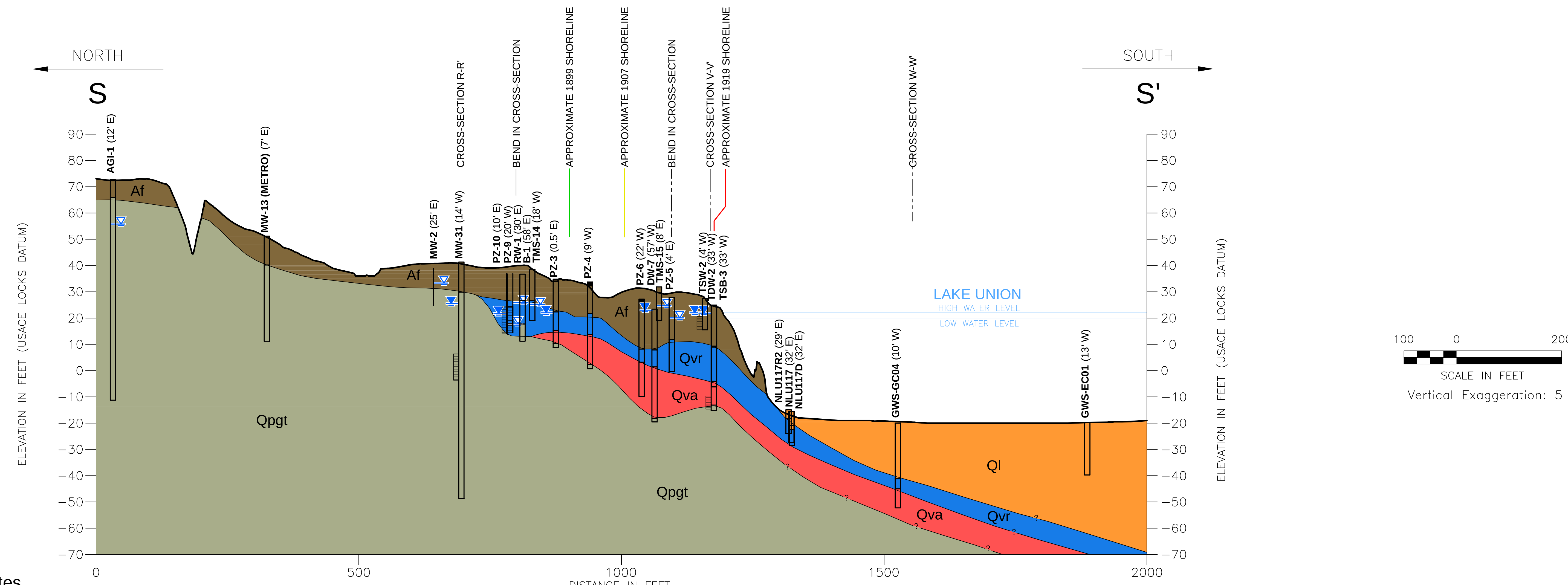

Notes

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2. This drawing is for information purposes. It is intended to assist in showing features discussed in an attached document. GeoEngineers, Inc. can not guarantee the accuracy and content of electronic files. The master file is stored by GeoEngineers, Inc. and will serve as the official record of this communication.
3. MW-02 was not used to interpret lithology.

Source: GWSA Tech Team 2011a (Revised Geologic CSM)

Geologic Units

- Asphalt and Sub-base
- Af - Fill
- Ql - Recent Lacustrine Deposits
- Qvr - Vashon Recessional Outwash (includes Qb)
- Qva - Vashon Advance Outwash
- Qpgt - Pre-Fraser Till (includes Qpgtm [Pre-Fraser Meltout Till], Qpgd [Pre-Fraser Diamict], and Qpgl [Pre-Fraser Glaciolacustrine Deposits])

Legend

- MW-26 (2' N)
- Sample Offset
- Sample ID
- Static groundwater level
- Groundwater level at time of drilling (ATD)
- Screen interval used to estimate hydraulic conductivity (K)
- Soil Classification
- Soil Contact

K Value Summary:

Well	Screen Elev (ft.)	K(cm/sec)
MW-31	6.3 to -3.7	$1x10^{-5}$
PZ-9	23.1 to 13.1	$2x10^{-3}$
PZ-10	22.3 to 12.3	$2x10^{-3}$
RW-1	23.4 to 13.4	$1x10^{-3}$
TSW-2	19.1 to 14.1	$3x10^{-3}$
TDW-2	-10.9 to -15.9	$2x10^{-2}$

Geologic Cross-Section S-S'

Gas Works Park Site
Seattle, Washington
Feasibility Study Bridging Document

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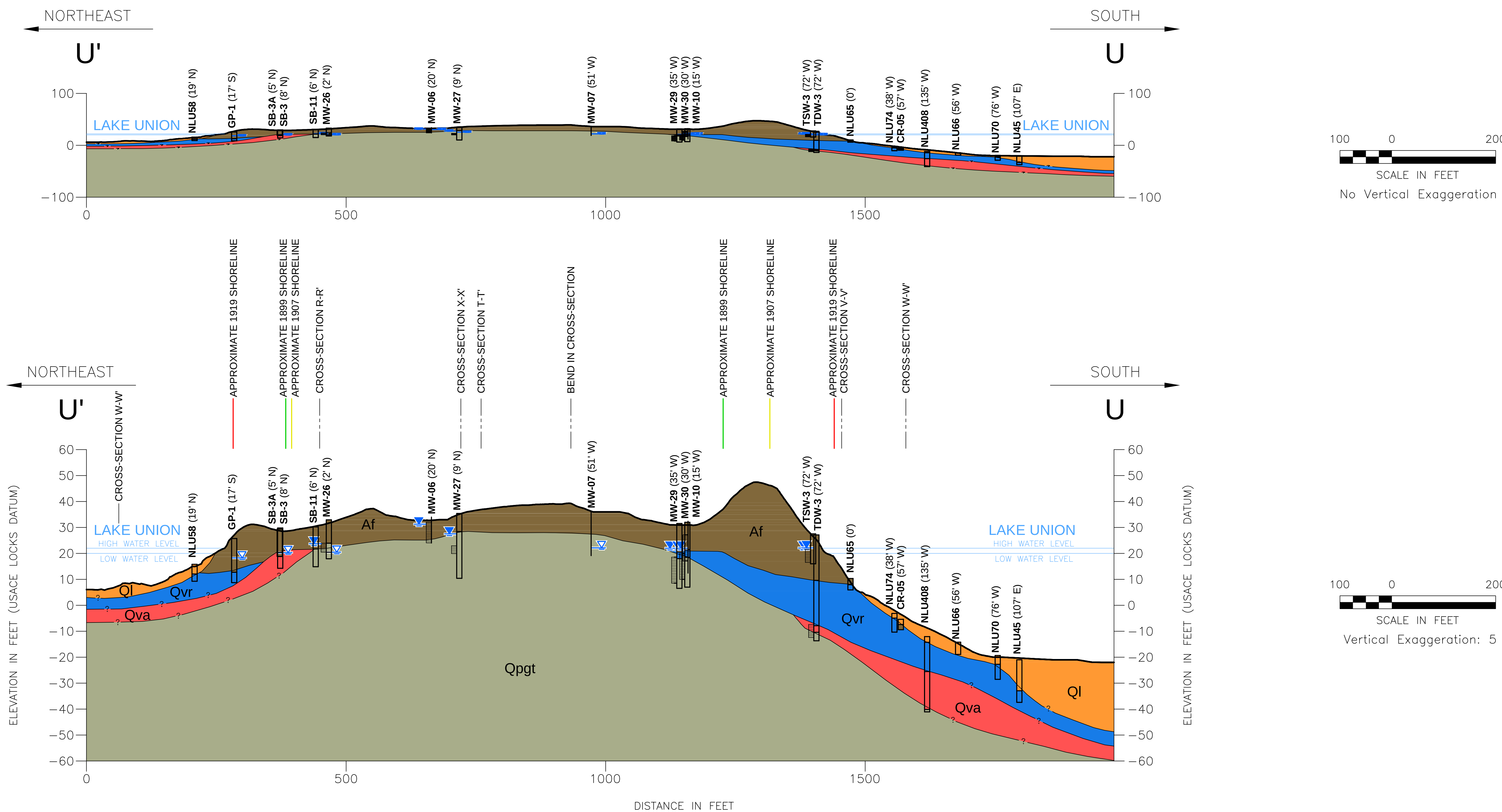
Figure A-3



Notes

1. The locations of all features shown are approximate.
2. This drawing is for information purposes. It is intended to assist in showing features discussed in an attached document. GeoEngineers, Inc. can not guarantee the accuracy and content of electronic files. The master file is stored by GeoEngineers, Inc. and will serve as the official record of this communication.
3. MW-10, MW-06, and MW-07 were not used to interpret lithology.

Source: GWSA Tech Team 2011a (Revised Geologic CSM)

Geologic Units

- Af - Fill
- Ql - Recent Lacustrine Deposits
- Qvr - Vashon Recessional Outwash (includes Qb)
- Qva - Vashon Advance Outwash
- Qpgt - Pre-Fraser Till (includes Qpgtm [Pre-Fraser Meltout Till], Qpgd [Pre-Fraser Diamict], and Qpgl [Pre-Fraser Glaciolacustrine Deposits])

Legend

- MW-26 (2' N)
- Sample Offset
- Sample ID
- Static groundwater level
- Groundwater level at time of drilling (ATD)
- Screen interval used to estimate hydraulic conductivity (K)
- Soil Classification
- Soil Contact

K Value Summary:

Well	Screen Elev (ft.)	K(cm/sec)
MW-26	23.9 to 20.4	$1x10^{-4}$
MW-06	32.1 to 24.1	$2x10^{-4}$
MW-27	22.9 to 19.9	$3x10^{-4}$
MW-29	18.5 to 8.5	$6x10^{-4}$
MW-30	19.9 to 9.9	$7x10^{-4}$
MW-10	27.7 to 17.7	$4x10^{-4}$
TSW-3	21.6 to 16.6	$3x10^{-3}$
TDW-3	-7.8 to -12.8	$2x10^{-2}$

Geologic Cross-Section U-U'

Gas Works Park Site
Seattle, Washington
Feasibility Study Bridging Document

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Figure A-4

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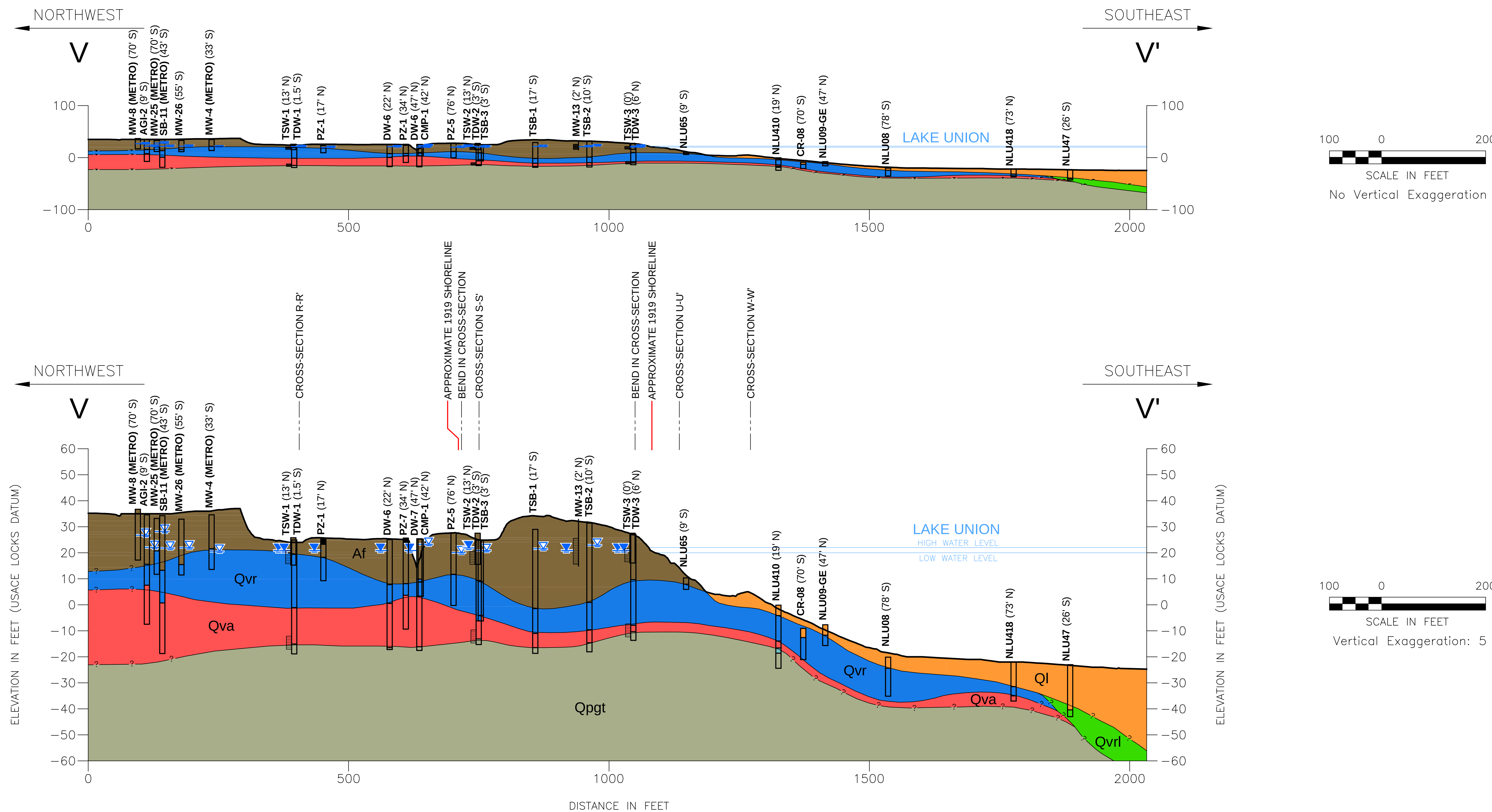


Notes

1. The locations of all features shown are approximate.
2. This drawing is for information purposes. It is intended to assist in showing features discussed in an attached document. GeoEngineers, Inc. can not guarantee the accuracy and content of electronic files. The master file is stored by GeoEngineers, Inc. and will serve as the official record of this communication.
3. MW-13 was not used to interpret lithology.

Source: GWSA Tech Team 2011a (Revised Geologic CSM)

Legend

Geologic Units

- Af - Fill
- Ql - Recent Lacustrine Deposits
- Qvrl - Vashon Recessional Glaciolacustrine Deposits
- Qvr - Vashon Recessional Outwash (includes Qb)
- Qva - Vashon Advance Outwash
- Qpgt - Pre-Fraser Till (includes Qpgtm [Pre-Fraser Meltout Till], Qpgd [Pre-Fraser Diamict], and Qpgl [Pre-Fraser Glaciolacustrine Deposits])

MW-26 (55' S)

- Sample Offset
- Sample ID
- Static groundwater level
- Groundwater level at time of drilling (ATD)
- Screen interval used to estimate hydraulic conductivity (K)
- Soil Classification
- Soil Contact

K Value Summary:

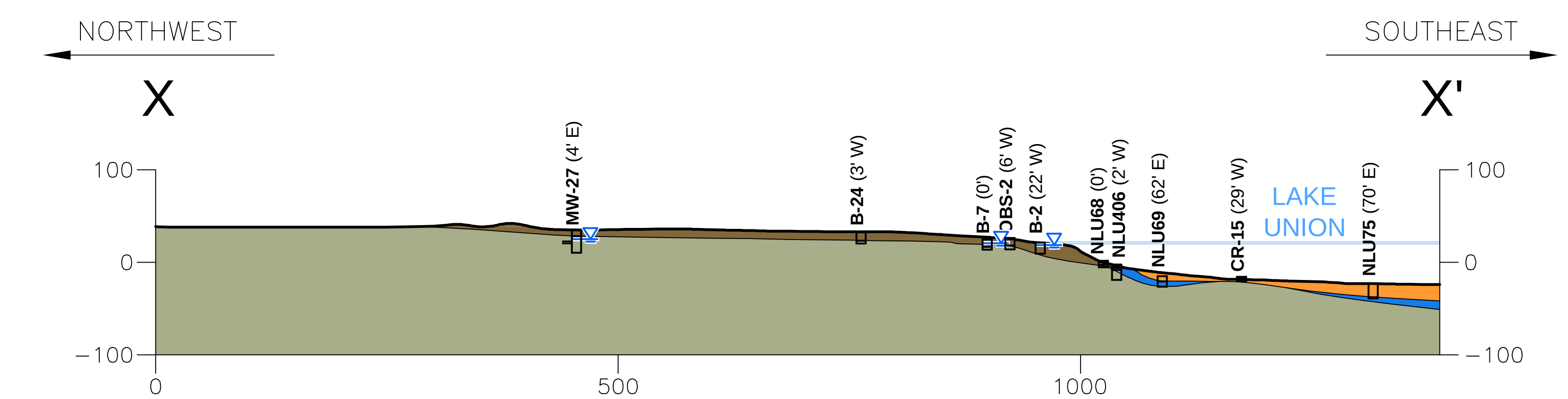
Well	Screen Elev (ft.)	K(cm/sec)
TSW-1	20.6 to 15.6	$2x10^{-2}$
TDW-1	-12.2 to -17.2	$4x10^{-3}$
TSW-2	19.1 to 14.1	$3x10^{-3}$
TDW-2	-10.9 to -15.9	$2x10^{-2}$
TSW-3	21.6 to 16.6	$3x10^{-3}$
TDW-3	-7.8 to -12.8	$2x10^{-5}$
MW-13	21.8 to 11.8	$2x10^{-2}$

Geologic Cross-Section V-V'

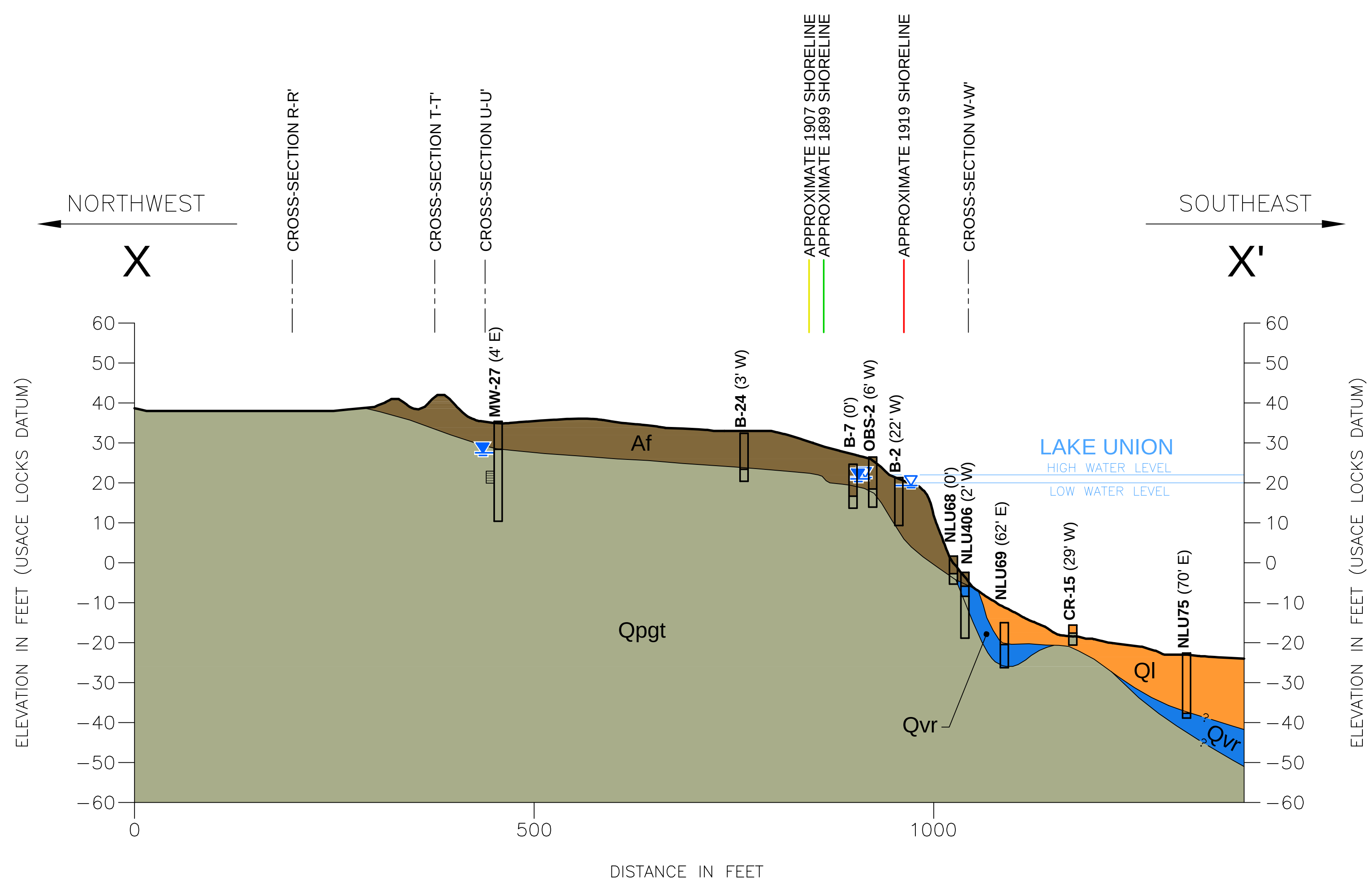
Gas Works Park Site
Seattle, Washington
Feasibility Study Bridging Document

GEOENGINEERS

Figure A-5



100 0 200
SCALE IN FEET
No Vertical Exaggeration



100 0 200
SCALE IN FEET
Vertical Exaggeration: 5

Notes

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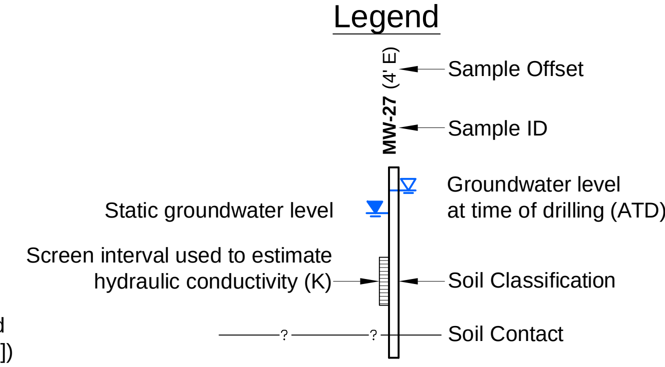
Source: GWSA Tech Team 2011a (Revised Geologic CSM)

Geologic Units

- Af - Fill
- Ql - Recent Lacustrine Deposits
- Qvr - Vashon Recessional Outwash (includes Qb)
- Qpgt - Pre-Fraser Till (includes Qpgtm [Pre-Fraser Meltout Till], Qpgd [Pre-Fraser Diamict], and Qpgl [Pre-Fraser Glaciolacustrine Deposits])

Legend



K Value Summary:

Well	Screen Elev (ft.)	K(cm/sec)
MW-27	22.9 to 19.9	$3x10^{-4}$

Geologic Cross-Section X-X'

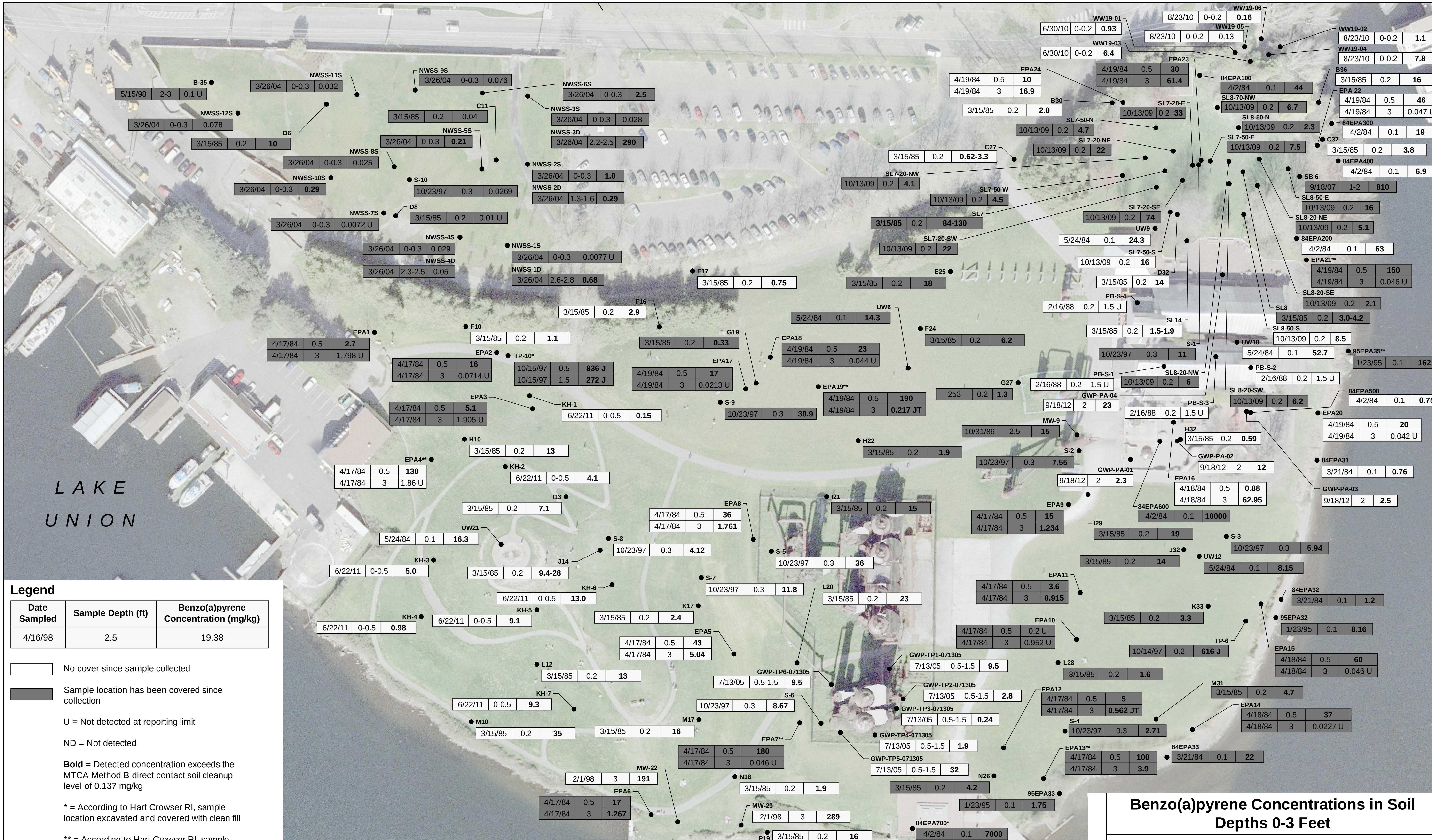
Gas Works Park Site
Seattle, Washington
Feasibility Study Bridging Document

GeoEngineers

Figure A-6

P:\0\0186864\01\CAD\Task 800 Feasibility Study\0186864-01 Geologic X-Sections.dwg\TAB:X Modified by tmichaud on Apr 30, 2013 - 11:12

Appendix B
Contaminant Concentrations in Soil Figures



Legend

Date Sampled	Sample Depth (ft)	Benzo(a)pyrene Concentration (mg/kg)
4/16/98	2.5	19.38

No cover since sample collected

Sample location has been covered since collection

U = Not detected at reporting limit

ND = Not detected

Bold = Detected concentration exceeds the MTCA Method B direct contact soil cleanup level of 0.137 mg/kg

* = According to Hart Crowser RI, sample location excavated and covered with clean fill

** = According to Hart Crowser RI, sample location reportedly covered with clean soil by City of Seattle in 1985

Mapping Rationale:

1. If multiple samples were taken from one location the concentrations are presented as a range from minimum to maximum values for that location.
2. Shaded samples collected prior to 2001 represent soil conditions at the depth indicated before capping and regrading of the site.

N S E W

100 0 100

FEET

Notes

1. Reference: Map prepared from Uplands RI figure provided by Hart Crowser, 2012.
2. Source: Base map prepared from aerial photo by City of Seattle, 2005.
3. The locations of all features shown are approximate.
4. This drawing is for information purposes. It is intended to assist in showing features discussed in an attached document. GeoEngineers, Inc. can not guarantee the accuracy and content of electronic files. The master file is stored by GeoEngineers, Inc. and will serve as the official record of this communication.

Benzo(a)pyrene Concentrations in Soil Depths 0-3 Feet

Gas Works Park Site
Seattle, Washington
Feasibility Study Bridging Document

GEOENGINEERS

Figure B-1

P:\0\0186864\01\CAD\Task 800 Feasibility Study\0186864-01 Fig B-1.dwg\TAB:11x17 - H modified by tmichaud on Apr 30, 2013 - 11:16

Legend

Date Sampled	Sample Depth (ft)	Naphthalene Concentration (mg/kg)
4/16/98	8-9.5	1200

No cover since sample collected

Sample location has been covered since collection

U = Not detected at reporting limit

ND = Not detected

J = Estimated Value

Bold = Detected concentration exceeds the MTCA Method B direct contact soil cleanup level of 3200 mg/kg referenced in the 1999 Consent Decree

* = According to Hart Crowser RI, sample location excavated and covered with clean fill

** = According to Hart Crowser RI, sample location reportedly covered with clean soil by City of Seattle in 1985

Mapping Rationale:

1. If multiple samples were taken from one location the concentrations are presented as a range from minimum to maximum values for that location.
2. Shaded samples collected prior to 2001 represent soil conditions at the depth indicated before capping and regrading of the site.

N W E S

100 0 100
FEET

Notes

1. Reference: Map prepared from Uplands RI figure provided by Hart Crowser, 2012.
2. Source: Base map prepared from aerial photo by City of Seattle, 2005.
3. The locations of all features shown are approximate.
4. This drawing is for information purposes. It is intended to assist in showing features discussed in an attached document. GeoEngineers, Inc. can not guarantee the accuracy and content of electronic files. The master file is stored by GeoEngineers, Inc. and will serve as the official record of this communication.

Naphthalene Concentrations in Soil Depths 0-3 Feet

Gas Works Park Site
Seattle, Washington
Feasibility Study Bridging Document

GEOENGINEERS

Figure B-2

P:\0\0186864\01\CAD\Task 800 Feasibility Study\0186864-01 Fig B-2.dwg\TAB:11x17 - H modified by tmichaud on Apr 30, 2013 - 11:22

Legend

Date Sampled	Sample Depth (ft)	Benzene Concentration (mg/kg)
4/16/98	8-9.5	1700

No cover since sample collected

Sample location has been covered since collection

U = Not detected at reporting limit

JT = Analyte present but below minimum quantifiable limit

NS = Not specified

Bold = Detected concentration exceeds the current MTCA Method B direct contact soil cleanup level of 18 mg/kg

* = According to Hart Crowser RI, sample location excavated and covered with clean fill

** = According to Hart Crowser RI, sample location reportedly covered with clean soil by City of Seattle in 1985

Mapping Rationale:

1. Based on the 1999 Consent Decree, benzene was not listed as a constituent of concern for soil (just groundwater). For comparison purposes, benzene concentrations are shown relative to the current MTCA Method B direct contact cleanup level of 18 mg/kg.
2. Shaded samples collected prior to 2001 represent soil conditions at the depth indicated before capping and regrading of the site.

N W E S

100 0 100

FEET

Notes

1. Reference: Map prepared from Uplands RI figure provided by Hart Crowser, 2012.
2. Source: Base map prepared from aerial photo by City of Seattle, 2005.
3. The locations of all features shown are approximate.
4. This drawing is for information purposes. It is intended to assist in showing features discussed in an attached document. GeoEngineers, Inc. can not guarantee the accuracy and content of electronic files. The master file is stored by GeoEngineers, Inc. and will serve as the official record of this communication.

Benzene Concentrations in Soil Depths 0-3 Feet

Gas Works Park Site
Seattle, Washington
Feasibility Study Bridging Document

GEOENGINEERS

Figure B-3

P:\0\0186864\01\CAD\Task 800 Feasibility Study\0186864-01 Fig B-3.dwg\TAB:11x17 - H modified by tmichaud on Apr 30, 2013 - 11:27

Legend

Date Sampled	Sample Depth (ft)	Arsenic Concentration (mg/kg)
4/16/98	3	7

No cover since sample collected

Sample location has been covered since collection

U = Not detected at reporting limit

Bold = Detected concentration exceeds the MTCA soil cleanup level of 20 mg/kg

** = According to Hart Crowser RI, sample location reportedly covered with clean soil by City of Seattle in 1985

Mapping Rationale:
1. Shaded samples collected prior to 2001 represent soil conditions at the depth indicated before capping and regrading of the site.

N W E S

100 0 100
FEET

Notes
1. Reference: Map prepared from Uplands RI figure provided by Hart Crowser, 2012.
2. Source: Base map prepared from aerial photo by City of Seattle, 2005.
3. The locations of all features shown are approximate.
4. This drawing is for information purposes. It is intended to assist in showing features discussed in an attached document. GeoEngineers, Inc. can not guarantee the accuracy and content of electronic files. The master file is stored by GeoEngineers, Inc. and will serve as the official record of this communication.

Arsenic Concentrations in Soil Depths 0-3 Feet

Gas Works Park Site
Seattle, Washington
Feasibility Study Bridging Document

GeoEngineers

Figure B-4

P:\0\0186864\01\CAD\Task 800 Feasibility Study\0186864-01 Fig B-4.dwg\TAB:11x17 - H modified by tmichaud on Apr 30, 2013 - 11:31

Legend

Date Sampled	Sample Depth (ft)	Benzo(a)pyrene Concentration (mg/kg)
9/19/07	10-11.5	1.5

U = Not detected at reporting limit

ND = Not detected

J = Estimated value

Bold = Detected concentration exceeds the MTCA Method B direct contact soil cleanup level of 0.137 mg/kg

Mapping Rationale:

1. Samples collected prior to 2001 represent soil conditions at the depth indicated before capping and regrading of the site.

N W E S

100 0 100

FEET

Notes

1. Reference: Map prepared from Uplands RI figure provided by Hart Crowser, 2012.
2. Source: Base map prepared from aerial photo by City of Seattle, 2005.
3. The locations of all features shown are approximate.
4. This drawing is for information purposes. It is intended to assist in showing features discussed in an attached document. GeoEngineers, Inc. can not guarantee the accuracy and content of electronic files. The master file is stored by GeoEngineers, Inc. and will serve as the official record of this communication.

Benzo(a)pyrene Concentrations in Soil Depths 3+ Feet

Gas Works Park Site
Seattle, Washington
Feasibility Study Bridging Document

GEOENGINEERS

Figure B-5

P:\0\0186864\01\CAD\Task 800 Feasibility Study\0186864-01 Fig B-5.dwg\TAB:11x17 - H modified by tmichaud on Apr 30, 2013 - 11:42

Legend

Date Sampled	Sample Depth (ft)	Naphthalene Concentration (mg/kg)
4/16/98	8-9.5	1200

U = Not detected at reporting limit

ND = Not Detected

T = Value is between the MDL and the RL

J = Estimated value

Bold = Detected concentration exceeds the MTCA Method B direct contact soil cleanup level of 3200 mg/kg referenced in the 1999 Consent Decree

Mapping Rationale:

1. Samples collected prior to 2001 represent soil conditions at the depth indicated before capping and regrading of the site.

Notes

1. Reference: Map prepared from Uplands RI figure provided by Hart Crowser, 2012.
2. Source: Base map prepared from aerial photo by City of Seattle, 2005.
3. The locations of all features shown are approximate.
4. This drawing is for information purposes. It is intended to assist in showing features discussed in an attached document. GeoEngineers, Inc. can not guarantee the accuracy and content of electronic files. The master file is stored by GeoEngineers, Inc. and will serve as the official record of this communication.

Naphthalene Concentrations in Soil Depths 3+ Feet

Gas Works Park Site
Seattle, Washington
Feasibility Study Bridging Document

GEOENGINEERS

Figure B-6

Legend

Date Sampled	Sample Depth (ft)	Benzene Concentration (mg/kg)
4/16/98	8-9.5	1700

Sample location remediated since collection

U = Not detected at reporting limit

JT = Analyte present but below minimum quantifiable limit

Bold = Detected concentration exceeds the current MTCA Method B direct contact soil cleanup level of 18 mg/kg

Mapping Rationale:

1. Based on the 1999 Consent Decree, benzene was not listed as a constituent of concern for soil (just groundwater). For comparison purposes, benzene concentrations are shown relative to the current MTCA Method B direct contact cleanup level of 18 mg/kg.
2. Samples collected prior to 2001 represent soil conditions at the depth indicated before capping and regrading of the site.

N W E S

100 0 100

FEET

Notes

1. Reference: Map prepared from Uplands RI figure provided by Hart Crowser, 2012.
2. Source: Base map prepared from aerial photo by City of Seattle, 2005.
3. The locations of all features shown are approximate.
4. This drawing is for information purposes. It is intended to assist in showing features discussed in an attached document. GeoEngineers, Inc. can not guarantee the accuracy and content of electronic files. The master file is stored by GeoEngineers, Inc. and will serve as the official record of this communication.

Benzene Concentrations in Soil Depths 3+ Feet

Gas Works Park Site
Seattle, Washington
Feasibility Study Bridging Document

GEOENGINEERS

Figure B-7

Legend

Date Sampled	Sample Depth (ft)	Arsenic Concentration (mg/kg)
4/16/98	3	7

Bold = Detected concentration exceeds the MTCA soil cleanup level of 20 mg/kg

U = Not detected at reporting limit

Mapping Rationale:
1. Samples collected prior to 2001 represent soil conditions at the depth indicated before capping and regrading of the site.

N W E S

100 0 100
FEET

Notes
1. Reference: Map prepared from Uplands RI figure provided by Hart Crowser, 2012.
2. Source: Base map prepared from aerial photo by City of Seattle, 2005.
3. The locations of all features shown are approximate.
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Arsenic Concentrations in Soil Depths 3+ Feet

Gas Works Park Site
Seattle, Washington
Feasibility Study Bridging Document

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Figure B-8

P:\0\0186864\01\CAD\Task 800 Feasibility Study\0186864-01 Fig B-8.dwg\TAB:11x17 - H modified by tmichaud on Apr 30, 2013 - 13:29

Appendix C
Contaminant Concentrations in Groundwater Figures

Source: Base map prepared from aerial photo provided by Floyd/Snider, 2010.

Notes

1. The locations of all features shown are approximate.
2. This drawing is for information purposes. It is intended to assist in showing features discussed in an attached document. GeoEngineers, Inc. can not guarantee the accuracy and content of electronic files. The master file is stored by GeoEngineers, Inc. and will serve as the official record of this communication.
3. Selected results are presented based on Uplands RI Figure 4-10/4-11 (HartCrowser, 2012) (not all results are depicted).

Reference: Map prepared from Uplands RI figure provided by Hart Crowser, 2012.

Exploration Location and Number

MW-22 / DW-5 — Monitoring Well

PZ-6 — Piezometer

MLS-1 — Multilevel Sampler

Date Sampled	Benzo(a)pyrene
10/21/97	4.97

U = Not detected at the reporting limit indicated

J = Estimated value

Bold = Detected concentration exceeds the MTCA Method B surface water cleanup level of 0.0296 µg/L

Concentrations in micrograms per liter (µg/L)

Benzo(a)pyrene Concentrations in Groundwater

Gas Works Park Site
Seattle, Washington
Feasibility Study Bridging Document

GEOENGINEERS

Figure C-1

Source: Base map prepared from aerial photo provided by Floyd/Snider, 2010.

Notes

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3. Selected results are presented based on Uplands RI Figure 4-10/4-11 (HartCrowser, 2012) (not all results are depicted).

Reference: Map prepared from Uplands RI figure provided by Hart Crowser, 2012.

Exploration Location and Number

- MW-22 / DW-5 — Monitoring Well
- PZ-6 — Piezometer
- MLS-1 — Multilevel Sampler

J = Estimated value

B = Analyte was also identified in the method blank

Bold = Detected concentration exceeds the MTCA Method B surface water cleanup level of 9,880 µg/L established under the Consent Decree

Concentrations in micrograms per liter (µg/L)

Date Sampled	Naphthalene (µg/L)
4/10/98	210

Naphthalene Concentrations in Groundwater

Gas Works Park Site
Seattle, Washington
Feasibility Study Bridging Document

GEOENGINEERS

Figure C-2

Source: Base map prepared from aerial photo provided by Floyd/Snider, 2010.

P:\0\0186864\01\CAD\Task 800 Feasibility Study\0186864-01 Fig C-3.dwg\TAB:11x17 - H modified by tmichaud on Apr 30, 2013 - 13:36

Notes

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

Reference: Map prepared from Uplands RI figure provided by Hart Crowser, 2012.

Exploration Location and Number

MW-22 / DW-5 Monitoring Well Screened within the Water Table Aquifer

PZ-6 Piezometer

MLS-1 Multilevel Sampler

Date Sampled	Benzene (µg/L)
2/11/10	220

Bold = Detected concentration exceeds the MTCA Method B surface water cleanup level of 43 µg/L established under the Consent Decree

Concentrations in micrograms per liter (µg/L)

Benzene Concentrations in Groundwater

Gas Works Park Site
Seattle, Washington
Feasibility Study Bridging Document

GEOENGINEERS

Figure C-3

Appendix D
TPAH Concentrations in Sediment Figures

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Remedial Investigation and Feasibility Study
Gas Works Sediment Western Study Area
City of Seattle

DRAFT

Figure 5.1
Surface Chemistry—TPAH

F:\projects\COS-GWSA\GIS\RIFS Report\Figure 5.1 (TPAH Contour).mxd

ECOLOGY REVIEW DRAFT May 25, 2007

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Remedial Investigation and Feasibility Study
Gas Works Sediment Western Study Area
City of Seattle

DRAFT

Figure 5.17
A Interval (0-3 ft)— TPAH

F:\projects\COS-GWSA\GIS\RIFS Report\Figure 5.17 (TPAH Contour A Interval).mxd

ECOLOGY REVIEW DRAFT May 25, 2007

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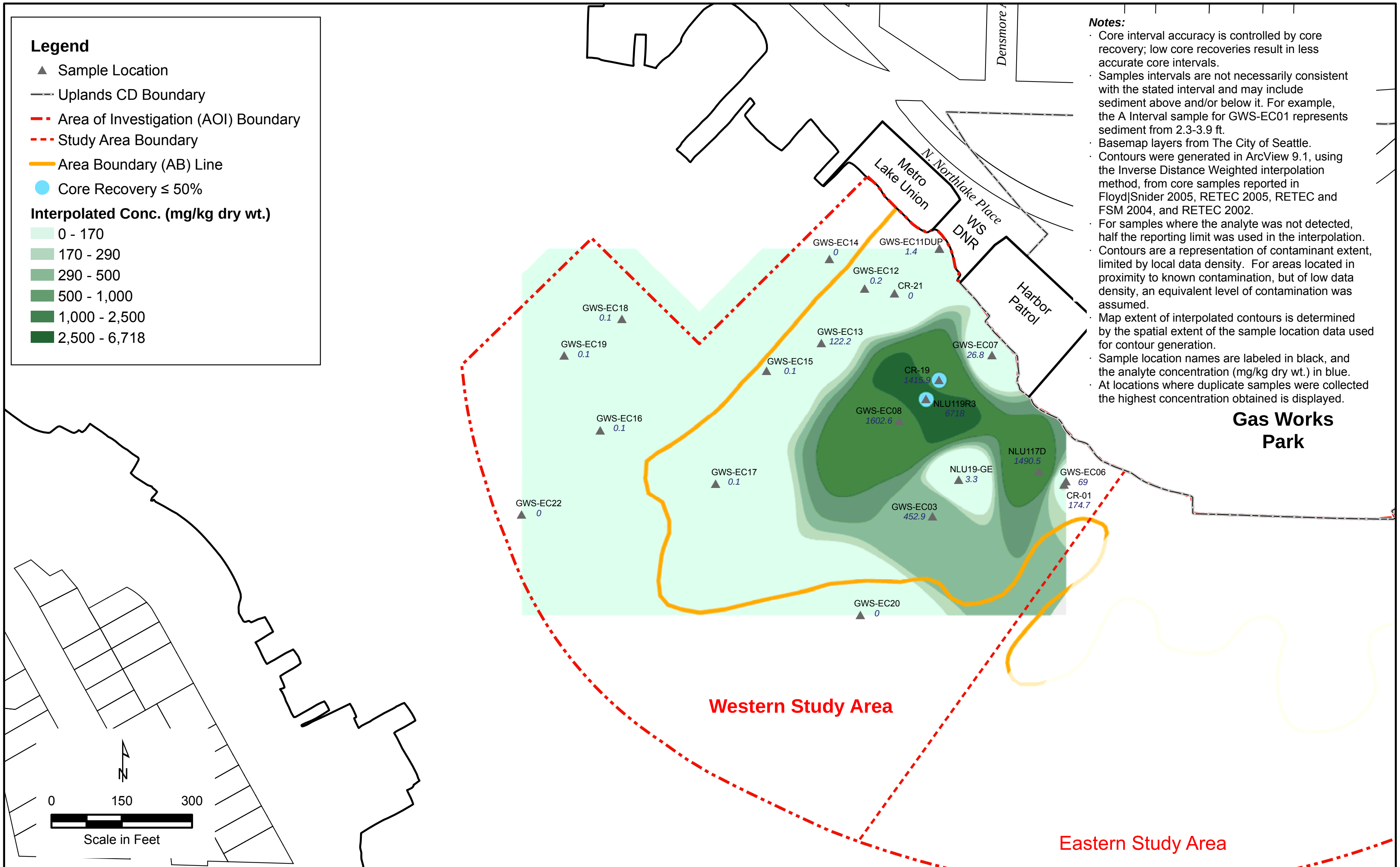
Remedial Investigation and Feasibility Study
Gas Works Sediment Western Study Area
City of Seattle

DRAFT

Figure 5.18
B Interval (3-6 ft)— TPAH

F:\projects\COS-GWSA\GIS\RIFS Report\Figure 5.18 (TPAH Contour B Interval).mxd

ECOLOGY REVIEW DRAFT May 25, 2007



Notes:
- Core interval accuracy is controlled by core recovery; low core recoveries result in less accurate core intervals.
- Samples intervals are not necessarily consistent with the stated interval and may include sediment above and/or below it. For example, the A Interval sample for GWS-EC01 represents sediment from 2.3-3.9 ft.
- Basemap layers from The City of Seattle.
- Contours were generated in ArcView 9.1, using the Inverse Distance Weighted interpolation method, from core samples reported in Floyd|Snider 2005, RETEC 2005, RETEC and FSM 2004, and RETEC 2002.
- For samples where the analyte was not detected, half the reporting limit was used in the interpolation.
- Contours are a representation of contaminant extent, limited by local data density. For areas located in proximity to known contamination, but of low data density, an equivalent level of contamination was assumed.
- Map extent of interpolated contours is determined by the spatial extent of the sample location data used for contour generation.
- Sample location names are labeled in black, and the analyte concentration (mg/kg dry wt.) in blue.
- At locations where duplicate samples were collected the highest concentration obtained is displayed.

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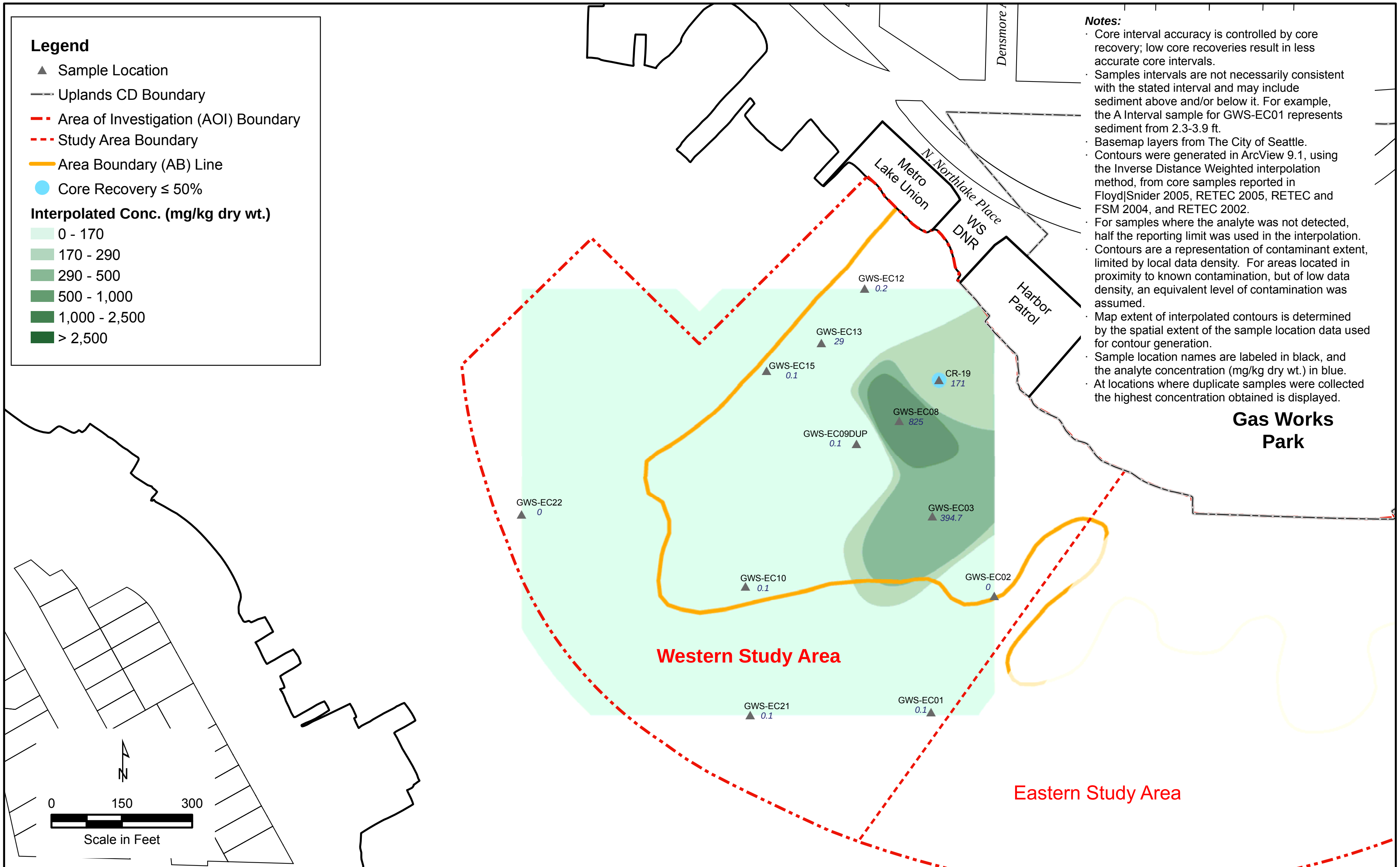
Remedial Investigation and Feasibility Study
Gas Works Sediment Western Study Area
City of Seattle

DRAFT

Figure 5.19
C Interval (6-9 ft)— TPAH

F:\projects\COS-GWSA\GIS\RIFS Report\Figure 5.19 (Contour C Interval).mxd

ECOLOGY REVIEW DRAFT May 25, 2007



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Remedial Investigation and Feasibility Study
Gas Works Sediment Western Study Area
City of Seattle

DRAFT

Figure 5.20
D Interval (9-12 ft)— TPAH

F:\projects\COS-GWSA\GIS\RIFS Report\Figure 5.20 (TPAH Contour D Interval).mxd

ECOLOGY REVIEW DRAFT May 25, 2007

0 100 200 Feet

N

SURFACE SEDIMENT SAMPLING STATIONS

PHASE 3 SAMPLING
- Grab Samples Collected in December 2004-April 2005 (RETEC)
- Grab Samples Collected in May 2005 (F|S)

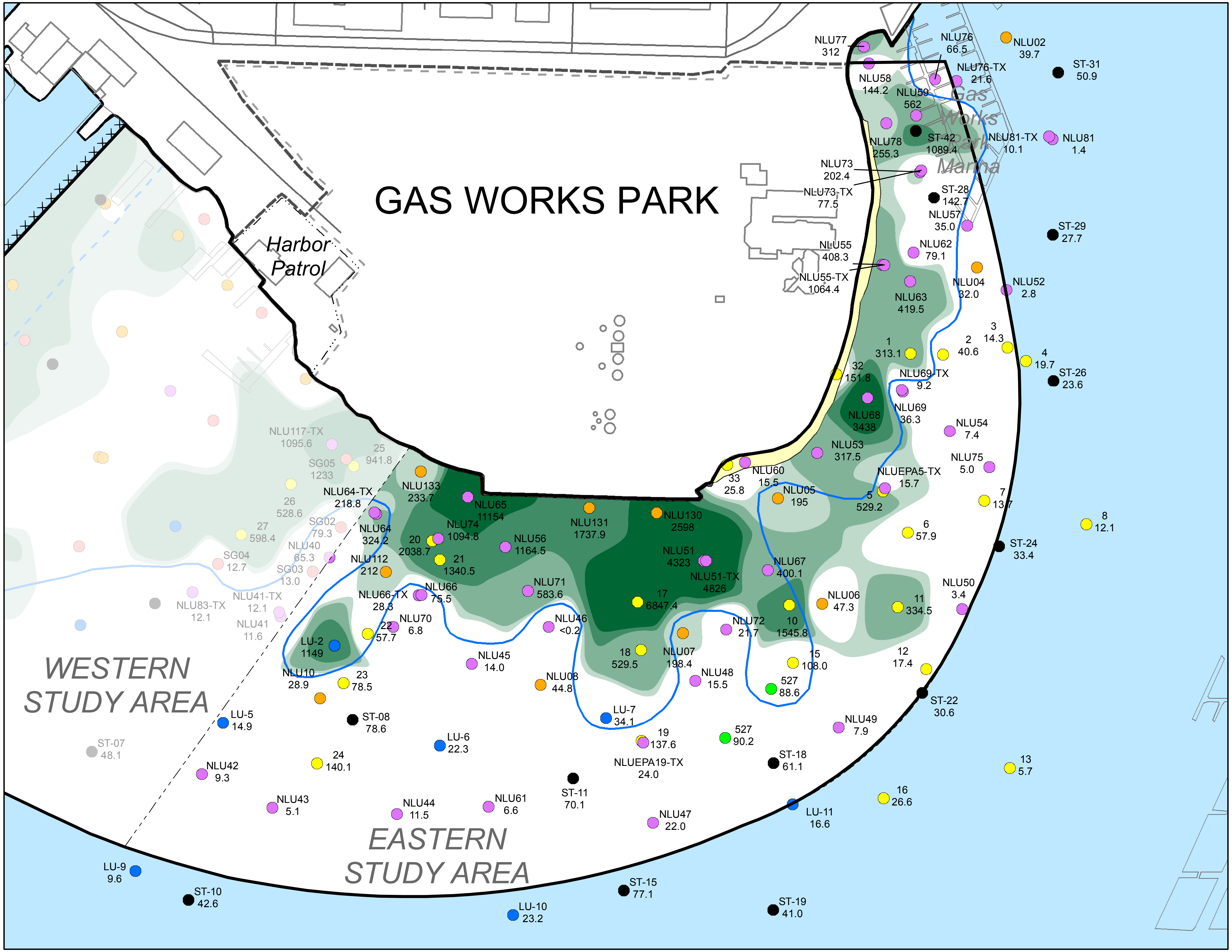
PHASE 2 SAMPLING
- Grab Samples Collected in Fall 2002 (RETEC)
- Grab Samples Collected in March/July 2002 (TAMU)

PHASE 1 SAMPLING
- Grab Samples Collected in September 1999 (RETEC)

MISCELLANEOUS SAMPLING
- Grab Samples Collected in 1995 (EPA)
- Grab Samples Collected from 1995-2000 (SEDQUAL)

- Area Boundary
- Area of Investigation (AOI)
- Uplands Boundary As Defined by the Consent Decree (December 1999)
- Division between Eastern and Western Study Areas
- Shipyard Consent Decree Boundary
- Harbor Patrol Boundary
- Gas Works Park Boundary

Interpolated TPAH Concentrations (mg/kg dry wt.)
- < 170
- 170 - 290
- 290 - 1000
- 1000 - 2500
- > 2500
- Unimpacted Shoreline Area
- Outside AOI - Interpolated concentrations not shown



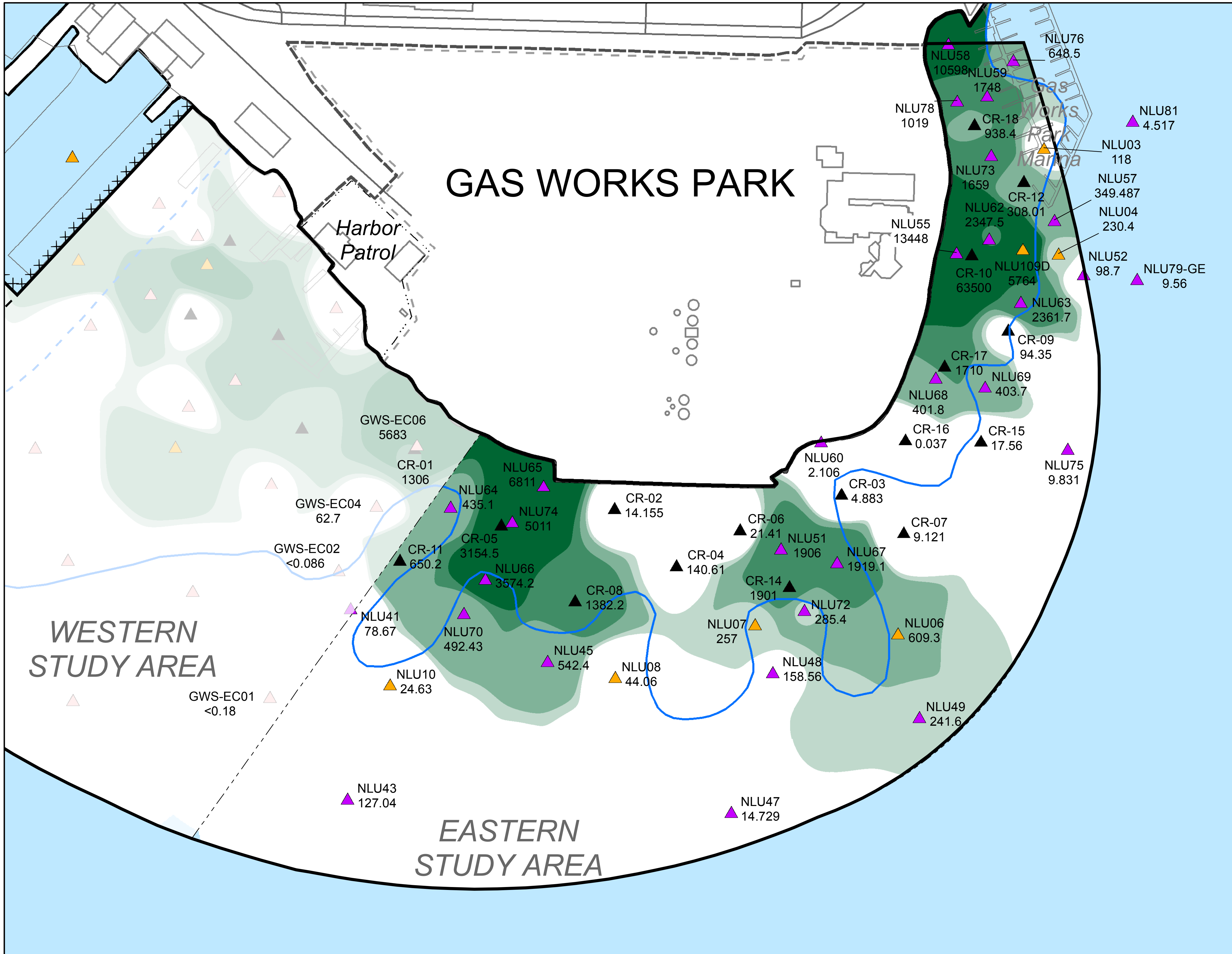
NOTES:
1. Basemap generated in ArcGIS version 8.1 from Seattle Public Utilities Geographic Systems data, 9/28/99. Overwater structure data updated, 12/18/03. Projection in Washington State Plane Coordinates, North Zone, HARN 1983/1991.
2. Concentration contour map generated through interpolation using an Inverse Distance Weighted (IDW) scheme (power = 6). Maximum reach from each sampling location is equal to 500 feet. Contoured interval may differ from actual data shown due to influence by neighboring data v alues.
3. Total polynuclear aromatic hydrocarbon (TPAH) concentrations represent the total sum of 16 individual PAH compounds. In accordance with Ecology's Sediment Management Standards, individual PAH concentrations below the detection limit (DL) were not included when calculating the sum .
4. RETEC split March 2002 samples reported for LU -1 through LU-11.
5. All surface samples were collected by grab sampler except NLU81 which was collected using 18" diver push cores, only top 4" sampled.

FILE: T:/LakeUnion_N83/Projects/NLU/ESA_RI_2006/Section5/Surface/tpah_int_epa33.mxd

RETEC

REVISION: 6

GAS WORKS SEDIMENT EASTERN STUDY AREA PSE10-18628-630	SURFACE SEDIMENT TPAH CONCENTRATIONS
DATE: 03/31/06 DWN. BY: KBL/ftc	FIGURE: 5-2



0 100 200 Feet

N

SUBSURFACE SEDIMENT SAMPLING STATIONS

PHASE 3 SAMPLING
- Core Samples Collected in December 2004-April 2005 (RETEC)
- Core Samples Collected in May 2005 (F|S)

PHASE 2 SAMPLING
- Core Samples Collected in Fall 2002 (RETEC)

PHASE 1 SAMPLING
- Core Samples Collected in September 1999 (RETEC)

- Area Boundary
- Area of Investigation (AOI)
- Uplands Boundary As Defined by the Consent Decree (December 1999)
- Division between Eastern and Western Study Areas
- Shipyard Consent Decree Boundary
- Gas Works Park Boundary
- Harbor Patrol Boundary

Interpolated TPAH Concentrations (mg/kg dry wt.)
- < 170
- 170 - 290
- 290 - 1000
- 1000 - 2500
- > 2500
- Outside AOI - Interpolated concentrations not shown

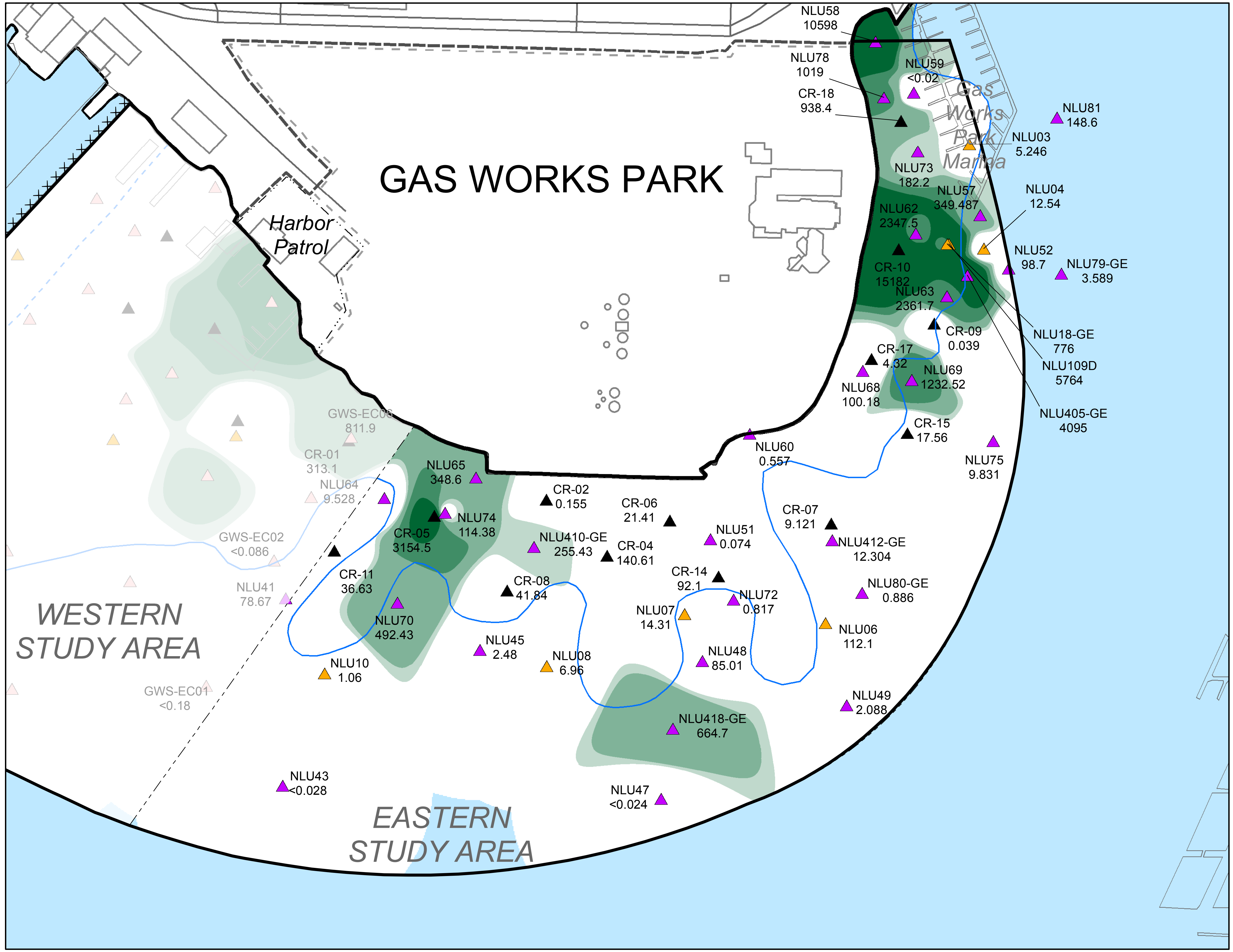
NOTES:
1. Basemap generated in ArcGIS version 8.1 from Seattle Public Utilities Geographic Systems data, 9/28/99. Overwater structure data updated, 12/18/03. Projection in Washington State Plane Coordinates, North Zone, HARN 1983/1991.
2. Concentration contour map generated through interpolation using an Inverse Distance Weighted (IDW) scheme (power = 6). Maximum reach from each sampling location is equal to 300 feet. Contours were estimated in areas with fewer data points. Contoured interval may differ from actual data shown due to influence by neighboring data values.
3. Total polynuclear aromatic hydrocarbon (TPA H) concentrations represent the total sum of 16 individual PAH compounds. In acc ordance with Ecology's Sediment Management Standards, individua l PAH concentrations below the detection limit (DL) were not included when calculating the sum .
4. RETEC split March 2002 samples reported for LU -1 through LU-11.
5. All surface samples were collected by grab sampler except NLU81 which was collected using 18" diver push cores, only top 4" sampled.

FILE: T:/LakeUnion_N83/Projects/NLU/ESA_RI_2006/Section5/Subsurface/tpah_int_A.mxd

RETEC

REVISION: 4

GAS WORKS SEDIMENT EASTERN STUDY AREA PSE10-18628-630	TPAH CONCENTRATIONS 0.33 - 3 FEET
DATE: 03/31/06 DWN. BY: KBL/ftc	FIGURE: 5-12



0 100 200 Feet

N

SURFACE SEDIMENT SAMPLING STATIONS

PHASE 3 SAMPLING

- Core Samples Collected in December 2004-April 2005 (RETEC)
- Core Samples Collected in May 2005 (F|S)

PHASE 2 SAMPLING

- Core Samples Collected in Fall 2002 (RETEC)

PHASE 1 SAMPLING

- Core Samples Collected in September 1999 (RETEC)

- Area Boundary
- Area of Investigation (AOI)
- Uplands Boundary As Defined by the Consent Decree (December 1999)
- Division between Eastern and Western Study Areas
- Shipyard Consent Decree Boundary
- Harbor Patrol Boundary
- Gas Works Park Boundary

Interpolated TPAH Concentrations (mg/kg dry wt.)

- < 170
- 170 - 290
- 290 - 1000
- 1000 - 2500
- > 2500
- Outside AOI - Interpolated concentrations not shown

NOTES:

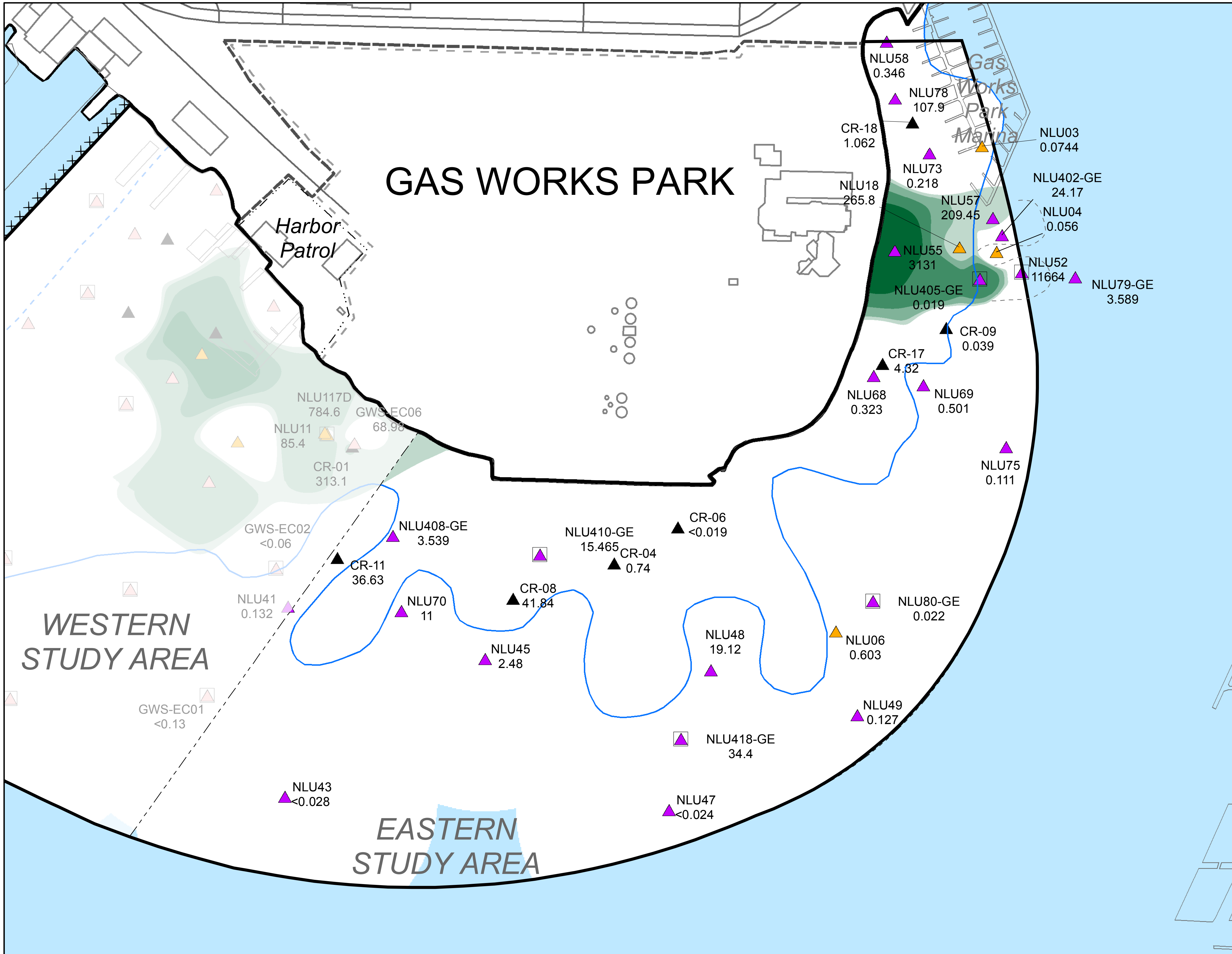
1. Basemap generated in ArcGIS version 8.1 from Seattle Public Utilities Geographic Systems data, 9/28/99. Overwater structure data updated, 12/18/03. Projection in Washington State Plane Coordinates, North Zone, HARN 1983/1991.
2. Concentration contour map generated through interpolation using an Inverse Distance Weighted (IDW) scheme (power = 6). Maximum reach from each sampling location is equal to 300 feet. Contours were estimated in areas with fewer data points. Contoured interval may differ from actual data shown due to influence by neighboring data values.
3. Total polynuclear aromatic hydrocarbon (TPA H) concentrations represent the total sum of 16 individual PAH compounds. In acc ordance with Ecology's Sediment Management Standards, individua l PAH concentrations below the detection limit (DL) were not included when calculating the sum .
4. RETEC split March 2002 samples reported for LU -1 through LU-11.
5. All surface samples were collected by grab sampler except NLU81 which was collected using 18" diver push cores, only top 4" sampled.

FILE: T:/LakeUnion_N83/Projects/NLU/ESA_RI_2006/Section5/Subsurface/tpah_int_B.mxd

RETEC

REVISION: 4

GAS WORKS SEDIMENT EASTERN STUDY AREA PSE10-18628-630	TPAH CONCENTRATIONS 3 - 6 FEET
DATE: 03/31/06 DWN. BY: KBL/ftc	FIGURE: 5-13



0 100 200 Feet

N

SURFACE SEDIMENT SAMPLING STATIONS
PHASE 3 SAMPLING
- Core Samples Collected in December 2004-April 2005 (RETEC)
- Core Samples Collected in May 2005 (F|S)

PHASE 2 SAMPLING
- Core Samples Collected in Fall 2002 (RETEC)

PHASE 1 SAMPLING
- Core Samples Collected in September 1999 (RETEC)
- Sample Start Depth >= 9 feet

- Area Boundary
- Area of Investigation (AOI)
- Uplands Boundary As Defined by the Consent Decree (December 1999)
- Division between Eastern and Western Study Areas
- Shipyard Consent Decree Boundary
- Harbor Patrol Boundary
- Gas Works Park Boundary

Interpolated TPAH Concentrations (mg/kg dry wt.)
- < 170
- 170 - 290
- 290 - 1000
- 1000 - 2500
- > 2500
- Outside AOI - Interpolated concentrations not shown
- Deeper than 9 feet

NOTES:
1. Basemap generated in ArcGIS version 8.1 from Seattle Public Utilities Geographic Systems data, 9/28/99. Overwater st ructure data updated, 12/18/03. Projection in Washington State Plane Coordinates, North Zone, HARN 1983/1991.
2. Concentration contour map generated through interpolation using an Inverse Distance Weighted (IDW) scheme (power = 6). Maximum reach from each sampling location is equal to 300 feet. Contours were estimated in areas with fewer data points. Contoured interval may differ from actual data shown due to influence by neighboring data values.
3. Total polynuclear aromatic hydrocarbon (TPAH) concentrations represent the total sum of 16 individual PAH compounds. In accordance with Ecology's Sediment Management Standards, individual PAH concentrations below the detection limit (DL) were not included when calculating the sum.
4. RETEC split March 2002 samples reported for LU-1 through LU-11.
5. All surface samples were collected by grab sampler except NLU81 which was collected using 18" diver push cores, only top 4" sampled.
6. Samples collected from a depth greater than 9 feet were not used in contouring.

FILE: T:/LakeUnion_N83/Projects/NLU/2005sampling/Subsurface/tpah_int_C2.mxd

RETEC

REVISION: 4

GAS WORKS SEDIMENT EASTERN STUDY AREA PSE10-18628-630	TPAH CONCENTRATIONS 6 - 9 FEET
DATE: 03/31/06 DWN. BY: KBL/ftc	FIGURE: 5-14

APPENDIX E
June 2008 Summary of Air Quality Evaluation Memorandum

FLOYD | SNIDER
strategy ▪ science ▪ engineering
Two Union Square • 601 Union Street • Suite 600
Seattle, Washington 98101 • tel: 206.292.2078 • fax: 206.682.7867

Memorandum

To: David Graves, Seattle Parks and Recreation Department

Copies: Marrel Livesay, Seattle Parks and Recreation Department ; Kathy Gerla, Law Department, and Teri Floyd

From: Jessi Massingale

Date: June 13, 2008

Project No: COS-GWP-UP

Re: **Summary of Air Quality Evaluation**

This memorandum presents a summary of the results of an air quality evaluation at Gas Works Park (Site) and the Seattle Police Department (SPD) Harbor Patrol Facility conducted by The Floyd|Snider Team on behalf of the City of Seattle.

INTRODUCTION

During late summer and early fall of 2006, numerous studies were taking place at the Gas Works Park Site to support the selection of sediment remedies. At this time, it was noticed that several uplands sections of the park had the distinct odor of mothballs, especially around the play barn, the old Manufactured Gas Plant (MGP) structures, and along the eastern shoreline where there were visible tar seeps. The City elected to conduct a year long air quality monitoring program to better understand the nature and significance of the odors.

The purpose of this evaluation was to measure the concentrations of key volatile organic compounds (VOCs) in ambient air during different seasons and at different locations.

The air quality evaluation consisted of three quarterly monitoring events conducted from spring 2007 to winter (January) 2008. To estimate the concentration range of VOCs quarterly[1] (seasonal) air monitoring events were conducted for a period of one year. Thermal desorption tube (TDT) sampling and high-sensitivity mass spectrometry (HS/MS) analysis was conducted during each of the three quarterly monitoring events. Additionally, continuous air monitoring for total aromatics using an aromatic-specific laser ionization detector (ARSLID) was conducted during the month of August as part of the second quarter (summer) monitoring event. The second quarter (summer) consisted of ARSLID sampling in August and TDT sampling in early

[1] The term quarterly has been used to represent the concept of seasonal measurements. Measurements taken at three times during the year: spring, summer, and winter are considered to represent the range of conditions that would be expected during a typical year-long period in Seattle.

September. These time periods were chosen to represent the warmer summer and fall months in Seattle and therefore an additional fall quarter monitoring event was not conducted. The first quarter of monitoring was conducted during spring, April 2007. The third quarter of monitoring was conducted during winter, January 2008.

Air samples were collected from five locations within the Park and Harbor Patrol facility (Figure 1). At each of the five sampling locations, one pair of replicate samples was collected on TDTs. Meteorological conditions during TDT sample collection were monitored using a Davis Vantage Pro Weather Station.

QUARTERLY SAMPLING AND ANALYSIS RESULTS

The complete quarterly air monitoring events and analytical results are presented in the Quarterly Air Sampling Data Reports (The Floyd|Snider Team 2007a, 2007b, 2008). A summary of the air quality evaluation is described below.

As shown in Table 1, five chlorinated VOCs were detected that are not chemicals of concern (COCs) at Gas Works. Their concentrations were less than 2 ng/L and were often just greater than the detection limit. In addition, they were generally around 1 percent of the total VOCs and were similar at different locations and different seasons as well as being similar to background and upwind locations. There is no indication that these compounds were released from the facility, nor does there appear to be an association with the facility.

Twelve aromatic hydrocarbons were detected in the air samples. They include benzene, alkylated benzenes such as toluene, and naphthalene (the most volatile of the polycyclic aromatic hydrocarbons [PAHs]). These VOCs are consistent with the COCs identified for the site.

In general, the highest concentrations of most analytes were detected during the summer sampling event and the lowest were detected in the winter (Table 1). There were a few exceptions to this trend within confined spaces such as under the Play Barn and in the Harbor Patrol Building, where winter concentrations for some analytes were higher than summer concentrations.

Except for a single sample collected from the Cracking Tower area, the rest of the samples had similar concentrations between quarterly events and locations. The one anomalous sample was collected from within the fenced area of the Cracking Towers (an area that is inaccessible to the public) in spring 2007. Its replicate was also analyzed. The detected concentrations of benzene in the two replicate samples were 870 ng/L and 0.9 ng/L. To better understand whether the structures (or soils) within the Cracking Tower area were contributing to the benzene, or whether the sample result might have been an anomaly, four additional TDT sampling locations—plus a screening level flux chamber air sample—were added to the second quarter (summer) monitoring event in the vicinity of the Cracking Towers. The results of the additional Cracking Tower samples collected during the second quarter (summer) monitoring event were consistent with the results of the Cracking Towers Area replicate sample, and did not significantly differ from the results of the other sampling locations. The detected benzene concentrations during the second and third quarters suggested that the first quarter (spring) elevated benzene and VOC concentrations were an anomaly.

The Prow upwind (background) benzene concentrations detected during the three quarters were within the Seattle Beacon Hill 2000 to 2002 background concentrations (Table 2) (PSCAA 2003). Naphthalene was not detected in the Prow upwind sample during any of the quarterly monitoring events.

ASIDE ON NE CORNER RESULTS

You have recently asked about air quality in the NE Corner based on the results of the NE Corner Investigation soil gas survey. The following is provided to clarify the differences between this ambient air quality monitoring and the NE Corner soil gas survey. The soil gas survey was conducted as a screening method to identify locations where total aromatics measured in the subsurface soil may be associated with the presence of shallow subsurface tar and/or DNAPL. The soil gas survey consisted of collecting soil gas from the subsurface, approximately 18 inches below the ground surface. The sampling probe was driven approximately 18 inches into the ground and sample tubing was connected to the portable ARSLID (Aromatic-Specific Laser Ionization Detector). The ARSLID monitor includes an internal sampling pump which pulls soil gas from the subsurface soils, and does not rely on passive diffusion and does not reflect any potential gas that would be present at the ground surface, which would be lower in any potential VOC concentrations. Additionally, the ARSLID detects and reports total aromatic hydrocarbons, as the air stream is drawn into the ARSLID, it is ionized and an electrical current is generated as the ions are drawn to electrodes via a potential bias. Therefore, any and all compounds which ionize upon exposure to the laser generate an electrical response. The presence or contribution of individual compounds to the total reading cannot be determined. For these reasons, the soil gas survey can not be used to predict air concentrations above ground.

The quarterly air samples collected from the Eastern Shoreline sampling location (where previous tar seeps were located and odors observed) is located just south of the meadow and within the extent of the NE Corner Investigation. The air samples collected at the Eastern Shoreline location were collected from a height equivalent to an average breathing zone, reflecting the ambient air quality at that location.

CONCLUSIONS

The detected concentrations of VOCs in air samples collected from both the Park sampling locations and Harbor Patrol locations do not exceed any of the OSHA occupational standards (PEL) that would be applicable to Park and Harbor Patrol employees.

Although air cleanup levels were not established under the existing cleanup action plan for the site, a modified Method B value appropriate for a park user has been defined for this memo. The value was calculated using the MTCA Method B equation in WAC 173-340-150, with a modification for the frequency of exposure. In the Method B default exposure, exposure is assumed to be for 100% of the time or the equivalent of 24 hr per day for 7 days per week. In the Park User scenario, the exposure was assumed to be for 4 hours per week. All other parameters remained the same.

Excluding the anomalous[2] air sample collected from within the fenced Cracking Tower area during the spring 2007, detected concentrations of all VOCs were below the park user scenario air standards. The maximum detected naphthalene concentration (6.8 ng/L) was approximately an order of magnitude below the park user air standard (58 ng/L). Additionally, the maximum naphthalene concentration was detected from within the locked Play Barn basement that is inaccessible to park users. This location was selected because it is near known areas of subsurface concentrations, is a “confined space,” and is below ground – it was expected to represent a “worst case” condition at the Park.

The average detected benzene concentration of (1.9 ng/L) and the maximum concentration (3.3 ng/L) were an order of magnitude below the park user air standard (13.3 ng/L). Additionally, the detected benzene concentrations are within the range of Seattle background benzene concentrations, ranging from 1.21 ng/L to 2.68 ng/L (Table 2).

The mothball like odor observed during the summer of 2006 was likely associated with elevated concentrations of naphthalene. During the subsequent Winter (January 2007) the Parks Department conducted tar maintenance actions, consistent with the Consent Decree, of excavating surface tar expressions along the eastern shoreline of the park (where naphthalene-like odors had been observed) and then covering the areas with gravel. Following the Parks Department maintenance actions, no odors were observed during the spring or summer of 2007. These actions resulted in a reduction of the previously observed odors and risks associated with VOC air concentrations.

Based on the results of the air quality evaluation no additional air sampling is recommended at the Gas Works Park site. The quarterly results showed that the detected concentrations of VOCs, benzene and naphthalene in particular do not exceed the park user scenario; and do not exceed OSHA occupational standards (PEL) that would be applicable to Park and Harbor Patrol employees. Since the concentrations are below both of these benchmarks, we believe that they are protective of human health.

REFERENCES

Puget Sound Clean Air Agency (PSCAA) and Washington State Department of Ecology (Ecology) 2003. Final Report: Puget Sound Air Toxics Evaluation. Seattle, Washington. October. http://www.pscleanair.org/airq/basics/psate_final.pdf

The Floyd|Snider Team. 2007a. *First Quarter (Spring) 2007 Air Sampling Data Report.* 22 June.

_____. 2007b. *Second Quarter (Summer) 2007 Air Sampling Data Report.* 11 November.

[2] Again, we believe that the spring 2007 sample with an elevated benzene concentration was an anomaly as neither the co-located replicate sample, nor subsequent air samples collected at the same location or adjacent to it showed the same level of concentrations.

_____. 2008. *Third Quarter (Winter) 2008 Air Sampling Data Report.* 8 April.

FIGURES

TABLES

Notes:
- Air sample locations are approximate.
- Air samples were collected using thermal desorption tubes (TDTs).
- Orthophoto provided by City of Seattle and dated 2005.

FLOYD | SNIDER strategy ▪ science ▪ engineering / TRENARY & ASSOCIATES, LLC	**Summary of Air Quality Evaluation** **Gas Works Park** **Seattle, Washington**	Figure 1 Air Sampling Locations

File: F:\projects\COS-GWP-UP\GIS\MXD\Figure 2.1 (Air Sampling Locations Summer Qtr 2007).mxd
Date: 10/9/2007

Table 1
Comparison of Quarterly Air Sampling Thermal Desorption Tube Quantitative Volatile Organic Compound Concentrations

Location	**Cracking Towers (CT)**				**East Shoreline (ES)**			**Harbor Patrol (HP)**			**Play Barn Basement (PBB)**			**Prow Upwind (PUP)**			**Samples**	
Sample Event	**Spring**		**Summer**	**Winter**	**Spring**	**Summer**	**Winter**	**Spring**	**Summer**	**Winter**	**Spring**	**Summer**	**Winter**	**Spring**	**Summer**	**Winter**	**Min**	**Max**
Sample ID	CT-042707	CT-042707-Rep	CT-091107	CT-011608	ES-042707	ES-091107	ES-011608	HP-042707	HP-091107	HP-011608	PBB-042707	PBB-091107	PBB-011608	PUP-042707	PUP-091107	PUP-011608		
Sample Date	4/27/2007		9/11/2007	1/16/2008	4/27/2007	9/11/2007	1/16/2008	4/27/2007	9/11/2007	1/16/2008	4/27/2007	9/11/2007	1/16/2008	4/27/2007	9/11/2007	1/16/2008		
Parameters (ng/L)																		
Total No. of detected VOCs	35	24	37	13	18	36	18	27	31	28	19	12	13	15	28	11		
Total VOCs	1300	390	280	110	120	250	150	230	240	380	130	180	110	120	200	100	110	1300
Chlorinated VOCs (ng/L)																		
Chloroform	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.9	ND	ND	ND	ND	ND	ND	0.9	0.9
Tetrachloroethene	0.4	0.7	1.6	ND	ND	1.2	0.5	0.4	1.3	0.6	ND	ND	0.5	ND	1	ND	0.4	1.6
Carbon tetrachloride	ND	ND	ND	ND	0.3	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.3	0.3
1,4-Dichlorobenzene	ND	ND	0.4	ND	ND	0.3	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.3	0.4
Methylene chloride	ND	ND	1.3	ND	ND	0.9	ND	ND	1	ND	ND	0.5	ND	ND	1.8	ND	0.5	1.3
Aromatic VOCs (ng/L)																		
Benzene	870	0.9	2.8	1.6	2.5	2.9	2	1.4	2.5	3.3	1.3	1.6	2.1	0.8	2.1	1.6	0.9	870
Toluene	74	15	13	4.7	3.9	9.9	7.7	7.7	12	10	3.5	5.8	8	3.3	7.9	4	3.5	74
Ethylbenzene	3.7	0.9	2.8	0.8	0.6	2	1	1.2	2.4	3.5	0.5	0.6	0.6	0.6	1.7	0.7	0.5	3.7
m,p -Xylene	6.9	2.8	8.1	2.3	2	5.8	3.1	4.1	7.8	11	2	2.2	1.9	1.8	5.2	1.9	1.9	11
o -Xylene	1.2	1	3.2	0.9	0.7	2.3	1.1	1.4	2.9	3.4	0.7	0.8	0.8	0.6	2.1	0.7	0.7	3.4
n -Propylbenzene	0.6	0.6	1	ND	ND	1.1	ND	0.3	0.9	1.2	ND	ND	ND	ND	0.8	ND	0.3	1.2
1,3,5-Trimethylbenzene	0.9	1	1.2	0.4	ND	1.5	ND	0.4	0.9	1.8	0.4	ND	ND	ND	1.2	ND	0.4	1.8
1,2,4-Trimethylbenzene	4.4	3.1	5.3	1.7	0.8	6.4	1.2	1.8	3.6	7.8	1.4	ND	0.8	0.9	4.2	1	0.8	7.8
p -Isopropytoluene	ND	ND	0.4	ND	ND	0.3	ND	ND	0.4	ND	ND	ND	ND	ND	ND	ND	0.3	0.4
Naphthalene	0.3	0.3	0.8	0.4	ND	2.5	0.4	0.4	1	0.7	1.9	6.8	1.6	ND	ND	ND	0.3	6.8
2-Methylnaphthalene	ND	ND	ND	ND	ND	0.4	ND	ND	0.5	0.3	0.5	1.6	ND	ND	ND	ND	0.3	1.6
Styrene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.4	ND	ND	ND	ND	0.4	0.4

Notes:

1 All samples were collected on thermal desorption tube (TDTs) over a period of approximately 3 1/2 to 4 1/2 hours. Samples were directly desorbed from the tubes with heat and analyzed by high-sensitivity mass spectrometry (HS/MS).

2 Only quantitative quarterly results are presented. Calculated semi-quantitative results are not shown.

ND Not detected.

VOC Volatile organic compound.

Table 2
Seattle Average Annual Background Volatile Organic Compound Concentrations (2000 to 2002)[1]

Site	Beacon Hill			Georgetown		
Year	**2000**	**2001**	**2002**	**2000**	**2001**	**2002**
Analyte (ng/L, μg/m^3)						
benzene	1.69	1.31	1.21	2.68	1.82	1.88
1,3-butadiene	0.18	0.11	0.09	0.24	0.13	0.22
carbon tetrachloride	0.63	0.63	0.63	0.69	0.63	0.69
chloroform	0.29	0.20	0.24	0.20	0.15	0.15
dichloromethane	5.38	1.53	NA	7.04	1.84	NA
tetrachloroethylene	0.20	0.14	0.27	0.47	0.34	0.41
trichloroethylene	0.27	0.16	0.11	0.64	0.38	0.54
acetaldehyde	1.51	1.30	1.49	1.84	1.22	1.46
formaldehyde	2.25	1.66	1.64	3.51	1.48	1.43

Notes:
1 Data obtained from Seattle Air Toxics 2000-02.xls (Ecology 2004).
NA Not available.

Table 3
Comparison of Maximum Air Monitoring Results

Parameters[1]	Maximum Result	Location and Time of Maximum	Maximum Upwind	Resident (Method B)	Park User (4 hr/wk)
Total No. of detected VOCs	37	Towers, summer	28	--	--
Total VOCs	1,300	Towers, spring	200	--	--
Chlorinated VOCs (ng/L)					
chloroform	0.9	Harbor Patrol, winter	ND	0.11	4.6
tetrachloroethene	1.6	Towers, summer	1.0	0.42	18
carbon tetrachloride	0.3	East Shore, spring	ND	0.17	7.1
1,4-Dichlorobenzene	0.4	Harbor Patrol, summer	ND	370	15,000
Methylene Chloride	1.3	Towers, summer	1.8	5.3	220
Aromatic VOCs (ng/L)					
benzene	870, 3.3[2]	Towers spring, Harbor Patrol summer	2.1	0.32	13.3
toluene	74, 15[2]	Towers, spring	7.9	2,200	92,000
ethylbenzene	3.7, 3.5[2]	Towers spring, Harbor Patrol winter	1.7	460	19,000
m,p-xylene	11	Harbor Patrol, winter	5.2	46	1,900
o-xylene	3.4	Harbor Patrol, winter	2.1	46	1,900
n-propylbenzene	1.2	Harbor Patrol, winter	0.8	NA	NA
1,3,5-trimethylbenzene	1.8	Harbor Patrol, winter	1.2	2.7	110
1,2,4-trimethylbenzene	7.8	Harbor Patrol, winter	4.2	2.7	110
p-Isopropytoluene	0.4	Harbor Patrol, summer	ND	NA	NA
naphthalene	6.8	Play Barn, summer	ND	1.4	58
2-methylnaphthalene	1.6	Play Barn, summer	ND	NA	NA
Styrene	0.4	Play Barn, summer	ND	4.4	180

Notes:

1 Complete quartelry air monitoring results are presented in Table 1.

2 As discussed in the first quarterly report, one sample from the cracking towers contained high concentrations of benzene and toluene that were not present in its replicate. This triggered additional sampling in the second quarter around the towers. The first number represents the sample with the high readings, the second number represents the maximum of all other samples.

NA Not available

ND Not detected

VOC Volatile organic compound

Appendix F

Gas works Park Environmental Cleanup, Phase 1 – Candidate Remedial Measures

(Provided on attached CD)

Gas Works Park Environmental Cleanup
Phase I – Candidate Remedial Measures

Seattle
Department of
Parks and Recreation

Parametrix, Inc.
and Associated Firms

July 15, 1996

LAW 09745

GAS WORKS PARK ENVIRONMENTAL CLEANUP

PHASE I - CANDIDATE REMEDIAL MEASURES

Prepared for

CITY OF SEATTLE
Legal Department
10th Floor Municipal Building
600 Fourth Avenue
Seattle, Washington 98104

Prepared by

PARAMETRIX, INC.
5808 Lake Washington Boulevard N.E.
Kirkland, Washington 98033

and associated firms

July 15, 1996

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1. INTRODUCTION

Gas Works Park is located at the north end of Lake Union, in Seattle, Washington. The site formerly included a coal and oil gasification plant operated from 1906 to 1956. Currently, the site is a public park owned and maintained by the City of Seattle Department of Parks and Recreation. Studies conducted at Gas Works Park in the 1980s confirmed the presence of chemicals of concern from the gasification plant operation in soil and groundwater beneath the site. The Parametrix, Inc. project team has assisted the City of Seattle and Washington Natural Gas in developing a phased approach to address those issues.

The objective of Phase I of the Gas Works Park environmental cleanup project is to identify potential candidate remedial measures and to calculate life cycle cost ranges for each candidate remedial measure. Chapter 2 of this report summarizes the existing chemical data collected at the site and the results of a recent field reconnaissance of the site groundwater monitoring wells. Chapter 3 describes a conceptual model developed for the Gas Works Park cleanup project. Chapter 4 identifies potential remedial alternatives, describes screening of remedial alternatives, and summarizes potential remedial alternatives to be included in life cycle cost estimates. Life cycle cost analyses for the final candidate remedial alternatives are presented in Chapter 5.

To develop this Phase I report, risk-based decision making was one of several tools used to identify and evaluate the potential candidate remedial measures. Risk-based decision-making uses a risk and exposure assessment methodology to help determine the scope of remedial action required—consistent with applicable laws and regulations. In this report, risk-based decision making is intended to provide a scientific and technical framework to support remedial measure selection. The Phase I work was conducted to be consistent with the Model Toxics Control Act, Chapter 173-340 WAC.

The American Society for Testing and Materials (ASTM) has issued a well-recognized standard for risk-based corrective action (RBCA). The Exposure Scenario Flowcharts in Chapter 3 of this report are based upon ASTM Designation 1739-95 and are adapted to promote understanding of the contaminants of concern at Gas Works Park—from their sources to their potential receptors. These flowcharts are used in the report to facilitate site investigation and to support a decision-making process that considers the ability of cleanup alternatives to reduce potential exposures to contaminants of concern. While it is as equally protective of human health and the environment as other investigative approaches, risk-based decision making also offers a technically sound and organizationally effective way to respond to the demand for efficient use of public resources in the remediation of Gas Works Park.

The Phase I work described in this report was completed by the Parametrix, Inc. project team. Hong West & Associates prepared field investigation work plans, conducted the site reconnaissance, and prepared Section 2.2 of this report. Key Environmental, Inc. identified and screened remedial alternatives and prepared Section 4 of this report. Parametrix, Inc. developed the site database, entered the site data, prepared data summary tables, prepared the conceptual site model diagrams, compiled the site bibliography, and produced this report. Parametrix and Key Environmental prepared the life-cycle cost estimates and remedial alternative descriptions presented in Chapter 5.

2. SUMMARY OF RELEVANT SITE INFORMATION

2.1 SUMMARY OF PREVIOUSLY COLLECTED CHEMICAL DATA

2.1.1 Objectives

The objectives of this task were to assemble and summarize previously collected chemical data for soil and water at the site, and to evaluate the condition of the existing groundwater monitoring wells.

2.1.2 Methodology

A bibliography (presented in Appendix A) lists: available documents containing site information; the results of field investigations; and data summaries for the Gas Work Park site. The documents were provided by Seattle's Department of Parks and Recreation and the City of Seattle Legal Department. The City of Seattle also provided GIS data on site topography, utilities, and park features. These data were used to compile the site map shown in Figure 2-1.

Chemical data previously collected for soil and water at the Gas Works Park site were entered into a relational database from which summary tables were generated. The sources for these chemical data are summarized in Appendix B.

Where available, data on sample depth, name of laboratory, and analytical method(s) used were included in the database. Where original laboratory reports were not provided in the available documents, data were taken from summary tables. All of the chemical values entered in the database were verified by an independent reviewer.

Water sampling stations consisted of on-site monitoring wells (MW-2, MW-3, MW-3D, and MW-5 through MW-21) and an off-site background monitoring well MW-1. Surface water sampling stations included several near-shore surface water runoff points. Soil samples included numerous shallow samples (3 feet or less) taken throughout the site (see Figure 2-1). A limited number of deeper soil samples came from the monitoring well borings.

2.1.3 Results

Summary tables for each detected and undetected compound appear in Appendix C. The detected data values include qualified data (those with a J, B, P, N, or M code).

MTCA Method B cleanup levels for groundwater, surface water, and soil were tabulated for each chemical tested in soil and groundwater at the site. MTCA Method B cleanup levels were obtained from the *Model Toxics Control Act Cleanup Levels and Risk Calculations (CLARC II) Update, Washington State Department of Ecology Publication 94-145, February 1996.*

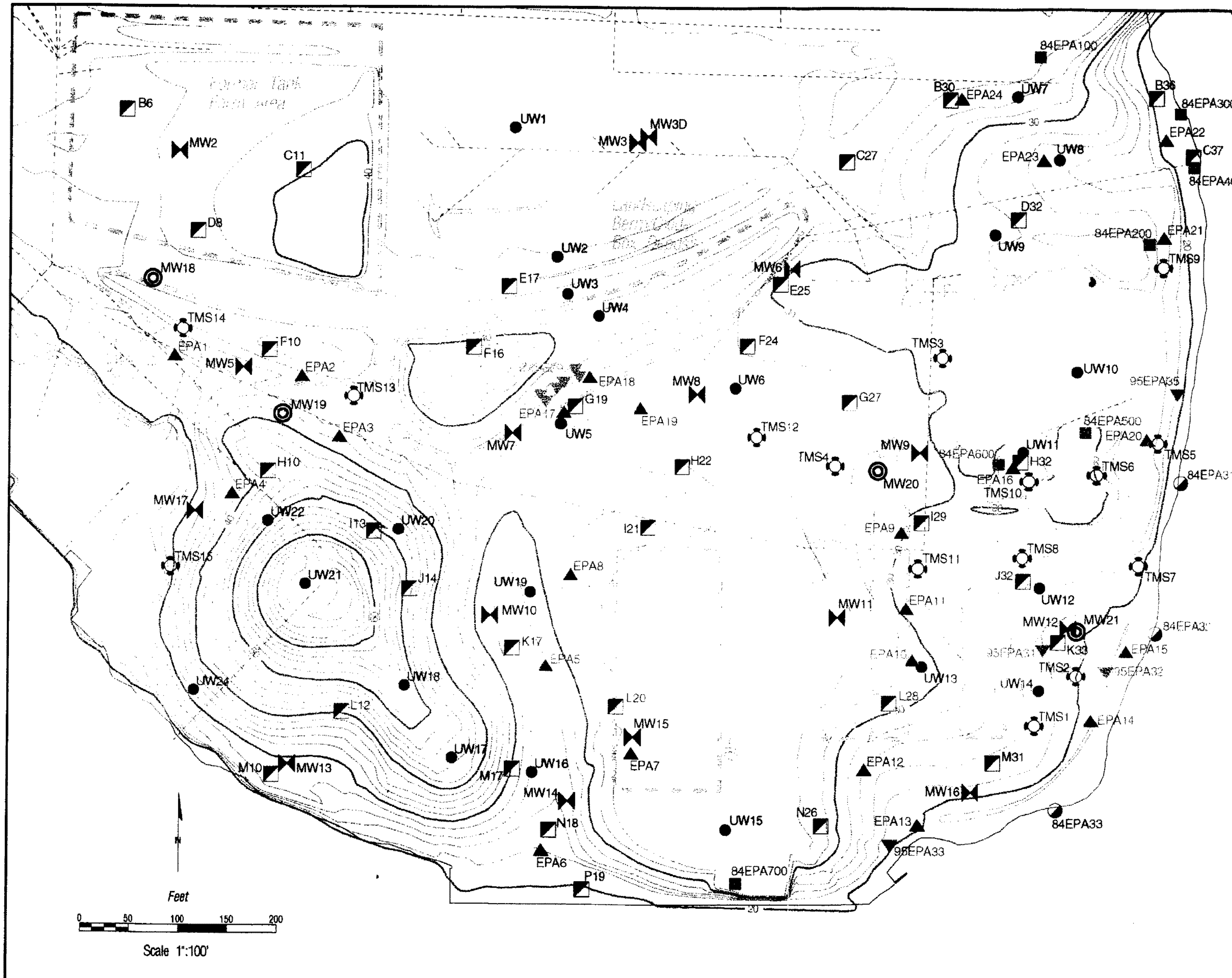

Figure 2-1

Site Map Showing Sampling Locations and Suspected Contamination Sources

Gas Works Park, Seattle, Washington

LEGEND

- Surface soil sample (EPA 1984)
- Surface soil and water sample (EPA 1984)
- 6 in. and 3 ft. soil sample (Ecology and Environment 1984)
- Surface soil sample (U. of Washington 1984)
- Surface soil sample (Tetra Tech 1985)
- Soil surface sample (HDR 1988)
- Soil and water sample (EPA 1995)
- Groundwater monitoring well (Tetra Tech 1987)
- Temporary groundwater monitoring well (HDR 1988)
- Groundwater monitoring well (HDR 1989)
- Contour interval (10 feet)
- Contour interval (2 feet)
- Sewer/drainage
- Coastline (approximate)
- Building

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Summary tables were generated from the database for three data categories: (1) shallow soils (6 inch or less in depth), Table 2-1; (2) deep soils (greater than 6 inches in depth), Table 2-2; and (3) groundwater and surface water, Table 2-3. Soil concentrations were compared to MTCA Method B soil cleanup levels. Water concentrations were compared to MTCA Method B cleanup levels for (1) groundwater and (2) surface water. The percentage of detected concentrations for each chemical that exceeded the applicable MTCA Method B cleanup level was calculated to assist in evaluating the distribution of the data.

2.2 RECONNAISSANCE OF CURRENT SITE CONDITIONS

2.2.1 Introduction

The objectives of this task were to investigate the location and condition of groundwater monitoring wells at Gas Works Park in Seattle, Washington, and to assess the site for surface features such as tar seeps and erosion. The focus of this investigation was to determine the general condition of 21 existing monitoring wells at the site. These wells has not been used or accessed in approximately 10 years. A Site Reconnaissance Work Plan and a Site-Specific Health and Safety Plan were prepared before field activities began.

2.2.2 Field Methodology

At each of the wells located, the following information was collected:

- General condition of well (location, access, surface completion, depth, obstructions, etc.);
- Depth to groundwater;
- Presence and thickness of light or dense non-aqueous phase layer (NAPL), if any; and
- Organic vapor, hydrogen sulfide, explosive gas (with confirmation measurement for methane and carbon dioxide), oxygen, and hydrogen cyanide concentrations in and near well casings

A preliminary surficial reconnaissance of the site was also undertaken to note the presence of tar seeps and erosion features. Results of the surficial reconnaissance will be provided in the final Phase I report.

Table 2-1. Summary of detected chemical concentrations for shallow soils (6 inches or above) exceeding MTCA Method B soil cleanup levels, Gas Works Park.

Chemical Name	Detected Concentrations Number**	Maximum (mg/kg)	Minimum (mg/kg)	MTCA B Cleanup Level (Soil)	Percentage of Detected Concentrations Exceeding MTCA B (soil)
Metal					
Arsenic	27	47.5	2.9	7*	37%
PCB					
Aroclor-1254	23	2.724	0.033	1.60	30%
Semi-Volatile Organics					
Indeno(1,2,3-c,d)pyrene	73	11000	0.074	0.137	99%
Benzo(a)pyrene	97	10000	0.034	0.137	98%
Chrysene	75	6000	0.048	0.137	99%
Benzo(b)fluoranthene	76	4000	0.0089	0.137	97%
Benzo(a)anthracene	74	3000	0.03	0.137	99%
Dibenzo(a,h)anthracene	34	2000	0.266	0.137	100%
Benzo(k)fluoranthene	36	61.2	0.022	0.137	97%
Naphthalene	44	13000	0.13	3200	2%
Pyrene	75	18000	0.09	2400	3%
Fluoranthene	76	8000	0.01	3200	3%

* Natural background concentration in Puget Sound, Washington.

** Number of samples with concentrations of the specified chemical greater than the detection limit established for that chemical at the time of laboratory analysis.

MTCA = Model Toxics Control Act (WAC 173-340)

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Table 2-2. Summary of detected chemical concentrations for deep soils (below 6 inches) exceeding MTCA Method B soil cleanup levels, Gas Works Park.

Chemical Name	Detected Concentrations Number**	Maximum (mg/kg)	Minimum (mg/kg)	MTCA B Cleanup Level (Soil)	Percentage of Detected Concentrations Exceeding MTCA B (soil)
Metal					
Arsenic	24	30.4	1.4	7*	29%
Pesticide					
Heptachlor epoxide	15	0.615	0.0052	0.110	20%
Alpha-BHC	16	0.275	0.0026	0.159	6%
Beta-BHC	10	0.927	0.041	0.556	20%
Semi-Volatile Organics					
Benzo(a)pyrene	16	62.951	0.127	0.137	94%
Benzo(k)fluoranthene	11	46.872	0.037	0.137	82%
Chrysene	28	38.41	0.0116	0.137	68%
Indeno(1,2,3-c,d)pyrene	7	37.692	1.8	0.137	100%
Benzo(b)fluoranthene	20	19	0.023	0.137	75%
Benzo(a)anthracene	27	17.897	0.013	0.137	70%
Dibenzo(a,h)anthracene	6	2	0.042	0.137	83%

* Natural background concentration in Puget Sound, Washington.

** Number of samples with concentrations of the specified chemical greater than the detection limit established for that chemical at the time of laboratory analysis.

MTCA = Model Toxics Control Act (WAC 173-340)

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Table 2-3. Summary of detected chemical concentrations for water exceeding MTCA Method B groundwater and surface water cleanup levels, Gas Works Park.

	Detected Concentrations			MTCA B Cleanup Level		Comparison of Detected Concentrations to MTCA B Cleanup Levels	
Chemical Name	Number*	Maximum (µg/L)	Minimum (µg/L)	Groundwater (µg/L)	Surface Water (µg/L)	Percentage of Detected Concentrations Exceeding MTCA B Groundwater	Percentage of Detected Concentrations Exceeding MTCA B Surface Water
Metal							
Arsenic	17	60	2	0.0582	0.0982	100%	100%
Cyanide, Total	17	8600	10	320	51900	53%	
Pesticide							
Heptachlor	2	1.2	0.02	0.0194	0.000129	100%	100%
Semi-Volatile Organics							
Benzo(a)anthracene	5	4500	2.6	0.0120	0.0296	100%	100%
Chrysene	6	4200	3	0.0120	0.0296	100%	100%
Benzo(k)fluoranthene	2	3600	1.1	0.0120	0.0296	100%	100%
Benzo(a)pyrene	5	2200	0.046	0.0120	0.0296	100%	100%
Benzo(b)fluoranthene	4	2000	11	0.0120	0.0296	100%	100%
Indeno(1,2,3-c,d)pyrene	5	1900	0.038	0.0120	0.0296	100%	100%
Dibenzo(a,h)anthracene	2	45	0.35	0.0120	0.0296	100%	100%
Naphthalene	33	170000	0.21	320	9880	73%	33%
p-toluidine	1	110	110	0.461		100%	
Carbazole	4	590	30	4.38		100%	
Pyridine	1	1600	1600	16.0		100%	
Pyrene	9	32000	0.055	480	2590	11%	11%
Fluoranthene	9	41000	0.06	640	90.2	11%	
2,6-Dimethylphenol	1	410	410	9.60		100%	
3,4-Dimethylphenol	1	500	500	16.0		100%	
Fluorene	11	20000	0.3	640	3460	9%	9%
4-Methylphenol	2	1500	60	80.0		50%	
2,4-Dimethylphenol	2	1000	1.1	320	553	50%	50%
2-Methylphenol	2	2200	550	800		50%	
Anthracene	6	12000	0.11	4800	25900	17%	
m-cresol	1	1500	1500	800		100%	
Volatile Organics							
Benzene	31	620000	0.11	1.51	43.0	97%	87%
Styrene	4	3800	33	1.46		100%	
Toluene	23	150000	0.12	1600	48500	65%	9%
Ethylbenzene	26	11000	0.57	800	6910	42%	8%
1,2-Dichloroethane (total)	1	2.9	2.9	0.481	59.4	100%	
m,p-xylene	14	27000	5	16000		7%	
Dichloromethane	1	7	7	5.83	960	100%	

* Number of samples with concentrations of the specified chemical greater than the detection limit established for that chemical at the time of laboratory analysis.

MTCA = Model Toxics Control Act (WAC 173-340)

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2.2.3 Results

2.2.3.1 Well Inspection Results

Eighteen of the 21 wells were located, inspected, and measured. Table 2-4 shows the measured groundwater, NAPL, and well depths. The field team was unable to locate wells MW-1, MW-2, and MW-18 using available location maps, well log location descriptions, limited electromagnetic (metal detector) surveying, and shallow (<0.5 ft) excavation.

Wells MW-3 through MW-17 were completed at ground surface with 6.25-inch-diameter, flush-mounted, cast-iron, locking, utility valve boxes. These valve boxes were not watertight by design. Because most of the valve boxes were severely corroded and/or damaged, 18 of the valve boxes inspected were replaced or repaired. Wells MW-19 through MW-21 were completed at the surface with 8-inch-diameter, flush-mounted, steel, watertight, locking monitoring well covers, all of which were found in operable condition. All of the wells inspected were of 2-inch diameter PVC construction, with threaded or slip-fit (non-watertight) caps. Many of the wells had standing water inside the valve box to the level of the well casing, indicating that storm water may have been entering the wells.

Wells MW-5 and MW-9 contained (0.25 and 4.67 ft, respectively) a black, tarry. dense NAPL at the well bottom. Well MW-9 vented methane and carbon dioxide gas when opened. None of the other wells inspected were found to contain light or dense NAPL, organic vapors, hydrogen sulfide, explosive gas, or hydrogen cyanide. Well MW-9 was the only well inspected in which the threaded cap was tightly affixed, providing an airtight seal. It is possible that other wells may accumulate methane gas if airtight caps are affixed.

2.2.3.2 Well Construction Log Analysis

Evaluation of the available well logs revealed that most of the wells are not in compliance with Washington State Department of Ecology Minimum Standards for Construction and Maintenance of Wells (Chapter 173-160 WAC). These standards adopted in 1988 (after the wells were installed). Table 2-5 summarizes well completion information as indicated on available well logs. The main well construction features not in compliance are listed here:

- Non-watertight well caps on all wells
- Bentonite seals less than 2 ft thick in most wells
- Filter packs not extended 3 ft above screen in most wells
- MW-1 through MW-16 are constructed of PVC with glued joints
- No permanently affixed well identification numbers on any wells
- No annular space seal in some wells (including the deep well, MW-3D)

Table 2-4. Gas Works Park groundwater level data, April 29 through May 1, 1996.

Well	Well Log Depth (feet TOC)	Well Depth Measured (feet TOC)	Ground Water level (feet TOC)	TOC Elevation (feet COS)	DNAPL Thickness (feet)	Water Elevation (feet COS)	Comments
MW-1	34.3						Unable to locate
MW-2	13			25.54			Unable to locate
MW-3	11	9.48	4.93	25.55		20.62	
MW-3D	57.6	57.3	13.5	25.64		12.14	
MW-5	18.3	17.95	11.13	22.6	0.25	11.47	Black, tarry liquid at well bottom
MW-6	9.9	9.48	1.62	20.61		18.99	
MW-7	17.1	16.72	9.27	22.72		13.45	
MW-8	18	18.75	6.52	23.22		16.70	
MW-9	20.8	20.59	6.7	21.16	4.67	14.46	Black, tarry liquid at well bottom, well venting methane and CO2
MW-10	15.3	15.02	8.47	19.02		10.55	
MW-11	30	29.67	10.75	25.03		14.28	
MW-12	9.5	9.24	3.19	12.18		8.99	
MW-13	17	17.01	10.37	19.35		8.98	
MW-14	10	9.25	4.71	13.71		9.00	
MW-15	18	19.28	14.69	24.57		9.88	
MW-16	10.5	10.23	0.08	9.95		9.87	
MW-17	17.3	17.34	10.94				
MW-18							Unable to locate
MW-19		28.06	13.63				
MW-20		26.63	6.97				
MW-21		20.45	3.08				

Notes:

TOC - from top of casing
COS - City of Seattle Datum
DNAPL - Dense non-aqueous phase layer. No light NAPL was detected in any wells.
BLANK indicates no data available

LAW 09760

Table 2-5. Gas Works Park well construction data summary.

Well	Well Depth From TOC	Well Screen Length	Bentonite Seal Thickness	Comments
MW-1	34.3	10	1.5	Filter pack is mixed sand and boring cuttings
MW-2	13	10	2	Entire bentonite seal surrounds screen
MW-3	11	9.3	0.5	Bentonite seal adjacent to screen
MW-3D	57.6	3	3	Bentonite seal 44.6' above top of screen (cuttings from 10-47')
MW-5	18.3	10		
MW-6	9.9	8	0.5	Bentonite seal adjacent to screen
MW-7	17.1	10	1	
MW-8	18	10	3.5	
MW-9	20.8	10	6	
MW-10	15.3	10	1.5	
MW-11	30	10	1.5	
MW-12	9.5	8.2	0.8	Part of bentonite seal surrounds screen
MW-13	17	10	3	
MW-14	10	7	1	Bentonite seal adjacent to screen
MW-15	18	10	2	
MW-16	10.5	8	1	
MW-17	17.3	10	5.8	
MW-18				
MW-19				
MW-20				
MW-21				

Notes:

TOC - from top of casing
BLANK indictaes no data available
MW 1-16 are 2" PVC with welded joints
MW 2-16 have threaded PVC caps (not watertight)
MW-17-21 have slip-fit caps (not watertight) on angled or jagged 2" casing (may require cutting to fit watertight caps)

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2.2.4 Recommendations

The existing Gas Works Park monitoring wells are technically not in compliance with the current Ecology well construction regulations; however, these factors are not expected to compromise the collection of representative groundwater quality samples and water-level measurements from those wells to support the selection of a preferred remedial alternative in the focused feasibility study. If subsequent well development indicates conditions that prevent collection of representative groundwater samples from particular wells, those wells will be deleted from the sampling program.

Prior to any planned groundwater sampling, the following actions are recommended:

- Fit watertight caps to all wells to keep surface water from entering the wells.

- Prepare a Sampling and Analysis Plan that includes well development procedures.

- Update the existing Health and Safety Plan.

- Develop all wells to ensure that screens have not become clogged over the years. Wells in which the bentonite seal was placed around or adjacent to the well screen (MW-2, MW-3, MW-3D, MW-6, MW-12, MW-14) should be developed with minimal surging to avoid drawing bentonite into the wells. Properly contain and dispose of development water.

- Be prepared to replace additional valve boxes. The 6.25-inch cast iron valve boxes are not suited to be monitoring well covers; they are subject to rusting and breakage and are easily broken during opening and closing.

- Well MW-3D should be properly abandoned (by redrilling and grouting) if any contamination of concern is found in MW-3. Well MW-3D was constructed with no effective annular seal and may act as a potential conduit for contamination to enter deeper zones.

3. CONCEPTUAL SITE MODEL

3.1 OBJECTIVES

A conceptual site model was developed for the Gas Works Park environmental cleanup project to:

- Gain an understanding of contaminant sources, contaminant transport mechanisms, exposure pathways, and receptors—as defined by available site data.
- Guide the analysis of candidate remedial measures by illustrating how each remedial measure interrupts the pathway from source to receptor.

3.2 CONCEPTUAL SITE MODEL FORMAT

Discussions among representatives of Seattle's Department of Parks and Recreation, Washington Natural Gas, the Department of Ecology, and the Parametrix project team resulted in selection of the Exposure Scenario Flowchart from "Standard Guide for Risk-Based Corrective Action Applied at Petroleum Release Sites" (ASTM Designation 1739-95) as the base format. This flowchart provides a clear and convenient means to track a contaminant from source to a potential receptor. The initial "menu" of flowchart components was modified to fit the Gas Works Park site.

3.2.1 Composite Conceptual Site Model

Figure 3-1 shows the composite conceptual site model developed for the Gas Works Park Site. The following sections described site-specific adaptations of the conceptual site model to reflect conditions at Gas Works Park.

3.2.1.1 Primary Sources

The four "default" primary source descriptions shown in the upper left corner of the composite conceptual site model apply specifically to petroleum-contaminated sites, and are not applicable to the Gas Works Park site. Six suspected primary contaminant source areas specific to the Gas Works Park site were identified from existing site data; these are listed in the lower left corner of Figure 3-1. These suspected sources are related to activities that occurred during the operation of the manufactured gas plant (MGP) at what is now the Gas Works Park site. A brief description of each suspected source area follows.

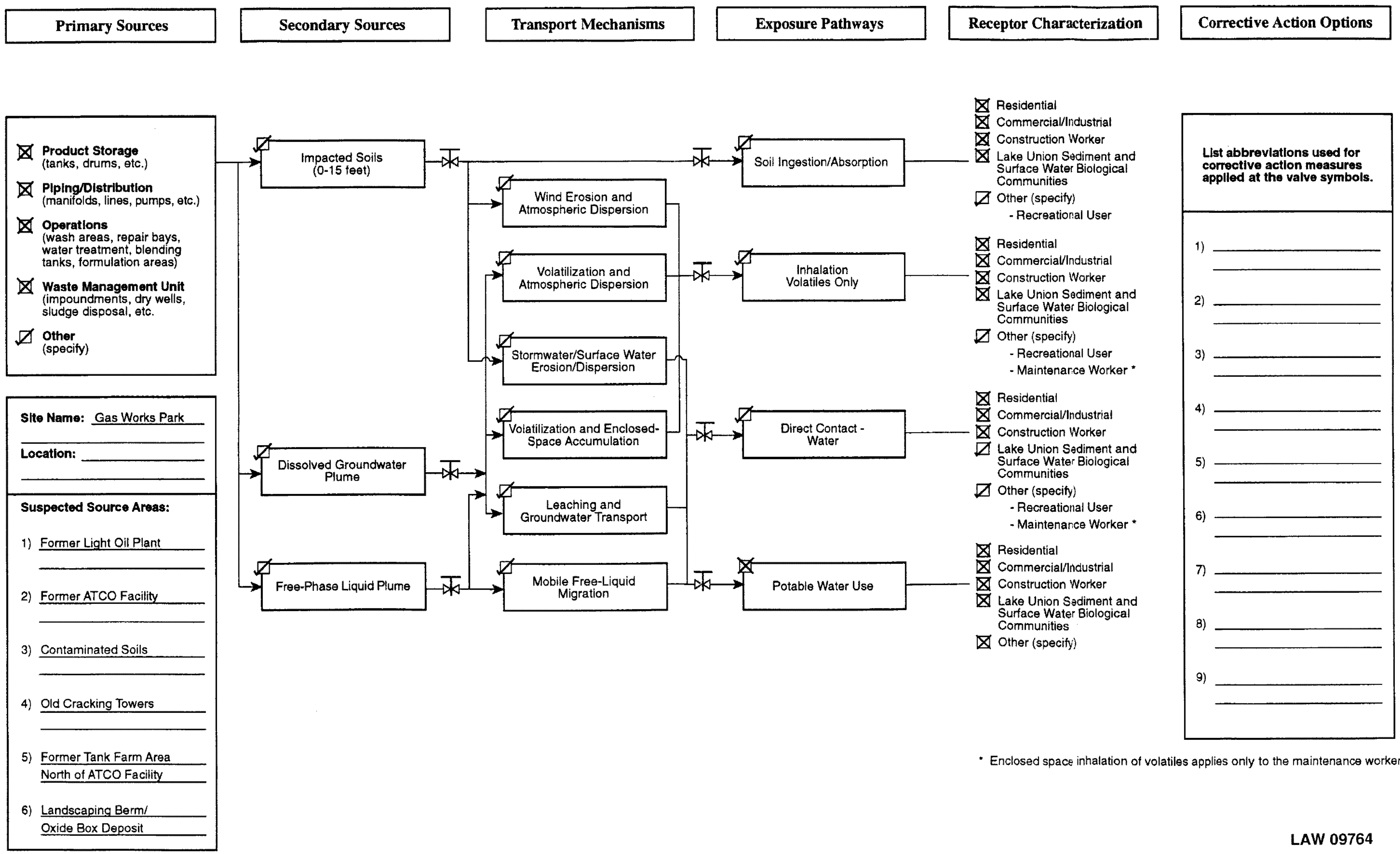

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Figure 3-1.
Composite Conceptual Site Model

Former Light Oil Plant

The MGP operation included a light oil plant that was located immediately east of the Old Cracking Towers and south of the present-day Play Barn (see Figure 2-1). Light oils were removed from the gas by the light oil scrubber (located adjacent to present-day monitoring well MW-9) and stored in tanks formerly located in the southwest corner of the present-day park. This tank farm reportedly included a 122,000-gallon benzene storage tank (Tetra Tech, June 1987).

Former ATCO Facility

Coal tar and creosote produced at the MGP in the early 1900s was delivered to the American Tar Company (ATCO) plant, formerly located immediately north of present-day Kite Hill (see Figure 2-1). ATCO used a steam distillation process to refine the tar into various grades of tar and pitch. Tar seeps observed seasonally on the northern slope of Kite Hill are likely attributable to buried residual tar from this suspected source area.

Contaminated Soils

A 1989 study by the U.S. Geological Survey identified a geologic layer comprised of MGP-derived waste materials (including tar, oily residues, cinders, brick fragments, and wood chips) mixed with soil. The USGS referred to this layer as the "Gas Works deposit" and described the unit as occurring throughout most of the site, at a thickness of up to 9 ft. Artificial fill (put in place when the park was constructed) of variable thickness overlies the Gas Works deposit.

Old Cracking Towers

The fenced area in the south central part of Gas Works Park contains original structures from the MGP collectively referred to in the Draft Environmental Impact Statement (Parametrix, Inc., November 1989) as "Old Cracking Towers." These structures are grouped into clusters of process units (including oil gas generators, wash boxes, and primary and secondary scrubbers) that facilitated the "cracking" of crude oil into natural gas and various by-products. Residual contaminants may be present in these former process vessels and in the underlying soils. Although institutional controls (fencing) presently limit direct access to this area, the potential exists for migration of contaminants from the Old Cracking Towers.

Former Tank Farm Area North of ATCO

A tank farm that reportedly stored No. 4 and No. 5 oil was formerly located in the northwest corner of the present Gas Works Park site (Tetra Tech, June 1987; see Figure 2-1). Monitoring well MW-2, drilled in the central part of this area, encountered a "tarry material" in soil samples to a depth of at least 14 ft.

Landscaping Berm/Oxide Box Deposit

Waste materials that included oxide wood chips, oil spill material, and tar-saturated soil were reportedly deposited within the landscaping berm northeast of Kite Hill during construction of Gas Works Park (Tetra Tech, June 1987; see Figure 2-1). The wood chips are residuals from the former "oxide boxes" or "dry boxes" that were filled with wood chips coated with iron oxide. The scrubbed gas was passed through the wood chips to remove hydrogen sulfide and hydrogen cyanide.

3.2.1.2 Secondary Sources

Primary source contaminants are thought to have impacted secondary sources including Gas Works Park soils and groundwater. Groundwater secondary sources include both dissolved and free-phase liquid plumes.

3.2.1.3 Transport Mechanisms

Potential transport mechanisms include wind erosion/atmospheric dispersion, volatilization/atmospheric dispersion, surface water erosion/transport, volatilization/enclosed space accumulation, leaching/groundwater transport, and mobile free-liquid migration.

3.2.1.4 Exposure Pathways

On the basis of known site and regional conditions and discussions with the Department of Ecology, use of groundwater beneath the Gas Works Park site as a potable water supply is not feasible: therefore the "Potential Water Use" box was eliminated.

3.2.1.5 Receptor Characterization

The sole receptors specific to Gas Works Park are recreational users and maintenance workers on the upland portion of the park, and Lake Union sediment and surface water biological communities. All other receptors were eliminated from consideration.

3.2.2 Conceptual Site Models for Primary Source

Using the composite conceptual site model (see Figure 3-1) as a guide, conceptual site models were developed for each identified primary source, as shown on Figures 3-2 through 3-7. Only model components (boxes) that pertained to each specific source were retained in each model.

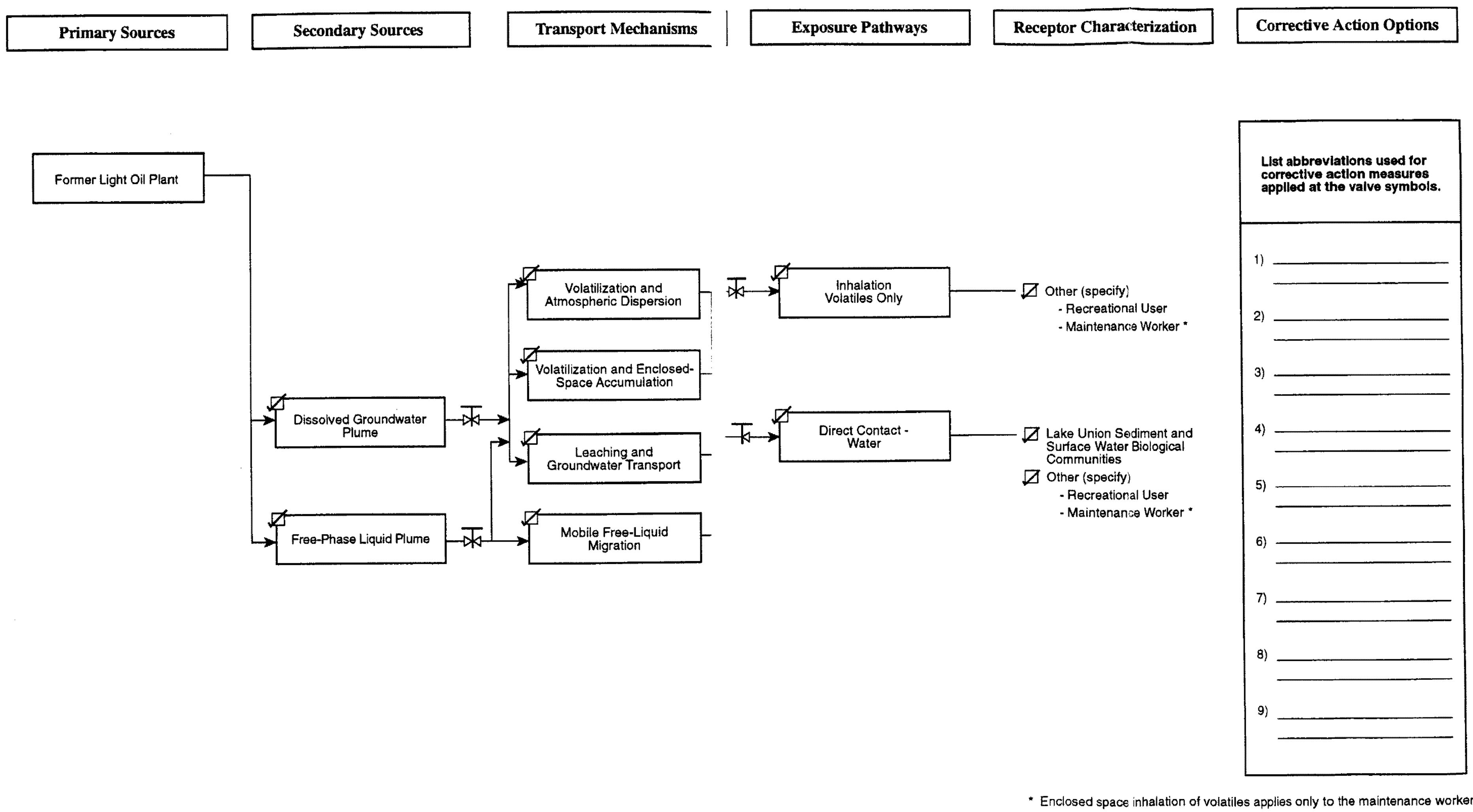

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Figure 3-2. Conceptual Site Model, Former Light Oil Plant

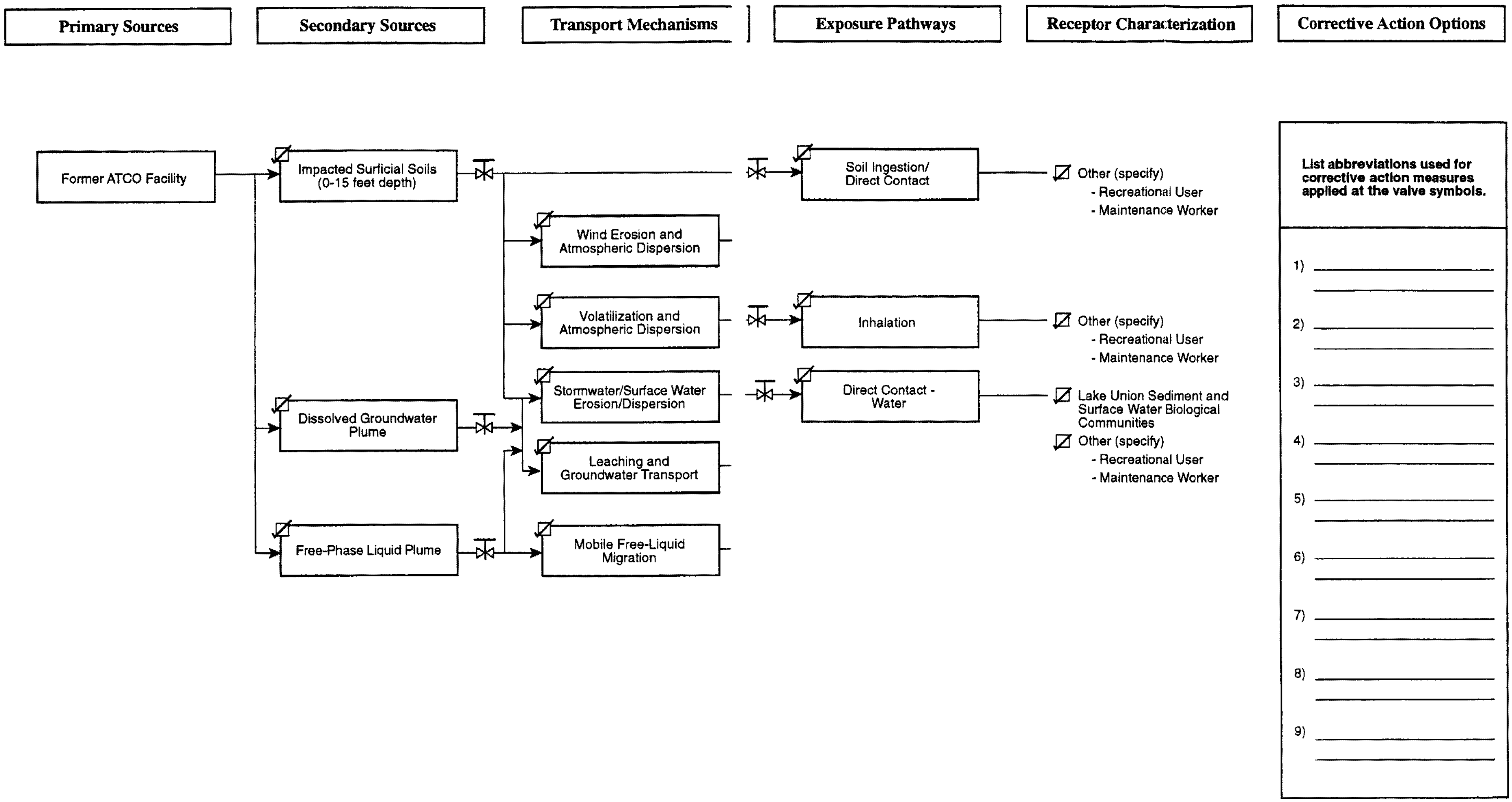

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Figure 3-3.
Conceptual Site Model,
Former ATCO Facility

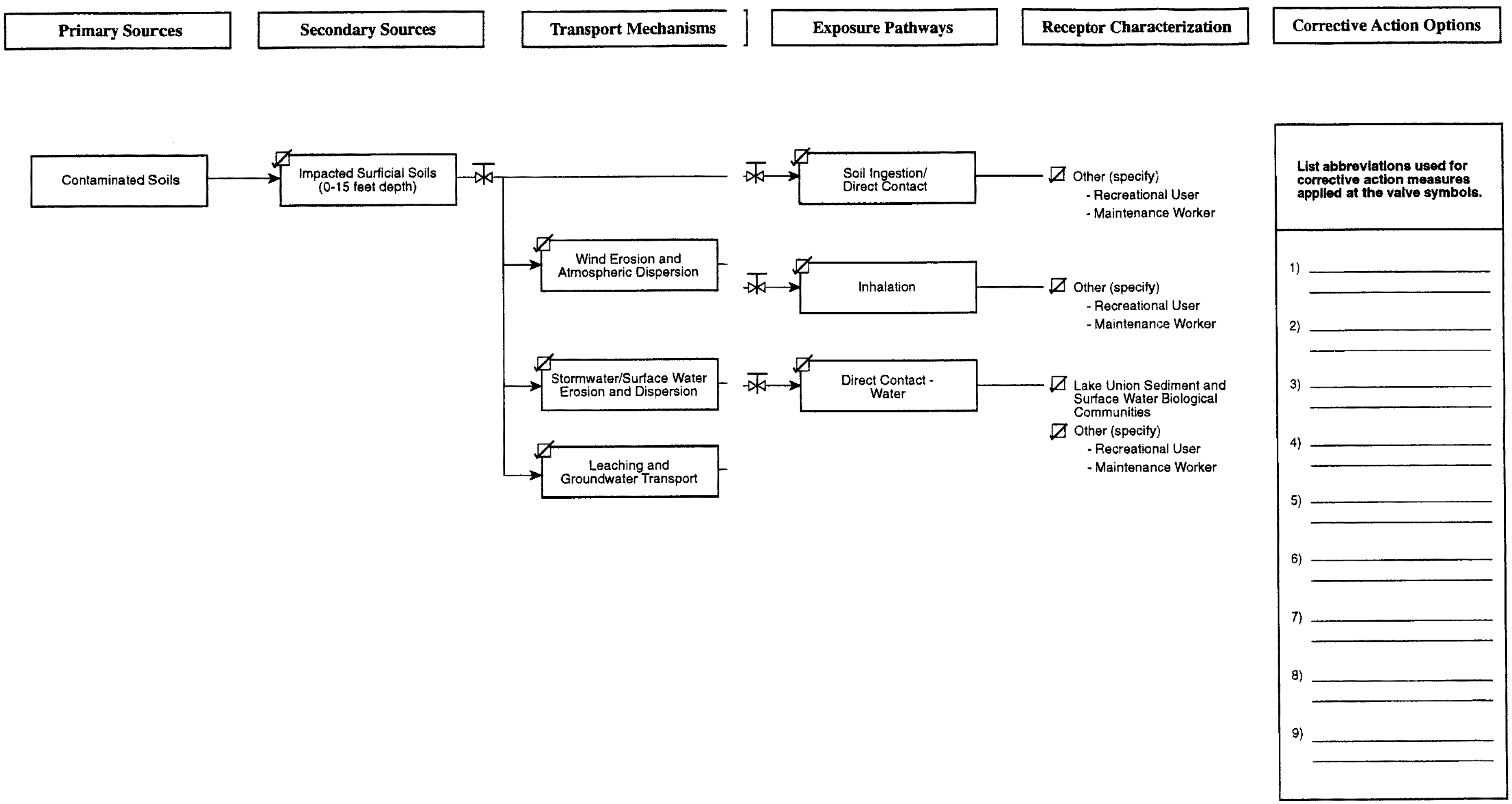

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Figure 3-4.
Conceptual Site Model, Contaminated Soils

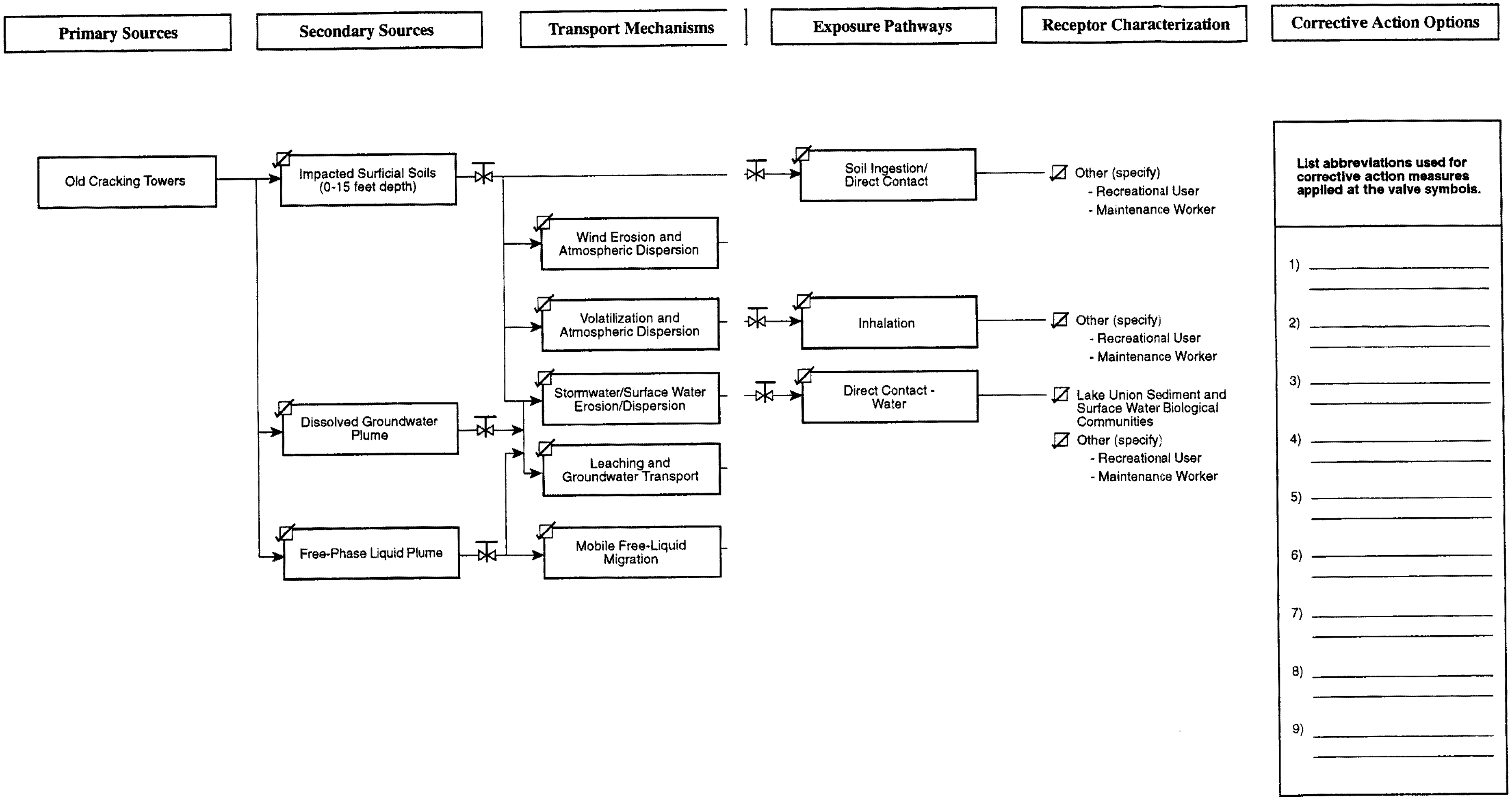

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Figure 3-5.
Conceptual Site Model,
Old Cracking Towers

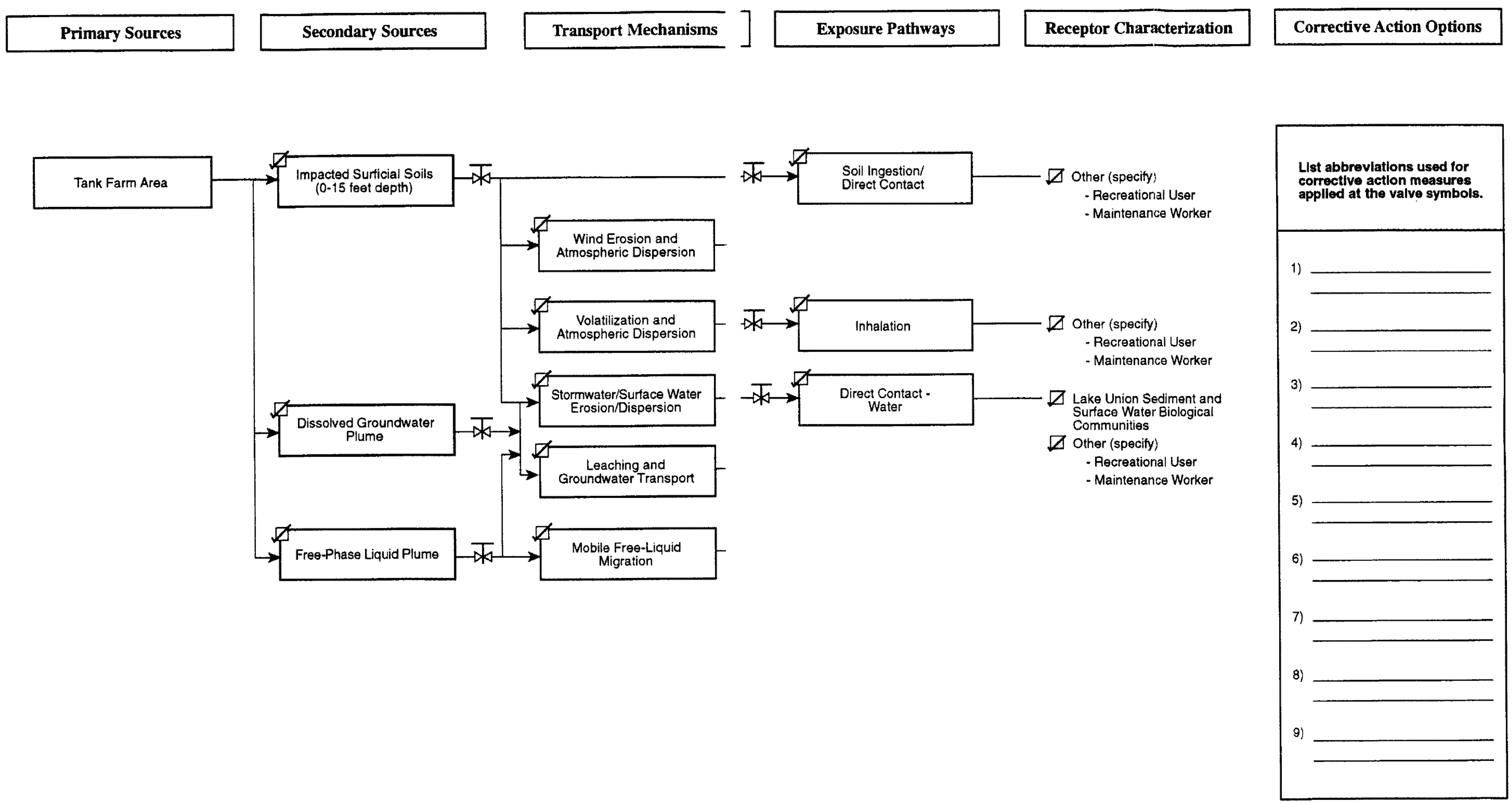

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Figure 3-6.
Conceptual Site Model, Former Tank Farm Area

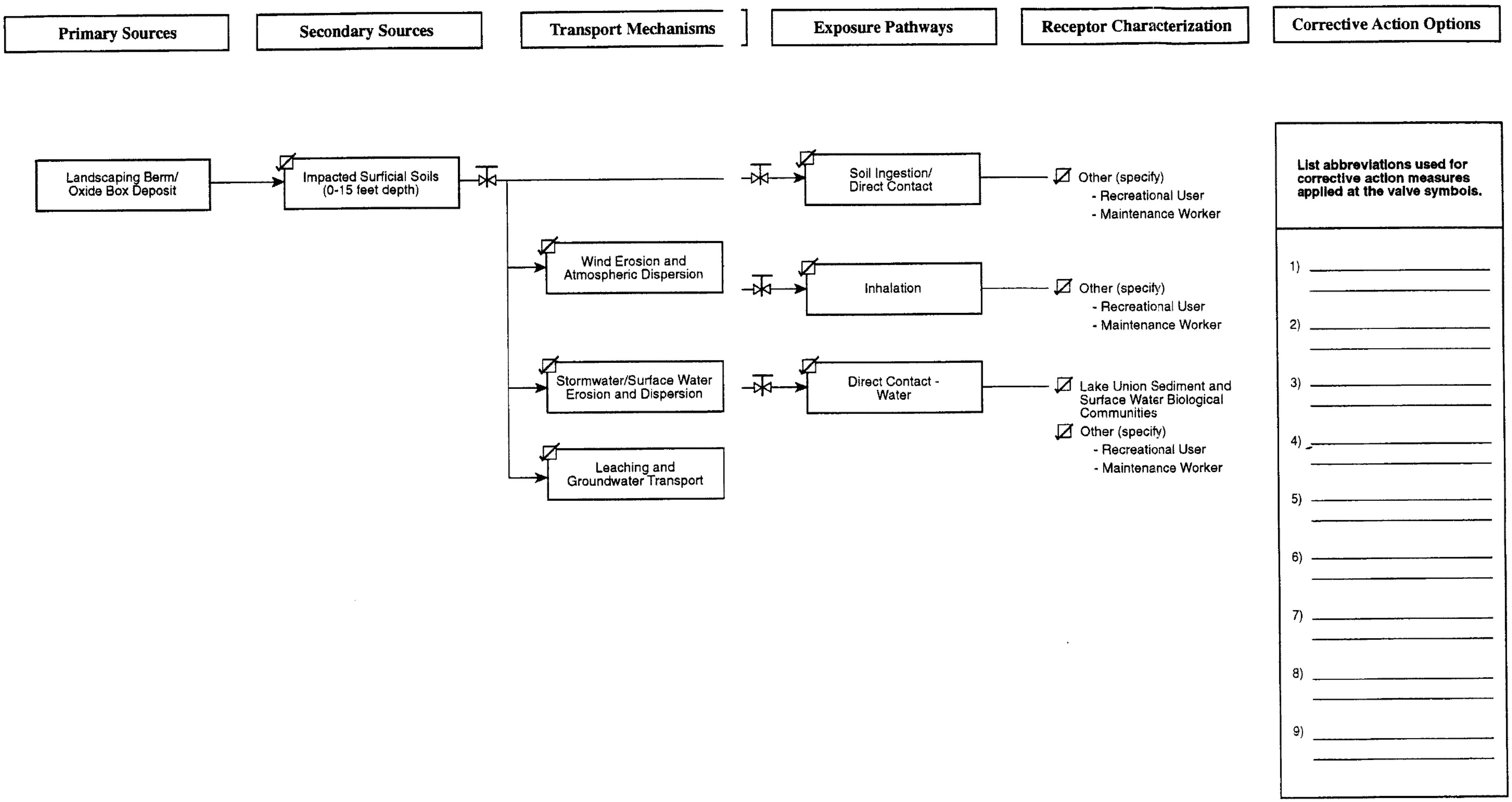

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Figure 3-7.
Conceptual Site Model,
Landscaping Berm/Oxide Box Deposit

4. IDENTIFICATION AND SCREENING OF REMEDIAL ALTERNATIVES

4.1 OBJECTIVES

The objective of this task was to perform a preliminary identification and screening of potential remedial alternatives applicable for site soils and groundwater. The screening is intended to evaluate remedial alternatives potentially applicable for Gas Works Park based on a conservative set of cleanup goals. The constituents of interest (COI) and their respective Method B Cleanup Levels, potential exposure pathways and receptors used to target the areas for remediation are based on the information presented in previous sections. Also included for comparison purposes are potential remedial alternatives that address a less conservative cleanup goal scenario than the MTCA Method B Cleanup Levels.

4.2 SCREENING CRITERIA

4.2.1 Selection of Contaminant Indicator Parameters

Data from previous studies, the compilation of MTCA Method B Cleanup Levels, and the development of the conceptual site model established a base for selecting indicator parameters, to define the impacted media that were considered in the development and screening of remedial alternatives.

The primary COI related to the coal gasification, by-product, and oil gas operations include polynuclear aromatic hydrocarbons (PAHs), volatile organics compounds (VOCs), trace metals, and cyanide. Other classes of COI have been detected at the site and include pesticides and polychlorinated biphenyls (PCBs). Tables 2-1 through 2-3 summarized the detected concentrations of COI and included the frequency at which those concentrations exceed Method B Cleanup Levels. Carcinogenic PAH compounds were most frequently above Method B Cleanup Levels for soil. Other compounds detected above the MTCA Method B soil cleanup level were arsenic, PCBs, and pesticides. These were not selected as indicator parameters because of their relatively lower concentrations with respect to Cleanup Levels.

In groundwater, benzene and naphthalene were selected as indicator parameters. This selection was based on their greater frequency of detection compared to other compounds and their concentration relative to Method B cleanup levels for surface water.

4.2.2 Summary of Exposure Pathways and Potential Receptors

According to the site conceptual model, the pathways and potential receptors that will have to be addressed have been refined to the following for the respective media:

Media	Pathway	Receptor
Soils	Ingestion/Direct Contact Inhalation	Recreational User/Maintenance Worker Recreational User/Maintenance Worker
Groundwater	Direct Contact (discharge to Lake Union) Inhalation (volatiles)	Recreational User/Maintenance Worker Lake Union sediment and surface water biological communities Recreational User/Maintenance Worker

4.2.3 Summary of MTCA Criteria

The initial selection of remedial alternatives for preliminary screening was developed in light of the technologies appropriate to MTCA and those proven effective for similar sites and COI. The criteria used in the screening process were derived from WAC 173-340-360 and were used in combination with site-specific conditions. The MTCA criteria used in the preliminary screening exercise consisted of:

- Technology preference according to MTCA;
- Effectiveness (including permanence and restoration time frame);
- Implementability; and
- Order of magnitude costs.

Community concerns, if any, will also need to be addressed as part of the alternative selection process. However, community concern screening is not included as part of this document, as sufficient information has not been obtained at this point to adequately address this issue.

4.2.4 Other Potential Factors Used in Remedial Alternative Screening

4.2.4.1 General Discussion of DNAPL and Its Potential Effect at Gas Works Park

On-site groundwater has been compared to the MTCA Method B cleanup levels as illustrated in Section 2.0. This comparison indicates that essentially the entire site exceeds the criteria for a number of organic species and for arsenic. Also, DNAPL (dense, non-aqueous phase liquid) has historically been found in three monitoring wells on-site and was recorded in two wells during the recent level measurement event. In addition to the direct evidence of DNAPL, elevated constituent concentration in groundwater in several areas of the site are likely the result of past DNAPL releases.

Coal tar-derived DNAPLs typically have specific gravities of approximately 1.05 to 1.1 and are up to 17 times more viscous than water. These constituents can most accurately be described as slightly DNAPLs, as the specific gravity of the liquids is close to that of water. Combined with their high viscosity, coal tar-derived DNAPLs tend to behave differently in the environment than high-density, low-viscosity DNAPLs more commonly encountered at remedial sites, such as trichloroethylene. Coal tar-derived DNAPLs move much more slowly through the subsurface and respond to a greater extent to hydraulic gradients, in addition to gravitational forces. This results in a significant degree of horizontal migration of coal tar-based DNAPLs. In general, it is very difficult to predict a pattern of occurrence following years of migration.

In addition to being difficult to locate, coal tar-derived DNAPLs tend to have high residual concentrations in saturated zone soils, often on the order of 15% to 30% of the pore volume. This results in a substantial mass of free-phase product remaining in the saturated zone after the mobile fraction of DNAPL has been removed (or has migrated away). EPA has recognized the difficulty of effectively remediating source areas affected by DNAPLs in the Office of Solid Waste and Emergency Response's Directive "Guidance for Evaluating the 1993 Technical Impractibility of Ground-Water Restoration." Several approaches to remediating coal tar-derived DNAPLs have been evaluated. These techniques, including surfactant, solvent, and steam floods, have been proven somewhat effective in reducing the time required to recover the mobile fraction of DNAPL, but have not generally been successful in reducing the mass of DNAPL remaining in the saturated zone beyond that achievable through conventional recovery techniques.

Where present in the saturated zone, coal tar-derived DNAPLs will present a long-term source of organic constituents dissolving into groundwater, and cannot be effectively remediated at this time. Due to this continued source area for dissolved-phase groundwater impacts, remediating the entire groundwater plume will not be practical at Gas Works Park.

While permanent, effective remediation of the entire groundwater plume will not be practical at Gas Works Park, measures to control the discharge of constituents dissolved in groundwater are available. Protection of potential receptors can be achieved through a reduction in the concentration of constituents in groundwater prior to its discharge to Lake Union; through a reduction in the quantity of groundwater discharging to Lake Union; or through a combination of concentration and flow reductions.

4.2.4.2 EPA Presumptive Remedies

EPA has issued as draft guidance a fact sheet entitled, "Presumptive Remedies: Site Characterization and Remedy Selection For Contaminated Soil at Manufactured Gas Plant Sites" (USEPA January 31, 1994). This draft guidance, which was developed on the basis of effectiveness of various remedies, has been taken into consideration in the selection screening of potential alternatives for Gas Works Park.

The fact sheet establishes the following as presumptive remedies for soil contaminated with coal tar at Superfund MGP sites:

- Incineration, and
- Bioremediation followed by capping and/or institutional controls.

Several site-specific factors considered in the application of these at Gas Works Park are discussed in more detail in subsequent sections. The factors include the current and anticipated site use as a public recreational park and the inherent limitations in the application of the presumptive remedies, the advent and refinement of less costly but equally effective technologies, and limitations due to the physical attributes of the site.

4.3 SUMMARY OF SITE-SPECIFIC FACTORS USED IN SCREENING ASSUMPTIONS

This section describes the procedures used to develop estimates of the areas and volumes of soils and groundwater that will need to be remediated at Gas Works Park. Also, the results of the evaluation are tabulated and discussed.

4.3.1 Method B Cleanup Levels

As discussed in Section 4.2.1, based on the screening of site data versus the Method B Cleanup Levels, a number of constituents have been identified that exceed Method B Cleanup Levels in soils and groundwater. These constituents have been evaluated to determine whether any individual constituent(s) exceed the Method B Cleanup Levels to a greater degree site-wide, and could therefore be used as the basis of the alternative analysis. This approach of assigning representative constituents reduces the level of effort required in progressive steps throughout this evaluation, but it still allows detailed evaluation of all constituents based on a selected remedial alternative.

The following table provides an overview of the constituents identified as representative for soil and groundwater at Gas Works Park based on Method B Cleanup Levels:

Media	Constituent Group	Representative Constituent
Soil	Carcinogenic PAHs	Benzo(a)pyrene
Groundwater	Non-Carcinogenic PAHs BETX	Naphthalene Benzene

Isoconcentration plots based on linear interpolation (a conservative approach given the log-normal distribution of constituent concentrations normally associated with remedial site data) have been prepared for each of these media and representative constituents. These isoconcentration plots provide a means of identifying areas on-site likely to exceed a given constituent concentration. Using this approach facilitated a relatively automated estimation of the areal extent and volume of surficial soils exceeding the Method B Cleanup Levels for the representative constituents.

4.3.2 Soils

Cleanup measures for contaminated soils at Gas Works Park could include measures to contain impacted soil, measures to treat those soils in situ, and/or use of a number of other technologies that require prior excavation of impacted soils. Development and evaluation of each alternative approach requires that the areas and volumes of impacted soil be defined. Since this Phase I effort is intended to provide input for future planning purposes, it was determined that use of a range of reasonable soil contaminant concentration values would be most beneficial to this process. This range was developed using two approaches as described below.

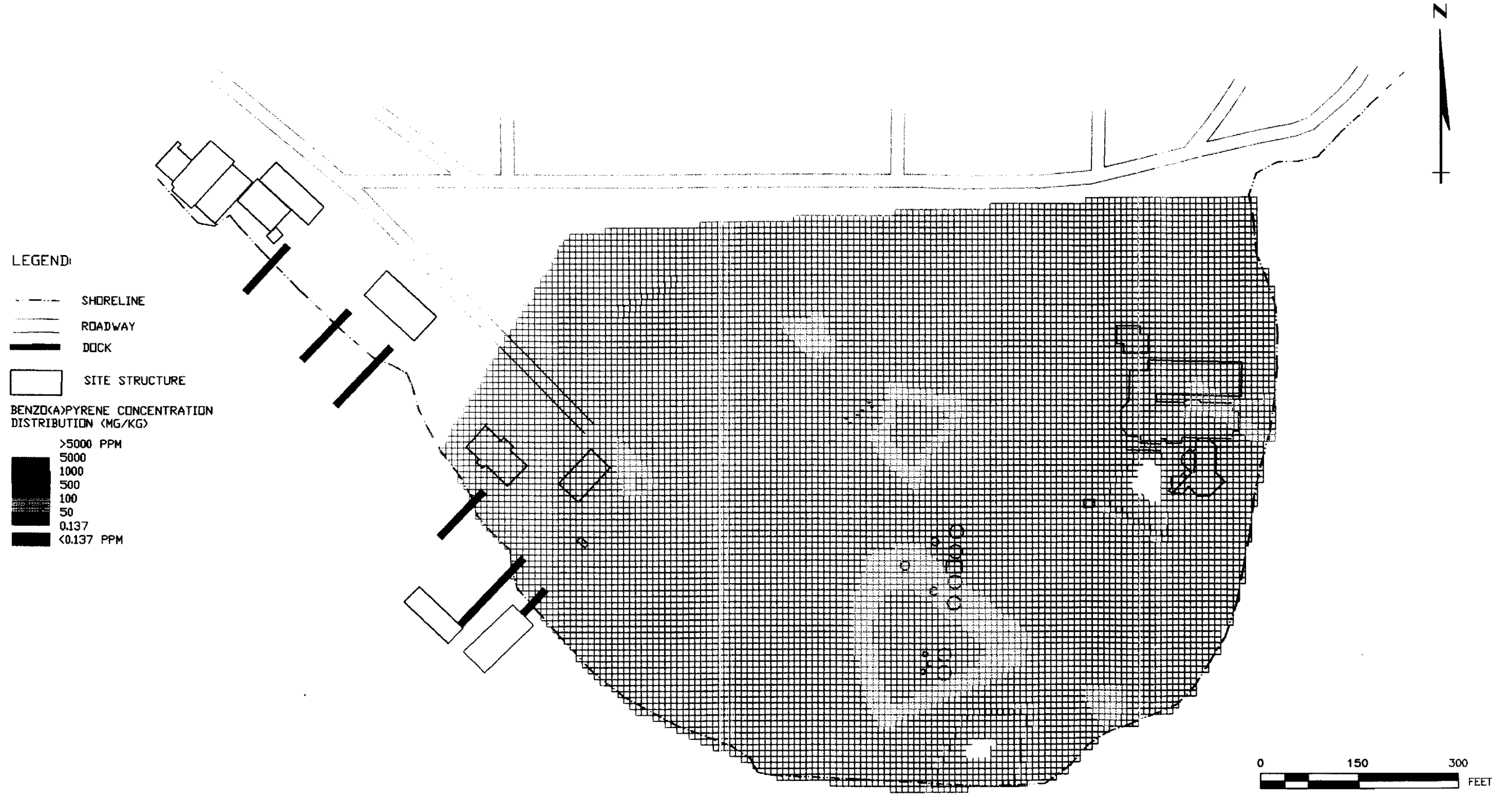
First, the upper end of the areal extent of impacted soil was developed by comparing the site data to the Method B Cleanup Level for benzo(a)pyrene in residential soil. As was shown in Tables 2-1 and 2-2, 99% of the surface soil and 94% of the subsurface samples from the site exceed the Method B cleanup levels for benzo(a)pyrene in residential soil. The resultant areal extent of impacted soil using this conservative approach is the entire 20.5-acre park, as illustrated by Figure 4-1. Because 25% of the park area is currently covered with hard surface (parking lots, roads, structures) which limit exposure of the soils, an area of 154 acres is used for estimating soil quantities and cover area.

A less conservative approach was then developed to focus on potential soil "hot spots" at the site. Figure 4-1 clearly illustrates that soil concentrations are not uniform across the site and that areas of comparatively higher concentration can be defined. For this initial assessment, a concentration of 50 mg/kg was selected as the basis for defining these hot spots. The 50 mg/kg level of benzo(a)pyrene is not based on a site-specific risk calculation, but rather has been selected to clearly depict "hot spots" evident through the evaluation of surface soil data. The area represented by a benzo(a)pyrene concentration in soil above 50 mg/kg is approximately 2.3 acres, or about 1/10 of the total park area (see Figure 4-1).

Each area of impact can then be converted to a soil volume by assigning a depth of excavation. The resultant soil volume depends upon the depth of excavation assumed. For purposes of this document, a 2-ft excavation depth was selected. MTCA defines the point of compliance for soil, based on direct contact, as the upper 15 ft (WAC 173-340-740(6)(c)). Use of the shallower 2-ft depth for this volume analysis will be supported by implementation of deed restrictions on the Gas Works Park property to prohibit deep excavation and re-distribution of soil. Using the 2-ft excavation depth, the range of soil volumes reasonably associated with cleanup of Gas Works Park ranges from a high of 49,700 yd^3 (based on excavating the 15.4-acre vegetated park area) to a lower estimate of 8,200 yd^3 (based on excavating the 2.3-acre "hot spots").

4.3.3 Groundwater

Cleanup measures for contaminated groundwater at Gas Works Park can be grouped into two general classes: in situ measures, involving containment and/or treatment without removal from the ground; and pump and treat measures, involving pumping groundwater out of the ground for



LAW 09778

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GAS WORKS PARK
SEATTLE, WASHINGTON

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CHKD:	DATE:	
APPD:	DATE:	
SCALE:	1"=150'	

SHALLOW SOIL ISOCONCENTRATION DISTRIBUTION OF BENZO(A)PYRENE (MG/KG)
REMEDIAL ALTERNATIVE SCREENING
SEATTLE, WASHINGTON

REMEDIAL ALTERNATIVE SCREENING
PARAMETRIX, INC.

DRAWING NUMBER 96-111
FIGURE 4-1

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1			
2			
3			

treatment in external facilities. Development and evaluation of each alternative approach requires that the areas and volumes of impacted groundwater be defined.

Volume estimates for impacted groundwater are based on the estimated flow rate of groundwater migrating from impacted areas to Lake Union. This approach is consistent with the discussion provided in Section 4.2.4.1 concerning DNAPL as a continuing groundwater contaminant source and the impracticability of remediating entire groundwater plume volumes.

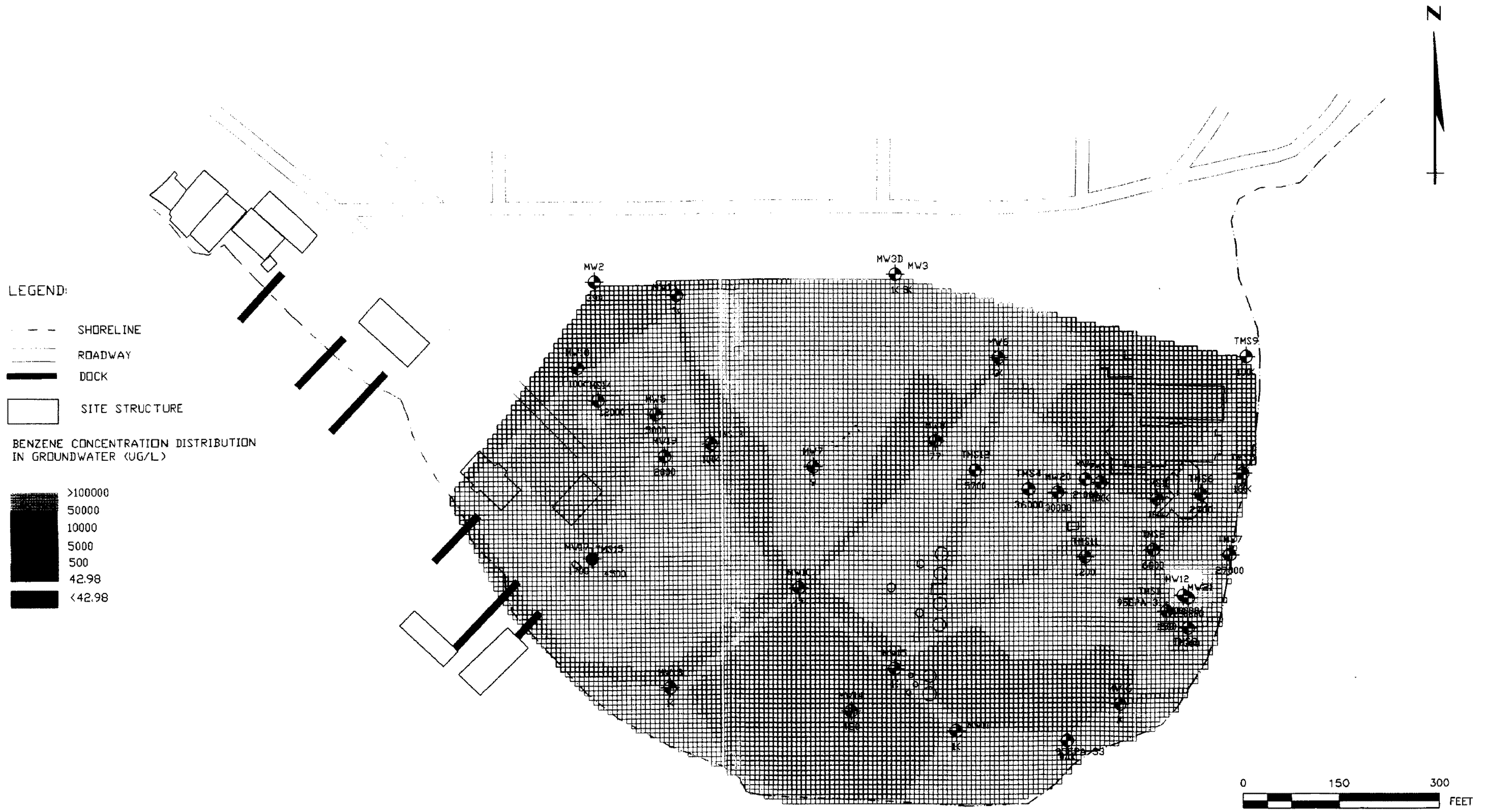
Since this Phase 1 effort is intended to provide input for future planning purposes, it was determined that using a range of reasonable groundwater contaminant concentration values would be most beneficial. This range was developed using two approaches described below.

First, the upper end of the areal extent of contaminated groundwater was developed by comparing the site data to the Method B cleanup levels for benzene and naphthalene. Groundwater isoconcentration plots for benzene (Figure 4-2) and naphthalene (Figure 4-3) indicate similar areas of contaminant concentration exceeding Method B cleanup levels. The resultant areal extent of impacted groundwater using this conservative approach is the entire surficial area of the 20.5-acre park (15.4 acres vegetated), a lineal extent of contaminant concentration exceedance along the Lake Union shoreline of approximately 1,900 ft, and a total estimated flow rate of contaminated groundwater approximating the site-wide estimate of 14.5 gpm by Tetra Tech (1987).

A less conservative approach was then developed to focus on potential groundwater "hot spots" at the site. Figures 4-2 and 4-3 clearly illustrate that groundwater concentrations are not uniform across the site and that areas of higher concentration can be defined. For this initial assessment, a concentration of 500 μg/L of benzene was selected as the basis for defining these hot spots. The 500 μg/L level of benzene is not based on a site-specific risk calculation, but rather has been selected to clearly depict "hot spots" evident through the evaluation of groundwater data. The two areas represented by benzene concentrations in groundwater above 500 μg/L total approximately 8.8 acres (see Figure 4-2), which corresponds to a lineal extent of contaminant concentration exceedance along the Lake Union shoreline of approximately 560 ft, and an estimated groundwater flow rate to Lake Union of approximately 4.3 gpm.

4.4 METHODOLOGY FOR INDIVIDUAL ALTERNATIVE SCREENING

In Sections 4.5 through 4.7 of the report, alternatives are identified for soil and groundwater (the media of interest) and each alternative is described and screened based on the screening criteria. Due to the different media volumes that result from the Method B Cleanup Levels or a risk-based approach, the cost screening identifies unit costs or general lump sum costs only. The total costs by media for each of the alternatives are summarized in tables at the end of the alternative screening.



LAW 09780

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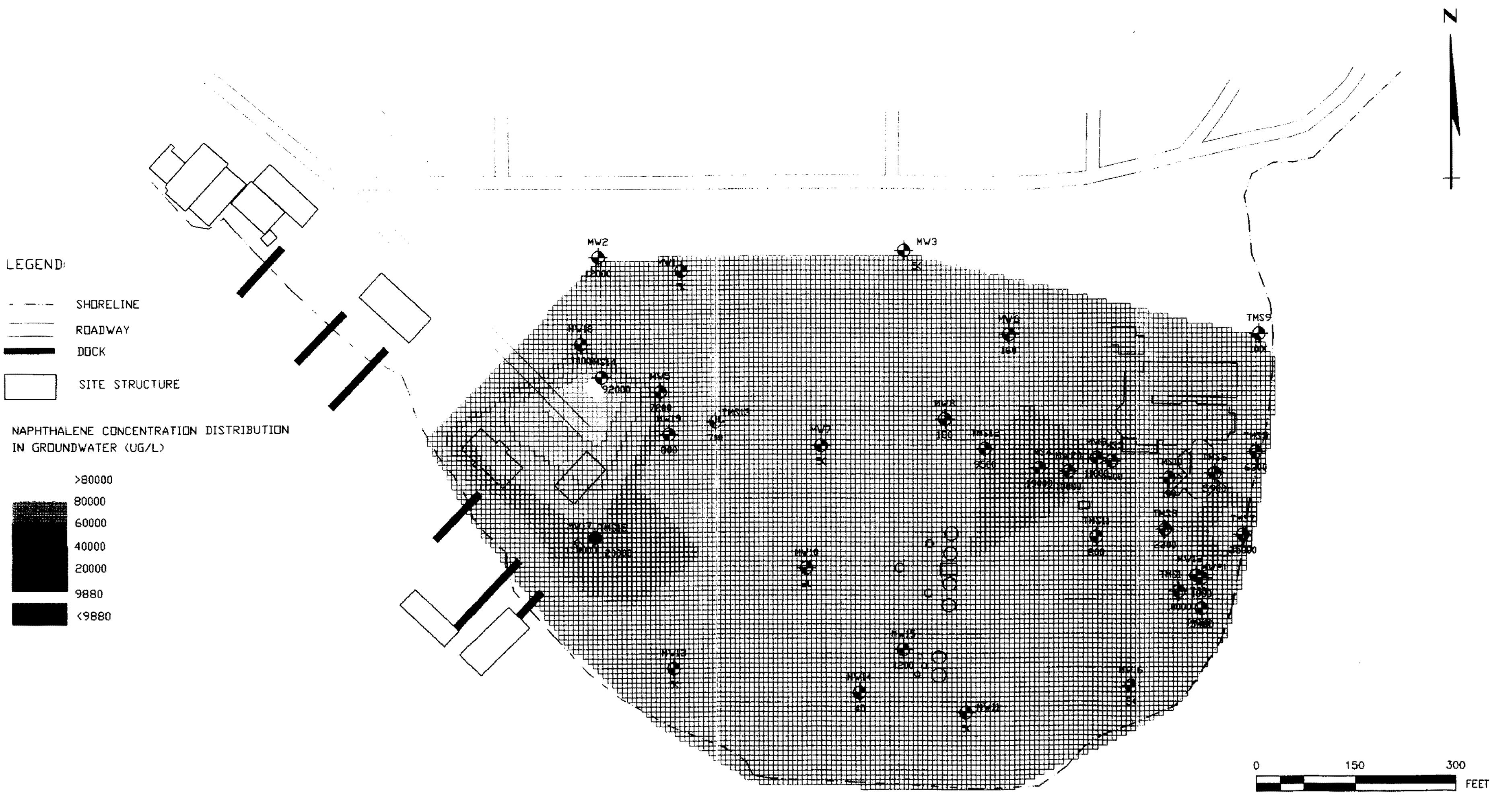
SHALLOW GROUNDWATER ISOCONCENTRATION DISTRIBUTION OF BENZENE (UG/L)
REMEDIAL ALTERNATIVE SCREENING
SEATTLE, WASHINGTON

REMEDIAL ALTERNATIVE SCREENING
PARAMETRIX, INC.

DRAWING NUMBER 96-111
FIGURE 4-2



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CITY OF SEATTLE
GAS WORKS PARK
SEATTLE, WASHINGTON

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SCALE:	1"=150'

KEY ENVIRONMENTAL INCORPORATED

SHALLOW GROUNDWATER ISOCONCENTRATION DISTRIBUTION OF NAPHTHALENE (UG/L)
REMEDIAL ALTERNATIVE SCREENING
SEATTLE, WASHINGTON

REMEDIAL ALTERNATIVE SCREENING
PARAMETRIX, INC.

DRAWING NUMBER 96-111
FIGURE 4-3

4.5 PRELIMINARY SCREENING OF ALTERNATIVES FOR SOILS

4.5.1 In-Place Cover

In-place cover includes minor grading of impacted soils, followed by cover with clean material. Several ancillary tasks, including installation and maintenance of erosion and sedimentation control measures, are required to implement a surficial cover. This remedial action is generally designed to eliminate direct contact with impacted surface soils, and therefore is considered an engineering control. Institutional controls including deed restrictions to control future site uses are often combined with an in-place cover. Cover may be used at Gas Works Park in conjunction with removal of heavily contaminated or tar-like solid materials occurring in limited areas of the site.

4.5.1.1 Technology Preference per MTCA

In-place cover is primarily an isolation technique, and therefore ranks sixth out of seven in technology preference under MTCA. However, this alternative does allow for continued beneficial use of impacted soil as fill on-site, which can be considered a preferred use for this environmental media. Therefore, this alternative does include a beneficial reuse of material, which is the most preferred technology under the MTCA preference (WAC 173-340-360 (4)(a)). The possible exception to the reuse argument would be the tar-like materials, which are not suitable for fill material due to their plastic nature. These materials could potentially be isolated through implementation of a cover; however, they would not be effectively reused for their original purpose.

4.5.1.2 Effectiveness

In-place cover can be effective in eliminating risks due to dermal contact, ingestion, and, to a limited extent, inhalation of volatile constituents (see Section 3 for potential transport mechanisms), and infiltration of precipitation-induced runoff. For the COI at Gas Works Park, dermal contact and ingestion are the only significant risks posed by surficial soils (no VOCs have been detected in surficial soils exceeding the Method B Cleanup Levels).

Surficial cover can be implemented quickly; however, short-term disturbance to the park users would occur. This remedy can be implemented to achieve improvements in the park through consideration of future uses and appropriate landscaping and design. A number of options for installation of a surficial cover can be implemented, including simple vegetative cover, structural fill (aggregate) cover, and specialized park use covers (such as asphaltic parking surfaces, boardwalks, non-accessible plantings, etc.). The effectiveness of these cover options can be enhanced through inclusion of a geotextile or similar barrier between the impacted surficial soils and the clean cover. The optional barrier prevents mixing of the clean and impacted materials by natural forces and biota, and also serves as an indicator layer should the cover be eroded over time.

4.5.1.3 Implementability

Surficial cover is technically implementable. Implementation does require planning for future site use, erosion and sedimentation control, storm water run-off, and control of precipitation-induced infiltration. However, these requirements are common to all invasive alternatives, and should be readily achievable for Gas Works Park. Installation of a surficial cover may be limited in some instances by steep slopes (i.e., the sides of Kite Hill), although design changes such as the inclusion of a geogrid could address these limitations.

4.5.1.4 Order-of-Magnitude Costs

Basic vegetated surficial cover, not including a geotextile barrier, is estimated to cost between $100,000 and $125,000 per acre, which includes minor grading, 2 ft of topsoil cover, final grading and raking, seeding and mulching, and erosion control measures for the project duration. The addition of a geotextile barrier would add approximately $10,000 per acre. Alternative park use options would need to be evaluated individually to develop more accurate cost information. As noted above, this alternative would likely be combined with limited source removal of tar-like materials and potentially more highly impacted soils. Costs to remove and reuse or dispose of these materials off-site are provided below in the discussions of these alternatives.

4.5.2 <u>In-Place Capping</u>

In-place capping includes minor grading of impacted soils, followed by installation of a low-permeability physical barrier system incorporating a flexible membrane liner or soil (clay) barrier, along with support components such as geotextile layers, fine aggregate (sand) protective layers, and in some cases, drainage layers. A vegetative cover is generally placed over the low-permeability layer, although other cover options suitable for the future site use could be considered. A number of ancillary tasks, including installation and maintenance of erosion and sedimentation control measures, are required to implement a surficial cap. This remedial action is generally designed to eliminate direct contact with impacted soils, reduce or eliminate precipitation based infiltration, and prevent volatile constituent emissions, therefore, the in-place cap alternative is considered an engineering control. Institutional controls including deed restrictions to control future site uses are often combined with an in-place cap.

4.5.2.1 Technology Preference According to MTCA

In-place capping is primarily an isolation technique, and therefore ranks sixth out of seven in technology preference. However, similar to the in-place cover alternative, this alternative does allow for continued beneficial use of impacted soil as fill on-site; this can be considered a preferred use for this environmental media. Beneficial reuse of material, which is the most preferred technology under MTCA, is also provided by this alternative.

4.5.2.2 Effectiveness (Including Permanence and Restoration Time Frame)

In-place capping is generally effective in eliminating risks due to dermal contact, ingestion, and inhalation of volatile constituents. For the constituents of concern at Gas Works Park, dermal contact, ingestion, and volatization are the only significant pathways posed by surficial soils. Unlike the surficial cover alternative discussed above, a cap would significantly reduce precipitation-based infiltration and potential constituent leaching to groundwater. The value of the reduction in infiltration rates associated with a surficial cap will need to be assessed based on the evaluation of remedial alternatives for groundwater.

In-place capping can be implemented quickly; however, short-term disturbance to the park users would occur. Low-permeability caps are generally more permanent than in-place covers. Synthetic membrane liner systems (including geotextile protective layers) are particularly suitable to vegetated areas, as multiple physical barriers and warning layers are present. Potential cover options and future site uses are more limited with the in-place cap alternative than with the in-place cover alternative, as heavy equipment loads are generally avoided in capped areas.

4.5.2.3 Implementability

Implementation of an in-place cap is considered technically achievable. Steep slopes and widely uneven terrain may require additional grading and/or special construction techniques. Implementation would require planning for future site use, erosion and sedimentation control, and storm water run-off design. However, these requirements should be readily achievable for Gas Works Park.

4.5.2.4 Order-of-Magnitude Costs

A single synthetic membrane liner cap including two geotextile layers and a total of 12 inches of fine aggregate (or a synthetic drainage layer) and a vegetative cover suitable for foot traffic (12 inches of select fill and 6 inches of topsoil) is estimated to cost approximately $350,000 per acre, which includes minor initial grading, final grading and raking, seeding and mulching, and erosion control measures for the project duration. Alternatives using native low-permeability materials or improved strength for greater heavy equipment loads would need further evaluation.

4.5.3 <u>Biodegradation—In Situ or Ex Situ</u>

Biodegradation is an enhancement to the natural process of biological degradation of constituents. This process is effective on a range of constituents, mainly organic and some inorganic compounds (cyanides). The constituents of concern at Gas Works Park are generally amenable to biodegradation in soils, with the exception of metals, mainly arsenic.

Biodegradation has been promoted as an alternative to address constituents at MGP sites for some time. EPA has included biodegradation followed by capping and/or institutional controls as an overall remedial action in the 1994 draft guidance document regarding presumptive remedies for MGP sites (as previously discussed in Section 4.2.4.2).

4.5.3.1 Technology Preference According to MTCA

Biodegradation, to the extent that it is effective, is considered a destruction technology. Destruction technologies rank second out of seven in the MTCA cleanup technologies preference ranking. Soils that are either treated *in situ* or *ex situ* and subsequently returned to the site as fill can be considered to be reused for an intended purpose (as fill), and therefore would at least partly qualify as a beneficial reuse, which is the most preferred technology type under MTCA.

4.5.3.2 Effectiveness (Including Permanence and Restoration Time Frame)

Biodegradation has been found to be effective at some MGP sites. However, the technology has proven slow and unreliable when carcinogenic PAHs are present at levels greatly exceeding the remedial goals for the site. In general, biodegradation is most suitable for sites that exhibit mean constituent concentrations near or below the remedial goals, but which require remediation due to hot spots and inconsistent analytical results that increase the data variability. Often reductions in concentration noted during biodegradation projects can not be definitively attributed to biodegradation. If the mechanism of achieving the remedial goal is critical, advanced studies are required during the remedial project to confirm the percentage of constituent reduction achieved through biological mechanisms.

Biodegradation processes range widely in the restoration time frame. *Ex situ* slurry-phase reactors provide the greatest potential kinetic rates, while *in situ* land farming techniques provide the lowest potential kinetic rates. A review of the July 1994 EPA document "Bioremediation In The Field" indicates a number of planned pilot and full scale applications for biodegradation. However, the same document indicates that projects that have proceeded through the pilot- and/or full-scale implementation have exhibited a high rate of failure in meeting remedial objectives. Also, costs to implement biodegradation presented in this document range from approximately $100 to $600 per ton. Biodegradation would likely be effective if the remedial goals and initial mean soil concentrations in the target area are within an order of magnitude.

4.5.3.3 Implementability

Biodegradation is considered technically implementable. Independent vendors are available who can assist in developing either an *in situ* or *ex situ* biodegradation program. A competitive approach may help reduce costs, or a program can be developed to allow local resources available to the City of Seattle to be used to the maximum extent practical. One issue that will need to be addressed, especially for *in situ* options, is the potential for increased constituent migration due to infiltration and the increased mobility of constituents during enhanced biodegradation. The combination of increased infiltration and natural biosurfactant production during biodegradation may result in an increase in loading to groundwater that needs to be addressed, or potentially mitigated, through the use of an *ex situ* approach. Additional considerations that will need to be addressed include the following:

- Duration of treatment and impact on park uses;
- Security of treatment cells;
- Public perception of ongoing treatment process, especially potentially unsightly *ex situ* processes; and,
- Typical construction-related issues including erosion and sedimentation control, storm water run-off control, grading and vegetation, or other end use of treatment areas and/or cells.

4.5.3.4 Order-of-Magnitude Costs

Biodegradation costs typically range from $75 to $400 per cubic yard, with *ex situ* systems typically being more costly than *in situ* systems. *Ex situ* systems have the advantage of better control of potential constituent infiltration to the shallow aquifer on site. A cost of $200 per cubic yard is assumed as a median cost for a biodegradation system with some control of infiltration rates.

4.5.4 Fixation

Fixation refers to the process of mixing site soils and/or wastes with adjuncts designed to reduce the leachability, toxicity, or friability of constituents. Adjuncts typically used include pozzolanic materials (cements), clay minerals (bentonite), and various industrial by-products such as fly ash or kiln dust. Specialty adjuncts are provided by a number of vendors as proprietary products, often designed to reduce the leachability or toxicity of specific classes of constituents.

4.5.4.1 Technology Preference According to MTCA

Fixation is an immobilization technology, and therefore ranks fourth out of seventh in order of preference under MTCA. Depending upon the end use of the materials treated using a fixation technology, a beneficial reuse may also be part of the remedial approach. This is the most preferred approach under MTCA.

4.5.4.2 Effectiveness (Including Permanence and Restoration Time Frame)

Fixation is generally effective for metals and inorganic species such as cyanides. Fixation has been demonstrated to be at least partly effective for semi-volatile organic constituents, especially PCBs and dioxin wastes. Carcinogenic polycyclic aromatic hydrocarbons (PAHs) may not be as effectively immobilized through fixation. However, fixation with pozzolanic materials (cements) can be effective in eliminating exposure pathways due to ingestion and dermal contact by reducing the friable nature of soils. The result is a monolithic mass of hard, durable material.

The permanence of fixation technologies varies depending upon the constituents targeted and the adjuncts employed. Inorganic species are generally fixated through chemical mechanisms. Fixation of materials treated in this manner is permanent, in the absence of an unforeseen environmental disaster such as an acid spill. Organics are generally fixated through physical mechanisms, and fixation for these constituents may be less permanent depending upon erosion, spalling, and similar physical processes which could release the constituents slowly over time.

4.5.4.3 Implementability

Fixation is commonly implemented either *in situ* or *ex situ* to stabilize wet, reactive, or corrosive materials prior to landfill or site closure. Several mixing approaches can be used, including *in situ* methods capable of adding adjuncts and mixing soils in place at depths to 70 ft if required. Fixation generally requires lab-scale testing to develop a suitable mix to achieve the desired treatment levels. Fixation may also include simulated aging studies to estimate the long-term effectiveness of the mix design.

4.5.4.4 Order-of-Magnitude Costs

Fixation costs range widely depending upon the mix design and subsequent cost of adjuncts. Also, the cost of disposal, if applicable, increases with the addition of adjuncts to the soil/waste material. Unit costs for fixation are estimated to range from $25 to $50 per cubic yard.

4.5.5 Asphaltic Road Base Use

Site soils meeting certain physical requirements (hard, granular aggregates are preferred; clays and silts cannot be used in significant amounts) can be blended with asphaltic materials to create materials suitable for use as a road base. Either a cold-mix process, which uses a bituminous/water emulsion, or a hot-mix process, using an emulsion or straight bituminous asphalt, can be used. The cold-mix processes have the advantage of reduced volatile constituent emission and lower equipment costs. Hot-mix processes generate higher-strength road base materials and handle tar-like materials better, as the heat may effectively melt the tars into the asphaltic concrete matrix.

4.5.5.1 Technology Preference According to MTCA

This technology is an immobilization technology, which ranks fourth out of seven in preference under MTCA. Also, this technology generally includes beneficial reuse of the processed soils and wastes as on-site road base. Reuse is the most preferred approach under MTCA.

4.5.5.2 Effectiveness (Including Permanence and Restoration Time Frame)

Asphaltic emulsion processes are typically effective in reducing the leachability of both metals and organic constituents of interest, mainly through physical processes. However, this process is not effective in reducing the total concentration of organic constituents (especially PAHs) which are present in significant concentrations in asphaltic products. Therefore, this technology can only be successful when the reduced risks associated with the reduction in the leachability of constituents and the friability of the treated soils/wastes can be demonstrated.

This technology can be implemented relatively quickly. The permanence of this approach depends upon the end use, and will generally be long-lived if the road base is used for a permanent roadway.

4.5.5.3 Implementability

One major limitation in the implementation of this alternative is the extent of surficial soils requiring treatment. There may be a need for road-base material for future park uses; however, it is unlikely that a significant portion of the soils exceeding Method B cleanup levels can be used as road base. Also, this alternative would still require some form of cover over areas where soils were excavated for processing, as deeper soils are likely to be impacted to a similar extent. An additional significant implementability issue is the nature of the site soils to be treated. As the targeted surficial soils are a combination of fill, debris, and imported topsoil, it is likely that a considerable percentage of the materials are not ideal for use in generating asphaltic road base. These would need to be addressed separately.

4.5.5.4 Order-of-Magnitude Costs

Costs for excavating, sizing, and processing materials using the asphalt process are estimated to range from between $105 and $140 per cubic yard, depending upon the availability of a vendor with the proper equipment and permits to complete the work.

4.5.6 Excavate, Transport and Reuse Off-Site, Replace with Clean Fill On-Site

This alternative includes the excavation of target materials, loading, material transportation off-site, off-site reuse of the materials, placement of clean fill on-site, and establishment of vegetation or other surface treatments. A number of associated tasks related to evaluation of the material suitability for off-site processing/re-use would be necessary prior to implementation of this alternative. Depending on the physical and chemical nature of the soils, the site materials could be used as a fuel supplement at an industrial/utility boiler, to provide minerals at a cement kiln or clay manufacturing facility, or recycled as feedstock at a coke or coal tar by-products facility (tar-like materials only).

4.5.6.1 Technology Preference According to MTCA

This alternative is a reuse or recycling technology. Reuse or recycling technologies rank first out of seven in the MTCA cleanup technologies preference ranking. Some of these options would also result in the destruction of constituents, an option that is ranked second under MTCA.

4.5.6.2 Effectiveness (Including Permanence and Restoration Time Frame)

The reuse technologies are extremely effective in processing the materials to eliminate or concentrate the constituents of interest. The materials would be removed from the site and thus permanently eliminate associated risks. This technology can be implemented following the completion of site investigations and treatability testing by the various vendors.

4.5.6.3 Implementability

One major limitation in the implementation of this technology is the amount of surficial soils that would be acceptable for this alternative. Reuse as a fuel requires significant BTU value, which may not be obtained from high-moisture-content soils. The other reuse/recycle options are also dependent on the physical and chemical characteristics of the materials. Reuse/recycling at a coke or by-products facility is more suited for pure-product type materials; therefore, this is not likely to be a feasible option due to the high levels of ash in the soils. Also, this alternative would still require some form of cover for the soils exposed as a result of the excavation activities, since the subsurface soils are anticipated to contain site constituents at levels requiring action.

4.5.6.4 Order-of-Magnitude Costs

Costs for reusing the target materials are estimated to be about $50 per ton at an electric utility boiler and range from between $200 to $400 per ton at a coke or by-product facility (depending on the availability of vendors with the necessary permits and equipment to perform the work). Costs for use as a raw material substitute in cement can be as low as $20 to $40 per ton.

An effort is currently underway to locate local vendors capable of reusing materials from the Gas Works Park. Due to the high cost of transporting materials, this alternative will not be cost competitive with the off-site thermal desorption technology discussed in section 4.5.7, unless an appropriately permitted vendor can be located in Washington or the surrounding states.

4.5.7 Excavate, Transport, Treat or Dispose Of, Replace with Clean Fill On-Site

This alternative includes the excavation of target materials, loading, material transportation off-site, off-site treatment of the materials, off-site disposal, placement of clean fill on-site, and establishment of vegetation or other surface facilities. A number of associated tasks related to evaluation of the materials suitability for off-site processing/disposal would be necessary prior to implementation of this alternative. Primarily, the waste classification of the materials would dictate whether the materials could be landfill directly as a non-hazardous waste, thermally desorbed to achieve the Universal Treatment Standards, or thermally desorbed and delisted followed by beneficial reuse as clean fill.

4.5.7.1 Technology Preference According to MTCA

This alternative ranges from an off-site disposal to destruction or detoxification technology. Off-site disposal technologies rank fifth out of seven in the MTCA cleanup technologies preference ranking. Destruction technologies rank second.

4.5.7.2 Effectiveness (Including Permanence and Restoration Time Frame)

The thermal technologies are very effective in isolating or destroying the constituents of concern. The materials would be removed from the site and permanently eliminate risks associated with these materials. This technology can be implemented following the completion of site investigations and treatability testing by the various vendors.

4.5.7.3 Implementability

One major limitation in the implementation of this technology is the combination of PAHs and arsenic in the target materials. Thermal desorption could effectively remove the PAH compounds, but may not reduce the arsenic concentrations. Thermal treatment technologies may be limited by the capacity of the treatment units available in the Seattle area, and are typically used for smaller volumes of materials. The materials could require additional testing to determine final treatment or disposal. Also, this alternative would still require some form of cover for the soils exposed as a result of the excavation activities, since the subsurface soils are anticipated to contain site constituents at levels requiring action.

4.5.7.4 Order-of-Magnitude Costs

Costs for excavating, transporting, and thermally desorbing the target materials are estimated to be about $60 per ton, depending on the availability of vendors with the necessary permits and equipment to perform the work.

4.5.8 Excavate, Off-Site Landfill, Site Fill

Off-site landfill disposal of the target materials includes excavation, transport, and landfill disposal (without treatment), followed by the placement of clean material to cover the site.

LAW 09790

4.5.8.1 Technology Preference According to MTCA

Off-site landfilling is a disposal technique, and therefore ranks fifth in preference out of seven for cleanup technologies.

4.5.8.2 Effectiveness

Off-site landfilling of the target materials is an effective remedy. This alternative would require an in-place cover. The in-place cover can be effective in eliminating risks due to dermal contact, ingestion and, to a limited extent, inhalation of volatile constituents, as discussed above. Surficial cover would not significantly reduce precipitation-based infiltration to groundwater.

4.5.8.3 Implementability

Off-site landfill disposal is technically feasible; however, the cost to implement this approach may be prohibitive for large volumes. Implementation may require a material blending evaluation to ensure that the target materials would not test as toxicity-characteristic wastes and would be acceptable at a residual waste landfill. Planning will also be required for construction of the surface cover as discussed for the *In-Place Cover* alternative.

4.5.8.4 Order-of-Magnitude Costs

Off-site landfilling transport and disposal costs are estimated to be about $50 per ton for materials that are not toxicity-characteristic residual wastes. The surficial cover is estimated to cost about $100,000 to $125,000 per acre, which includes 2 ft of topsoil cover, final grading and raking, seeding and mulching, and erosion control measures for the project duration. Costs to restore the park have not been included. Alternative park use options will need to be evaluated individually to cost information.

4.5.9 Cost Summary for Soils Alternatives

Table 4-1 summarizes estimated costs to implement the soils alternatives based on Method B cleanup levels. Table 4-2 similarly summarizes selected alternatives based on a higher soil cleanup level (50 mg/kg BAP).

4.6 PRELIMINARY SCREENING OF IN SITU ALTERNATIVES FOR GROUNDWATER

Alternatives for groundwater remediation at Gas Works Park have been organized into two general classes: *In Situ* approaches and *Pump and Treat* approaches. The *In Situ* approaches do not remove the groundwater from its environment, whereas *Pump and Treat* approaches remove the groundwater and bring it to the surface for treatment.

LAW 09791

Table 4-1. Costs for soil alternatives to remediate for Method B cleanup levels, Gas Works Park Site, City of Seattle, Washington.

Alternative	Qty	Unit	Unit $	Total $
In-Place Cover	15.4	Acres	125,000	1,925,000
In-Place Cap	15.4	Acres	350,000	5,390,000
Biodegradation	49,700	CY	200	9,940,000
Fixation				
-Mix and Fix Soils	49,700	CY	50	2,485,000
-Fill/Cover	15.4	Acres	125,000	1,925,000
		Total		**4,410,000**
Asphalt Road Base				
-Process	49,700	CY	140	6,958,000
-Fill/Cover	15.4	Acres	125,000	1,925,000
		Total		**8,883,000**
Off-Site Thermal Desorption				
-Excavate	49,700	CY	10	497,000
-T&D	74,600	Ton	60	4,476,000
-Fill/Cover	15.4	Acres	125,000	1,925,000
		Total		**6,898,000**
Off-Site Landfill				
-Excavate	49,700	CY	10	497,000
-T&D	74,600	Ton	50	3,730,000
-Fill/Cover	15.4	Acres	125,000	1,925,000
		Total		**6,152,000**

Note: Costs do not include restoration of the park facilities, construction contingencies engineering design, construction oversight, or city administration costs.

The *In Situ Groundwater* alternatives reviewed herein consist of the following:

- Natural Attenuation
- Physical Barriers
- Enhanced Biodegradation
- Physical/Chemical Treatment

LAW 09792

Table 4-2. **Costs for soil alternatives to remediate areas exceeding 50 mg/kg benzo(a)pyrene, Gas Works Park Site, City of Seattle, Washington.**

Alternative	Qty	Unit	Unit $	Total $
In-Place Cap	2.3	Acres	350,000	805,000
Fixation				
-Mix and Fix Soils	8,200	CY	50	410,000
-Fill/Cover	2.3	Acres	125,000	288,000
			Total	**698,000**
Asphalt Road Base				
-Process	8,200	CY	140	1,148,000
-Fill/Cover	2.3	Acres	125,000	288,000
			Total	**1,436,000**
Off-Site Thermal Desorption				
-Excavate	8,200	CY	10	82,000
-T&D	12,300	Ton	60	738,000
-Fill/Cover	2.3	Acres	125,000	288,000
			Total	**1,108,000**
Off-Site Landfill				
-Excavate	8,200	CY	10	82,000
-T&D	12,300	Ton	50	615,000
-Fill/Cover	2.3	Acres	125,000	288,000
			Total	**985,000**

Note: Costs do not include restoration of the park facilities, construction contingencies, engineering design, construction oversight, or city administration costs. Costs are based on soil areas likely to exceed 50 mg/kg of benzo(a)pyrene.

Each of these alternatives is reviewed and screened in accordance with the screening criteria defined in Section 4.2. The total cost of each alternative is presented in tables following the screening.

4.6.1 Natural Attenuation

Natural attenuation refers to a combination of naturally occurring processes, including biological and chemical degradation, retardation, dilution, detoxification, and source depletion, which result in the limitation of migration and long-term reduction in concentrations of constituents of concern. Natural attenuation of constituents is often sufficient to meet risk-based cleanup goals. Application of natural attenuation as an alternative requires demonstration of the following:

- The current conditions do not result in an unacceptable risk to receptors;
- The mechanism of natural attenuation is sufficiently well-documented to predict that receptors will not be exposed to unacceptable risk in the future; and
- Adequate monitoring of natural attenuation and potential future risks is included in the alternative that assure risks do not increase to unacceptable levels for receptors.

These requirements are typically met through development of fate and transport models that predict the constituent levels in the future, risk assessments of both current and future conditions, and development and implementation of monitoring programs that include recalibration of site models and re-evaluation of risks to potential receptors in the future.

4.6.1.1 Technology Preference According to MTCA

Natural attenuation is the least aggressive remedial technology, and would be ranked last (seventh of seven) based on the technology preference provided in MTCA.

4.6.1.2 Effectiveness (Including Permanence and Restoration Time Frame)

Accurate estimation of the effectiveness of natural attenuation would require a considerable effort in modeling and model calibration. Natural attenuation does not currently eliminate potential exposure of groundwater and/or surface water receptors to constituents above the Method B cleanup levels. The applicability of natural attenuation would depend upon the remedial action objectives finally established for groundwater. Natural attenuation would be a permanent remedy once the remedial objectives were met. It is possible that a significant portion of the site groundwater could be addressed through natural attenuation, depending upon the results of a risk assessment and/or wasteload allocation model for groundwater discharge into Lake Union.

4.6.1.3 Implementability

Natural attenuation is inherently implementable. Additional site data would be required initially to develop an appropriate fate and transport model, and over time to calibrate the model and support periodic risk assessments. These data-gathering efforts would present minor disruptions to park use, but would be implementable.

4.6.1.4 Order-of-Magnitude Costs

Natural attenuation does require development of a fate and transport model, and demonstration of current and future risks to potential receptors. These tasks would be completed initially as a capital expense. Parameters including biological and chemical degradation rates, partitioning coefficients, dispersion coefficients, toxicity translators, and the mass of any NAPLs would need to be measured or estimated based on site data. Also, sufficient groundwater data would be required to support a predictive model. These tasks (including data collection) are estimated to cost approximately $200,000 for the 20.5-acre site. In addition, long term monitoring, modeling, and risk evaluations are anticipated to be required; these are estimated to cost an additional $70,000 per year.

4.6.2 Physical Barriers—Sheet Pile Walls, Slurry Walls, Jet Grout Walls, One-Pass Liner Walls

Physical barriers could be installed to prevent impacted groundwater from migrating to Lake Union. This could be accomplished with a downgradient barrier; however, some means of addressing groundwater migrating into impacted areas from upgradient locations and from precipitation-based infiltration would need to be included. One alternative would include a surficial cap over the impacted area (which, using Method B cleanup levels, is essentially the entire site), and a fully encompassing physical barrier around the perimeter of the cap. A second alternative would include installation of a downgradient barrier with wing walls of sufficient length to generate a stagnation zone across the site. To be effective, this approach would also require a surficial cap over impacted soils.

4.6.2.1 Technology Preference According to MTCA

Physical barriers are isolation technologies; these rank sixth of seven based on the MTCA technology preference.

4.6.2.2 Effectiveness (Including Permanence and Restoration Time Frame)

Physical barriers alone can be effective in greatly reducing the loading of constituents to Lake Union. However, physical barriers are never perfect, and some migration of groundwater through the barrier would inevitably occur. The addition of a surficial cap is essential to the performance of a physical barrier alternative that does not include some means of treating groundwater (barriers which include groundwater treatment are discussed separately below).

4.6.2.3 Implementability

Installation of a physical barrier may be difficult, due to the Gas Works deposit and drift deposit (geologic units identified by the USGS [1989]). The Gas Works deposit is likely to contain debris associated with former plant operations. The drift deposit is likely to include cobbles.

These obstructions may deform sheet pile walls, and may negatively effect the integrity of a slurry trench. One-pass systems would provide a positive barrier if installed; however, these systems cannot be used in areas where large-sized debris are located.

One possible means of implementing a physical barrier would be to install the barrier off-shore in Lake Union. This could be accomplished using a sheet pile wall, placed sufficiently off-shore to avoid encountering the Gas Works deposit. If successfully placed, the area on the park side of the sheet pile wall would need to be filled to prevent potential contact with impacted groundwater. This would have the beneficial effect of increasing the park area. Implementation of an off-shore barrier may be difficult to implement due to potential permitting restrictions. However, some type of barrier is likely to be implementable.

Order-of-Magnitude Costs

The cost to install a physical barrier on land is estimated to be approximately $500 per lineal ft, based on a 30-ft depth. Installation in Lake Union is estimated to cost approximately $700 per lineal ft, which includes an allowance for placement of fill behind the barrier. A downgradient barrier along the entire shoreline (to address Method B cleanup levels) would be approximately 1,900 ft long. One or more shorter barriers could be considered if cleanup action levels established for the site reduce the areas of groundwater to be addressed.

An upgradient barrier may also be required to prevent migration of groundwater towards the site. To address the entire site, this barrier would be approximately 1,400 ft long. A surficial cap would be required over areas of the site to prevent infiltration-induced groundwater flow.

4.6.3 Enhanced Biodegradation

Enhanced biodegradation of constituents in groundwater is accomplished through the addition of an electron acceptor (i.e., oxygen, peroxide, nitrate, etc.) and/or nutrients. These can be introduced through air sparging with liquid- or gas-phase nutrient addition, circulation well techniques, or conventional injection wells or trenches.

Demonstrating the potential effectiveness of biodegradation generally requires, at a minimum, a site model that accounts for constituent fate and transport, hydrogeology, and source area effects. Biodegradation, which is often proposed as an enhancement to a natural attenuation alternative, would be implemented as needed based on long-term monitoring of constituent migration and attenuation. Implementation of biodegradation generally requires a monitoring program similar to natural attenuation, but with added emphasis on demonstrating the biological degradation of constituents.

LAW 09796

4.6.3.1 Technology Preference According to MTCA

Biodegradation, a destruction technology, ranks second out of seven in MTCA technology preference.

4.6.3.2 Effectiveness (Including Permanence and Restoration Time Frame)

Biodegradation for dissolved-phase constituents in groundwater can be effective; however, the approach is limited to degradable constituents. The organic constituents of concern are all generally amenable to biodegradation.

Biodegradation of constituents in groundwater does require a sufficient distance between source areas and potential receptors to allow the process to meet the remedial objectives. The Method B cleanup levels are extremely low, and it is very unlikely that biodegradation alone would be successful in achieving these levels site-wide. However, biodegradation may be effective in reducing organic contaminant loading to Lake Union in portions of the contaminant plume downgradient from the source area. Biodegradation would achieve positive results relatively quickly, and would likely reach steady-state within a period of 1 to 2 years for migrating groundwater.

4.6.3.3 Implementability

Biodegradation could be implemented along the site border with Lake Union in a relatively unobtrusive manor. No significant technical limitations are known at this time. The presence of the low-permeability clay/silt layer would need to be considered in the design of the enhancement delivery system(s); however, this unit where present might assist in the operation of some delivery systems.

4.6.3.4 Order-of-Magnitude Costs

In situ biodegradation costs have been estimated based on installation of a system along the 1,900-lineal-ft shoreline of Lake Union. A biocurtain system has been estimated for this preliminary screening, assumed to include approximately 80 sparging points. The capital costs to design and install this system is estimated to be approximately $1,000,000. Annual operating costs would need to include monitoring of the system and evaluating its performance, as well as system maintenance. The annual cost is estimated to be approximately $200,000.

4.6.4 Physical/Chemical Treatment (Recirculation Wells, Funnel/Gate)

Several technologies provide conventional physical/chemical treatment unit operations through an *in situ* approach. Two general system categories involve recirculation well technologies and funnel/gate technologies. Recirculation wells can work without a physical barrier, while funnel/gate systems depend upon a physical barrier to direct migrating groundwater to the treatment system. These treatment systems, which are designed to be integrated with the recirculation well or funnel/gate systems, are typically installed below ground.

Recirculation well technologies are not passive, but rather incorporate active pumping of groundwater, integral treatment of the well system effluent, and pumped recharge of treated water into the aquifer upgradient of the well system. Recirculation wells generally provide a more aggressive approach, as flow rates can be maximized. Funnel/gate systems use a subsurface barrier to force groundwater flow into a series of funnel/gate systems and through integral treatment units, with gravity discharge of treated water into the aquifer downgradient of the funnel/gate array. Funnel/gate systems are passive, as flow rates are set by the natural aquifer discharge, which has been estimated to be approximately 14.5 gpm by Tetra Tech (1987). Treatment unit operations possible for these systems include biological treatment, activated carbon adsorption, ion exchange, air stripping, DNAPL recovery, oil and grease absorption, and chemical oxidation

Significant advantages of these approaches over conventional pump and treat approaches include lower capital cost, less above-ground equipment, potentially less pumping equipment, potentially less sludge generation and disposal, and reduced permitting and discharge fee costs.

4.6.4.1 Technology Preference According to MTCA

The technology preference under MTCA for this approach would depend on the treatment process employed. Overall, these systems would most probably be considered separation or volume reduction, followed by reuse, destruction, or similar technology. This would result in a preference ranking of third of seven under MTCA.

4.6.4.2 Effectiveness (Including Permanence and Restoration Time Frame)

These technologies could be effective in meeting Method B cleanup levels, depending upon the unit processes employed. The funnel/gate technology relies on the effectiveness of a physical barrier to direct flow through the treatment units. This would result in some groundwater not being treated due to imperfections inherent in all physical barrier installations. Treatment for arsenic could be accomplished using this approach, although the process would be greatly simplified if only organic constituents needed to be addressed.

This alternative could be implemented relatively quickly. The recirculation well approach would require a period of time during which currently impacted groundwater was treated within the radius of influence of the well, whereas the funnel/gate approach would achieve results immediately for groundwater migrating through the gates. For either option, the remedial action would not likely be effective in remediating free-phase product or source areas affected by residual product. These systems may, therefore, be required to operate continuously.

4.6.4.3 Implementability

Installation of a physical barrier for the funnel/gate approach may be difficult on-site, but may be achievable a short distance off-shore in Lake Union (to avoid the Gas Works Deposit materials). The recirculation well approach should be implementable, although a thorough review of the site hydrogeology would be required and potential fouling parameters fully evaluated prior to implementation. Treatment for arsenic using either approach would require a specialized treatment process, but likely could be achieved if required.

4.6.4.4 Order-of-Magnitude Costs

Two process options have been discussed. The recirculation well approach, if applied site-wide, is estimated to require installation of approximately 20 wells. Each well would operate as an independent system, and would cost approximately $80,000 complete. Annual operating costs would vary depending upon the loading rates, but these are estimated to be approximately $160,000. Costs include integral treatment systems.

The funnel/gate technology would require installation of a physical barrier along the shoreline of Lake Union, at an estimated cost of approximately $1,330,000. Approximately 10 gates would be required, which are estimated to cost approximately $45,000 each. Annual operating costs are also estimated to be approximately $160,000. Costs include integral treatment systems.

These alternatives could be reduced considerably if a risk assessment or modeling approach addressing mass discharge to Lake Union was used to reduce the lineal extent of the areas of groundwater to be remediated.

4.7 PUMP AND TREAT

The *Pump and Treat* groundwater alternatives require a combination of a recovery system, treatment system, and discharge option. Due to the large number of possible permutations of these three subparts, recovery systems and treatment/discharge systems are considered separately. Each of these elements is reviewed and screened in accordance with the screening criteria defined in Section 4.2.

4.7.1 Recovery Systems

Although technologies exist for recovery of impacted groundwater, recovery wells are the most commonly applied technology, and, where effective, are generally the lowest cost option. Recovery trenches are also widely used; they are particularly effective for hydraulic containment of groundwater in less permeable and/or "thin" aquifers (aquifers with saturated thicknesses near or less than 10 ft). Alternative recovery approaches, which are less frequently used but could be effective at Gas Works Park, include horizontal wells and well point systems. Lastly, a number of vendors provide a "one pass" system consisting of a combined vertical membrane barrier and a horizontal recovery pipe. This approach would be useful for a combined hydraulic barrier and groundwater recovery approach.

The geology of the Gas Plant Park presented by HDR (June 1989) indicates strata of relatively low permeability. However, this description of site lithology notes the presence of the drift unit underlying the surficial Gas Works deposit and less permeable clay/sandy clay/silty clay layers. Drift units typically exhibit higher hydraulic conductivities than those calculated by HDR, and this unit may provide a greater radius of influence for recovery wells than inferred from the transmissivity values presented by HDR. This is supported by the calculated groundwater flow rates reported by Tetra Tech, which indicated a total groundwater flow of approximately 14.5 gpm, equating to a transmissivity significantly greater than that estimated by HDR. Therefore, a recovery well system will be used as the baseline approach for this preliminary screening of alternatives. Other approaches could be further evaluated, should groundwater recovery be included in the remedial alternative(s) retained for further evaluation and life-cycle cost estimating.

4.7.1.1 Technology Preference According to MTCA

The recovery system itself will not establish the preference under MTCA; this will depend mainly on the treatment technology and final disposition of treatment by-products and wastes. These factors are addressed in the treatment system discussion below.

4.7.1.2 Effectiveness (Including Permanence and Restoration Time Frame)

Groundwater pump and treat can be applied to either achieve hydraulic containment of the target plume area migrating towards a potential receptor (containment system), or as a means to remove the constituent mass from the entire plume, including source areas (source area reduction system). Typically, MGP sites are affected by DNAPLs and other source areas not readily addressed through groundwater pump and treat.

At Gas Works Park, DNAPL has been identified historically at three locations, and recently measured at two locations. In addition, due to previous site grading, the Gas Works deposit, consisting of debris and fill originating from the former plant operations, has been placed in direct contact with groundwater migrating towards Lake Union along portions of the site shoreline. These two potential source areas are not likely amenable to pump and treat technologies, due to the extremely slow dissolution of the moderate- to low-solubility constituents of interest (ranging from benzene, solubility 1,780 mg/L, to five- and six-ring PAHs, solubility 0.004 mg/L or lower). It is not possible to accurately calculate the number of theoretical pore volumes or the overall time required to remediate these source areas through groundwater pump and treat; however, general estimates for remediating DNAPL-impacted areas through pump and treat approaches typically range in the hundreds of years.

Based on the limitations of pump and treat in remediating source areas, this technology will be considered further for containment purposes only. For this purpose, pump and treat can be highly effective. A two- or three-dimensional groundwater flow model is typically used in the development of the pump and treat system for well placement and sizing of the recovery and treatment system components.

HDR (June 1989) completed a groundwater modeling exercise using the analytical model WELFLO. Tetra Tech estimated approximately 14.5 gpm of groundwater currently migrates toward Lake Union. The design flow rate of a recovery well system would need to be greater than this flow rate, as some withdrawal of surface water from Lake Union would occur near the recovery wells, increasing the overall flow rate. This could be addressed by including a physical barrier downgradient of the recovery well network, resulting in increased capital expense but reduced long-term operating costs.

The recovery system will need to be designed and monitored to assure capture of the target groundwater. Containment using a physical barrier in conjunction with pump and treat provides a more positive groundwater control system. Physical barrier systems and surficial caps can be combined to reduce the flow rate required to be recovered, resulting in reduced long-term costs and more positive groundwater control.

Once the system has been modeled and designed, implementation can proceed rapidly. The permanence of pump and treat depends upon the nature of the source areas and the duration of active treatment. It is possible that some areas of the site not directly affected by existing source areas could be effectively remediated using pump and treat.

4.7.1.3 Implementability

Pump and treat technologies have been successfully implemented at MGP sites, and based on the available data, would be technically implementable at Gas Works Park. The recovery components of a pump and treat system could be designed to minimize potential impacts on future site users by specifying installation of the equipment in enclosures below grade.

4.7.1.4 Order-of-Magnitude Costs

The recovery portion of a pump and treat system to address the entire site and to meet Method B cleanup levels was estimated based on an average recovery well spacing of 200 ft; this is consistent with the spacing provided by HDR (June 1989). Based on this spacing, approximately 10 recovery wells would be required along the shoreline of Lake Union. The estimated cost for each recovery well, complete with pumps and controls, is $12,000. Piping, utilities, and control wiring for 1,900 ft of interceptor along the shoreline is estimated to cost $50/ft. Alternative approaches, such as recovery trenches, would generally be more expensive than this approach; however, if the recovery well spacing needs to be decreased significantly in areas of the site, alternative approaches may be feasible in those areas.

The cost of installing a recovery well system to address only the areas of elevated constituent concentration would be reduced. Should the cleanup levels increase based on water quality protection levels for Lake Union or similar factors, the lineal extent of the groundwater capture zone required along the shoreline of Lake Union could be decreased. As an initial estimate, the lineal extent of shoreline required to be addressed based on a 500 μg/L cleanup level would be approximately 750 ft. This would reduce the installation costs of a recovery well system.

4.7.2 Treatment/Discharge Systems

Groundwater treatment and discharge systems generally include a number of unit processes. Typical processes for MGP site groundwaters include oil/water separation, coalescing separation, aeration and/or air stripping, pH adjustment, chemical precipitation, flocculation, settling, dissolved air flotation, media filtration, activated carbon adsorption, biological treatment, chemical oxidation (usually UV-enhanced), and ion exchange or specialty resin absorption for certain metals. These various unit operations are typically assembled into process trains, including pretreatment for oil removal, pretreatment for inorganic species removal, and main treatment for organic constituent removal.

HDR (June 1989) completed treatability testing on a number of treatment approaches including: chemical oxidation using UV light-enhanced peroxide; oil/water separation using coalescing media, followed by activated carbon; and biological treatment using a fixed-film reactor. Based on these studies, HDR recommended that a UV/peroxide treatment process be further evaluated. A more recent review of the treatability data and, more significantly, the knowledge gained in the industry during the 7 years since this study was undertaken, indicates that the HDR conclusion would not likely be made today. While UV/peroxide has been effective at a number of MGP or related sites, the process has proven expensive to operate and maintain.

The degree of treatment required will depend upon the discharge options available. At many MGP and related sites, the local municipal wastewater treatment plant (POTW) has been able to accept recovered groundwater following gravity separation of free oils. Where possible, this scenario generally results in a cost of treatment well below any potential cost to treat groundwater for direct National Pollutant Discharge Elimination System (NPDES) discharge or reinjection. However, if the POTW limitations require advanced treatment, it is generally more cost effective to achieve sufficiently low levels of treatment to allow direct discharge under an NPDES permit, thereby avoiding POTW tap-in and usage fees.

Based on the Metro POTW limitations described in the HDR report, the only constituents that exceeded the Metro limitations in place at that time were benzene and toluene. These two constituents could be readily treated using an air stripping technology coupled with an off-gas treatment scheme such as vapor phase-activated carbon. Air stripping for volatile constituents with off-gas treatment is usually considerably less expensive than the range of alternatives designed to treat the entire organic loading (including semivolatile constituents) in the groundwater. Therefore, given the available information, this approach would be suitable for discharge to the Metro POTW.

Discharge to Lake Union or injection into the shallow aquifer on- or off-site would require advanced treatment of organic constituents. Biological treatment can in some cases meet water quality-based limitations; however, technology-based limitations are often enforced, thus requiring tertiary polishing.

The treatment scheme most often found effective for advanced treatment of groundwaters at MGP sites is activated carbon, following an effective pretreatment process train. A typical system would include: a gravity oil/water separation tank; a coalescing oil/water separator (if significant NAPL is expected to be recovered); pH adjustment; chemical addition and/or aeration for metals precipitation and flocculation (if required); gravity separation or dissolved air floatation; media filtration; and final activated carbon adsorption. In addition to these processes, recovered oils and solids handling systems are generally required.

This "classical" treatment approach provides a high level of treatment for both organic and inorganic constituents. However, the cost to install and operate a fully integrated system with appropriate controls and safety interlocks is correspondingly high. Options to reduce the costs of these systems range from purchase of complete package systems from vendors to elimination of all unit processes that are not absolutely necessary. If carefully employed, these measures typically result in a lower capital cost and can result in a lower operating cost.

To complete this screening, a conservative approach has been adopted. A conventional treatment system designed to meet technology-based treatment standards has been assumed. As noted above, pump and treat could potentially be implemented with a reduced level of treatment, depending upon the discharge options available.

4.7.2.1 Technology Preference According to MTCA

Treatment options for the organic constituents of interest can be considered destruction technologies; these rank second of seven under the MTCA technology preference list. Activated carbon adsorption provides a volume reduction initially by adsorbing constituents from a large mass of treated water onto a relatively small mass of activated carbon. However, organic constituents are thermally destroyed in the commercial regeneration of activated carbon. Biological degradation and chemical oxidation are direct destruction technologies.

4.7.2.2 Effectiveness (Including Permanence and Restoration Time Frame)

Treatment and discharge of groundwater recovered as part of a pump and treat alternative is a proven approach whose effectiveness depends upon system construction and operation. Treatment and discharge are not permanent at sites where significant free-phase source areas are present, and such systems may need to be replaced at the end of their service life. Package treatment systems can be procured from vendors in as little as 10 weeks, whereas custom design and construction of systems can require 2 years or more to complete.

4.7.2.3 Implementability

Groundwater treatment and discharge is a common component of remedial programs at MGP sites and is considered technically implementable. One implementation factor with a significant effect on the treatment and discharge alternative will be the requirements for discharge to the Metro POTW, as this discharge option appears to be the only means of implementing an above-ground system at reasonable cost.

4.7.2.4 Order-of-Magnitude Costs

The cost to install a groundwater treatment and discharge system based on a "classical" high-quality permanent treatment system designed to treat 20 gpm of site groundwater (which includes an allowance for incidental withdrawal of 5.5 gpm of surface water from Lake Union) is estimated at $1,000,000. The annual cost to maintain this system is estimated at $200,000.

Should the Metro POTW be able to accept groundwater following oil/water separation, the cost of a system including oil/water separation only designed to treat and discharge 20 gpm, is approximately $200,000 to construct and $35,000 per year to operate.

4.8 COST SUMMARY FOR GROUNDWATER

Table 4-3 presents a summarizes estimated costs to implement the groundwater alternative based on MTCA Method B cleanup levels, while Table 4-4 presents selected alternatives to remediate source areas exceeding 500 μg/L of benzene.

4.9 SUMMARY OF COMBINED ALTERNATIVES FOR PRESENT WORTH ANALYSIS

The screening of soil and groundwater alternatives, based on MTCA criteria, presented in sections 4.5 through 4.8 has been used to develop a reduced list of combined alternatives for life cycle cost analysis. Table 4-5 summarizes the individual soil and groundwater alternatives evaluated and provides a screening conclusion for each alternative.

Some alternatives have been eliminated from further consideration, while others have been determined suitable in combination with other alternatives. The screening process and resulting combined alternatives for soils and groundwater are discussed below in sections 4.9.1 and 4.9.2 respectively.

Table 4-3. Costs for groundwater alternatives to remediate Method B cleanup levels, Gas Works Park Site, City of Seattle, Washington.

Alternative	Qty	Unit	Unit $	Total $	Cost $/yr
Natural Attenuation	1	EA	200,000	200,000	70,000
Physical Barrier - Lake	1900	LF	700	1,330,000	10,000
Physical Barrier - Upgradient	1400	LF	500	700,000	10,000
Cap Entire Site	15.4	Acres	350,000	5,390,000	30,000
Enhanced Biodegradation	80	Spg Pnts	12,500	1,000,000	200,000
Recirculating Well*	20	Ea Well	80,000	1,600,000	160,000
Funnel and Gate*					
- Physical Barrier	1900	LF	700	1,330,000	160,000
- Gate	10	Ea Gate	45,000	450,000	160,000
		Total		**1,780,000**	**320,000**
Pump and Treat					
- Pumping Wells	10	Ea Well	12,000	120,000	12,000
- Piping System	1900	LF	50	95,000	9,800
- Oil/Water Separation				200,000	35,000
- Activated Carbon				1,000,000	200,000
		Total		**1,415,000**	**256,800**

* Costs include integral treatment systems. Costs do not include construction contingencies, engineering design, construction oversight, or city administration costs.

4.9.1 Soils

Seven individual alternatives were developed for soils. As noted in Table 4-5, four alternatives (biodegradation, fixation, asphaltic road base, and off-site reuse) were eliminated from consideration for life cycle cost estimates because other alternatives were more protective of human health and the environment at significantly lower cost.

The individual soil alternatives that were retained include surficial cover, surficial cap, and excavation of hot spots with off-site treatment and disposal. Through the screening process, it was noted that these alternatives could be combined in a number of ways to arrive at effective overall alternatives.

Table 4-4. **Costs for groundwater alternatives to remediate areas exceeding 500 μg/L of benzene, Gas Works Park Site, City of Seattle, Washington.**

Alternative	Qty	Unit	Unit $	Capital Total $	O&M Cost $/Yr
Physical Barrier - Lake	760	LF	700	532,000	10,000
Physical Barrier - Inland	2,500	LF	500	1,250,000	10,000
Cap Impacted Areas	9	Acres	350,000	3,150,000	20,000
Enhanced Biodegradation	40	Spg Pnts	12,500	500,000	90,000
Recirculating Well*	10	Ea Well	80,000	800,000	80,000
Funnel and Gate*					
-Physical Barrier	760	LF	700	532,000	40,000
-Gate	4	Ea Gate	45,000	180,000	40,000
		Total		**712,000**	**80,000**
Pump and Treat					
-Pumping Wells	4	Ea Well	12,000	48,000	6,000
-Piping System	1,200	LF	50	60,000	4,000
-Oil/Water Separation				200,000	25,000
-Activated Carbon				700,000	100,000
		Total		**1,008,000**	**135,000**

*Costs include integral treatment systems. Costs do not include construction contingencies, engineering deign, construction over sight, or city administration costs.

Both the surficial cover and surficial cap alternatives have been modified to include limited excavation and off-site treatment/disposal. This modification improves these alternatives by effectively addressing materials that may be unsuitable or incompatible with the two containment alternatives. For example, tar-like materials that are physically unsuitable for use as structural fill can be excavated and treated off-site, while less impacted soils can be covered or capped on-site.

The following summarizes the soils alternatives recommended for life cycle cost analysis:

- Surficial cover with excavation and off-site treatment and disposal of "hot spots"
- Surficial cap with excavation and off-site treatment and disposal of "hot spots"

4.9.2 Groundwater

Five individual alternatives were developed for groundwater. As noted in Table 4-5, one alternative, pump and treat, has been eliminated, while two alternatives, biodegradation and *in situ* physical/chemical treatment, have been retained solely in combination with other alternatives. The pump and treat alternative has been eliminated due to the impracticability of remediating groundwater site-wide, and due to the availability of alternatives that are equally effective in reducing constituent loading to Lake Union, with lower long-term costs.

Biodegradation has been combined with the natural attenuation alternative. These alternatives are mutually compatible, and both require similar effectiveness monitoring. The *in situ* physical/chemical alternative has been combined as part of the physical barrier alternative for life cycle costing. These alternatives are also mutually compatible as both can be accomplished through installation of physical barriers. The funnel/gate approach can be used in various physical barrier configurations to treat groundwater that builds up on the park side of the barrier prior to discharge to Lake Union.

The following summarizes the groundwater alternatives selected for life cycle cost analysis:

- Upgradient physical barrier contained with surficial cover or cap (for soils).
- Partial site funnel/gate physical and chemical treatment, combined with surficial cover or cap (for soils).
- Partial site natural attenuation and enhanced biodegradation, combined with surficial cover or cap (for soils).

A number of options within each of these alternatives are further evaluated as part of the life cycle cost estimating process.

Table 4-5. Alternative screening table preliminary screening of alternatives Gas Works Park Site City of Seattle, Washington.

Media	Alternative	Screening Comments
Soil	Surficial Cover	*Retain* - Protects park users from direct contact and may reduce infiltration.
	Surficial Cap	*Retain* - Protects park users from direct contact and reduces infiltration; high maintenance requirement.
	In Situ Biodegradation	*Eliminate* - Not compatible with park uses and of limited effectiveness.
	In Situ Fixation	*Eliminate* - Not effective in reducing organic constituent concentrations.
	Asphaltic Road Base	*Eliminate* - High cost due to soil type; limited on-site need.
	Off-Site Reuse	*Retain* - High costs due to limited local market and off-spec site materials. Highest preference under MTCA. Additional research will be conducted.
	Off-Site Treatment/Disposal	*Retain* - Most cost-effective for small volumes of concentrated material.
Groundwater	Natural Attenuation	*Retain* - Most effective in combination with source control measures. May not be suitable as stand-alone measure.
	Physical Barriers	*Retain* - May be effective in controlling on-site as well as off-site groundwater flow.
	In Situ Biodegradation	*Retain* - May provide effective and permanent contaminant reduction. Ideal in combination with natural attenuation.
	In Situ Physical/Chemical	*Retain* - May provide effective and permanent contaminant reduction. Ideal in combination with physical barriers.
	Pump and Treat	*Eliminate* - Does not provide effective or permanent source reduction. Can be used to control groundwater flow but at higher cost than other options.

5. ECONOMIC ANALYSIS

The planning-level life-cycle cost estimates for construction and operation of five remediation alternatives have been developed and are summarized below. The complete cost breakdowns for each alternative are included as Table S-1 through S-5. These cost estimates should be within +30% and -20% of the actual cost. However, there are a number of issues presented below that, once determined, will likely alter the cost estimates presented in this section.

All of the remediation alternatives assume that up to 10% of the site area ("hot spots" of about 2.3 acres) will require removal to a depth of about 2 ft. The estimates assume all work is performed by a private contractor and does not include park redevelopment. Life cycle cost analyses for the five remediation alternatives are summarized as follows:

Alternative 1. The entire Gas Works Park site that is not currently covered with pavement or buildings would be conveyed with the surficial soil cover (vegetated topsoil) identified in Section 4.5.1. This option also includes a geotextile barrier between the existing soils and the surficial cover for increased protection/stability. This would cost an estimated $4,998,400.

Alternative 2. This alternative provides a design approach similar to Alternative 1, with addition of a surficial cap (identified in Section 4.5.2), in combination with the surficial cover soil. The surficial cap consists of a low-permeability geomembrane and geonet drainage system. This alternative would cost an estimated $6,599,100.

Alternative 3. An upgradient cutoff wall (described in Section 4.6.2) would be combined with the surficial cover (Alternative 1), at an estimated cost of $6,526,100. The cutoff wall combined with the surficial cap (Alternative 2) would cost an estimated $8,126,800.

Alternative 4. A partial downgradient cutoff wall (Section 4.6.2) and funnel/gate treatment cells identified (Section 4.6.4) would be the key components of this alternative. The application of the cutoff wall and treatment cells is limited to about 450 feet (with 75-ft wingwalls) of the southeast shoreline to remediate the contaminant plume downgradient from the former light oil plant. Combined with a surficial cover, this alternative would cost an estimated $7,010,400. Combined with a surficial cap, this alternative would cost an estimated $8,611,100.

Alternative 5. A partial system of enhanced biodegradation using sparging points (identified in Section 4.6.3) would be installed. The application of the sparging points is limited to a 600-ft arc on the southeast shoreline to remediate the downgradient portion of the contaminant plume associated with the former light-oil plant. Combined with a surficial cover, this alternative would cost an estimated $6,952,800. Combined with a surficial cap, this alternative would cost an estimated $8,553,500.

Table 5-1. Life Cycle Cost Analysis - Alternative 1: Hot spot removal and surficial cover with geotextile barrier.

Item No.	Item Description		Quantity	Units	Unit Price	Extension
1	General Requirements		7%	LS	$188,000	$188,000
2	Mobilization		5%	LS	$134,300	$134,300
3	Hot Spot Soils Excavation/Stockpile		8,200	CY	$20	$164,000
4	Hot Spot Soils Handling/Trans./Disp. (non-haz)	75%	9,200	TON	$45	$414,000
5	Hot Spot Soils Handling/Trans./Disp. (haz)	25%	3,100	TON	$250	$775,000
6	Backfill Placement		8,200	CY	$15	$123,000
7	8-oz Geotextile		74,500	SY	$1.80	$134,100
8	18" Topsoil		37,300	CY	$15.00	$559,500
9	Final Grading & Seed Prep.		15.4	AC	$1,000	$15,400
10	Irrigation System		11.8	AC	$30,500	$359,900
11	Hydroseed (seed/mulch/fert.)		15.4	AC	$2,500	$38,500
12	Surface Water Management		20.5	AC	$5,000	$102,500
13	Surficial Cover O&M	8%	20	YR	$50,000	$490,900
	SUBTOTAL					**$3,499,100**
14	Contingency (on items 3 through 13)		25%			$827,800
15	Engineering (on items 3 through 12)		10%			$268,600
16	Construction Eng./Inspection (on items 3 through 12)		10%			$268,600
17	Construction Env. Monitoring (on items 3 through 12)		5%			$134,300
	TOTAL					**$4,998,400**

Budget Assumptions

General:* *References Sections 4.3.2 (hot spots) and 4.5.1 (cover). Does not include park redevelopment. Construction estimates are based on complete installation by a private contractor. Surficial cover is not specified to significantly reduce infiltration of precipitation but rather to limit contact with underlying soil. Surficial cover is placed only over non-hard-surface areas.

1 Contractor's administrative costs, overhead, and profit (% based on similar projects).
2 Contractor's mobilization and demobilization costs (% based on similar projects).
3 Hot spot soils volume based on 2.3 acres, 2 ft deep, with a 10% expansion factor. Soil density estimated at 1.5 tons/cy.
4 Estimated unit cost for non-hazardous soils handling, transport, and disposal in an eastern Washington/Oregon landfill.
5 Estimated unit cost for hazardous soils handling, transport, and disposal in an eastern Oregon landfill (without treatment).
6 Locally available, clean, pit-run gravel.
7 Geotextile provides protection layer between existing soils and surficial cover (Only over non-hard-surface areas).
8 Topsoil cover.
9 Estimated unit cost for raking and non-amendment soil preparation.
10 Estimated area and unit cost based on Parks Department estimates.
11 Estimated unit cost based on similar Parks Department projects.
12 Estimated unit cost for ditches, bioswales, and control structures. Also includes erosion control during construction.
13 O&M present worth costs are based upon noted interest rate and duration.
14 Contingency based on similar clean-up projects with possible unknown limits of contamination.
15 Preparation of construction bid documents (plans, specifications, and engineer's estimate).
16 Third-party construction engineering, inspection, and construction quality assurance.
17 Third-party environmental monitoring during construction (air, water, and soil).

Payment of Washington State sales tax not required for remediation projects.

Table 5-2. Life Cycle Cost Analysis - Alternative 2: Hot spot removal, low permeable cap using geomembrane infiltration barrier, and geonet drainage system.

Item No.	Item Description		Quantity	Units	Unit Price	Extension
1	General Requirements		7%	LS	$245,400	$245,400
2	Mobilization		5%	LS	$175,300	$175,300
3	Hot Spot Soils Excavation/Stockpile		8,200	CY	$20	$164,000
4	Hot Spot Soils Handling/Trans./Disp. (non-haz)	75%	9,200	TON	$45	$414,000
5	Hot Spot Soils Handling/Trans./Disp. (haz)	25%	3,100	TON	$250	$775,000
6	Backfill Placement		8,200	CY	$15	$123,000
7	Subgrade Preparation		15.4	AC	$1,500	$23,100
8	8-oz Geotextile		74,500	SY	$1.80	$134,100
9	50-mil Geomembrane		74,500	SY	$4.00	$298,000
10	Geonet Drainage System		74,500	SY	$6.00	$447,000
11	18" Topsoil		37,300	CY	$15.00	$559,500
12	Final Grading & Seed Prep.		15.4	AC	$1,000	$15,400
13	Irrigation System		11.8	AC	$30,500	$359,900
14	Hydroseed (seed/mulch/fert.)		15.4	AC	$2,500	$38,500
15	Surface Water Management		20.5	AC	$7,500	$153,800
16	Surficial Cap O&M	8%	20	YR	$75,000	$736,400
	SUBTOTAL					**$4,662,400**
17	Contingency (on items 3 through 16)		25%			$1,060,400
18	Engineering (on items 3 through 15)		10%			$350,500
19	Construction Eng./Inspection (on items 3 through 15)		10%			$350,500
20	Construction Env. Monitoring (on items 3 through 15)		5%			$175,300
	TOTAL					**$6,599,100**

Budget Assumptions

General: ***References Sections 4.3.2 (hot spots) and 4.5.2 (cap). Does not include park redevelopment.***
Construction estimates are based on complete installation by a private contractor.
Cap covers only non-hard-surface areas.

1 Contractor's administrative costs, overhead, and profit (% based on similar projects).
2 Contractor's mobilization and demobilization costs (% based on similar projects).
3 Hot spot soils volume based on 2.3 acres, 2 ft deep, with a 10% expansion factor. Soil density estimated at 1.5 tons/cy.
4 Estimated unit cost for non-hazardous soils handling, transport, and disposal in an eastern Washington/Oregon landfill.
5 Estimated unit cost for hazardous soils handling, transport, and disposal in an eastern Oregon landfill (without treatment).
6 Locally available, clean, pit-run gravel.
7 Subgrade preparation includes vegetation removal, raking, and smooth rolling.
8 Geotextile provides protection layer between existing soils and surficial cap (Only over non-hard-surface areas).
9 High density polyethylene (HDPE) geomembrane used to reduce cost and impact of hauling clay/soil.
10 Geonet drainage system used to reduce cost and impact of gravel hauling.
11 Topsoil cover.
12 Estimated unit cost for raking and non-amendment soil preparation.
13 Estimated area and unit cost based on Parks Department estimates.
14 Estimated unit cost based on similar Parks Department projects.
15 Estimated unit cost for ditches, bioswales, and control structures. Also includes erosion control during construction.
16 O&M present worth costs are based upon noted interest rate and duration.
17 Contingency based on similar clean-up projects with possible unknown limits of contamination.
18 Preparation of construction bid documents (plans, specifications, and engineer's estimate).
19 Third-party construction engineering, inspection, and construction quality assurance.
20 Third-party environmental monitoring during construction (air, water, and soil).
Payment of Washington State sales tax not required for remediation projects.

Table 5-3. Life Cycle Cost Analysis - Alternative 3: Hot spot removal, upgradient cutoff wall, and surficial cover or cap.

Item No.	Item Description		Quantity	Units	Unit Price	Extension
1	General Requirements		7%	LS	$242,200	$242,200
2	Mobilization		5%	LS	$173,000	$173,000
3	Hot Spot Soils Excavation/Stockpile		8,200	CY	$20	$164,000
4	Hot Spot Soils Handling/Trans./Disp. (non-haz)	75%	9,200	TON	$45	$414,000
5	Hot Spot Soils Handling/Trans./Disp. (haz)	25%	3,100	TON	$250	$775,000
6	Backfill Placement		8,200	CY	$15	$123,000
7	Upgradient Cutoff Wall		1,400	LF	$500	$700,000
8	Subgrade Preparation		15.4	AC	$1,500	$23,100
9	8-oz Geotextile		74,500	SY	$1.80	$134,100
10	18" Topsoil		37,300	CY	$15.00	$559,500
11	Final Grading & Seed Prep.		15.4	AC	$1,000	$15,400
12	Irrigation System		11.8	AC	$30,500	$359,900
13	Hydroseed (seed/mulch/fert.)		15.4	AC	$2,500	$38,500
14	Surface Water Management		20.5	AC	$7,500	$153,800
15	Surficial Cap O&M	8%	20	YR	$75,000	$736,400
	SUBTOTAL					**$4,611,900**
16	Contingency (on items 3 through 15)		25%			$1,049,200
17	Engineering (on items 3 through 14)		10%			$346,000
18	Construction Eng./Inspection (on items 3 through 14)		10%			$346,000
19	Construction Env. Monitoring (on items 3 through 14)		5%			$173,000
	TOTAL					**$6,526,100**
	TOTAL (with cap rather than cover)					**$8,126,800**

Budget Assumptions

General: ***References Sections 4.3.2 (hot spots), 4.5.1 (cover), and 4.6.2 (upgradient cutoff wall). Does not include park redevelopment. Construction estimates are based on complete installation by a private contractor. Similar to Alternative 1 with addition of upgradient cutoff wall.***

1 Contractor's administrative costs, overhead, and profit (% based on similar projects).
2 Contractor's mobilization and demobilization costs (% based on similar projects).
3 Hot spot soils volume based on 2.3 acres, 2 ft deep, with a 10% expansion factor. Soil density estimated at 1.5 tons/cy.
4 Estimated unit cost for non-hazardous soils handling, transport, and disposal in an eastern Washington/Oregon landfill.
5 Estimated unit cost for hazardous soils handling, transport, and disposal in an eastern Oregon landfill (without treatment).
6 Locally available, clean, pit-run gravel.
7 Upgradient cutoff wall consists of 1,400-foot long, 25-foot deep grouted sheetpile wall constructed on land.
8 Subgrade preparation includes vegetation removal, raking, and smooth rolling.
9 Geotextile provides barrier between existing soils and surficial cover.
10 Topsoil cover.
11 Estimated unit cost for raking and non-amendment soil preparation.
12 Estimated area and unit cost based on Parks Department estimates.
13 Estimated unit cost based on similar Parks Department projects.
14 Estimated unit cost for ditches, bioswales, and control structures. Also includes erosion control during construction.
15 O&M present worth costs are based upon noted interest rate and duration.
16 Contingency based on similar clean-up projects with possible unknown limits of contamination.
17 Preparation of construction bid documents (plans, specifications, and engineer's estimate).
18 Third-party construction engineering, inspection, and construction quality assurance.
19 Third-party environmental monitoring during construction (air, water, and soil).

Payment of Washington State sales tax not required for remediation projects.

Table 5-4. Life Cycle Cost Analysis - Alternative 4: Hot spot removal, partial downgradient funnel and gate with integral treatment components, and surficial cover or cap.

Item No.	Item Description		Quantity	Units	Unit Price	Extension
1	General Requirements		7%	LS	$234,000	$234,000
2	Mobilization		5%	LS	$167,100	$167,100
3	Hot Spot Soils Excavation/Stockpile		8,200	CY	$20	$164,000
4	Hot Spot Soils Handling/Trans./Disp. (non-haz)	75%	9,200	TON	$45	$414,000
5	Hot Spot Soils Handling/Trans./Disp. (haz)	25%	3,100	TON	$250	$775,000
6	Backfill Placement		8,200	CY	$15	$123,000
7	Downgradient Cutoff Wall		600	LF	$700	$420,000
8	Funnel Gate Treatment Cells		4	EA	$45,000	$180,000
9	Subgrade Preparation		15.4	AC	$1,500	$23,100
10	8-oz Geotextile		74,500	SY	$2.25	$167,600
11	18" Topsoil		37,300	CY	$15.00	$559,500
12	Final Grading & Seed Prep.		15.4	AC	$1,000	$15,400
13	Irrigation System		11.8	AC	$30,500	$359,900
14	Hydroseed (seed/mulch/fert.)		15.4	AC	$2,500	$38,500
15	Surface Water Management		20.5	AC	$5,000	$102,500
16	Surficial Cover O&M	8%	20	YR	$50,000	$490,900
17	Funnel and Gate O&M	8%	20	YR	$80,000	$785,500
	SUBTOTAL					**$5,020,000**
18	Contingency (on items 3 through 17)		25%			$1,154,700
19	Engineering (on items 3 through 15)		10%			$334,300
20	Construction Eng./Inspection (on items 3 through 15)		10%			$334,300
21	Construction Env. Monitoring (on items 3 through 15)		5%			$167,100
	TOTAL					**$7,010,400**
	TOTAL (with cap rather than cover)					**$8,611,100**

Budget Assumptions

General: ***References Sections 4.3.2 (hot spots), 4.5.1 (cover), 4.6.2 (cutoff walls), and 4.6.4 (funnel and gate). Does not include park redevelopment. Construction estimates are based on complete installation by a private contractor. Similar to Alternative 1 with addition of cutoff wall and funnel and gate treatment.***

1. Contractor's administrative costs, overhead, and profit (% based on similar projects).
2. Contractor's mobilization and demobilization costs (% based on similar projects).
3. Hot spot soils volume based on 2.3 acres, 2 ft deep, with a 10% expansion factor. Soil density estimated at 1.5 tons/cy.
4. Estimated unit cost for non-hazardous soils handling, transport, and disposal in an eastern Washington/Oregon landfill.
5. Estimated unit cost for hazardous soils handling, transport, and disposal in an eastern Oregon landfill (without treatment).
6. Locally available, clean, pit-run gravel.
7. Cutoff wall is a 600-foot long (with wingwalls), 30-foot deep grouted sheetpile wall constructed on southeast shore.
8. Groundwater directed to four gates installed in lake or near shore.
9. Subgrade preparation includes vegetation removal, raking, and smooth rolling.
10. Geotextile provides barrier between existing soils and surficial cover.
11. Topsoil cover.
12. Estimated unit cost for raking and non-amendment soil preparation.
13. Estimated area and unit cost based on Parks Department estimates.
14. Estimated unit cost based on similar Parks Department projects.
15. Estimated unit cost for ditches, bioswales, and control structures. Also includes erosion control during construction.
16. O&M present worth costs for surficial cover are based upon noted interest rate and duration.
17. O&M present worth costs for funnel and gates are based upon noted interest rate and duration.
18. Contingency based on similar clean-up projects with possible unknown limits of contamination.
19. Preparation of construction bid documents (plans, specifications, and engineer's estimate).
20. Third-party construction engineering, inspection, and construction quality assurance.
21. Third-party environmental monitoring during construction (air, water, and soil).

Payment of Washington State sales tax not required for remediation projects.

Table 5-5. **Life Cycle Cost Analysis - Alternative 5: Hot spot removal, natural attenuation with partial groundwater biodegradation, and surficial cover or cap.**

Item No.	Item Description		Quantity	Units	Unit Price	Extension
1	General Requirements		7%	LS	$142,000	$142,000
2	Mobilization		5%	LS	$101,400	$101,400
3	Hot Spot Soils Excavation/Stockpile		8,200	CY	$20	$164,000
4	Hot Spot Soils Handling/Trans./Disp. (non-haz)	75%	9,200	TON	$45	$414,000
5	Hot Spot Soils Handling/Trans./Disp. (haz)	25%	3,100	TON	$250	$775,000
6	Attenuation Modeling and Risk Assessment		1	LS	$300,000	$300,000
7	Biodegradation (using sparging points)		30	SP	$12,500	$375,000
8	Subgrade Preparation		15.4	AC	$1,500	$23,100
9	8-oz Geotextile		74,500	SY	$1.80	$134,100
10	18" Topsoil		37,300	CY	$15.00	$559,500
11	Final Grading & Seed Prep.		15.4	AC	$1,000	$15,400
12	Irrigation System		11.8	AC	$30,500	$359,900
13	Hydroseed (seed/mulch/fert.)		15.4	AC	$2,500	$38,500
14	Surface Water Management		20.5	AC	$5,000	$102,500
15	Surficial Cover O&M	8%	20	YR	$10,000	$98,200
16	Start-up Biodegradation System O&M	8%	3	YR	$175,000	$451,000
17	Mature Biodegradation System O&M	8%	17	YR	$125,000	$905,100
	SUBTOTAL					**$4,958,700**
18	Contingency (on items 3 through 17)		25%			$1,178,800
19	Engineering (on items 3 through 14)		10%			$326,100
20	Construction Eng./Inspection (on items 3 through 14)		10%			$326,100
21	Construction Env. Monitoring (on items 3 through 14)		5%			$163,100
	TOTAL					**$6,952,800**
	TOTAL (with cap rather than cover)					**$8,553,500**

Budget Assumptions

General: ***References Sections 4.3.2 (hot spots), 4.5.1 (cover), and 4.6.3 (enhanced biodegradation). Does not include park redevelopment. Construction estimates are based on complete installation by a private contractor. Surficial cover is not specified to reduce infiltration of precipitation.***

1 Contractor's administrative costs, overhead, and profit (% based on similar projects).
2 Contractor's mobilization and demobilization costs (% based on similar projects).
3 Hot spot soils volume based on 2.3 acres, 2 ft deep, with a 10% expansion factor. Soil density estimated at 1.5 tons/cy.
4 Estimated unit cost for non-hazardous soils handling, transport, and disposal in an eastern Washington/Oregon landfill.
5 Estimated unit cost for hazardous soils handling, transport, and disposal in an eastern Oregon landfill (without treatment).
6 Attenuation modeling costs include data gathering, F&T model development, and risk assessment.
7 Groundwater treatment using biodegradation includes sparging point installation along 600 ft of the southeast shoreline.
8 Subgrade preparation includes vegetation removal, raking, and smooth rolling.
9 Geotextile provides barrier between existing soils and surficial cover.
10 Topsoil cover.
11 Estimated unit cost for raking and non-amendment soil preparation.
12 Estimated area and unit cost based on Parks Department estimates.
13 Estimated unit cost based on similar Parks Department projects.
14 Estimated unit cost for ditches, bioswales, and control structures. Also includes erosion control during construction.
15 O&M present worth costs for surficial cover are based upon noted interest rate and duration.
16 Present worth costs for biodegradation system O&M and performance monitoring for first three years.
17 Present worth costs for biodegradation system O&M and performance monitoring for remaining 17 years.
18 Contingency based on similar clean-up projects with possible unknown limits of contamination.
19 Preparation of construction bid documents (plans, specifications, and engineer's estimate).
20 Third-party construction engineering, inspection, and construction quality assurance.
21 Third-party environmental monitoring during construction (air, water, and soil).

Payment of Washington State sales tax not required for remediation projects.

APPENDIX A

GAS WORKS PARK BIBLIOGRAPHY

GAS WORKS PARK BIBLIOGRAPHY

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Richard Haag Associates, Inc. April 1985. Contract Documents for Gas Works Parks Fence and Path Improvements, Prepared for the City of Seattle Department of Parks and Recreation.

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Tetra Tech, Inc. March 1985. Sampling and Analysis Plan, Gas Works Park Supplemental Soils Testing. Prepared for City of Seattle Department of Parks and Recreation. 115 pp.

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U.S. Environmental Protection Agency. 1984. EPA Grab Samples.

U.S. Environmental Protection Agency. November 28, 1995. Expanded Site Inspection Report, Washington Natural Gas, Seattle Plant, prepared by the Office of Environmental Assessment for the Office of Environmental Cleanup. Environmental Protection Agency, Region 10, Seattle, Washington.

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Gas Works Park, Record of Soil Sampling and Analyses, Information provided to EPA, Department of Parks and Recreation, April 1984.

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APPENDIX B

SUMMARY OF DATA SOURCES FOR CHEMICAL DATABASE

SUMMARY OF DATA SOURCES FOR CHEMICAL DATABASE

Ecology and Environment, Inc. July 18, 1984. Gas Works Park—Summary of Results. Prepared for U.S. EPA, Region 10, Seattle, Washington. 6-page report plus data tables.

Soil sample data- composite samples at 24 locations
- 0-6 in - 24 samples - VOCs, SVOCs, metals, cyanide, pesticides/PCBs
- 0-3 ft - 24 samples - VOCs, SVOCs, metals, cyanide, pesticides/PCBs

HDR Engineering, Inc. October 31, 1988. Final Report. Focused Field Investigation and Irrigation Feasibility Study, Gas Works Park. Prepared for City of Seattle Department of Parks and Recreation. 81 pages plus appendices.

Table 3.4 - BTX&N data from 15 temporary groundwater monitoring stations
Table 3.6 - pH data for 6 surficial soil samples
Appendix D - groundwater - VOCs - 17 samples (wells MW-1 through MW-16)
metals, PAHs, VOCs - 1 sample (well MW-17)

HDR Engineering, Inc. June 26, 1989 draft. Groundwater Contaminant Migration Control System Conceptual Design Report. 58 pages plus appendices.

Table 2.3 - Summary of sampling results (VOCs, SVOCs, and TPH) for new wells (MW-18 through MW-21)

Tetra Tech, Inc. September 1985. Gas Works Park Supplemental Soils Testing, Phase I Surface Soils Analysis. Prepared for City of Seattle Department of Parks and Recreation. 24 pages.

Table 3 - Summary of PAH data for surficial soil samples (upper 2 inches) - 34 samples

Tetra Tech, Inc. June 1987. Supplemental Data Report, Gas Works Park Groundwater Investigation and Site Evaluation. Prepared for City of Seattle Department of Parks and Recreation. 9 data appendices.

Appendix G - Soil from monitoring well borings - SVOCs - 11 samples
Appendix H - Groundwater - metals, cyanide, VOCs, pesticides/PCBs - 17 samples

Turney, G.L., and D.F. Goerlitz. 1989. Groundwater Contamination at an Inactive Coal and Oil Gasification Plant Site, Gas Works Park, Seattle, Washington. U.S. Geological Survey Water-Resources Investigations Report 88-4224. Prepared in cooperation with the City of Seattle, Department of Parks and Recreation.

Table 1 - Summary of semivolatile organic compounds in groundwater - 17 samples

University of Washington, June 18, 1984. Memorandum from David Kalman, Assistant Professor, to Mr. Chuck Kleeberg, City of Seattle.

Surface soil sample results (upper 1 inch)
  benzo(a)pyrene - 24 samples
  PAHs - 5 samples

U.S. Environmental Protection Agency. 1984. EPA Grab Samples.

On-shore grab samples - 3 water and 3 soil - semivolatile organic compounds
7 surficial soil samples - semivolatile organic compounds

U.S. Environmental Protection Agency. November 28, 1995. Expanded Site Inspection Report, Washington Natural Gas, Seattle Plant, prepared by the Office of Environmental Assessment for the Office of Environmental Cleanup. Environmental Protection Agency, Region 10, Seattle, Washington.

Metals, cyanide, SVOCs, VOCs:
  2 Seep samples (#31 and 32)
  2 Shoreline sediments (#32 and 33)
  1 Soil sample (#35)

APPENDIX C

SUMMARY OF NONDETECTED CONTAMINANTS IN SOIL AND WATER

Table

Table C-1. Summary of detected chemical concentrations in shallow soil samples (6 inches or less in depth), Gas Works Park.

CAS Number	Chemical Name	Category	MTCA Method B (Soil)	Number of Values	Maximum (mg/kg)	Mimimum (mg/kg)
PH	pH	Conventional		6	5500	5000
7429-90-5	Aluminum	Metal		3	16100	9310
7440-36-0	Antimony	Metal		1	5.7	5.7
7440-38-2	Arsenic	Metal	7*	27	47.5	2.9
7440-39-3	Barium	Metal	5600	3	470	90.5
7440-41-7	Beryllium	Metal	0.6*	27	0.48	0.12
7440-43-9	Cadmium	Metal	80	27	11.3	0.27
7440-70-2	Calcium	Metal		3	5440	3810
7440-47-3	Chromium	Metal		27	154	15
7440-48-4	Cobalt	Metal		3	15.5	6.94
7440-50-8	Copper	Metal	2960	27	215	15
57-12-5	Cyanide, Total	Metal	1600	27	458	0.56
7439-89-6	Iron	Metal		3	27400	14500
7439-92-1	Lead	Metal		27	431	9
7439-95-4	Magnesium	Metal		3	11100	2060
7439-96-5	Manganese	Metal	11200	3	362	119
7439-97-6	Mercury	Metal	24	27	12.9	0.0424
7440-02-0	Nickel	Metal	1600	27	180	0.44
7440-09-7	Potassium	Metal		3	781	521
7782-49-2	Selenium	Metal	400	13	0.6	0.1
7440-22-4	Silver	Metal	400	26	15.3	0.05
7440-23-5	Sodium	Metal		3	813	378
7440-62-2	Vanadium	Metal	560	3	132	48.3
7440-66-6	Zinc	Metal	24000	27	455	41
11097-69-1	Aroclor-1254	PCB	1.60	23	2.724	0.033
11096-82-5	Aroclor-1260	PCB		22	0.934	0.03
72-54-8	4,4'-DDD	Pesticide	4.17	1	0.68	0.68
72-55-9	4,4'-DDE	Pesticide	2.94	1	0.185	0.185
50-29-3	4,4'-DDT	Pesticide	2.94	1	1.16	1.16
92-52-4	1,1'-Biphenyl	Semi-Volatile Organics	4000	2	55	4.3
575-41-7	1,3-Dimethylnaphthalene	Semi-Volatile Organics		5	22	2.3
571-61-9	1,5 Dimethyl Naphthalene	Semi-Volatile Organics		5	19	1
90-12-0	1-Methylnaphthalene	Semi-Volatile Organics		5	34	9.3
605-02-7	1-Phenyl Naphthalene	Semi-Volatile Organics		1	40	40
105-67-9	2,4-Dimethylphenol	Semi-Volatile Organics	1600	1	0.921	0.921
CAS-30	2,5-Dimethyl Phenanthrene	Semi-Volatile Organics		2	4.9	1.3
613-12-7	2-Methylanthracene	Semi-Volatile Organics		3	32	4.9
91-57-6	2-Methylnaphthalene	Semi-Volatile Organics		23	17.3	0.05
95-48-7	2-Methylphenol	Semi-Volatile Organics	4000	2	0.818	0.0929
CAS-2	2-Propenylbenzene	Semi-Volatile Organics		1	18	18
26914-17-0	4-Methyl-9H-Fluorene	Semi-Volatile Organics		1	1.7	1.7
106-44-5	4-Methylphenol	Semi-Volatile Organics	400	2	1.81	0.164
108121-76-2	9,10-Anthracenedione	Semi-Volatile Organics		1	28	28

Table C-1. Summary of detected chemical concentrations in shallow soil samples (6 inches or less in depth), Gas Works Park.

CAS Number	Chemical Name	Category	MTCA Method B (Soil)	Number of Values	Maximum (mg/kg)	Mimimum (mg/kg)
CAS-28	9H-Fluoren-9-One	Semi-Volatile Organics		2	12	9.7
83-32-9	Acenaphthene	Semi-Volatile Organics	4800	31	58	0.02
208-96-8	Acenaphthylene	Semi-Volatile Organics		41	3000	0.05
120-12-7	Anthracene	Semi-Volatile Organics	24000	66	1000	0.068
56-55-3	Benzo(a)anthracene	Semi-Volatile Organics	0.137	74	3000	0.03
50-32-8	Benzo(a)pyrene	Semi-Volatile Organics	0.137	97	10000	0.034
205-99-2	Benzo(b)fluoranthene	Semi-Volatile Organics	0.137	76	4000	0.0089
239-35-0	Benzo(b)Naphtho-(2,1-D)Thiophen	Semi-Volatile Organics		3	9.9	0.7
203-12-3	Benzo(g,h,i)fluoranthene	Semi-Volatile Organics		5	38	0.57
191-24-2	Benzo(g,h,i)perylene	Semi-Volatile Organics		73	23000	0.11
205-82-3	Benzo(j)fluoranthene	Semi-Volatile Organics		1	25	25
207-08-9	Benzo(k)fluoranthene	Semi-Volatile Organics	0.137	36	61.2	0.022
65-85-0	Benzoic acid	Semi-Volatile Organics	320000	2	3.41	2.79
117-81-7	Bis (2-ethylhexyl)phthalate	Semi-Volatile Organics	71.43	22	67	0.27
85-68-7	Butyl benzyl phthalate	Semi-Volatile Organics	16000	1	0.43	0.43
86-74-8	Carbazole	Semi-Volatile Organics	50	3	29.3	0.0624
218-01-9	Chrysene	Semi-Volatile Organics	0.137	75	6000	0.048
84-74-2	Di-n-Butylphthalate	Semi-Volatile Organics	8000	1	0.16	0.16
117-84-0	Di-n-octylphthalate	Semi-Volatile Organics	1600	2	0.37	0.13
53-70-3	Dibenzo(a,h)anthracene	Semi-Volatile Organics	0.137	34	2000	0.266
132-64-9	Dibenzofuran	Semi-Volatile Organics		14	23	0.024
132-65-0	Dibenzothiophene	Semi-Volatile Organics		6	69	1.6
206-44-0	Fluoranthene	Semi-Volatile Organics	3200	76	8000	0.01
86-73-7	Fluorene	Semi-Volatile Organics	3200	46	2000	0.07
243-17-4	II-H-Benzo(b)fluorene	Semi-Volatile Organics		1	2	2
193-39-5	Indeno(1,2,3-c,d)pyrene	Semi-Volatile Organics	0.137	73	11000	0.074
78-59-1	Isophorone	Semi-Volatile Organics	1053	1	0.1	0.1
91-20-3	Naphthalene	Semi-Volatile Organics	3200	44	13000	0.13
98-95-3	Nitrobenzene	Semi-Volatile Organics	40	1	0	0
85-01-8	Phenanthrene	Semi-Volatile Organics		76	14000	0.0097
CAS-37	Phenanthrene, 1-methyl-7-(1	Semi-Volatile Organics		3	6.38	0.119
108-95-2	Phenol	Semi-Volatile Organics	48000	2	1.09	0.648
129-00-0	Pyrene	Semi-Volatile Organics	2400	75	18000	0.09
7704-34-9	Sulfur	Semi-Volatile Organics		1	27	27
71-55-6	1,1,1-Trichloroethane	Volatile Organics	72000	1	0.0072	0.0072
71-43-2	Benzene	Volatile Organics	34.5	1	0.043	0.043
CAS-18	Benzene, (1-methylethyl)	Volatile Organics		1	0.0023	0.0023
67-66-3	Chloroform	Volatile Organics	164	3	0.0557	0.00021
75-71-8	Dichlorodifluoromethane	Volatile Organics	16000	1	0.0016	0.0016
100-41-4	Ethylbenzene	Volatile Organics	8000	6	0.014	0.0023
91-20-3	Naphthalene	Volatile Organics	3200	1	0.41	0.41
108-88-3	Toluene	Volatile Organics	16000	5	0.012	0.0023
*Natural background concentration in Puget Sound, Washington						

Table C-2. Summary of detected chemical concentrations in deep soil samples (greater than 6 inches in depth), Gas Works Park.

CAS Number	Chemical Name	Category	MTCA Method B (Soil)	Number of Values	Maximum (mg/kg)	Mimimum (mg/kg)
7440-36-0	Antimony	Metal		24	0.2	0.2
7440-38-2	Arsenic	Metal	7*	24	30.4	1.4
7440-41-7	Beryllium	Metal	0.6*	24	0.48	0.13
7440-43-9	Cadmium	Metal	80	24	4	0.26
7440-47-3	Chromium	Metal		24	76	19
7440-50-8	Copper	Metal	2960	24	105	28
57-12-5	Cyanide, Total	Metal	1600	24	340	1.2
7439-92-1	Lead	Metal		24	196	41
7439-97-6	Mercury	Metal	24	24	0.74	0.074
7440-02-0	Nickel	Metal	1600	24	99	0.45
7782-49-2	Selenium	Metal	400	9	0.2	0.1
7440-22-4	Silver	Metal	400	24	5.9	0.04
7440-28-0	Thallium	Metal	5.60	24	0.2	0.2
7440-66-6	Zinc	Metal	24000	24	545	42
72-54-8	4,4'-DDD	Pesticide	4.17	13	0.132	0.0074
72-55-9	4,4'-DDE	Pesticide	2.94	4	0.251	0.025
50-29-3	4,4'-DDT	Pesticide	2.94	17	0.114	0.0077
309-00-2	Aldrin	Pesticide	00.059	3	0.021	0.0066
959-98-8	Alpha Endosulfan	Pesticide		9	0.117	0.0191
319-84-6	Alpha-BHC	Pesticide	0.159	16	0.275	0.0026
33213-65-9	Beta Endosulfan	Pesticide		11	0.297	0.007
319-85-7	Beta-BHC	Pesticide	0.556	10	0.927	0.041
319-86-8	Delta-BHC	Pesticide		1	0.0031	0.0031
60-57-1	Dieldrin	Pesticide	0.063	3	0.0375	0.0135
1031-07-8	Endosulfan sulfate	Pesticide		1	1.312	1.312
72-20-8	Endrin	Pesticide	24	13	0.187	0.0061
7421-93-4	Endrin Aldehyde	Pesticide		7	0.429	0.0036
58-89-9	Gamma-BHC (Lindane)	Pesticide	0.769	13	0.731	0.021
76-44-8	Heptachlor	Pesticide	0.222	1	0.01	0.01
1024-57-3	Heptachlor expoxide	Pesticide	0.110	15	0.615	0.0052
95-95-4	2,4,5-Trichlorophenol	Semi-Volatile Organics	8000	1	0.96	0.96
91-57-6	2-Methylnaphthalene	Semi-Volatile Organics		5	6.3	0.31
83-32-9	Acenaphthene	Semi-Volatile Organics	4800	11	1.9	0.0014
208-96-8	Acenaphthylene	Semi-Volatile Organics		26	6.069	0.008
120-12-7	Anthracene	Semi-Volatile Organics	24000	9	3.4	0.0108
56-55-3	Benzo(a)anthracene	Semi-Volatile Organics	0.137	27	17.897	0.013
50-32-8	Benzo(a)pyrene	Semi-Volatile Organics	0.137	16	62.951	0.127
205-99-2	Benzo(b)fluoranthene	Semi-Volatile Organics	0.137	20	19	0.023
191-24-2	Benzo(g,h,i)perylene	Semi-Volatile Organics		6	16	0.042
207-08-9	Benzo(k)fluoranthene	Semi-Volatile Organics	0.137	11	46.872	0.037
65-85-0	Benzoic acid	Semi-Volatile Organics	320000	1	0.29	0.29
117-81-7	Bis (2-ethylhexyl)phthalate	Semi-Volatile Organics	71.43	12	9.831	0.038
218-01-9	Chrysene	Semi-Volatile Organics	0.137	28	38.41	0.0116

Table C-2. Summary of detected chemical concentrations in deep soil samples (greater than 6 inches in depth), Gas Works Park.

CAS Number	Chemical Name	Category	MTCA Method B (Soil)	Number of Values	Maximum (mg/kg)	Mimimum (mg/kg)
53-70-3	Dibenzo(a,h)anthracene	Semi-Volatile Organics	0.137	6	2	0.042
132-64-9	Dibenzofuran	Semi-Volatile Organics		5	3.9	0.046
206-44-0	Fluoranthene	Semi-Volatile Organics	3200	31	26	0.0106
86-73-7	Fluorene	Semi-Volatile Organics	3200	19	6.5	0.0036
193-39-5	Indeno(1,2,3-c,d)pyrene	Semi-Volatile Organics	0.137	7	37.692	1.8
91-20-3	Naphthalene	Semi-Volatile Organics	3200	28	46	0.0069
98-95-3	Nitrobenzene	Semi-Volatile Organics	40	1	0.79	0.79
87-86-5	Pentachlorophenol	Semi-Volatile Organics	8.33	2	0.46	0.052
85-01-8	Phenanthrene	Semi-Volatile Organics		28	26	0.0186
129-00-0	Pyrene	Semi-Volatile Organics	2400	31	43	0.0048
71-43-2	Benzene	Volatile Organics	34.5	2	0.082	0.0058
75-09-2	Dichloromethane	Volatile Organics	133	24	0.802	0.0034
100-41-4	Ethylbenzene	Volatile Organics	8000	3	0.837	0.006
108-88-3	Toluene	Volatile Organics	16000	1	0.266	0.266
*Natural background concentration in Puget Sound, Washington						

Table C-3. Summary of detected chemical concentrations in water samples, Gas Works Park.

CAS Number	Chemical Name	Category	MTCA Method B Groundwater	MTCA Method B Surface Water	Number of Values	Maximum (ug/L)	Minimum (ug/L)
DO	Dissolved Oxygen	Conventional			15	3800	0
PH	pH	Conventional			16	8.2	5.5
SPCOND	specific conductivity	Conventional			16	5280	242
TEMPC	temperature (C)	Conventional			16	15.5	10.5
7429-90-5	Aluminum	Metal			2	690	324
7440-38-2	Arsenic	Metal	0.0582	0.0982	17	60	2
7440-39-3	Barium	Metal	1120		2	117	25.1
7440-42-8	Boron	Metal	1440		16	480	30
7440-43-9	Cadmium	Metal	8	20.3	12	4	1
7440-70-2	Calcium	Metal			2	140000	43300
7440-47-3	Chromium	Metal			3	15	2
7440-50-8	Copper	Metal	592	2660	10	59	1
57-12-5	Cyanide, Total	Metal	320	51900	17	8600	10
7439-89-6	Iron	Metal			2	2400	919
7439-92-1	Lead	Metal			3	70	3.72
7439-95-4	Magnesium	Metal			2	14800	6810
7439-96-5	Manganese	Metal	2240		2	1060	770
7439-97-6	Mercury	Metal	4.8		13	1.1	0.1
7440-02-0	Nickel	Metal	320	1100	12	156	4
7440-09-7	Potassium	Metal			2	2280	1300
7782-49-2	Selenium	Metal	80		2	1	1
7440-23-5	Sodium	Metal			2	25600	9700
7440-62-2	Vanadium	Metal	112		2	8.6	5.9
7440-66-6	Zinc	Metal	4800	16500	18	606	6
50-29-3	4,4'-DDT	Pesticide	0.257	0.000356	2	0.03	0.03
76-44-8	Heptachlor	Pesticide	0.0194	0.000129	2	1.2	0.02
92-52-4	1,1'-Biphenyl	Semi-Volatile Organics	800		4	70	10
CAS-33	1,1a,6,6a-Tetrahydrocycloprop(a)indeno	Semi-Volatile Organics			3	250	50
575-41-7	1,3-Dimethylnaphthalene	Semi-Volatile Organics			2	60	20
571-58-4	1,4-Dimethylnaphthalene	Semi-Volatile Organics			1	10	10
CAS-1	1-Ethyl-2-methylbenzene	Semi-Volatile Organics			4	1200	120
1127-76-0	1-Ethylnaphthalene	Semi-Volatile Organics			1	10	10
90-12-0	1-Methylnaphthalene	Semi-Volatile Organics			10	1100	20
CAS-4	1-Phenylethanone	Semi-Volatile Organics			1	520	520
CAS-7	1H,3H-Naphtho(1,8-cd)-pyran-1,3-dione	Semi-Volatile Organics			1	150	150
697-82-5	2,3,5-Trimethylphenol	Semi-Volatile Organics			1	250	250
1462-84-6	2,3,6-Trimethylpyridine	Semi-Volatile Organics			1	80	80
CAS-3	2,3-Dihydro-(1H)-indene	Semi-Volatile Organics			4	40	10
CAS-6	2,3-Dihydro-(1H)-indene-1-one	Semi-Volatile Organics			3	610	140
581-40-8	2,3-Dimethylnaphthalene	Semi-Volatile Organics			6	100	10
526-75-0	2,3-Dimethylphenol	Semi-Volatile Organics			1	340	340
583-61-9	2,3-Dimethylpyridine	Semi-Volatile Organics			1	220	220

Table C-3. Summary of detected chemical concentrations in water samples, Gas Works Park.

CAS Number	Chemical Name	Category	MTCA Method B Groundwater	MTCA Method B Surface Water	Number of Values	Maximum (ug/L)	Minimum (ug/L)
527-60-6	2,4,6-Trimethylphenol	Semi-Volatile Organics			1	180	180
108-75-8	2,4,6-Trimethylpyridine	Semi-Volatile Organics			1	160	160
105-67-9	2,4-Dimethylphenol	Semi-Volatile Organics	320	553	2	1000	1.1
108-47-4	2,4-Dimethylpyridine	Semi-Volatile Organics			1	930	930
1198-37-4	2,4-Dimethylquinolin	Semi-Volatile Organics			1	50	50
95-87-4	2,5-Dimethylphenol	Semi-Volatile Organics			1	1500	1500
576-26-1	2,6-Dimethylphenol	Semi-Volatile Organics	9.6		1	410	410
877-43-0	2,6-Dimethylquinolin	Semi-Volatile Organics			1	40	40
30230-52-5	2-Ethyl-4-methylphenol	Semi-Volatile Organics			1	470	470
1122-69-6	2-Ethyl-6-methylpyridine	Semi-Volatile Organics			1	130	130
90-00-6	2-Ethylphenol	Semi-Volatile Organics			2	150	100
91-57-6	2-Methylnaphthalene	Semi-Volatile Organics			8	1400	0.21
95-48-7	2-Methylphenol	Semi-Volatile Organics	800		2	2200	550
109-06-8	2-Methylpyridine	Semi-Volatile Organics			1	2100	2100
91-63-4	2-Methylquinolin	Semi-Volatile Organics			1	800	800
CAS-2	2-Propenylbenzene	Semi-Volatile Organics			5	550	100
95-65-8	3,4-Dimethylphenol	Semi-Volatile Organics	16		1	500	500
108-68-9	3,5-Dimethylphenol	Semi-Volatile Organics			1	2500	2500
618-45-1	3-isopropylphenol	Semi-Volatile Organics			1	120	120
767-60-2	3-Methylindene	Semi-Volatile Organics			4	1600	100
104-55-2	3-Phenyl-2-propanal	Semi-Volatile Organics			1	220	220
360-68-9	3B-Coprostanol	Semi-Volatile Organics			1	1.7	1.7
106-44-5	4-Methylphenol	Semi-Volatile Organics	80		2	1500	60
108-89-4	4-Methylpyridine	Semi-Volatile Organics			1	1900	1900
491-35-0	4-Methylquinolin	Semi-Volatile Organics			1	70	70
83-32-9	Acenaphthene	Semi-Volatile Organics	960	643	12	180	0.2
208-96-8	Acenaphthylene	Semi-Volatile Organics			10	20000	0.7
120-12-7	Anthracene	Semi-Volatile Organics	4800	25900	6	12000	0.11
CAS-35	Benz(e)acephenanthrylene	Semi-Volatile Organics	960	643	1	2.1	2.1
56-55-3	Benzo(a)anthracene	Semi-Volatile Organics	0.0120	0.0296	5	4500	2.6
50-32-8	Benzo(a)pyrene	Semi-Volatile Organics	0.0120	0.0296	5	2200	0.046
205-99-2	Benzo(b)fluoranthene	Semi-Volatile Organics	0.0120	0.0296	4	2000	11
191-24-2	Benzo(g,h,i)perylene	Semi-Volatile Organics			5	1800	0.058
207-08-9	Benzo(k)fluoranthene	Semi-Volatile Organics	0.0120	0.0296	2	3600	1.1
11095-43-5	Benzothiophene	Semi-Volatile Organics			9	590	10
86-74-8	Carbazole	Semi-Volatile Organics	4.38		4	590	30
218-01-9	Chrysene	Semi-Volatile Organics	0.0120	0.0296	6	4200	3
84-74-2	Di-n-Butylphthalate	Semi-Volatile Organics	1600	2910	1	0.11	0.11
53-70-3	Dibenzo(a,h)anthracene	Semi-Volatile Organics	0.0120	0.0296	2	45	0.35
132-64-9	Dibenzofuran	Semi-Volatile Organics			2	60	0.072
132-65-0	Dibenzothiophene	Semi-Volatile Organics			1	10	10
28804-88-8	Dimethylnaphthalene	Semi-Volatile Organics			3	400	80

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Table C-3. Summary of detected chemical concentrations in water samples, Gas Works Park.

CAS Number	Chemical Name	Category	MTCA Method B Groundwater	MTCA Method B Surface Water	Number of Values	Maximum (ug/L)	Minimum (ug/L)
206-44-0	Fluoranthene	Semi-Volatile Organics	640	90.2	9	41000	0.06
86-73-7	Fluorene	Semi-Volatile Organics	640	3460	11	20000	0.3
95-13-6	Indene	Semi-Volatile Organics			7	13000	10
193-39-5	Indeno(1,2,3-c,d)pyrene	Semi-Volatile Organics	0.0120	0.0296	5	1900	0.038
119-65-3	Isoquinolin	Semi-Volatile Organics			1	80	80
491-30-5	Isoquinolinone	Semi-Volatile Organics			1	5700	5700
108-39-4	m-cresol	Semi-Volatile Organics	800		1	1500	1500
25586-38-3	Methylbenzofuran	Semi-Volatile Organics			1	140	140
91-20-3	Naphthalene	Semi-Volatile Organics	320	9880	33	170000	0.21
106-49-0	p-toluidine	Semi-Volatile Organics	0.461		1	110	110
87-86-5	Pentachlorophenol	Semi-Volatile Organics	0.729	4.91	1	0.18	0.18
85-01-8	Phenanthrene	Semi-Volatile Organics			11	47000	0.71
108-95-2	Phenol	Semi-Volatile Organics	9600	1110000	2	560	340
129-00-0	Pyrene	Semi-Volatile Organics	480	2590	9	32000	0.055
110-86-1	Pyridine	Semi-Volatile Organics	16		1	1600	1600
59-31-4	Quinolinone	Semi-Volatile Organics			1	5500	5500
25551-13-7	Trimethylbenzene	Semi-Volatile Organics			4	760	380
TPH	TPHs	TPH			2	8000	6400
107-06-2	1,2-Dichloroethane (total)	Volatile Organics	0.481	59.4	1	2.9	2.9
67-64-1	Acetone	Volatile Organics	800		5	60	10
71-43-2	Benzene	Volatile Organics	1.51	43.0	31	620000	0.11
75-00-3	Chloroethane	Volatile Organics			1	13	13
75-09-2	Dichloromethane	Volatile Organics	5.83	960	1	7	7
100-41-4	Ethylbenzene	Volatile Organics	800	6910	26	11000	0.57
108-38-3	m,p-xylene	Volatile Organics	16000		14	27000	5
95-47-6	o-xylene	Volatile Organics	16000		12	9900	1.1
100-42-5	Styrene	Volatile Organics	1.46		4	3800	33
108-88-3	Toluene	Volatile Organics	1600	48500	23	150000	0.12
1330-20-7	Total Xylenes	Volatile Organics	16000		8	6100	6.1

Table C-4. Summary of nondetected chemical concentrations in shallow soil samples (6 inches or less in depth), Gas Works Park.

CAS Number	Chemical Name	Category	MTCA Method B Soil	Number of Samples	Maximum (mg/kg)	Minimum (mg/kg)
7440-36-0	Antimony	Metal		26	4	0.2
7782-49-2	Selenium	Metal	400	14	0.4	0.1
7440-22-4	Silver	Metal	400	1	0.3	0.3
7440-28-0	Thallium	Metal	5.6	27	0.5	0.2
12674-11-2	Aroclor 1016 (PCB)	PCB	5.6	24	0.21	0.027
11104-28-2	Aroclor-1221	PCB		24	0.21	0.027
11141-16-5	Aroclor-1232	PCB		24	0.21	0.027
53469-21-9	Aroclor-1242	PCB		24	0.21	0.027
12672-29-6	Aroclor-1248	PCB		24	0.21	0.027
11097-69-1	Aroclor-1254	PCB	1.6	1	0.033	0.033
11096-82-5	Aroclor-1260	PCB		2	0.033	0.033
72-54-8	4,4'-DDD	Pesticide	4.17	23	0.01	0.001
72-55-9	4,4'-DDE	Pesticide	2.94	23	0.01	0.001
50-29-3	4,4'-DDT	Pesticide	2.94	23	0.01	0.001
309-00-2	Aldrin	Pesticide	0.0588	24	0.01	0.001
959-98-8	Alpha Endosulfan	Pesticide		24	0.01	0.001
319-84-6	Alpha-BHC	Pesticide	0.16	24	0.01	0.001
33213-65-9	Beta Endosulfan	Pesticide		24	0.01	0.001
319-85-7	Beta-BHC	Pesticide	0.56	24	0.01	0.001
57-74-9	Chlordane	Pesticide	0.77	24	0.01	0.001
319-86-8	Delta-BHC	Pesticide		24	0.01	0.001
60-57-1	Dieldrin	Pesticide	0.0625	24	0.01	0.001
1031-07-8	Endosulfan sulfate	Pesticide		24	0.01	0.001
72-20-8	Endrin	Pesticide	24	24	0.01	0.001
7421-93-4	Endrin Aldehyde	Pesticide		24	0.01	0.001
58-89-9	Gamma-BHC (Lindane)	Pesticide	0.769	24	0.01	0.001
76-44-8	Heptachlor	Pesticide	0.222	24	0.01	0.001
1024-57-3	Heptachlor expoxide	Pesticide	0.110	24	0.01	0.001
8001-35-2	Toxaphene	Pesticide	0.909	24	0.63	0.08
92-52-4	1,1'-Biphenyl	Semi-Volatile Organics	4000	0		
120-82-1	1,2,4-Trichlorobenzene	Semi-Volatile Organics	400	26	18	0.02
95-50-1	1,2-Dichlorobenzene	Semi-Volatile Organics	7200	26	1.8	0.02
122-66-7	1,2-Diphenylhydrazine	Semi-Volatile Organics	1.25	26	9	0.1
122-66-7	1,2-Diphenylhydrazine	Semi-Volatile Organics	1.25	26	9	0.1
541-73-1	1,3-Dichlorobenzene	Semi-Volatile Organics		26	1.8	0.02
575-41-7	1,3-Dimethylnaphthalene	Semi-Volatile Organics		0		
106-46-7	1,4-Dichlorobenzene	Semi-Volatile Organics	41.7	26	1.8	0.02
571-61-9	1,5 Dimethyl Naphthalene	Semi-Volatile Organics		0		
90-12-0	1-Methylnaphthalene	Semi-Volatile Organics		0		
605-02-7	1-Phenyl Naphthalene	Semi-Volatile Organics		0		
7396-38-5	2,4,5,7-Tetramethyl Phenanthrene	Semi-Volatile Organics		0		
95-95-4	2,4,5-Trichlorophenol	Semi-Volatile Organics	8000	26	9	0.1
88-06-2	2,4,6-Trichlorophenol	Semi-Volatile Organics	90.9	26	9	0.107
120-83-2	2,4-Dichlorophenol	Semi-Volatile Organics	240	26	4.5	0.107

Table C-4. Summary of nondetected chemical concentrations in shallow soil samples (6 inches or less in depth), Gas Works Park.

CAS Number	Chemical Name	Category	MTCA Method B Soil	Number of Samples	Maximum (mg/kg)	Minimum (mg/kg)
105-67-9	2,4-Dimethylphenol	Semi-Volatile Organics	1600	26	4.5	0.0568
51-28-5	2,4-Dinitrophenol	Semi-Volatile Organics	160	26	45	0.3
121-14-2	2,4-Dinitrotoluene	Semi-Volatile Organics	160	26	9	0.1
CAS-30	2,5-Dimethyl Phenanthrene	Semi-Volatile Organics		0		
606-20-2	2,6-Dinitrotoluene	Semi-Volatile Organics	80	26	9	0.1
91-58-7	2-Chloronapthalene	Semi-Volatile Organics		26	1.8	0.02
95-57-8	2-Chlorophenol	Semi-Volatile Organics	400	26	1.8	0.06
930-68-7	2-Cyclohexen-1-one,3,5,5-t	Semi-Volatile Organics		2	0.451	0.107
613-12-7	2-Methylanthracene	Semi-Volatile Organics		0		
91-57-6	2-Methylnaphthalene	Semi-Volatile Organics		4	1.8	0.4
95-48-7	2-Methylphenol	Semi-Volatile Organics	4000	25	3.6	0.04
88-74-4	2-Nitroaniline	Semi-Volatile Organics		2	0.451	0.107
88-75-5	2-Nitrophenol	Semi-Volatile Organics		26	4.5	0.107
CAS-2	2-Propenylbenzene	Semi-Volatile Organics		0		
91-94-1	3,3'-Dichlorobenzidine	Semi-Volatile Organics	2.22	26	3.6	0.04
7343-06-8	3,4,5,6-Tetramethyl Phenanthrene	Semi-Volatile Organics		2	13	1.3
360-68-9	3B-Coprostanol	Semi-Volatile Organics		3	9.02	1.14
534-52-1	4,6-Dinitro-2-methylphenol	Semi-Volatile Organics		26	45	0.3
101-55-3	4-Bromophenyl phenyl ether	Semi-Volatile Organics		26	9	0.1
59-50-7	4-Chloro-3-methylphenol	Semi-Volatile Organics		2	0.451	0.107
106-47-8	4-Chloroaniline	Semi-Volatile Organics	320	2	0.451	0.107
7005-72-3	4-Chlorophenyl phenyl ether	Semi-Volatile Organics		26	3.6	0.04
26914-17-0	4-Methyl-9H-Fluorene	Semi-Volatile Organics		0		
106-44-5	4-Methylphenol	Semi-Volatile Organics	400	25	3.6	0.04
100-01-6	4-Nitroaniline	Semi-Volatile Organics		2	0.451	0.107
100-02-7	4-Nitrophenol	Semi-Volatile Organics		26	45	0.3
CAS-27	5-Chloro-IH-benzotriazole	Semi-Volatile Organics		0		
108121-76-2	9,10-Anthracenedione	Semi-Volatile Organics		0		
CAS-28	9H-Fluoren-9-One	Semi-Volatile Organics		0		
83-32-9	Acenaphthene	Semi-Volatile Organics	4800	44	200	0.04
208-96-8	Acenaphthylene	Semi-Volatile Organics		34	10	0.1
62-53-3	Aniline	Semi-Volatile Organics	175	3	0.451	0
120-12-7	Anthracene	Semi-Volatile Organics	24000	8	0.6	0.002
92-87-5	Benzidine	Semi-Volatile Organics	0.00435	26	27	0.214
56-55-3	Benzo(a)anthracene	Semi-Volatile Organics	0.137	2	0.2	0.01
50-32-8	Benzo(a)pyrene	Semi-Volatile Organics	0.137	2	0.2	0.01
239-35-0	Benzo(b)Naphtho-(2,1-D)Thiophen	Semi-Volatile Organics		0		
203-12-3	Benzo(g,h,i)fluoranthene	Semi-Volatile Organics		0		
191-24-2	Benzo(g,h,i)perylene	Semi-Volatile Organics		2	2	0.02
205-82-3	Benzo(j)fluoranthene	Semi-Volatile Organics		0		
207-08-9	Benzo(k)fluoranthene	Semi-Volatile Organics	0.137	1	0.005	0.005
65-85-0	Benzoic acid	Semi-Volatile Organics	320000	25	18	0.2
100-51-6	Benzyl alcohol	Semi-Volatile Organics	24000	26	9	0.1
111-91-1	Bis (2-chloroethoxy) methane	Semi-Volatile Organics		26	1.8	0.02

Table C-4. Summary of nondetected chemical concentrations in shallow soil samples (6 inches or less in depth), Gas Works Park.

CAS Number	Chemical Name	Category	MTCA Method B Soil	Number of Samples	Maximum (mg/kg)	Minimum (mg/kg)
111-44-4	Bis (2-chloroethyl) ether	Semi-Volatile Organics	0.909	26	1.8	0.02
39638-32-9	Bis (2-chloroisopropyl) ether	Semi-Volatile Organics	3200	26	1.8	0.02
117-81-7	Bis (2-ethylhexyl)phthalate	Semi-Volatile Organics	71.429	6	0.6	0.202
85-68-7	Butyl benzyl phthalate	Semi-Volatile Organics	16000	25	1.8	0.06
58-08-2	CAFFEINE	Semi-Volatile Organics		2	0.451	0.107
218-01-9	Chrysene	Semi-Volatile Organics	0.137	1	0.01	0.01
84-74-2	Di-n-Butylphthalate	Semi-Volatile Organics	8000	27	12.8	0.02
117-84-0	Di-n-octylphthalate	Semi-Volatile Organics	1600	25	1.8	0.06
53-70-3	Dibenzo(a,h)anthracene	Semi-Volatile Organics	0.137	40	6	0.04
132-64-9	Dibenzofuran	Semi-Volatile Organics		13	1.8	0.02
132-65-0	Dibenzothiophene	Semi-Volatile Organics		0		
84-66-2	Diethyl phthalate	Semi-Volatile Organics	64000	26	1.8	0.02
131-11-3	Dimethyl phthalate	Semi-Volatile Organics	80000	26	1.8	0.02
86-73-7	Fluorene	Semi-Volatile Organics	3200	28	2	0.02
118-74-1	Hexachlorobenzene	Semi-Volatile Organics	0.625	26	4.5	0.05
87-68-3	Hexachlorobutadiene	Semi-Volatile Organics	12.8	26	4.5	0.05
77-47-4	Hexachlorocyclopentadiene	Semi-Volatile Organics	560	26	36	0.4
67-72-1	Hexachloroethane	Semi-Volatile Organics	71.4	26	3.6	0.04
243-17-4	II-H-Benzo(b)fluorene	Semi-Volatile Organics		0		
193-39-5	Indeno(1,2,3-c,d)pyrene	Semi-Volatile Organics	0.137	2	2	0.01
78-59-1	Isophorone	Semi-Volatile Organics	1053	24	1.8	0.02
99-09-2	m-Nitroaniline	Semi-Volatile Organics		4	0.902	0.214
621-64-7	N-Nitroso-di-n-propylamine	Semi-Volatile Organics	0.143	26	18	0.107
62-75-9	N-Nitrosodimethylamine	Semi-Volatile Organics	0.0196	2	0.902	0.214
86-30-6	N-Nitrosodiphenylamine(1)	Semi-Volatile Organics	204	26	27	0.107
91-20-3	Naphthalene	Semi-Volatile Organics	3200	32	10	0.1
98-95-3	Nitrobenzene	Semi-Volatile Organics	40	25	1.8	0.02
54548-50-4	p-Chloro-m-cresol	Semi-Volatile Organics		24	0.9	0.03
87-86-5	Pentachlorophenol	Semi-Volatile Organics	8.33	27	27	0.114
108-95-2	Phenol	Semi-Volatile Organics	48000	25	18	0.0568
129-00-0	Pyrene	Semi-Volatile Organics	2400	1	0.02	0.02
110-86-1	Pyridine	Semi-Volatile Organics	80	2	0.902	0.214
7704-34-9	Sulfur	Semi-Volatile Organics		0		
630-20-6	1,1,1,2-Tetrachloroethane	Volatile Organics	38.5	2	0.258	0.0025
71-55-6	1,1,1-Trichloroethane	Volatile Organics	72000	26	0.0077	0.002
79-34-5	1,1,2,2-Tetrachloroethane	Volatile Organics	5	26	0.258	0.002
79-00-5	1,1,2-Trichloroethane	Volatile Organics	17.5	26	0.258	0.002
75-34-3	1,1-Dichloroethane	Volatile Organics	8000	26	0.258	0.002
75-35-4	1,1-Dichloroethene	Volatile Organics	1.67	26	0.258	0.002
563-58-6	1,1-Dichloropropene	Volatile Organics		2	0.258	0.0025
96-18-4	1,2,3-Trichloropropane	Volatile Organics	0.143	2	0.258	0.0025
120-82-1	1,2,4-Trichlorobenzene	Volatile Organics	400	2	0.516	0.005
96-12-8	1,2-Dibromo-3-chloropropane	Volatile Organics	0.714	2	0.258	0.0025
106-93-4	1,2-Dibromoethane	Volatile Organics	0.0118	2	0.258	0.0025

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Table C-4. Summary of nondetected chemical concentrations in shallow soil samples (6 inches or less in depth), Gas Works Park.

CAS Number	Chemical Name	Category	MTCA Method B Soil	Number of Samples	Maximum (mg/kg)	Minimum (mg/kg)
95-50-1	1,2-Dichlorobenzene	Volatile Organics	7200	2	0.258	0.0025
107-06-2	1,2-Dichloroethane (total)	Volatile Organics	11.0	26	0.258	0.002
78-87-5	1,2-Dichloropropane	Volatile Organics	14.7	26	0.258	0.002
541-73-1	1,3-Dichlorobenzene	Volatile Organics		2	0.258	0.0025
142-28-9	1,3-Dichloropropane	Volatile Organics		2	0.258	0.0025
106-46-7	1,4-Dichlorobenzene	Volatile Organics	41.7	2	0.258	0.0025
594-20-7	2,2-Dichloropropane	Volatile Organics		2	0.258	0.0025
78-93-3	2-Butanone	Volatile Organics	48000	2	1.29	0.0125
110-75-8	2-Chloroethylvinyl ether	Volatile Organics		24	0.0077	0.002
95-49-8	2-Chlorotoluene	Volatile Organics	1600	2	0.258	0.0025
95-49-8	2-Chlorotoluene	Volatile Organics	1600	2	0.258	0.0025
591-78-6	2-Hexanone	Volatile Organics		2	0.516	0.005
CAS-17	2-Pentanone, 4-methyl	Volatile Organics		2	0.258	0.0025
106-43-4	4-Chlorotoluene	Volatile Organics		2	0.258	0.0025
67-64-1	Acetone	Volatile Organics	8000	2	2.58	0.025
107-02-8	Acrolein	Volatile Organics	1600	24	0.038	0.01
107-13-1	Acrylonitrile	Volatile Organics	1.85	24	0.0077	0.002
71-43-2	Benzene	Volatile Organics	34.5	26	0.258	0.002
CAS-18	Benzene, (1-methylethyl)	Volatile Organics		2	0.258	0.0025
CAS-19	Benzene, (1-methylpropyl)	Volatile Organics		2	0.258	0.0025
87-61-6	Benzene, 1,2,3-trichloro	Volatile Organics		2	1.29	0.0125
95-63-6	Benzene, 1,2,4-trimethyl	Volatile Organics		2	0.258	0.0025
108-67-8	Benzene, 1,3,5-trimethyl	Volatile Organics		2	0.258	0.0025
CAS-22	Benzene, 1-methyl-4-(1-m	Volatile Organics		2	0.258	0.0025
108-86-1	Bromobenzene	Volatile Organics		2	0.258	0.0025
74-97-5	Bromochloromethane	Volatile Organics		2	0.258	0.0025
75-27-4	Bromodichloromethane	Volatile Organics	16.1	26	0.258	0.002
75-25-2	Bromoform	Volatile Organics	127	26	0.258	0.002
74-83-9	Bromomethane	Volatile Organics	112	26	0.258	0.002
CAS-24	Butylbenzene	Volatile Organics		2	0.258	0.0025
75-15-0	Carbon disulfide	Volatile Organics	8000	2	0.516	0.005
56-23-5	Carbon tetrachloride	Volatile Organics	7.69	26	0.258	0.002
108-90-7	Chlorobenzene	Volatile Organics	1600	26	0.258	0.002
75-00-3	Chloroethane	Volatile Organics		26	0.258	0.002
67-66-3	Chloroform	Volatile Organics	164	24	0.0077	0.002
74-87-3	Chloromethane	Volatile Organics	76.9	26	0.258	0.002
156-59-2	cis-1,2-Dichloroethene	Volatile Organics	800	2	0.258	0.0025
10061-01-5	cis-1,3-Dichloropropene	Volatile Organics		26	0.274	0.002
124-48-1	Dibromochloromethane	Volatile Organics	11.9	27	0.258	0.002
74-95-3	Dibromomethane	Volatile Organics		2	0.258	0.0025
75-71-8	Dichlorodifluoromethane	Volatile Organics	16000	25	0.258	0.002
75-09-2	Dichloromethane	Volatile Organics	133	26	1.01	0.0023
100-41-4	Ethylbenzene	Volatile Organics	8000	21	0.258	0.002
87-68-3	Hexachlorobutadiene	Volatile Organics	12.8	2	0.258	0.0025

Table C-4. Summary of nondetected chemical concentrations in shallow soil samples (6 inches or less in depth), Gas Works Park.

CAS Number	Chemical Name	Category	MTCA Method B Soil	Number of Samples	Maximum (mg/kg)	Minimum (mg/kg)
108-38-3	m,p-xylene	Volatile Organics	160000	3	0.516	0.005
91-20-3	Naphthalene	Volatile Organics	3200	2	0.516	0.0091
95-47-6	o-xylene	Volatile Organics	160000	3	0.258	0.0025
100-42-5	Styrene	Volatile Organics	33.3	2	0.258	0.0025
98-06-6	tert-Butylbenzene	Volatile Organics		2	0.258	0.0025
127-18-4	Tetrachloroethene	Volatile Organics	19.6	26	0.258	0.002
108-88-3	Toluene	Volatile Organics	16000	22	0.258	0.002
1330-20-7	Total Xylenes	Volatile Organics	160000	3	0.516	0.005
156-60-5	trans-1,2-Dichloroethene	Volatile Organics	1600	26	0.258	0.002
10061-02-6	trans-1,3-Dichloropropene	Volatile Organics		26	0.243	0.002
79-01-6	Trichloroethene	Volatile Organics	90.9	26	0.258	0.002
75-69-4	Trichlorofluoromethane	Volatile Organics	24000	26	0.258	0.002
75-01-4	Vinyl Chloride	Volatile Organics	0.526	26	0.258	0.002

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Table C-5. Summary of nondetected chemical concentrations in deep soil samples (greater than 6 inches in depth), Gas Works Park.

CAS Number	Chemical Name	Category	MTCA Method B Soil	Number of Samples	Maximum (mg/kg)	Minimum (mg/kg)
7782-49-2	Selenium	Metal	400	15	0.1	0.1
12674-11-2	Aroclor 1016 (PCB)	PCB	5.6	24	0.0058	0.0043
11104-28-2	Aroclor-1221	PCB		24	0.0058	0.0043
11141-16-5	Aroclor-1232	PCB		24	0.0058	0.0043
53469-21-9	Aroclor-1242	PCB		24	0.0058	0.0043
12672-29-6	Aroclor-1248	PCB		24	0.0058	0.0043
11097-69-1	Aroclor-1254	PCB	1.600	24	0.0058	0.0043
11096-82-5	Aroclor-1260	PCB		24	0.0058	0.0043
72-54-8	4,4'-DDD	Pesticide	4.167	11	0.0058	0.0043
72-55-9	4,4'-DDE	Pesticide	2.941	20	0.0058	0.0043
50-29-3	4,4'-DDT	Pesticide	2.941	7	0.0048	0.0043
309-00-2	Aldrin	Pesticide	0.0588	21	0.0058	0.0043
959-98-8	Alpha Endosulfan	Pesticide		15	0.0052	0.0043
319-84-6	Alpha-BHC	Pesticide	0.159	8	0.0051	0.0043
33213-65-9	Beta Endosulfan	Pesticide		13	0.0048	0.0043
319-85-7	Beta-BHC	Pesticide	0.556	14	0.0052	0.0043
57-74-9	Chlordane	Pesticide	0.769	24	0.0058	0.0043
319-86-8	Delta-BHC	Pesticide		23	0.0058	0.0043
60-57-1	Dieldrin	Pesticide	0.0625	21	0.0058	0.0043
1031-07-8	Endosulfan sulfate	Pesticide		23	0.0058	0.0043
72-20-8	Endrin	Pesticide	24	11	0.0048	0.0043
7421-93-4	Endrin Aldehyde	Pesticide		17	0.0058	0.0043
58-89-9	Gamma-BHC (Lindane)	Pesticide	0.769	11	0.0058	0.0044
76-44-8	Heptachlor	Pesticide	0.222	23	0.0058	0.0043
1024-57-3	Heptachlor expoxide	Pesticide	0.110	9	0.0058	0.0043
8001-35-2	Toxaphene	Pesticide	0.909	24	0.0058	0.0043
120-82-1	1,2,4-Trichlorobenzene	Semi-Volatile Organics	400	34	7.5	0.0106
95-50-1	1,2-Dichlorobenzene	Semi-Volatile Organics	7200	34	7.5	0.0106
122-66-7	1,2-Diphenylhydrazine	Semi-Volatile Organics	1.25	24	2.078	0.0213
122-66-7	1,2-Diphenylhydrazine	Semi-Volatile Organics	1.25	24	2.078	0.0213
541-73-1	1,3-Dichlorobenzene	Semi-Volatile Organics		34	7.5	0.0106
106-46-7	1,4-Dichlorobenzene	Semi-Volatile Organics	41.7	34	7.5	0.0106
95-95-4	2,4,5-Trichlorophenol	Semi-Volatile Organics	8000	9	7.5	0.33
88-06-2	2,4,6-Trichlorophenol	Semi-Volatile Organics	90.9	34	7.5	0.0106
120-83-2	2,4-Dichlorophenol	Semi-Volatile Organics	240	34	7.5	0.0106
105-67-9	2,4-Dimethylphenol	Semi-Volatile Organics	1600	34	7.5	0.0106
51-28-5	2,4-Dinitrophenol	Semi-Volatile Organics	160	34	7.5	0.053
121-14-2	2,4-Dinitrotoluene	Semi-Volatile Organics	160	34	7.5	0.0213
606-20-2	2,6-Dinitrotoluene	Semi-Volatile Organics	80	34	7.5	0.0213
91-58-7	2-Chloronapthalene	Semi-Volatile Organics		34	7.5	0.0106
95-57-8	2-Chlorophenol	Semi-Volatile Organics	400	34	7.5	0.0106
91-57-6	2-Methylnaphthalene	Semi-Volatile Organics		5	0.73	0.33
95-48-7	2-Methylphenol	Semi-Volatile Organics	4000	10	7.5	0.33
88-74-4	2-Nitroaniline	Semi-Volatile Organics		10	7.5	0.33

Table C-5. Summary of nondetected chemical concentrations in deep soil samples (greater than 6 inches in depth), Gas Works Park.

CAS Number	Chemical Name	Category	MTCA Method B Soil	Number of Samples	Maximum (mg/kg)	Minimum (mg/kg)
88-75-5	2-Nitrophenol	Semi-Volatile Organics		34	7.5	0.0213
91-94-1	3,3'-Dichlorobenzidine	Semi-Volatile Organics	2.22	34	7.5	0.0213
534-52-1	4,6-Dinitro-2-methylphenol	Semi-Volatile Organics		34	7.5	0.0213
101-55-3	4-Bromophenyl phenyl ether	Semi-Volatile Organics		34	7.5	0.0106
59-50-7	4-Chloro-3-methylphenol	Semi-Volatile Organics		10	7.5	0.33
106-47-8	4-Chloroaniline	Semi-Volatile Organics	320	10	7.5	0.33
7005-72-3	4-Chlorophenyl phenyl ether	Semi-Volatile Organics		34	7.5	0.0106
106-44-5	4-Methylphenol	Semi-Volatile Organics	400	10	7.5	0.33
100-01-6	4-Nitroaniline	Semi-Volatile Organics		10	7.5	0.33
100-02-7	4-Nitrophenol	Semi-Volatile Organics		34	10.389	0.106
83-32-9	Acenaphthene	Semi-Volatile Organics	4800	23	1.039	0.0106
208-96-8	Acenaphthylene	Semi-Volatile Organics		8	0.899	0.0106
120-12-7	Anthracene	Semi-Volatile Organics	24000	25	1.039	0.0106
92-87-5	Benzidine	Semi-Volatile Organics	0.00435	24	4.156	0.0426
56-55-3	Benzo(a)anthracene	Semi-Volatile Organics	0.137	7	0.73	0.0034
50-32-8	Benzo(a)pyrene	Semi-Volatile Organics	0.137	18	1.905	0.0213
205-99-2	Benzo(b)fluoranthene	Semi-Volatile Organics	0.137	14	1.86	0.0213
191-24-2	Benzo(g,h,i)perylene	Semi-Volatile Organics		28	2.078	0.0213
207-08-9	Benzo(k)fluoranthene	Semi-Volatile Organics	0.137	23	2.078	0.0213
65-85-0	Benzoic acid	Semi-Volatile Organics	320000	9	7.5	0.33
100-51-6	Benzyl alcohol	Semi-Volatile Organics	24000	10	7.5	0.33
111-91-1	Bis (2-chloroethoxy) methane	Semi-Volatile Organics		34	7.5	0.0213
111-44-4	Bis (2-chloroethyl) ether	Semi-Volatile Organics	0.909	34	7.5	0.0106
39638-32-9	Bis (2-chloroisopropyl) ether	Semi-Volatile Organics	3200	34	7.5	0.0213
117-81-7	Bis (2-ethylhexyl)phthalate	Semi-Volatile Organics	71.4	22	7.5	0.0106
85-68-7	Butyl benzyl phthalate	Semi-Volatile Organics	16000	34	7.5	0.0106
218-01-9	Chrysene	Semi-Volatile Organics	0.137	6	0.73	0.0034
84-74-2	Di-n-Butylphthalate	Semi-Volatile Organics	8000	34	7.5	0.0106
117-84-0	Di-n-octylphthalate	Semi-Volatile Organics	1600	34	7.5	0.0106
53-70-3	Dibenzo(a,h)anthracene	Semi-Volatile Organics	0.137	28	2.078	0.0213
132-64-9	Dibenzofuran	Semi-Volatile Organics		5	2.4	0.33
84-66-2	Diethyl phthalate	Semi-Volatile Organics	64000	34	7.5	0.0106
131-11-3	Dimethyl phthalate	Semi-Volatile Organics	80000	34	7.5	0.0106
206-44-0	Fluoranthene	Semi-Volatile Organics	3200	3	0.73	0.37
86-73-7	Fluorene	Semi-Volatile Organics	3200	15	0.952	0.0106
118-74-1	Hexachlorobenzene	Semi-Volatile Organics	0.625	34	7.5	0.0106
87-68-3	Hexachlorobutadiene	Semi-Volatile Organics	12.8	34	7.5	0.0106
77-47-4	Hexachlorocyclopentadiene	Semi-Volatile Organics	560	34	7.5	0.0106
67-72-1	Hexachloroethane	Semi-Volatile Organics	71.4	34	7.5	0.0106
193-39-5	Indeno(1,2,3-c,d)pyrene	Semi-Volatile Organics	0.137	27	2.078	0.0213
78-59-1	Isophorone	Semi-Volatile Organics	1053	34	7.5	0.0106
99-09-2	m-Nitroaniline	Semi-Volatile Organics		20	7.5	0.33
621-64-7	N-Nitroso-di-n-propylamine	Semi-Volatile Organics	0.143	34	7.5	0.0213
62-75-9	N-Nitrosodimethylamine	Semi-Volatile Organics	0.0196	24	1.039	0.0106

Table C-5. Summary of nondetected chemical concentrations in deep soil samples (greater than 6 inches in depth), Gas Works Park.

CAS Number	Chemical Name	Category	MTCA Method B Soil	Number of Samples	Maximum (mg/kg)	Minimum (mg/kg)
86-30-6	N-Nitrosodiphenylamine(1)	Semi-Volatile Organics	204	34	7.5	0.0106
91-20-3	Naphthalene	Semi-Volatile Organics	3200	6	0.952	0.0023
98-95-3	Nitrobenzene	Semi-Volatile Organics	40	33	7.5	0.0106
54548-50-4	p-Chloro-m-cresol	Semi-Volatile Organics		24	2.078	0.0213
87-86-5	Pentachlorophenol	Semi-Volatile Organics	8.33	32	7.5	0.0213
85-01-8	Phenanthrene	Semi-Volatile Organics		6	0.73	0.0068
108-95-2	Phenol	Semi-Volatile Organics	48000	34	7.5	0.0106
129-00-0	Pyrene	Semi-Volatile Organics	2400	3	0.73	0.37
71-55-6	1,1,1-Trichloroethane	Volatile Organics	72000	26	0.03	0.0027
79-34-5	1,1,2,2-Tetrachloroethane	Volatile Organics	5	26	0.03	0.0027
79-00-5	1,1,2-Trichloroethane	Volatile Organics	17.5	26	0.03	0.0027
75-34-3	1,1-Dichloroethane	Volatile Organics	8000	26	0.03	0.0027
75-35-4	1,1-Dichloroethene	Volatile Organics	1.67	26	0.03	0.0027
107-06-2	1,2-Dichloroethane (total)	Volatile Organics	11.0	26	0.03	0.0027
78-87-5	1,2-Dichloropropane	Volatile Organics	14.7	26	0.03	0.0027
110-75-8	2-Chloroethylvinyl ether	Volatile Organics		26	0.03	0.0027
107-02-8	Acrolein	Volatile Organics	1600	26	1.224	0.032
107-13-1	Acrylonitrile	Volatile Organics	1.85	26	1.224	0.0063
71-43-2	Benzene	Volatile Organics	34.5	24	0.03	0.0027
75-27-4	Bromodichloromethane	Volatile Organics	16.1	26	0.03	0.0027
75-25-2	Bromoform	Volatile Organics	127	26	0.03	0.0027
74-83-9	Bromomethane	Volatile Organics	112	26	0.03	0.0027
56-23-5	Carbon tetrachloride	Volatile Organics	7.69	26	0.03	0.0027
108-90-7	Chlorobenzene	Volatile Organics	1600	26	0.03	0.0027
75-00-3	Chloroethane	Volatile Organics		26	0.03	0.0027
67-66-3	Chloroform	Volatile Organics	164	26	0.03	0.0027
74-87-3	Chloromethane	Volatile Organics	76.9	26	0.03	0.0027
10061-01-5	cis-1,3-Dichloropropene	Volatile Organics		26	0.03	0.0027
124-48-1	Dibromochloromethane	Volatile Organics	11.9	26	0.03	0.0027
75-71-8	Dichlorodifluoromethane	Volatile Organics	16000	26	0.03	0.0027
75-09-2	Dichloromethane	Volatile Organics	133	2	0.017	0.0063
100-41-4	Ethylbenzene	Volatile Organics	8000	23	0.0133	0.0027
127-18-4	Tetrachloroethene	Volatile Organics	19.6	26	0.03	0.0027
108-88-3	Toluene	Volatile Organics	16000	25	0.03	0.0027
156-60-5	trans-1,2-Dichloroethene	Volatile Organics	1600	26	0.03	0.0027
10061-02-6	trans-1,3-Dichloropropene	Volatile Organics		26	0.06	0.0055
79-01-6	Trichloroethene	Volatile Organics	90.9	26	0.03	0.0027
75-69-4	Trichlorofluoromethane	Volatile Organics	24000	26	0.03	0.0027
75-01-4	Vinyl Chloride	Volatile Organics	0.526	26	0.03	0.0027

Table C-6. Summary of nondetected chemical concentrations in water samples, Gas Works Park

Cas Number	Chemical Name	Category	MTCA Method B Groundwater	MTCA Method B Surface Water	Number of Samples	Maximum (ug/L)	Minimum (ug/L)
7440-36-0	Antimony	Metal			2	40	40
7440-38-2	Arsenic	Metal	0.0582	0.0982	1	1	1
7440-41-7	Beryllium	Metal	0.0203	0.0793	18	10	0.5
7440-43-9	Cadmium	Metal	8	20.3	6	2	0.4
7440-47-3	Chromium	Metal			15	10	1
7440-48-4	Cobalt	Metal			2	10	10
7440-50-8	Copper	Metal	592	2660	8	20	1
57-12-5	Cyanide, Total	Metal	320	51900	1	10	10
7439-92-1	Lead	Metal			15	5	2
7439-97-6	Mercury	Metal	4.8		5	0.5	0.1
7440-02-0	Nickel	Metal	320	1100	6	20	1
7782-49-2	Selenium	Metal	80		16	2	1
7440-22-4	Silver	Metal	80	25900	18	50	1
7440-28-0	Thallium	Metal	1.12	1.56	2	1	1
12674-11-2	Aroclor 1016 (PCB)	PCB	1.12		5	10	0.1
11104-28-2	Aroclor-1221	PCB			5	10	0.1
11141-16-5	Aroclor-1232	PCB			5	10	0.1
12674-11-2	Aroclor-1242/1016	PCB	1.12		5	10	0.1
12672-29-6	Aroclor-1248	PCB			5	10	0.1
11097-69-1	Aroclor-1254	PCB	0.32		5	10	0.1
11096-82-5	Aroclor-1260	PCB			5	10	0.1
72-54-8	4,4'-DDD	Pesticide	0.365	0.000504	7	1	0.01
72-55-9	4,4'-DDE	Pesticide	0.257	0.000356	7	1	0.01
50-29-3	4,4'-DDT	Pesticide	0.257	0.000356	5	1	0.01
309-00-2	Aldrin	Pesticide	0.00515	8.16E-05	7	1	0.01
786-19-6	Carbophenothion	Pesticide	2.08		7	0.01	0.01
57-74-9	Chlordane	Pesticide	0.0673	0.000354	7	10	0.1
333-41-5	Diazinon	Pesticide	14.4		7	0.01	0.01
60-57-1	Dieldrin	Pesticide	0.00547	8.67E-05	7	1	0.01
115-29-7	Endosulfan	Pesticide	96	57.6	7	1	0.01
72-20-8	Endrin	Pesticide	4.8	0.196	7	1	0.01
563-12-2	Ethion	Pesticide	8		7	0.01	0.01
58-89-9	Gamma-BHC (Lindane)	Pesticide	0.0673	0.0384	7	1	0.01
76-44-8	Heptachlor	Pesticide	0.0194	0.000129	5	1	0.01
1024-57-3	Heptachlor expoxide	Pesticide	0.00962	6.36E-05	7	1	0.01
121-75-5	Malathion	Pesticide	320		7	0.01	0.01
72-43-5	Methoxychlor	Pesticide	80	8.36	7	1	0.01
298-00-0	Methyl Parathion	Pesticide	4		7	0.01	0.01
953-17-3	Methyl Trithion	Pesticide			7	0.01	0.01
2385-85-5	Mirex	Pesticide	0.0486		7	1	0.01
CAS-14	Naphthalenes, Polychlor.	Pesticide			7	10	0.1
56-38-2	Parathion	Pesticide	96		7	0.01	0.01
72-56-0	Perthane	Pesticide	48		5	10	0.1
8001-35-2	Toxaphene	Pesticide	0.0795	0.000450	7	100	1

Table C-6. Summary of nondetected chemical concentrations in water samples, Gas Works Park

Cas Number	Chemical Name	Category	MTCA Method B Groundwater	MTCA Method B Surface Water	Number of Samples	Maximum (ug/L)	Minimum (ug/L)
92-52-4	1,1'-Biphenyl	Semi-Volatile Organics	800		11	5	5
CAS-33	1,1a,6,6a-Tetrahydrocycloprop(a)indeno	Semi-Volatile Organics			12	5	5
120-82-1	1,2,4-Trichlorobenzene	Semi-Volatile Organics	80		2	0.26	0.25
95-50-1	1,2-Dichlorobenzene	Semi-Volatile Organics	720	4200	2	0.26	0.25
122-66-7	1,2-Diphenylhydrazine	Semi-Volatile Organics	0.109	0.325	2	0.26	0.25
122-66-7	1,2-Diphenylhydrazine	Semi-Volatile Organics	0.109	0.325	2	0.26	0.25
541-73-1	1,3-Dichlorobenzene	Semi-Volatile Organics			2	0.26	0.25
575-41-7	1,3-Dimethylnaphthalene	Semi-Volatile Organics			13	5	5
106-46-7	1,4-Dichlorobenzene	Semi-Volatile Organics	1.82	4.86	2	0.26	0.25
571-58-4	1,4-Dimethylnaphthalene	Semi-Volatile Organics			14	5	5
CAS-1	1-Ethyl-2-methylbenzene	Semi-Volatile Organics			11	5	5
1127-76-0	1-Ethylnaphthalene	Semi-Volatile Organics			14	5	5
90-12-0	1-Methylnaphthalene	Semi-Volatile Organics			5	5	5
CAS-4	1-Phenylethanone	Semi-Volatile Organics			14	5	5
CAS-7	1H,3H-Naphtho(1,8-cd)-pyran-1,3-dione	Semi-Volatile Organics			14	5	5
697-82-5	2,3,5-Trimethylphenol	Semi-Volatile Organics			14	5	5
1462-84-6	2,3,6-Trimethylpyridine	Semi-Volatile Organics			14	5	5
CAS-3	2,3-Dihydro-(1H)-indene	Semi-Volatile Organics			11	5	5
CAS-6	2,3-Dihydro-(1H)-indene-1-one	Semi-Volatile Organics			12	5	5
581-40-8	2,3-Dimethylnaphthalene	Semi-Volatile Organics			9	5	5
526-75-0	2,3-Dimethylphenol	Semi-Volatile Organics			14	5	5
583-61-9	2,3-Dimethylpyridine	Semi-Volatile Organics			14	5	5
95-95-4	2,4,5-Trichlorophenol	Semi-Volatile Organics	1600		2	0.26	0.25
88-06-2	2,4,6-Trichlorophenol	Semi-Volatile Organics	7.95	3.93	2	0.26	0.25
527-60-6	2,4,6-Trimethylphenol	Semi-Volatile Organics			14	5	5
108-75-8	2,4,6-Trimethylpyridine	Semi-Volatile Organics			14	5	5
120-83-2	2,4-Dichlorophenol	Semi-Volatile Organics	48	191	2	0.26	0.25
105-67-9	2,4-Dimethylphenol	Semi-Volatile Organics	320	553	15	5	0.25
108-47-4	2,4-Dimethylpyridine	Semi-Volatile Organics			14	5	5
1198-37-4	2,4-Dimethylquinolin	Semi-Volatile Organics			14	5	5
51-28-5	2,4-Dinitrophenol	Semi-Volatile Organics	32	3460	2	10.6	10.1
121-14-2	2,4-Dinitrotoluene	Semi-Volatile Organics	32	1360	2	1.3	1.2
95-87-4	2,5-Dimethylphenol	Semi-Volatile Organics			14	5	5
576-26-1	2,6-Dimethylphenol	Semi-Volatile Organics	9.6		14	5	5
877-43-0	2,6-Dimethylquinolin	Semi-Volatile Organics			14	5	5
606-20-2	2,6-Dinitrotoluene	Semi-Volatile Organics	16		2	0.26	0.25
91-58-7	2-Chloronapthalene	Semi-Volatile Organics			2	0.26	0.25
95-57-8	2-Chlorophenol	Semi-Volatile Organics	80	96.7	2	0.26	0.25
930-68-7	2-Cyclohexen-1-one,3,5,5-t	Semi-Volatile Organics			2	0.26	0.25
30230-52-5	2-Ethyl-4-methylphenol	Semi-Volatile Organics			14	5	5
1122-69-6	2-Ethyl-6-methylpyridine	Semi-Volatile Organics			14	5	5
90-00-6	2-Ethylphenol	Semi-Volatile Organics			13	5	5
91-57-6	2-Methylnaphthalene	Semi-Volatile Organics			9	5	0.26
95-48-7	2-Methylphenol	Semi-Volatile Organics	800		15	5	0.25

Table C-6. Summary of nondetected chemical concentrations in water samples, Gas Works Park

Cas Number	Chemical Name	Category	MTCA Method B Groundwater	MTCA Method B Surface Water	Number of Samples	Maximum (ug/L)	Minimum (ug/L)
109-06-8	2-Methylpyridine	Semi-Volatile Organics			14	5	5
91-63-4	2-Methylquinolin	Semi-Volatile Organics			14	5	5
88-74-4	2-Nitroaniline	Semi-Volatile Organics			2	0.26	0.25
88-75-5	2-Nitrophenol	Semi-Volatile Organics			2	0.26	0.25
CAS-2	2-Propenylbenzene	Semi-Volatile Organics			10	5	5
91-94-1	3,3'-Dichlorobenzidine	Semi-Volatile Organics	0.194	0.04616	2	0.26	0.25
95-65-8	3,4-Dimethylphenol	Semi-Volatile Organics	16		14	5	5
108-68-9	3,5-Dimethylphenol	Semi-Volatile Organics			14	5	5
618-45-1	3-isopropylphenol	Semi-Volatile Organics			14	5	5
767-60-2	3-Methylindene	Semi-Volatile Organics			11	5	5
104-55-2	3-Phenyl-2-propanal	Semi-Volatile Organics			14	5	5
360-68-9	3B-Coprostanol	Semi-Volatile Organics			1	5	5
534-52-1	4,6-Dinitro-2-methylphenol	Semi-Volatile Organics			2	5.3	5
101-55-3	4-Bromophenyl phenyl ether	Semi-Volatile Organics			2	0.26	0.25
59-50-7	4-Chloro-3-methylphenol	Semi-Volatile Organics			2	0.26	0.25
106-47-8	4-Chloroaniline	Semi-Volatile Organics	64		2	0.26	0.25
7005-72-3	4-Chlorophenyl phenyl ether	Semi-Volatile Organics			2	0.26	0.25
106-44-5	4-Methylphenol	Semi-Volatile Organics	80		15	5	0.25
108-89-4	4-Methylpyridine	Semi-Volatile Organics			14	5	5
491-35-0	4-Methylquinolin	Semi-Volatile Organics			14	5	5
100-01-6	4-Nitroaniline	Semi-Volatile Organics			2	0.26	0.25
100-02-7	4-Nitrophenol	Semi-Volatile Organics			2	1.3	1.2
83-32-9	Acenaphthene	Semi-Volatile Organics	960	643	9	5000	0.26
208-96-8	Acenaphthylene	Semi-Volatile Organics			15	100	0.26
62-53-3	Aniline	Semi-Volatile Organics	15.4		2	0.26	0.25
CAS-35	Benz(e)acephenanthrylene	Semi-Volatile Organics	960	643	1	0.26	0.26
92-87-5	Benzidine	Semi-Volatile Organics	0.00038	0.00032	2	0.26	0.25
56-55-3	Benzo(a)anthracene	Semi-Volatile Organics	0.0120	0.0296	1	0.26	0.26
207-08-9	Benzo(k)fluoranthene	Semi-Volatile Organics	0.0120	0.0296	1	0.26	0.26
65-85-0	Benzoic acid	Semi-Volatile Organics	64000		2	5.3	5
11095-43-5	Benzothiophene	Semi-Volatile Organics			6	5	5
100-51-6	Benzyl alcohol	Semi-Volatile Organics	4800		2	0.26	0.25
111-91-1	Bis (2-chloroethoxy) methane	Semi-Volatile Organics			2	0.26	0.25
111-44-4	Bis (2-chloroethyl) ether	Semi-Volatile Organics	0.0398	0.854	2	0.26	0.25
39638-32-9	Bis (2-chloroisopropyl) ether	Semi-Volatile Organics	320	42000	2	0.26	0.25
117-81-7	Bis (2-ethylhexyl)phthalate	Semi-Volatile Organics	6.25	3.56	2	0.26	0.25
85-68-7	Butyl benzyl phthalate	Semi-Volatile Organics	3200	1250	2	0.26	0.25
58-08-2	CAFFEINE	Semi-Volatile Organics			2	0.26	0.25
86-74-8	Carbazole	Semi-Volatile Organics	4.375		13	5	0.25
218-01-9	Chrysene	Semi-Volatile Organics	0.0120	0.0296	15	5	0.26
84-74-2	Di-n-Butylphthalate	Semi-Volatile Organics	1600	2910	1	0.25	0.25
117-84-0	Di-n-octylphthalate	Semi-Volatile Organics	320		2	0.26	0.25
53-70-3	Dibenzo(a,h)anthracene	Semi-Volatile Organics	0.0120	0.0296	2	5000	0.26
132-64-9	Dibenzofuran	Semi-Volatile Organics			15	5	0.26

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Table C-6. Summary of nondetected chemical concentrations in water samples, Gas Works Park

Cas Number	Chemical Name	Category	MTCA Method B Groundwater	MTCA Method B Surface Water	Number of Samples	Maximum (ug/L)	Minimum (ug/L)
132-65-0	Dibenzothiophene	Semi-Volatile Organics			14	5	5
84-66-2	Diethyl phthalate	Semi-Volatile Organics	12800	28400	2	0.26	0.25
131-11-3	Dimethyl phthalate	Semi-Volatile Organics	16000	72000	2	0.26	0.25
28804-88-8	Dimethylnaphthalene	Semi-Volatile Organics			12	5	5
206-44-0	Fluoranthene	Semi-Volatile Organics	640	90.2	16	130	5
86-73-7	Fluorene	Semi-Volatile Organics	640	3460	9	5	0.26
118-74-1	Hexachlorobenzene	Semi-Volatile Organics	0.0547	0.00047	2	0.26	0.25
87-68-3	Hexachlorobutadiene	Semi-Volatile Organics	0.561	29.9	2	0.26	0.25
77-47-4	Hexachlorocyclopentadiene	Semi-Volatile Organics	112	4180	2	2.6	2.5
67-72-1	Hexachloroethane	Semi-Volatile Organics	6.25	5.33	2	0.26	0.25
95-13-6	Indene	Semi-Volatile Organics			8	5	5
119-65-3	Isoquinolin	Semi-Volatile Organics			14	5	5
491-30-5	Isoquinolinone	Semi-Volatile Organics			14	5	5
108-39-4	m-cresol	Semi-Volatile Organics	800		14	5	5
99-09-2	m-Nitroaniline	Semi-Volatile Organics			4	0.53	0.5
25586-38-3	Methylbenzofuran	Semi-Volatile Organics			14	5	5
621-64-7	N-Nitroso-di-n-propylamine	Semi-Volatile Organics	0.0125	0.819	2	0.26	0.25
62-75-9	N-Nitrosodimethylamine	Semi-Volatile Organics	0.00172	4.89	2	0.53	0.5
86-30-6	N-Nitrosodiphenylamine(1)	Semi-Volatile Organics	17.9	9.73	2	0.26	0.25
91-20-3	Naphthalene	Semi-Volatile Organics	320	9880	12	100	0.26
98-95-3	Nitrobenzene	Semi-Volatile Organics	8	449	2	0.26	0.25
106-49-0	p-toluidine	Semi-Volatile Organics	0.461		14	5	5
87-86-5	Pentachlorophenol	Semi-Volatile Organics	0.729	4.91	1	0.53	0.53
85-01-8	Phenanthrene	Semi-Volatile Organics			10	5	0.26
CAS-37	Phenanthrene, 1-methyl-7-(1	Semi-Volatile Organics			2	0.26	0.25
108-95-2	Phenol	Semi-Volatile Organics	9600	1110000	15	5	0.25
129-00-0	Pyrene	Semi-Volatile Organics	480	2590	12	5	5
110-86-1	Pyridine	Semi-Volatile Organics	16		16	5	0.5
59-31-4	Quinolinone	Semi-Volatile Organics			14	5	5
25551-13-7	Trimethylbenzene	Semi-Volatile Organics			11	5	5
TPH	TPHs	TPH			2	5000	5000
630-20-6	1,1,1,2-Tetrachloroethane	Volatile Organics	1.68		2	1	1
71-55-6	1,1,1-Trichloroethane	Volatile Organics	7200	417000	27	5000	1
79-34-5	1,1,2,2-Tetrachloroethane	Volatile Organics	0.219	6.48	27	5000	1
79-00-5	1,1,2-Trichloroethane	Volatile Organics	0.768	25.3	27	5000	1
75-34-3	1,1-Dichloroethane	Volatile Organics	800		27	5000	1
75-35-4	1,1-Dichloroethene	Volatile Organics	0.0729	1.93	27	5000	1
563-58-6	1,1-Dichloropropene	Volatile Organics			2	1	1
96-18-4	1,2,3-Trichloropropane	Volatile Organics	0.00625		2	1	1
120-82-1	1,2,4-Trichlorobenzene	Volatile Organics	80		2	5	5
96-12-8	1,2-Dibromo-3-chloropropane	Volatile Organics	0.0312		2	2	2
106-93-4	1,2-Dibromoethane	Volatile Organics	0.000515		2	1	1
540-49-8	1,2-Dibromoethylene	Volatile Organics			8	1500	3
95-50-1	1,2-Dichlorobenzene	Volatile Organics	720	4200	10	1500	1

Table C-6. Summary of nondetected chemical concentrations in water samples, Gas Works Park

Cas Number	Chemical Name	Category	MTCA Method B Groundwater	MTCA Method B Surface Water	Number of Samples	Maximum (ug/L)	Minimum (ug/L)
107-06-2	1,2-Dichloroethane (total)	Volatile Organics	0.481	59.4	26	5000	1
78-87-5	1,2-Dichloropropane	Volatile Organics	0.643	23.2	27	5000	1
541-73-1	1,3-Dichlorobenzene	Volatile Organics			10	1500	1
142-28-9	1,3-Dichloropropane	Volatile Organics			10	1500	1
106-46-7	1,4-Dichlorobenzene	Volatile Organics	1.82	4.86	10	1500	1
594-20-7	2,2-Dichloropropane	Volatile Organics			2	1	1
78-93-3	2-Butanone	Volatile Organics	4800		19	50000	2
110-75-8	2-Chloroethylvinyl ether	Volatile Organics			8	1500	3
95-49-8	2-Chlorotoluene	Volatile Organics	160		4	1	1
591-78-6	2-Hexanone	Volatile Organics			19	50000	1
CAS-17	2-Pentanone, 4-methyl	Volatile Organics			2	1	1
106-43-4	4-Chlorotoluene	Volatile Organics			2	1	1
108-10-1	4-Methyl-2-pentanone	Volatile Organics	640		17	50000	10
67-64-1	Acetone	Volatile Organics	800		14	50000	2
71-43-2	Benzene	Volatile Organics	1.51	43.0	18	100	1
CAS-18	Benzene, (1-methylethyl)	Volatile Organics			2	1	1
CAS-19	Benzene, (1-methylpropyl)	Volatile Organics			2	1	1
87-61-6	Benzene, 1,2,3-trichloro	Volatile Organics			2	10	10
95-63-6	Benzene, 1,2,4-trimethyl	Volatile Organics			2	1	1
108-67-8	Benzene, 1,3,5-trimethyl	Volatile Organics			2	1	1
CAS-22	Benzene, 1-methyl-4-(1-m	Volatile Organics			2	1	1
108-86-1	Bromobenzene	Volatile Organics			2	1	1
74-97-5	Bromochloromethane	Volatile Organics			2	1	1
75-27-4	Bromodichloromethane	Volatile Organics	0.706	27.9	19	5000	1
75-25-2	Bromoform	Volatile Organics	5.54	219	27	25000	1
74-83-9	Bromomethane	Volatile Organics	11.2		27	50000	1
CAS-24	Butylbenzene	Volatile Organics			2	1	1
75-15-0	Carbon disulfide	Volatile Organics	800		19	5000	1
56-23-5	Carbon tetrachloride	Volatile Organics	0.337	2.66	27	5000	1
108-90-7	Chlorobenzene	Volatile Organics	160	5030	27	5000	1
75-00-3	Chloroethane	Volatile Organics			26	5000	1
67-66-3	Chloroform	Volatile Organics	7.17	283	27	5000	1
74-87-3	Chloromethane	Volatile Organics	3.37	133	27	50000	1
156-59-2	cis-1,2-Dichloroethene	Volatile Organics	80		2	1	1
10061-01-5	cis-1,3-Dichloropropene	Volatile Organics			27	5000	1
124-48-1	Dibromochloromethane	Volatile Organics	0.521	20.6	35	5000	1
74-95-3	Dibromomethane	Volatile Organics			2	1	1
75-71-8	Dichlorodifluoromethane	Volatile Organics	1600		10	1500	1
75-09-2	Dichloromethane	Volatile Organics	5.83	960	26	25000	1
100-41-4	Ethylbenzene	Volatile Organics	800	6910	23	5000	1
87-68-3	Hexachlorobutadiene	Volatile Organics	0.561	29.9	2	5	5
95-47-6	o-xylene	Volatile Organics	16000		8	100	1
100-42-5	Styrene	Volatile Organics	1.46		23	5000	1
98-06-6	tert-Butylbenzene	Volatile Organics			2	1	1

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Table C-6. Summary of nondetected chemical concentrations in water samples, Gas Works Park

Cas Number	Chemical Name	Category	MTCA Method B Groundwater	MTCA Method B Surface Water	Number of Samples	Maximum (ug/L)	Minimum (ug/L)
127-18-4	Tetrachloroethene	Volatile Organics	0.858	4.15	27	5000	1
108-88-3	Toluene	Volatile Organics	1600	48500	26	100	1
1330-20-7	Total Xylenes	Volatile Organics	16000		15	5000	1
156-60-5	trans-1,2-Dichloroethene	Volatile Organics	160	32800	19	5000	1
10061-02-6	trans-1,3-Dichloropropene	Volatile Organics			27	5000	0.94
79-01-6	Trichloroethene	Volatile Organics	3.98	55.6	27	5000	1
75-69-4	Trichlorofluoromethane	Volatile Organics	2400		10	1500	1
108-05-4	Vinyl Acetate	Volatile Organics	8000		17	50000	10
75-01-4	Vinyl Chloride	Volatile Organics	0.0230	2.92	35	5000	1

LAW 09844

APPENDIX G

1998 Gas Works Park Environmental Cleanup, Focused Feasibility Study, Table 14-1 - Comparison of Cleanup Action Alternatives

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Table 14-1 Comparison of Cleanup Action Alternatives

Alternatives	Evaluation Factors					
	Permanence			Restoration Time Frame	Park Use Compatibility and Public Concerns	Cost
	Threshold Criteria	Technology Preference (Rank with Respect to 7 MTCA Preferences)	Effectiveness and Implementability			
1 - No Action	• Acceptable protection of human health • No mitigation of potential benzene impacts from groundwater to Lake Union • Does not comply with cleanup standards or applicable laws • Does not provide compliance monitoring	• 7th (lowest), since only institutional controls will be continued	• Does not meet cleanup action levels for surficial soil or groundwater • Low short- and long-term effectiveness • By definition, fully implementable • No reduction of contaminant toxicity, mobility, or volume for impacted soils or groundwater	Not applicable	• No direct effect on current Park use; lack of long-term effectiveness may significantly effect future Park use	$0

Table 14-1 Comparison of Cleanup Action Alternatives (continued)

DRAFT

Alternatives	Evaluation Factors					
	Permanence			Restoration Time Frame	Park Use Compatibility and Public Concerns	Cost
	Threshold Criteria	Technology Preference (Rank with Respect to 7 MTCA Preferences)	Effectiveness and Implementability			
2 – Soil Cover	• Soil cover provides high degree of human health protection • Minimal mitigation of potential benzene impacts from groundwater to Lake Union • Complies with cleanup standards and applicable laws for soils only • Provides compliance monitoring	• 6th for containment of impacted surficial soils	• Meets cleanup action levels for surficial soils • Will not meet cleanup action levels for groundwater for many years • High short- and long-term effectiveness for isolation of the public from impacted surficial soils • Low short- and long-term effectiveness in mitigating potential benzene impacts from groundwater to Lake Union and meeting cleanup action levels for groundwater over time • No reduction of contaminant toxicity, mobility, or volume for impacted soils or groundwater • Highly implementable	• Short for surficial soils • Indefinite for ground-water	• Significant short-term impacts during construction • Full use of Park during O&M period	$2.8M

Table 14-1 Comparison of Cleanup Action Alternatives (continued)

DRAFT

Alternatives	Evaluation Factors					
	Permanence			Restoration Time Frame	Park Use Compatibility and Public Concerns	Cost
	Threshold Criteria	Technology Preference (Rank with Respect to 7 MTCA Preferences)	Effectiveness and Implementability			
3 – Air Sparging with Soil Vapor Extraction, Partial Geomembrane Cap, and Soil Cover	• Soil cover provides high degree of human health protection • Air sparging system provides high degree of mitigation of potential benzene impacts from groundwater to Lake Union • Complies with cleanup standards and applicable laws • Provides compliance monitoring	• 2nd for extraction and thermal destruction of benzene source materials • 6th for containment of surficial soils	• Meets cleanup action levels for surficial soils and groundwater • High short- and long-term effectiveness for isolation of the public from impacted surficial soils • Moderate short- and long-term effectiveness for mitigation of potential benzene impacts from groundwater to Lake Union • High degree of reduction of contaminant toxicity, mobility, and volume for impacted soils in the soil cover area • Highly implementable	• Short for surficial soil cover • Short to moderate for air sparging	• Significant short-term impacts during construction • Use of area south of Play Barn restricted occasionally during O&M period of air sparging system (approx. 3 yr) • Area of air sparging system restricted from future Park development during O&M period (approx. 3 yr)	$3.6M

Table 14-1 Comparison of Cleanup Action Alternatives (continued)

Alternatives	Evaluation Factors					
	Permanence			Restoration Time Frame	Park Use Compatibility and Public Concerns	Cost
	Threshold Criteria	Technology Preference (Rank with Respect to 7 MTCA Preferences)	Effectiveness and Implementability			
4 - Downgradient Cut-Off Wall and Soil Cover	• Soil cover provides high degree of human health protection • Cut-off wall provides high degree of mitigation of potential benzene impacts from groundwater to Lake Union • Complies with cleanup standards and applicable laws • Provides compliance monitoring	• 6th for containment of surficial soils, benzene source materials, and benzene-impacted groundwater	• Meets cleanup action levels for surficial soils and groundwater • High short- and long-term effectiveness for isolation of the public form impacted surficial soils • Moderate short-term and high long-term effectiveness for mitigation of potential benzene impacts from groundwater to Lake Union • No reduction of contaminant toxicity, mobility, and volume for impacted soils • Impacted groundwater: high degree of reduction in contaminant mobility; moderate degree of reduction in contaminant toxicity and volume • Highly implementable	• Short for surficial soil cover • Moderate to long for cut-off wall	• Significant short-term impacts during construction • Full use of Park during O&M period • Area of cut-off wall restricted from future Park development during long restoration period	$4.3M

Table 14-1 Comparison of Cleanup Action Alternatives (continued)

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Alternatives	Evaluation Factors					
	Permanence			Restoration Time Frame	Park Use Compatibility and Public Concerns	Cost
	Threshold Criteria	Technology Preference (Rank with Respect to 7 MTCA Preferences)	Effectiveness and Implementability			
5 - Excavation of Surficial Soils and Benzene Source with Off-Site Disposal	• Excavation of impacted soils provides high degree of human health protection • Long-term reduction in benzene concentrations in groundwater provide moderate to high degree of mitigation of potential benzene impacts from groundwater to Lake Union • Complies with cleanup standards and applicable laws • Provides compliance monitoring	• 5th for off-site disposal of surficial soils and benzene source materials	• Meets cleanup action levels for surficial soils • Meets cleanup action levels for groundwater in the long-term • High short- and long-term effectiveness for removal of impacted soils • Low short-term and moderate to high long-term effectiveness for mitigation of potential benzene impacts from groundwater to Lake Union • Potential toxicity reduction of impacted soils via off-site treatment • Moderate to high degree of reduction in toxicity, mobility, and volume of impacted groundwater in the long-term	• Short for soils removal • Moderate to long for groundwater	• Significant short-term impacts during construction • Full use of Park during O&M period	$19.9M

APPENDIX H

1999 Gas Works Park Environmental Cleanup, Cleanup Action Plan and SEPA Checklist

(Provided on attached CD)

VOLUME 4

GAS WORKS PARK ENVIRONMENTAL CLEANUP

CLEANUP ACTION PLAN AND SEPA CHECKLIST

Prepared for

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Department of Parks and Recreation
800 Maynard Avenue South, 3rd Floor
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Seattle, Washington 98134

June 18, 1999

DECLARATIVE STATEMENT

Consistent with Chapter 70.150D RCW, "Model Toxics Control Act", as implemented by Chapter 173-340 WAC, "Model Toxics Control Act Cleanup Regulation", it is determined by the Washington State Department of Ecology (Ecology) that these selected cleanup actions for the Gas Works Park site are protective of human health and the environment, attain Federal and State requirements which are applicable or relevant and appropriate, comply with cleanup actions, and provide for compliance monitoring. The cleanup actions also satisfy the preference expressed in WAC 173-340-360 for the use of permanent solutions within a reasonable timeframe, and consider public concerns raised during public comments on the draft Cleanup Action Plan.

This Cleanup Action Plan, and the work in support thereof, has been completed in compliance with Chapter 173-340-550 WAC, and hence is "substantial equivalent" of a Cleanup Action Plan conducted or supervised by Ecology.

Craig Thompson
Project Manager
Toxics Cleanup Program
Washington State Department of Ecology

6/18/99
Date

Jim Pendowski
Program Manager
Toxics Cleanup Program
Washington State Department of Ecology

6/18/99
Date

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1. INTRODUCTION

Gas Works Park (the Park) is the former location of a coal and oil gasification plant that operated from 1906 to 1956. The City of Seattle (the City) purchased the Park property from the Washington Natural Gas Company (now Puget Sound Energy) in 1962 and developed it into the Park, which opened in 1976. Studies conducted at the Park in the 1970s and 1980s indicated the presence of soil and groundwater contamination from the former gas plant operation. The Washington State Department of Ecology (Ecology), through execution of an Agreed Order dated August 1, 1997, required the City and Puget Sound Energy (PSE) to complete a Focused Feasibility Study (FFS) of cleanup alternatives and a Cleanup Action Plan (CAP) describing the recommended cleanup alternative. The FFS and supporting data are presented as Volumes 1 through 3 of the Gas Works Environmental Cleanup documents.

This CAP is Volume 4 of the Gas Works Park Environmental Cleanup documents and meets the requirements specified in Chapter 173-340-360(10) through (12) WAC, the Model Toxics Control Act (MTCA). The State Environmental Policy Act (SEPA) Checklist, Appendix A to this Cleanup Action Plan, has been completed per the requirements of Chapter 173-340-350(6)(h) WAC (the MTCA regulations) and of Chapter 197-11 WAC (the SEPA regulations). A determination of non-significance (DNS) for the actions proposed in this Cleanup Action Plan was declared by Ecology and is included as Appendix B.

2. SUMMARY OF SELECTED CLEANUP ACTIONS

2.1 UPWELLING TAR SOURCES

In 1997, the City and Puget Sound Energy (PSE) characterized known and suspected tar seeps at the Park, and conducted an interim action that removed and destroyed (by thermal desorption) as much of this material as practicable. The following year, additional tar surfaced from the general area of the previous excavations and was removed and treated. As part of this Cleanup Action Plan, the City and PSE will continue to remove and treat any residual tar which might seep from these and other areas[1].

2.2 SOIL

Much of the subsurface soil at Gas Works Park is contaminated with chemicals known as Polynuclear Aromatic Hydrocarbons (PAHs). Additionally, the site contains material that could be classified as Extremely Hazardous Waste[2] (EHW) under the State's Dangerous Waste Regulation (Ch. 173-303 WAC)[3]. Excavation and treatment of this material to a depth of 15 feet is technically impracticable[4].

Contact with underlying soils could result in unacceptable risks to Park users. Direct contact will be prevented by application of containment technologies and institutional controls. The proposed cleanup action for the Park includes placing a new vegetated soil cover over unpaved open areas in the north-central and southeastern portions of the Park. The soil cover will serve as a protective barrier between Park users and chemicals of concern.

2.3 GROUNDWATER

The groundwater at the southeast part of the Park is contaminated with oil, benzene, and other organics. An interim action to remove free product was initiated in October of 1998. The selected remedial action will consist of a system of air sparging and soil vapor extraction (SVE). This action will reduce contaminant concentrations in groundwater from 642 mg/L to 0.43 mg/L. Modeling of the biological attenuation of benzene estimates that, following treatment by air sparging/SVE, surface water criteria at discharge points into Lake Union will be met within 2 to 27 years. The

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[1] During the Public Comment period, concern was expressed about possible tar and free product seepage near the Prow area of the Park.
[2] In this case, material that contains in excess of 1% total polynuclear aromatic hydrocarbon content by weight.
[3] Washington Administrative Code
[4] Due to the complexities associated with coal tar migration in subsurface media at this site, coal tar accumulations would be difficult to locate. Conventional remediation methods, such as excavation, direct pumping, and groundwater treatment, generally are not effective for removing coal tar from the subsurface. It is estimated that less than 1 ton of material that could potentially be classified as EHW exists on site. This material is randomly distributed throughout the site and approximately 385,000 cubic yards of soil (much of it below the water table) would need to be excavated to ensure its complete removal. It is estimated that the cost of excavation and treatment would exceed $80,000,000. More information is available in the April 12, 1999 memorandum from ThermoRetec to Ecology "Extremely Hazardous Waste" (attached as Appendix C).

variation of restoration time frames depends primarily of the oxygen content of the aquifer. This cannot be accurately predicted before implementation of the air sparging/SVE remedial action and must be measured afterwards.

The groundwater at the western portion of the Park is contaminated with PAHs (including carcinogenic PAHs). Page 6-2 of the EPRI study (EPRI 1998) concluded that natural attenuation is reducing the concentrations of these chemicals to surface water cleanup criteria prior to their discharge into Lake Union. The City and Puget Sound Energy will be required to demonstrate that attenuation is actually occurring at a rate sufficient to meet surface water criteria within a reasonable restoration time frame. The effectiveness of attenuation as a remedial action will be evaluated during the first periodic review[5]. Should attenuation not be progressing as anticipated, other more active remedial actions may be required.

Additionally, due to concerns expressed during the public comment period[6], limited monitoring of MW-19 and MW-17 for chemicals of concern will be required.

2.4 SEDIMENTS

Sediment remediation (including sediment cleanup goals) is not addressed under this Cleanup Action Plan and will take place under a separate decree or order at a later date. Full analysis of any Gas Works Park upland to sediment pathways (including groundwater and shoreline erosion pathways) will be reserved for the next phase of cleanup analysis and action, under a separate decree or order.

2.5 INTERIM ACTION

The FFS field investigation of benzene-contaminated groundwater in the southeast part of the Park, confirmed the presence of light non-aqueous phase liquid (LNAPL), in the form of light oil containing a high percentage of benzene, in the soil pores immediately above the water table and floating on the water table. Results of the cleanup alternative analysis indicated that air sparging and soil vapor extraction, the technologies evaluated in detail, may not extract contamination efficiently due to the potential for emulsifying and dispersing the LNAPL.

With concurrence from Ecology, the City and PSE proceeded with development of plans for an interim action to remove LNAPL in the southeast area of the Park. The objectives of this interim action were to maximize elimination of LNAPL as the major some of benzene contamination to groundwater in this part of the Park, and to diminish the negative impacts that LNAPL could have on future cleanup actions.

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[5] WAC 173-340-420 Periodic review. (1) If the department selects or approves a cleanup action that results in hazardous substances remaining at a site at concentrations which exceed method A or method B cleanup levels established under WAC 173-340-700 through 173-340-760 or if conditional points of compliance have been established, the department shall review the cleanup action no less frequently than every five years after the initiation of such cleanup action to assure that human health and the environment are being protected.

[6] The hypothesis was proposed by Ecology's Northwest Regional Office that BTEX compounds in the groundwater could mobilize PAHs in the subsurface.

An "Interim Remedial Action Work Plan" was prepared by ThermoRetec (1998) to describe the rationale and implementation details for the interim action. The oil recovery system consists of a network of vertical wells in the southeastern shoreline area. The oil recovery was initiated in October 1998, at a time of year when Park use is greatly reduced. This timing also allowed oil recovery while the Lake Union and adjacent groundwater levels are lower, which is more favorable for oil recovery.

Mobile pumping equipment (e.g., vacuum truck) was used to recover oil and associated groundwater, and to minimize disruption of the park. From October to December, groundwater was pumped once or twice a week. Recovered oil was recycled by a fuel blending process at a permitted off-site facility. The oil recovery operation is ongoing.

3. CLEANUP STANDARDS

Cleanup of the Gas Works Park Site is being done under the authority of Chapter 70.105D RCW[7], *Hazardous Waste Cleanup – Model Toxics Control Act*, and its implementing regulation, Chapter 173-340 WAC, *The Model Toxics Control Act Cleanup Regulation* (MTCA). This law and regulation apply to the site in their entirety and govern all remedial actions at the site.

The most relevant sections of the statute and regulation with regard to this CAP are the following:

- RCW 70.105D.030(1)(b), which states in part that, " ... the department shall give preference to permanent solutions to the maximum extent practicable and shall provide for or require adequate monitoring to ensure the effectiveness of the remedial action.";
- RCW 70.105D.030(2), which states, "The department shall immediately implement all provisions of this chapter to the maximum extent practicable ... ";
- WAC 173-340-700 through -760, which specify how cleanup standards are to be set for the various environmental media of concern: groundwater, surface water, soil, sediment, and air; and
- WAC 173-340-360, Selection of cleanup actions. This specifies the requirements for cleanup actions and the criteria that are used to evaluate alternatives.

Taken together, the provisions of the statute and the regulation provide strong preference for permanent solutions, set specific cleanup standards for hazardous substances, and give specific requirements for selecting cleanup actions ("solutions"), including selecting remedies that are permanent to the maximum extent practicable.

3.1 SPECIFICATION OF CLEANUP STANDARDS

Specification of a cleanup standard for an environmental medium of concern (i.e., soil, groundwater, surface water, sediment, or air) requires specification of the following:

- Hazardous substance concentrations that protect human health and the environment. These concentrations are called cleanup levels. Indicator hazardous substances may be chosen from among the hazardous substances present at a site to define cleanup requirements.
- The location on the site where cleanup levels must be attained. This location is known as the point of compliance.
- Additional regulatory requirements that apply to a cleanup action because of the nature of the hazardous substances, type of action, location of the site, or other circumstances at the site. These requirements include legally applicable requirements promulgated under state or

[7] Revised Code of Washington

federal law and relevant and appropriate requirements that, while not legally applicable, address problems or situations sufficiently similar to those encountered at the site such that their use is well suited to the particular site. These "applicable or relevant and appropriate requirements" are usually referred to by the acronym ARARs.

3.2 SELECTION OF CLEANUP ACTIONS

Cleanup actions are selected according to the requirement that cleanup actions must meet the following: threshold requirements; the requirement to select cleanup actions that are permanent to the maximum extent practicable; consideration of restoration time frame; consideration of public concerns; preferences regarding cleanup technologies; and criteria for evaluating the degree to which alternative cleanup actions meet these requirements, considerations; and preferences. The process is set forth in WAC 173-340-360, Selection of cleanup actions.

The threshold requirements, which any cleanup action must meet to be considered for selection, are that the cleanup must:

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

Cleanup action alternatives which Ecology determines meet the above threshold requirements may then be considered for selection of an overall cleanup action.

Overall cleanup actions typically involve the use of several cleanup technologies or methods at a single site. In selecting an overall cleanup action from alternative choices that meet threshold requirements, the degree to which each alternative meets the following requirements is to be considered:

- Use of permanent solutions to the maximum extent practicable. A permanent solution meets cleanup standards without further action being required at the original site or any other site involved with the cleanup action, other than the approved disposal of any residue from preferred treatment technologies. In general, technologies, which reuse, recycle, destroy, or detoxify hazardous substances result in permanent solutions if residual hazardous substance concentrations are below cleanup levels established under MTCA. Containment of hazardous substances and/or institutional controls alone is not permanent solutions.

- Provision for a reasonable restoration time frame. Factors considered when establishing a reasonable restoration time frame include potential risks posed by the site to human health and the environment; the practicability of achieving a shorter restoration time; current and future use of the site, surrounding areas, and associated resources; availability of alternative water supplies; likely effectiveness and reliability of institutional controls; ability to control and monitor migration of hazardous substances from the site; toxicity of the hazardous substances at the site; and natural processes which reduce concentrations of hazardous substances and have been documented to occur at the site or under similar site conditions.

- Consideration of public concerns raised during the public comment on the CAP.

When considering alternatives, preference is to be given to those incorporating cleanup technologies that provide greater long-term effectiveness and more permanent reduction of toxicity, mobility, and volume. Technologies that address these issues are considered in the following order of descending preference: (1) reuse or recycle; (2) destroy or detoxify; (3) separate, reduce the volume of, and/or reuse, recycle, destroy, or detoxify; (4) immobilize; (5) dispose of on-site or off-site at an engineered facility; (6) isolate or contain; and (7) provide institutional controls and monitoring. Institutional controls and monitoring are to be used to supplement engineering controls, and are not to be used as a substitute for cleanup actions that would otherwise be technically possible [WAC 173-340-440(2)].

In considering the degree to which alternative cleanup actions use permanent solutions to the maximum extent practicable, the following criteria are to be considered: (1) Overall protectiveness of human health and the environment; (2) long-term effectiveness; (3) short-term effectiveness; (4) permanent reduction of toxicity, mobility, and volume of the hazardous substances; (5) ability to be implemented; (6) cleanup costs; and (7) degree to which community concerns are addressed.

3.3 REMEDIATION LEVELS (CLEANUP ACTION LEVELS)

One other important concept should be discussed with regard to selection of cleanup standards. This concept is termed "remediation level" (or "cleanup action level"). As discussed above, cleanup actions typically involve a combination of technologies, and often not all contamination is taken off-site. A remediation level is a concentration of a hazardous substance at a location within a medium at which a different cleanup technology will be used. There are often multiple remediation levels; e.g. one for removal and treatment/disposal and one for material that may be contained on-site. Remediation levels may be based upon the concentration of a hazardous substance, upon the location of the hazardous substance, and often both. Remediation levels may only be established after all threshold requirements are met. Cleanup actions, which incorporate remediation level(s), must still be protective of human health and the environment and permanent to the maximum extent practicable.

Typically, a lower-preference, less-permanent remedy (such as containment) might be used as the cleanup action to address contaminant concentrations between a remediation level that equals the cleanup the level and a higher remediation level. Where contaminant concentrations exceed this higher level, a more permanent cleanup action (such as removal and off-site disposal) would be applied.

When a remediation level is set for a site it means that cleanup levels will be attained for only a portion of the site and that contamination will be left on-site. Institutional controls are required for sites where contamination remains on-site above cleanup levels.

Cleanup levels and their point of compliance must set for all sites to develop the cleanup standard; remediation levels and associated locations where the remediation levels must be met may or may not be used at a particular site.

In the draft Focused Feasibility Study for Gas Works Park (Parametrix 1998), the City and PSE proposed remediation levels of 10 times the surface water cleanup criteria at inland locations. These remediation levels assumed a dilution and attenuation factor (DAF) of 10 from the point of measurement to the surface water body (Lake Union). During the public comment period, considerable concern was expressed over the validity of the assumptions used in deriving the DAF of 10. Ecology has determined that there is not sufficient evidence available to support the conclusion that an assumed DAF of 10 is protective of human health and the environment. As a result, after installation and operation of the air sparging/SVE treatment system, monitoring will be done to measure the actual DAF at the site and confirm that the remedy is protective.

3.4 CLEANUP LEVELS

3.4.1 Soil

Soil cleanup levels at the Park (MTCA Method B) are based upon a future residential exposure scenario. The current land use at the Park is recreational. Table 3-1 lists the chemicals of concern and their cleanup levels.

Arsenic levels at the site exceed the 90% percentile for the Puget Sound regional background level of 7.3 mg/kg but fall within the range of concentrations observed in the study by Ecology (1994). Considering the present and likely future use of the Park as a recreational area[8], the MTCA Method A value of 20 mg/kg for arsenic is protective of human health and is acceptable for use as a cleanup level at this site.

Table 3-1 indicates that 1997 soil sample results all exceed the Method B cleanup levels, and are therefore all retained as chemicals of concern. This does not, however, indicate that Park users or workers have been or are currently exposed to unacceptable levels of risk. The risk assessment performed by the University of Washington (Ongerth 1985) concluded that health risks estimated from exposures to PAHs in soils over most of the Park (typical concentrations on the order of 20 milligrams per kilogram) are comparable to or less than exposures received during daily living.

The risk assessment recommended that localized spots of higher PAH in soils be removed or covered with clean material, and that signs be posted to discourage people (mainly children) from placing soil in their mouths. The City immediately implemented these recommendations in 1985. Application of the Method B cleanup levels for soils, which are much lower than the concentrations

[8] Chemical concentrations protective of human health in a recreational exposure scenario are generally higher than those in a residential exposure scenario due to decreased contact time.

Table 3-1. Cleanup levels for soil, Gas Works Park.

Chemical of Interest	Maximum 1997 Detected Concentration (mg/kg)	MTCA Method B Soil Cleanup Level (mg/kg)	Retained as Chemical of Concern?
Inorganic Chemicals			
Arsenic	10.9	20(1)	**Yes**
Carcinogenic PAHs			
Benzo(a)anthracene	23.3	0.137	**Yes**
Benzo(b)fluoranthene	35.4	0.137	**Yes**
Benzo(k)fluoranthene	12.0	0.137	**Yes**
Benzo(a)pyrene	36.0	0.137	**Yes**
Chrysene	27.7	0.137	**Yes**
Dibenzo(a,h)anthracene	5.57	0.137	**Yes**
Indeno(1,2,3-cd)pyrene	44.4	0.137	**Yes**
Other PAHs			
Naphthalene	11.5	3,200	**Yes**
Pyrene	102	2,400	**Yes**
Fluoranthene	62.5	3,200	**Yes**

NOTES:
mg/kg = milligrams per kilogram
PAH = Polynuclear aromatic hydrocarbon
(1) MTCA Method A cleanup level; see discussion in Section 3.4.1

addressed in the risk assessment, is a conservative approach that provides an added level of protection to Park users and workers.

3.4.2 Groundwater

Groundwater cleanup levels at the Park are based on the protection of surface water and will be the MTCA Method B Surface Water Cleanup Levels. In arriving at this decision, Ecology considered that:

- The shallow groundwaters underneath the Park are not usable as a drinking water source[9]
- Lake Union is not usable as a drinking water source[10]
- There are known and projected points of entry of the groundwater into the surface water.

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[9] WAC 173-340-720(1)(c)

[10] WAC 173-340-720(1)(c)(ii) requires that the surface water body is not classified as a suitable domestic water supply source under chapter 173-201 WAC. Ecology's Northwest Regional Office has determined that Lake Union is not a suitable water supply source at the adjacent Metro Facilities North site.

- After the completion of cleanup actions, groundwater flow into surface waters will not result in exceedances of surface water cleanup levels at the point of entry or at any downstream location where it is reasonable to believe that hazardous substances may accumulate.

- Institutional controls will prevent the use of contaminated groundwater at any point between the source of hazardous substances and the point(s) of entry of the groundwater into the surface water

- It is unlikely that hazardous substances will be transported from the contaminated groundwater to groundwater that is a current or potential future source of drinking water at concentrations which exceed groundwater quality criteria published in chapter 173-200 WAC.

Table 3-2 lists the chemicals of concern for groundwater and their cleanup levels.

3.5 POINTS OF COMPLIANCE

A point of compliance is the point or points where cleanup levels established in accordance with WAC 173-340-720 through 173-340-760 must be attained.

When hazardous substances remain on-site as part of the cleanup action, the Department may approve a conditional point of compliance which shall be as close as practicable to the source of hazardous substances, not to exceed the property boundary. Where a conditional point of compliance is proposed, the person responsible for undertaking the cleanup action shall demonstrate that all practicable methods of treatment are to be utilized in the site cleanup.

3.5.1 Soil

The point of compliance is the point or points where the soil cleanup levels must be attained. For soil cleanup levels based on human exposure via direct contact, the point of compliance is established in soils throughout the site from the ground surface to 15 feet below the ground surface. Ecology recognizes that cleanup actions involving containment of hazardous substances will typically not meet the soil cleanup levels throughout the site to a depth of 15 feet. In these cases, the cleanup action may be determined to comply with cleanup standards, with the following provisions: a compliance monitoring program ensures the long-term integrity of the containment system; the cleanup action does not rely primarily on on-site disposal, isolation, or containment if it is practicable to reuse, destroy, or detoxify the hazardous substances; and long-term monitoring and institutional controls are implemented until residual hazardous substance concentrations no longer exceed site cleanup levels. [See (WAC 173-340-740(6)(c) and (d)]

MTCA requires that, for land to be returned to unrestricted use, soil cleanup levels be based on human exposure via direct contact with a point of compliance established in the soils throughout the site from the ground surface to 15 feet below the ground surface. This represents a reasonable estimate of the depth of soil that could be excavated and distributed at the soil surface as a result of site development activities [WAC 173-340-740(6)(c)]. However, Ecology recognizes that cleanup actions may be selected which involve containment of hazardous

Table 3-2. Cleanup levels for groundwater, Gas Works Park.

Chemical of Interest	Aqueous Solubility(1) (µg/L)	Maximum Leaching Test Concentrations (4) (µg/L)	Maximum 1997-1998 Detected Concentrations in All Wells (µg/L)	Maximum 1997-1998 Concentrations in Shoreline Wells(6) Conc. (µg/L)	Well No.	MTCA Method B Surface Water Cleanup Level(7) (µg/L)	Retained as Chemical of Concern?
Carcinogenic PAHs							
Benzo(a)anthracene	11	0.6	55	1.6	MLS-7	0.0296	Yes
Benzo(b)fluoranthene	1.5	< 0.6(5)	46.9	< 1.0	- -	0.0296	Yes
Benzo(k)fluoranthene	0.81	< 0.6(5)	32.3	< 1.0	- -	0.0296	Yes
Benzo(a)pyrene	6.3	0.1	70.1	1.4	MLS-7	0.0296	Yes
Chrysene	1.8(2)	0.4	57.2	0.2	MLS-7	0.0296	Yes
Dibenz(a,h)anthracene	0.5(2)	< 0.6(5)	1.4	< 1.0	- -	0.0296	Yes
Indeno(1,2,3-cd)pyrene	0.53(3)	< 0.6(5)	75.2	< 1.0	- -	0.0296	Yes
Other PAHs							
Fluoranthene	243	21	198	6.4	MLS-6	90.2	No
Fluorene	1,830	118	172	87	MLS-7	3,460	No
Naphthalene	32,200	19,800	16,000	16,000	MLS-7	9,880	Yes
Pyrene	129	23	246	9.7	MLS-6	2,590	No
Volatile Organic Chemicals							
Benzene	1,786,000	- -	642,000	256,000	MW-12	43	Yes
Ethylbenzene	156,000	- -	20,800	2,500	MW-12	6,910	Yes
Toluene	542,000	- -	222,000	35,900	MW-12	48,500	Yes

NOTES: µg/L = micrograms per liter N/A = Not Available
PAH = Polynuclear Aromatic Hydrocarbon
U = undetected at the given detection limit
(1) MacKay et al. 1992, unless otherwise noted
(2) Montgomery and Welkom 1990
(3) U.S. Army Corps of Engineers 1997
(4) EPRI 1998; from solubility leaching tests, unless otherwise noted
(5) Predicted based on comparison to benzo(a)anthracene, which has a higher aqueous solubility
(6) Shoreline wells include: MLS-6, DW-6, MLS-7, MW-16, MW-21, MW-22, MW-23, MW-24, and MW-25; MW-13 was not considered because it is screened in a lampblack deposit. PAH data are from low-flow purge sampling event conducted in April 1998 (EPRI 1998).
(7) See Section 3.4.2 for application of MTCA B surface water cleanup levels to groundwater
□ = Exceeds aqueous solubility

substances on site, in which case the soil cleanup levels will typically not be met throughout the site from the ground surface to 15 feet below the ground surface. In these cases, the cleanup action may be determined to comply with cleanup standards [WAC 173-340-740(6)(d)], provided the compliance monitoring program is designed to ensure the long-term integrity of the containment system, and long-term monitoring and institutional controls are continued until residual hazardous substance concentrations no longer exceed site cleanup levels [See WAC 173-340-360(8)].

The overall approach at Gas Works Park will be to contain contaminated soils that are accessible (i.e., not under buildings, pavements, or other permanent structures) with a vegetated soil cover (described in Section 4.1.2) and develop institutional controls for the site that will ensure proper long-term management of the residual contamination left on-site. Any contaminated soils encountered during construction or subgrade preparation will be stockpiled, tested, and manifested for off-site disposal and treatment, as appropriate.

3.5.2 Groundwater

At Gas Works Park, the affected groundwater flows into nearby surface water (Lake Union), and the cleanup level will be based on protection of the surface water. Ecology will approve a conditional point of compliance that is located within the surface water, as close as technically possible to the point or points where groundwater flows into the surface water.

Ecology recognizes the technical difficulties inherent in measuring compliance at the actual locations at the Park where hazardous substances may be released to the surface water as a result of groundwater flow. Therefore, compliance monitoring points will be located upland and measured concentrations extrapolated to the surface water-groundwater interface.

No suitable monitoring points presently exist on-site. Actual locations will be specified in the Compliance Monitoring Plan that will be prepared under WAC 173-340-410.

In order to utilize a conditional point of compliance as outlined above, the following must be met:

- Use of a dilution zone under WAC 173-201-035 to demonstrate compliance with surface water cleanup levels shall not be allowed [WAC 173-340-720(6)(d)(i)].

- Groundwater discharges shall be provided with all known available and reasonable methods of treatment prior to release into surface waters [WAC 173-340-720(6)(d)(ii)].

- Groundwater discharges shall not result in violations of sediment quality values published in chapter 173-204 WAC [WAC 173-340-720(6)(d)(iii)].

- Groundwater monitoring shall be performed to estimate contaminant flux rates and to address potential bioaccumulation problems resulting from surface water concentrations below method detection limits.[WAC 173-340-720(6)(d)(iv)].

4. DESCRIPTION OF THE PROPOSED CLEANUP ACTION

4.1 CLEANUP ACTION COMPONENTS

The proposed cleanup action consists of an engineered soil cover to prevent human exposure to contaminated soils, an air sparging and SVE system for treatment of benzene-contaminated soil and groundwater at the southeast part of the Park, and confirmational monitoring of the modeled natural attenuation of the groundwater at the western part of the Park. The locations of these systems at the Park are shown on Figure 4-1.

4.1.1 Air Sparging With Soil Vapor Extraction

4.1.1.1 Process Description

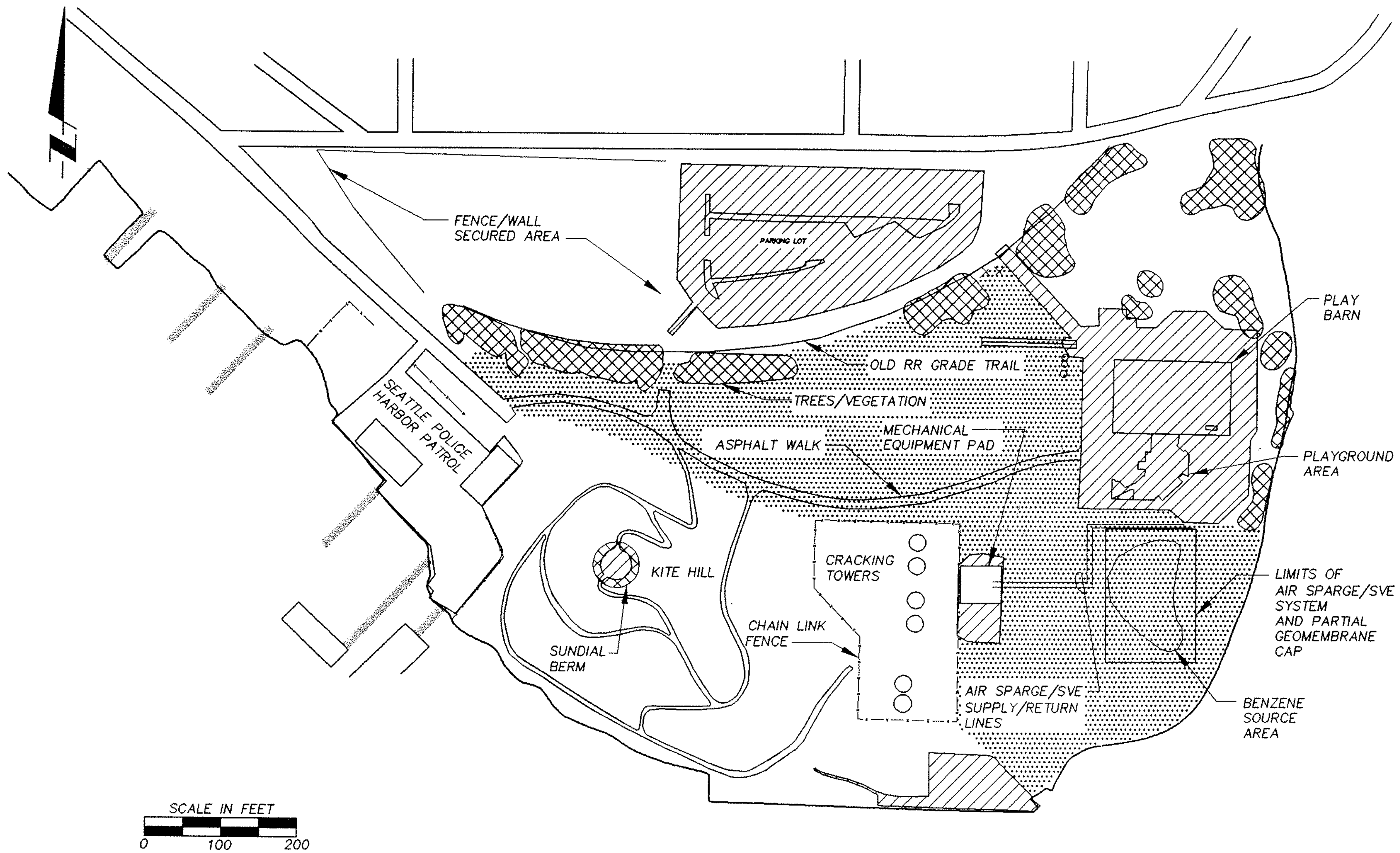
Air sparging is an in-situ process in which air is bubbled through a contaminated groundwater zone to remove volatile organic compounds such as BTEX (benzene, toluene, ethylbenzene, and xylene). Injected air bubbles move vertically and horizontally through the saturated soil zone, creating an underground air stripping process that removes contaminants through volatilization (Figure 4-2). Volatile compounds exposed to the sparged air convert to gas phase and are carried by the air into the unsaturated zone. SVE is used with air sparging to remove vapors from the unsaturated zone. Soil vapors collected by the SVE system are treated to control emissions of air pollutants.

Air sparging has seen a dramatic increase in use and acceptance in recent years, primarily because of its low cost, simplicity, and potential to greatly reduce remediation periods. In a report on innovative technologies, the U.S. Environmental Protection Agency estimated that air sparging is used 45 percent of the time (relative to other innovative technologies) at sites with contaminated groundwater (Environmental Technology 1997). The American Petroleum Institute (API) has assembled a database containing design and operating information on air sparging systems installed at 59 contaminated sites (Hinchee et al. 1995). Brown and Jasiolewicz (1992) estimated that the time and cost for remediating groundwater contaminated with volatile organic compounds may be reduced by as much as 50 percent using air sparging as compared to conventional pump and treat systems.

4.1.1.2 Description of Air Sparging/SVE System

The air sparging system at the Park will consist of six basic elements:

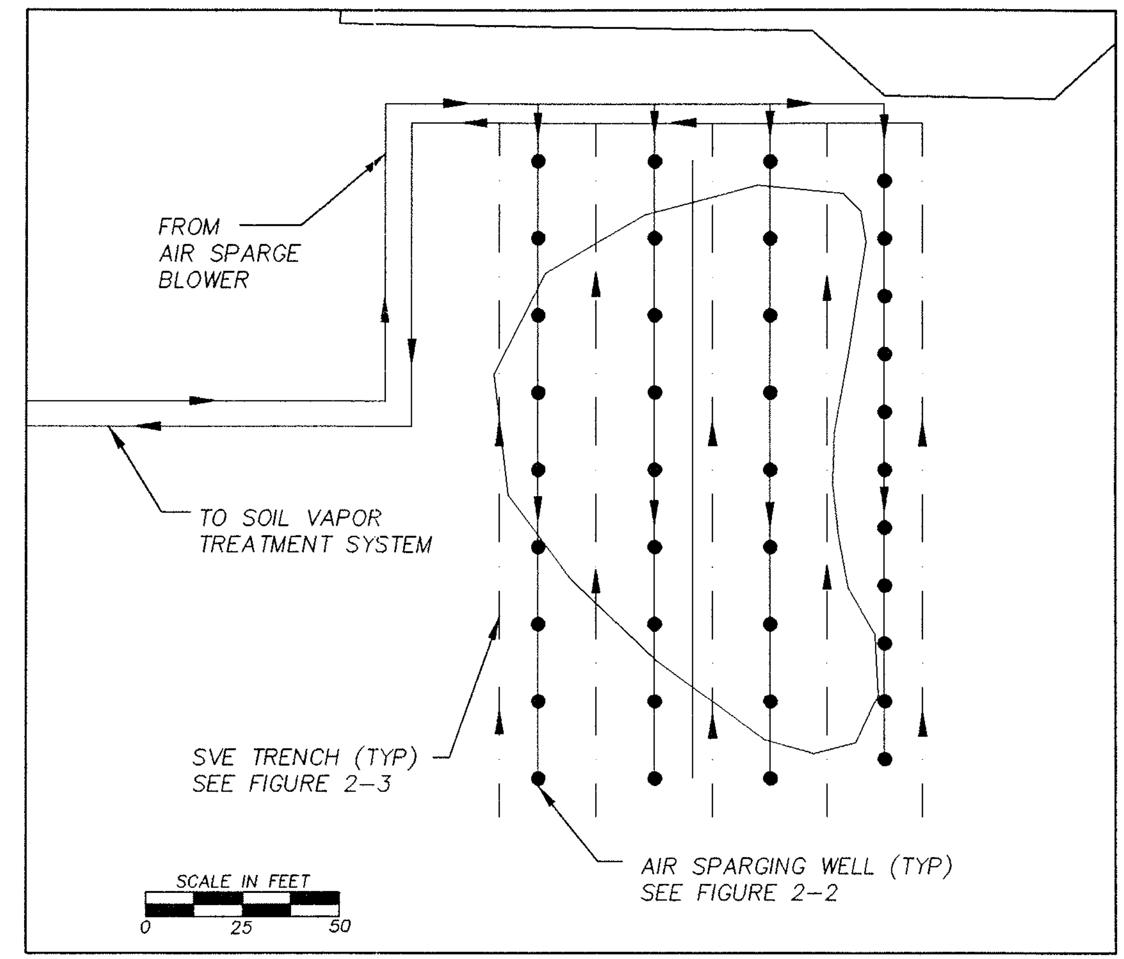
1. Air injection wells,
2. Air compressors or blowers and air distribution piping,
3. Soil vapor extraction system,
4. Geomembrane cap,
5. Soil vapor treatment, and
6. Groundwater monitoring wells.



AIR SPARGING/SVE SYSTEM

SITE PLAN

1"=200'



AIR SPARGING/SVE SYSTEM

CONCEPTUAL LAYOUT

1"=50'

LEGEND

———	SHORELINE BOUNDARY
— · —	PARK BOUNDARY
(hatched)	IMPERVIOUS AREAS (3.5 AC)
(cross-hatched)	TREES/VEGETATION
(dotted)	SOIL COVER (5.7 AC)
——▶——	AIR SUPPLY/RETURN LINE FLOW DIRECTION
—— ——	SVE TRENCH
●	AIR SPARGING WELL

ILE: FIG 1-1
ATE: 7/12/99

Figure 4-1
Plan View of Proposed Air Sparging/ Soil Vapor Extraction (SVE) System Gas Works Park

Each of these elements is described in the following sections. The description and sizing of components presented in this section are based on work completed during the FFS and are presented with a conceptual level of detail. More detailed design criteria will be developed and presented in the Engineering Report. Certain specific design elements presented in this CAP may change based on further detailed analysis in the Engineering Report.

Air Sparging Wells

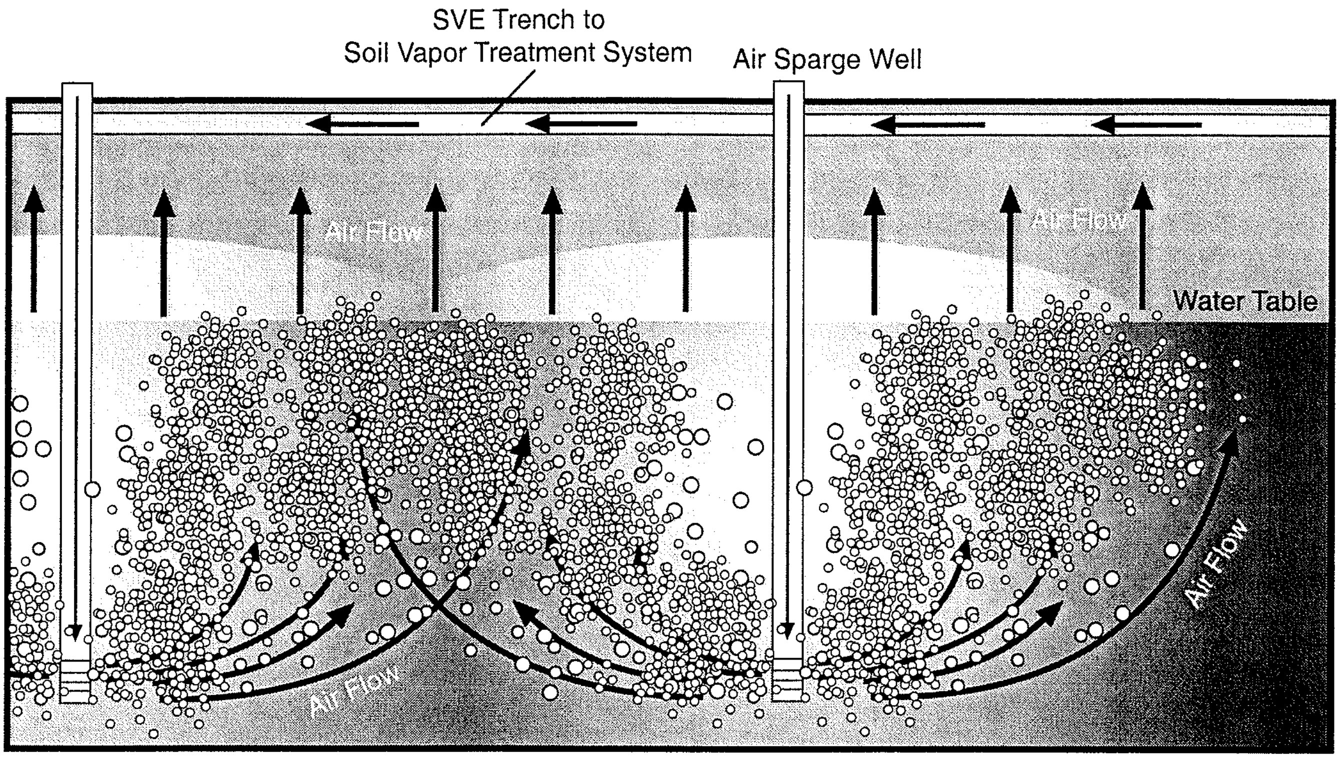
A typical air sparging well is shown on Figure 4-2. The air sparging wells will extend down to the Vashon Till and be constructed of 2-inch-diameter steel pipe. The bottom of each well will consist of 1 to 2 feet of well screen. The sparging wells will be completed by placing a sand or gravel pack around the well screen. A 1-ft bentonite seal will be placed above the sand or gravel pack. The well annulus will then be grouted to the ground surface. The sparge well will be flush at the ground surface with a vault cover to protect the well and piping.

Based on previous reports (RETEC 1998), the sparging system is expected to reduce benzene concentrations at the edge of the treatment zone to levels not greater than 430 μg/L. Preliminary estimates indicate that the area of influence of each sparging well may be as much as 35 feet (RETEC 1998). These estimates do not consider the influence of biological degradation, which will occur in the shallow groundwater zone and overlying unsaturated zone to some extent. As a result, cleanup times and BTEX removal rates may be better than expected.

A conceptual layout of sparging wells is shown on Figure 4-1. The layout shows closely-spaced sparging wells spaced at approximately 15 feet on center along the shoreline, downgradient of the source area. These wells will serve primarily to ensure containment of BTEX contamination and prevent further migration of contaminants to surface water. Performance monitoring wells will be located within the downgradient zone of sparging influence. Approximately three rows of additional wells will be located upland, in and around the original source area of contamination. These upland wells will primarily serve to facilitate cleanup of groundwater and soils in the most heavily contaminated area. The actual well spacing and total number of wells will be determined in the Engineering Report.

Blower System

Air will be injected into sparging wells under pressure with mechanical blowers. A pipe manifold constructed of small-diameter plastic pipe will be used to convey air from the blowers to each well (see Figure 4-1). The manifold will be located below grade and beneath the cover, as shown on Figure 4-3. The static water head above the sparge point, the air entry pressure of the saturated soils, and the air injection flow rate govern air injection pressure. Working pressures on the order of 15 pounds per square inch (psi) are typical. Airflow rates typically used in the field are between 3 to 10 standard cubic feet per minute (SCFM) (Rast 1997).



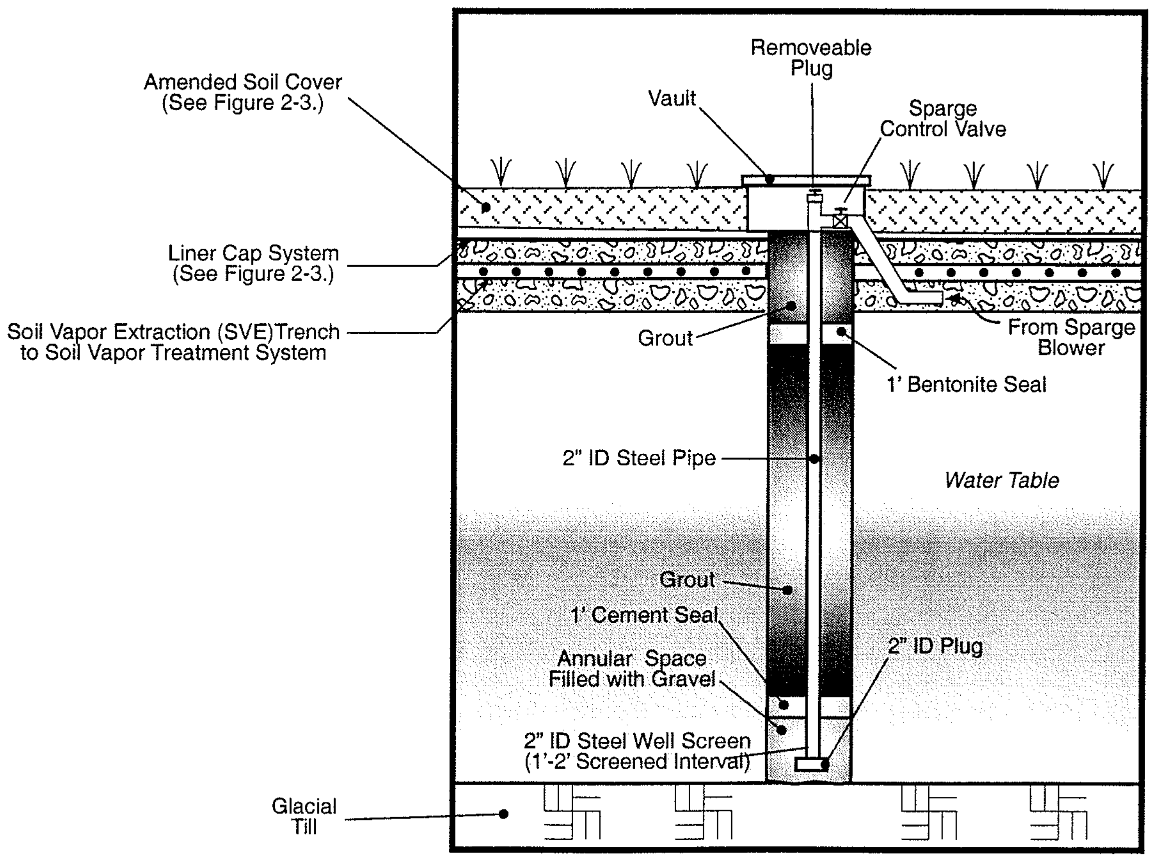
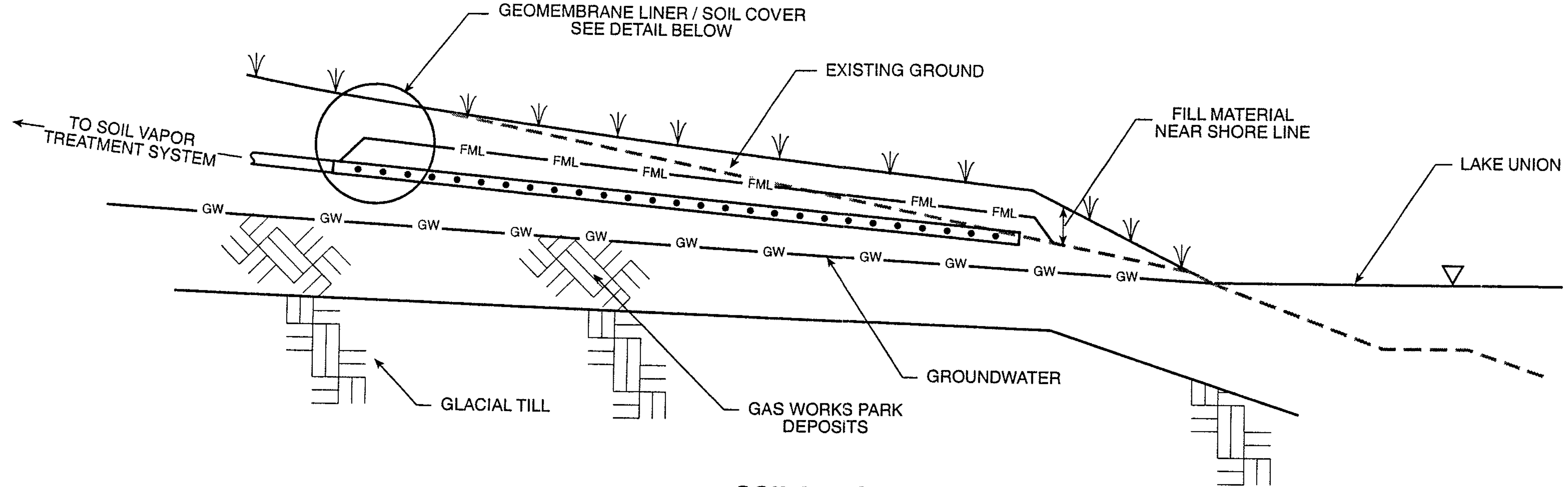
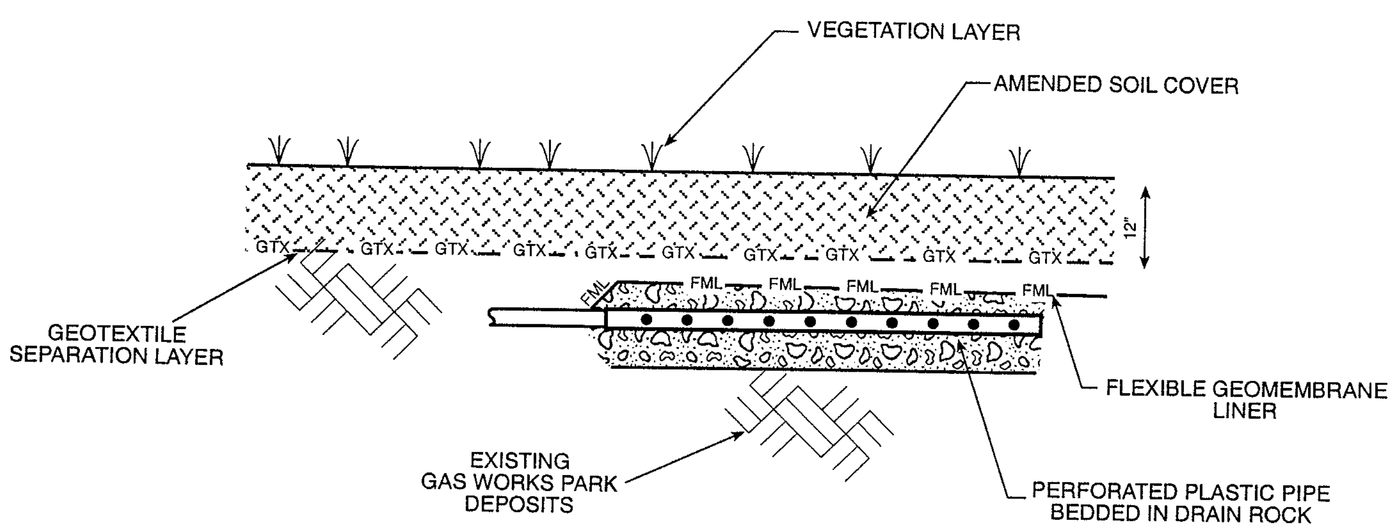


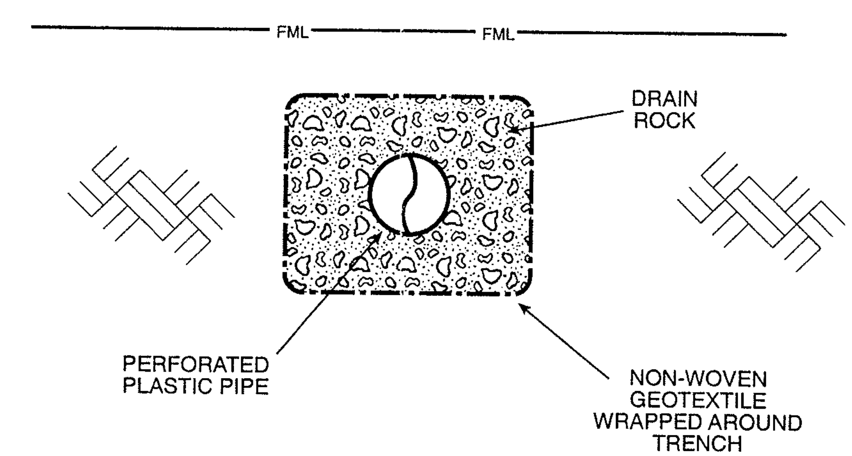
**Figure 4-2.
Proposed Air Sparging
System Detail
Gas Works Park**



SOIL VAPOR EXTRACTION (SVE) SECTION



SVE TRENCH, LINER, AND COVER SOIL DETAIL



SVE TRENCH END VIEW

Gasworks Park/55-2175-06(301) 7/99

- Glacial Till
- Gas Works Deposit
- Amended Soil Cover
- Drain Rock
- —FML— Flexible Geomembrane Liner
- —GTX— Composite Geotextile Separation Layer
- — — — Existing Ground
- —GW— Groundwater
- Final Grade / Vegetation Layer
- Perforated Plastic Pipe
- Solid Wall Plastic Pipe
- Non-woven Geotextile

NOT TO SCALE

Figure 4-3.
Proposed Soil Cover and Soil Vapor Extraction (SVE) System Detail
Gas Works Park

SVE System

Vapors that are mobilized by air sparging will be controlled by the SVE system, which consists of collection piping and a gas extraction blower. As shown on Figures 4-2 and 4-3, perforated pipe will be placed in gravel-filled trenches. The trenches and piping will be installed directly beneath the geomembrane cover and within the existing Gas Works soil deposits. As shown on the site layout (see Figure 4-1), approximately five trenches will be constructed, running parallel with the air sparging lines. The piping manifold will be connected to the extraction blower, which will pull a slight vacuum beneath the cover and remove gases from the soil. The SVE system, in combination with the cover system, will remove BTEX vapors from the vadose zone and prevent soil gas from migrating to the atmosphere.

Geomembrane Cap

To ensure that the vapor extraction system does not simply pull air from the atmosphere above the trenches, a low-permeability cover must be installed over the entire area of influence. The Park air sparging/SVE system will use a geomembrane liner system, consisting of an HDPE liner and geonet drainage system. The advantages of the geomembrane plastic cover versus clay are low profile (the geomembrane and geonet together are less than ½ inches thick), extremely low permeability, ease of construction, and lower cost. The geonet consists of an open ¼-inch-thick HDPE net that can drain as much water as 18 inches of free-draining gravel. The geonet will drain water that has infiltrated through the overlying clean cover soil. The water flowing off of the geonet will drain to the lower edge of the geomembrane and enter drain rock at the edge of Lake Union. The vegetated cover soil described in Section 4.1.2 will cover the geomembrane/geonet composite as well as the surrounding soils. The geotextile element of the vegetated cover soil will prevent clogging of the geonet.

Soil Vapor Treatment

Soil vapor collected by the SVE system will be piped through a treatment unit located with the blowers on a mechanical equipment pad (Figure 4-1). Soil vapor treatment options to be considered include oxidizers (catalytic, thermal, or electric), biofilters, and carbon.

Monitoring

A number of parameters will be tested to monitor the performance of the air sparging/SVE system. Performance parameters include BTEX concentration, dissolved oxygen (DO), water table elevation, and soil gas vacuum from the SVE system. The unsaturated zone will also be monitored for vacuum pressure to verify that the SVE system is successfully containing and preventing soil vapors from migrating to the atmosphere.

4.1.2 Soil Cover

The proposed cleanup action for the Park includes placing a new vegetated soil cover over unpaved open areas in the north-central and southeastern portions of the park (about 5.7 acres), as shown on

Figure 4-1. These areas of the Park experience heavy use and show signs of erosion and soil wear. The vegetated soil cover will be at least 12 inches thick and separate Park users from the chemicals of concern in existing surficial soils. The new vegetated soil cover will consist of (from top to bottom):

- Grass turf vegetation layer,
- 12 inches of sandy loam topsoil, and
- Geotextile fabric.

The vegetated soil cover will be compatible with the air sparging/SVE system described in Section 4.1.1 and will be placed over the partial geomembrane cap. A typical section of the vegetated soil cover is shown on Figure 4-3.

The grass turf vegetation layer will be a blend of grass seed mixes as approved by the City. The seed mix will be a durable blend capable of withstanding the heavy use associated with the Park in dry late-summer weather. The vegetation layer will minimize surface erosion and improve Park aesthetics. The vegetation layer will be the first layer of separation between Park users and the surficial soils; therefore, the vegetation layer will be a primary contributor to the effectiveness of the soil cover system.

The 12-inch sandy loam soil layer will be a free-draining soil that supports the vegetation layer. The free-draining nature of the soil will minimize surface erosion, improve the vegetation layer sustainability by resisting soil compaction from the heavy Park use, and enhance oxygen transfer to the underlying soils. The top 6 inches of the soil layer will be amended with organic material and approved fertilizers consistent with existing City specifications. The amendments will be tilled into the top 6 inches after soil placement and will enhance the establishment of a sustained vegetation layer.

A nonwoven geotextile layer will be placed over the existing Park deposits before soil placement. The geotextile will physically separate the existing soils from the overlying vegetative soil layer, and thus eliminate commingling of these soils. The geotextile will also provide a visual barrier that will alert maintenance workers or others if the vegetative soil layer has been compromised. The geotextile will not be installed near any existing Park vegetation, and the final design will ensure that both existing and proposed vegetation are not adversely affected by geotextile placement.

Before the soil cover is placed, the existing soil surface must be prepared. This subgrade preparation will consist of minor site grading to correct surface water problems (such as ponding or erosion), installation of surface water drainage structures and piping, and installation of irrigation mainlines and some laterals. Also, existing grass and herbaceous vegetation will be removed or, at a minimum, sprayed with an appropriate herbicide to prevent growth through the new soil cover, and the surface will be scarified to enhance air infiltration into the soil. Measures will be taken to ensure that the vegetative cover soil effectively blends with the surrounding vegetated and paved areas. The transition areas will be excavated and tapered so that a berm is not formed at the transition edge that could collect surface water or present a tripping hazard. Contaminated soils encountered during subgrade preparation will be stockpiled, tested, and manifested for off-site disposal.

4.2 COMPLIANCE MONITORING

Chapter 173-340-410 WAC specifies the following types of compliance monitoring regarding cleanup actions:

- Protection monitoring: Confirm that human health and the environment are adequately protected during construction, operation, and maintenance of the cleanup action

- Performance Monitoring: Confirm that the cleanup action has attained cleanup standards and other appropriate performance standards.

- Confirmational Monitoring: Confirm the long-term effectiveness of the cleanup action once cleanup standards and other appropriate performance standards have been attained.

A compliance monitoring plan will be prepared as part of the cleanup action design report submittal. This plan will address compliance monitoring for soil, groundwater, surface water runoff, waste materials, and construction work environment, and will include a Sampling and Analysis Plan (SAP) and data analysis procedures that meet requirements specified in Chapter 173-340-820 WAC. Compliance monitoring anticipated for the Park site is described in the following sections.

4.2.1 Soil

During construction of the soil cover and air sparging/soil vapor extraction system, excavated soils will be stockpiled and tested to determine off-site disposal or recycling options. After the cover is in place, the condition of the cover will be checked on a regular basis by Park maintenance crews, and an irrigation plan will be developed to ensure the viability of the turf. Soil generated during any future Park construction projects will be stockpiled and characterized for off-site disposal or recycling (see Section 7).

4.2.2 Water

No dewatering of groundwater is anticipated during construction of the cleanup action. Controls will be established during construction to divert clean surface water runoff away from the construction area and prevent discharges from the work area. After the construction has been completed, a network of monitoring wells will be established over the Park area, including installation of new monitoring wells to supplement the existing well network. The monitoring well locations, testing frequency, and chemical parameters will be specified in the SAP.

4.2.3 Waste Materials

Waste materials encountered during construction will be managed in the same manner as soils, as described in Section 4.2.1.

5. SUMMARY OF NON-SELECTED CLEANUP ACTIONS AND JUSTIFICATION FOR THE PROPOSED CLEANUP ACTION

5.1 EVALUATION CRITERIA

Requirements for evaluating and selecting cleanup actions under MTCA are specified in Chapter 173-340-360 WAC. Criteria to be used in this process are summarized as follows:

- Meet threshold requirements:
  - Protection of human health and the environment
  - Compliance with MTCA cleanup standards and applicable state and federal laws
  - Provision for compliance monitoring

- Use permanent solutions to the maximum extent practicable:
  - Technology preference for cleanup of contamination (in order of decreasing preference):
    1) Reuse or recycling
    2) Destruction or detoxification
    3) Separation or volume reduction followed by (1) or (2)
    4) Immobilization
    5) On-site or off-site disposal at a permitted facility
    6) Isolation or containment with engineering controls
    7) Institutional controls and monitoring
  - Short-term and long-term effectiveness
  - Implementability

- Provide for a reasonable restoration time frame

- Possess a cost that is proportionate to the incremental degree of protection achievable over a lower preference cleanup action

5.2 COMPARATIVE EVALUATION AND SELECTION OF RECOMMENDED ALTERNATIVE

The five remedial action alternatives described in the FFS were compared with respect to the MTCA criteria, as shown in Table 5-1. On the basis of this analysis, Alternative 3 (air sparging with soil vapor extraction, partial geomembrane cap, and soil cover) was selected as the recommended cleanup action alternative. The rationale for this selection is summarized as follows:

- Alternative 1 (no action) is not acceptable, because it does not meet cleanup levels for soil or groundwater and provides no mitigation of potential benzene impacts from groundwater to Lake Union. Although the interim action (described in Section 2 of this report) was implemented to remove recoverable benzene oil, residual benzene in the soil pores and dissolved in groundwater greatly minimize the potential for natural attenuation to decrease benzene concentrations in the long term, resulting in an indefinite restoration time frame.

Table 5-1. Comparison of cleanup action alternatives.

Alternatives	Evaluation Factors					
	Permanence					
	Threshold Criteria	Technology Preference (Rank with Respect to 7 MTCA Preferences)	Effectiveness and Implementability	Restoration Time Frame	Park Use Compatibility and Public Concerns	Cost
1–No Action	• Acceptable protection of human health • No mitigation of potential benzene impacts from groundwater to Lake Union • Does not comply with cleanup standards or applicable laws • Does not provide compliance monitoring	• 7th (lowest), since only institutional controls will be continued	• Does not meet cleanup levels for soil or groundwater • Low short- and long-term effectiveness • By definition, fully implementable • No reduction of contaminant toxicity, mobility, or volume for impacted soils or groundwater	Not applicable	• No direct effect on current Park use; lack of long-term effectiveness may significantly effect future Park use	$0

Table 5-1. Comparison of cleanup action alternatives (continued).

Alternatives	Evaluation Factors					
	Permanence					
	Threshold Criteria	Technology Preference (Rank with Respect to 7 MTCA Preferences)	Effectiveness and Implementability	Restoration Time Frame	Park Use Compatibility and Public Concerns	Cost
2–Soil Cover	• Soil cover provides high degree of human health protection • Minimal mitigation of potential benzene impacts from groundwater to Lake Union • Complies with cleanup standards and applicable laws for soil only • Provides compliance monitoring	• 6th for containment of impacted soil	• Meets cleanup levels for surficial soil • Will not meet cleanup levels for groundwater for many years • High short- and long-term effectiveness for isolation of the public from impacted soil • Low short- and long-term effectiveness in mitigating potential benzene impacts from groundwater to Lake Union and meeting cleanup action levels for groundwater over time • No reduction of contaminant toxicity, mobility, or volume for impacted soil or groundwater • Highly implementable	• Short for soil • Indefinite for ground-water	• Significant short-term impacts during construction • Full use of Park during O&M period	$2.8M

Table 5-1. Comparison of cleanup action alternatives (continued).

Alternatives	Evaluation Factors					
	Permanence					
	Threshold Criteria	Technology Preference (Rank with Respect to 7 MTCA Preferences)	Effectiveness and Implementability	Restoration Time Frame	Park Use Compatibility and Public Concerns	Cost
3–Air Sparging with Soil Vapor Extraction, Partial Geomembrane Cap, and Soil Cover	• Soil cover provides high degree of human health protection • Air sparging system provides high degree of mitigation of potential benzene impacts from groundwater to Lake Union • Complies with cleanup standards and applicable laws • Provides compliance monitoring	• 2nd for extraction and thermal destruction of benzene source materials • 6th for containment of soil	• Meets cleanup levels for soil and groundwater • High short- and long-term effectiveness for isolation of the public from impacted surficial soils • Moderate short- and long-term effectiveness for mitigation of potential benzene impacts from groundwater to Lake Union • High degree of reduction of contaminant toxicity, mobility, and volume for impacted soils in the soil cover area • Highly implementable	• Short for soil cover • Short to moderate for air sparging	• Significant short-term impacts during construction • Use of area south of Play Barn restricted occasionally during O&M period of air sparging system (approx. 3 yr) • Area of air sparging system restricted from future Park development during O&M period (approx. 3 yr)	$3.6M

Table 5-1. Comparison of cleanup action alternatives (continued).

Alternatives	Evaluation Factors					
	Permanence					
	Threshold Criteria	Technology Preference (Rank with Respect to 7 MTCA Preferences)	Effectiveness and Implementability	Restoration Time Frame	Park Use Compatibility and Public Concerns	Cost
4–Downgradient Cut-Off Wall and Soil Cover	• Soil cover provides high degree of human health protection • Cut-off wall provides high degree of mitigation of potential benzene impacts from groundwater to Lake Union • Complies with cleanup standards and applicable laws • Provides compliance monitoring	• 6th for containment of soil, benzene source materials, and benzene-impacted groundwater	• Meets cleanup levels for surficial soils and groundwater • High short- and long-term effectiveness for isolation of the public form impacted soil • Moderate short-term and high long-term effectiveness for mitigation of potential benzene impacts from groundwater to Lake Union • No reduction of contaminant toxicity, mobility, and volume for impacted soil • Impacted groundwater: high degree of reduction in contaminant mobility; moderate degree of reduction in contaminant toxicity and volume • Highly implementable	• Short for surficial soil cover • Moderate to long for cut-off wall	• Significant short-term impacts during construction • Full use of Park during O&M period • Area of cut-off wall restricted from future Park development during long restoration period	$4.3M

Table 5-1. Comparison of cleanup action alternatives (continued).

Alternatives	Evaluation Factors: Permanence – Threshold Criteria	Evaluation Factors: Permanence – Technology Preference (Rank with Respect to 7 MTCA Preferences)	Evaluation Factors: Permanence – Effectiveness and Implementability	Evaluation Factors: Restoration Time Frame	Evaluation Factors: Park Use Compatibility and Public Concerns	Evaluation Factors: Cost
5–Excavation of Surficial Soils and Benzene Source with Off-Site Disposal	• Excavation of impacted soil provides high degree of human health protection • Long-term reduction in benzene concentrations in groundwater provide moderate to high degree of mitigation of potential benzene impacts from groundwater to Lake Union • Complies with cleanup standards and applicable laws • Provides compliance monitoring	• 5th for off-site disposal of surficial soils and benzene source materials	• Meets cleanup levels for soil • Meets cleanup action levels for groundwater in the long-term • High short- and long-term effectiveness for removal of impacted soil • Low short-term and moderate to high long-term effectiveness for mitigation of potential benzene impacts from groundwater to Lake Union • Potential toxicity reduction of impacted soil via off-site treatment • Moderate to high degree of reduction in toxicity, mobility, and volume of impacted groundwater in the long-term	• Short for soil removal • Moderate to long for groundwater	• Significant short-term impacts during construction • Full use of Park during O&M period	$19.9M

- Alternative 2 (soil cover) meets cleanup levels for soil. However, this alternative will not meet cleanup action levels for groundwater and provides no mitigation of potential impacts from groundwater to Lake Union, for the same reasons described above for Alternative 1.

- Alternative 3 (air sparging with soil vapor extraction, partial geomembrane cap, and soil cover) is the recommended cleanup alternative, because it meets cleanup levels in a short time frame and for a cost that is proportionate to the degree of protection to human health and the environment (with respect to the other alternatives).

- Alternative 4 (downgradient cutoff wall) meets cleanup levels for soil and groundwater, but applies a lower technology preference, has only a moderate short-term effectiveness, and requires a longer restoration time frame, at a cost exceeding that of Alternative 3.

- Alternative 5 (excavation of unsaturated soil and benzene source with off-site disposal) provides high long-term effectiveness with respect to removal of impacted unsaturated soil and residual benzene source material in saturated soil but at a cost that is about 5.5 times that of Alternative 3. The incremental cost of this option is substantial and disproportionate to the incremental degree of protection that it would achieve over a cleanup action of equal or lower preference.

6. IMPLEMENTATION SCHEDULE

Figure 6-1 presents the planned implementation schedule for the proposed cleanup action described in Section 2. The final design of the cleanup actions will begin with approval of the final Cleanup Action Plan. Construction will begin after final design, contract document (plans and specifications) preparation, and contract bidding.

The items presented as design and construction of cleanup systems include: the air sparging/soil vapor extraction system and impermeable geomembrane cap; subgrade preparation and incidental hot spot removal; and cover soil placement (geotextile, soil, irrigation system, hydroseeding, and surface water management). Post-cleanup monitoring and maintenance will begin immediately after construction is complete.

All durations shown in the proposed implementation schedule are approximate, and are based on information available as presented in this report. Since final design of the cleanup action is yet to be completed, the exact nature of these systems and therefore the time required to implement them cannot be known at this time. The ultimate implementation schedule will therefore be different from the target schedule presented in Figure 6-1.

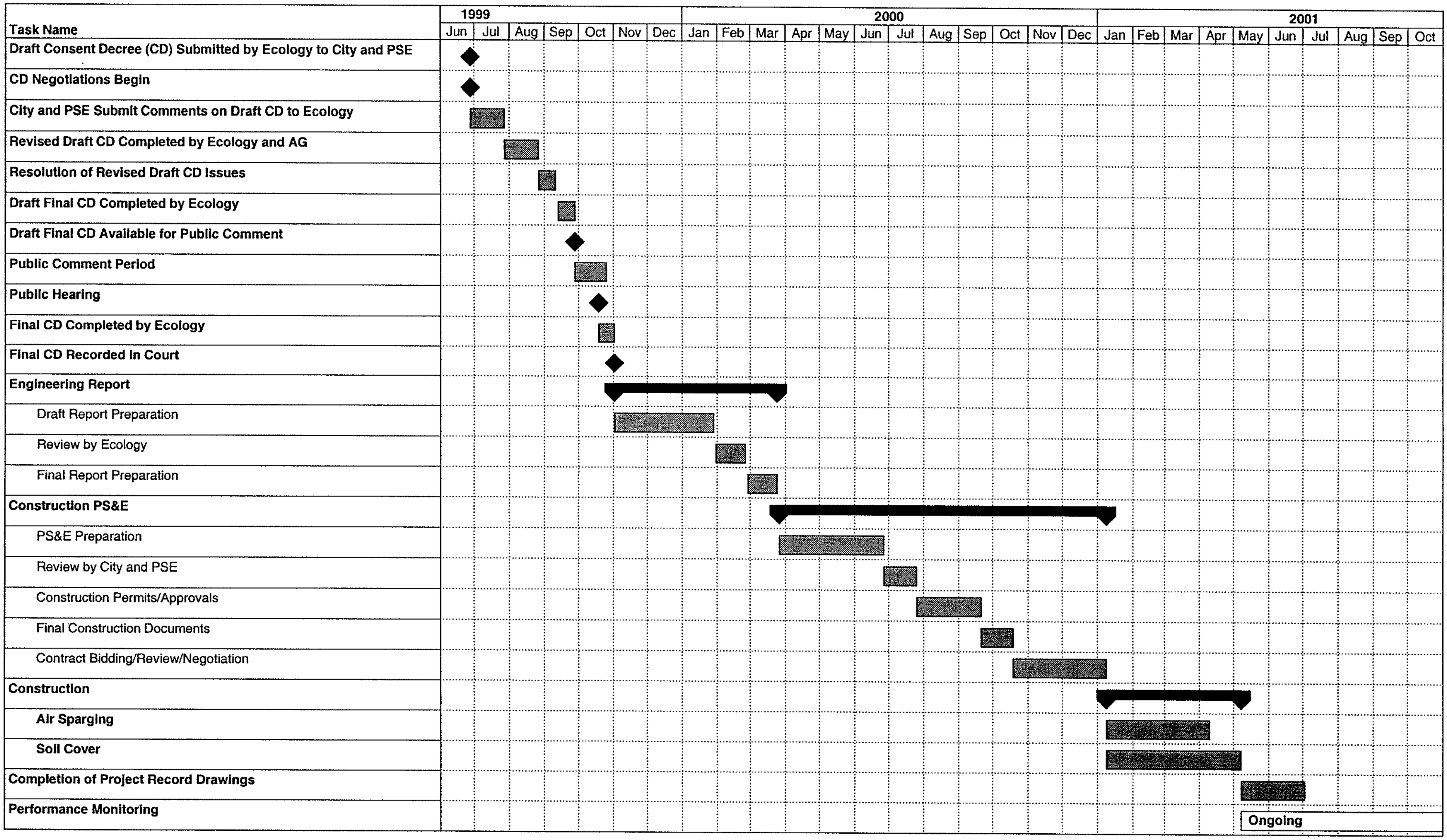


Figure 6-1. Preliminary Implementation Schedule for Gas Works Park Cleanup Action

7. INSTITUTIONAL CONTROLS AND SITE USE RESTRICTIONS

Institutional controls, as defined by Chapter 173-340-440(1), are measures undertaken to limit or prohibit activities that may interfere with the integrity of a cleanup action, or result in exposure to hazardous substances at the site. Institutional controls are incorporated into the cleanup action proposed for the Park because residual concentrations of hazardous substances in soil and groundwater will remain at the site after cleanup action implementation, as described in Section 11 of this Cleanup Action Plan. The following institutional controls will be incorporated into the proposed cleanup action for the Park:

Physical Measures

- Maintenance and improvement (as necessary) of existing fencing around the cracking towers and the northwest area of the Park;
- Inspection and maintenance of the soil cover system; and
- Maintenance and improvement (as necessary) of existing warning signs in place at the Park. These signs warn users not to eat dirt, drink water from Lake Union, wade in Lake Union, or swim in Lake Union.

Restrictive Covenant for the Park and Harbor Patrol Properties

- Restriction of activities that could disturb soils or shallow groundwater at the Park;
- Procedures to be followed for Park projects that may disturb soil or groundwater (such as development of contingency plans for characterization and disposal or hazardous substances);
- Prohibition of extraction of shallow groundwater beneath the site for purposes other than remediation; and
- Construction requirements for any deep wells or borings that might penetrate the glacial till layer, to prevent introduction of shallow contamination into deeper groundwater zones.

8. JUSTIFICATION FOR SELECTING LOWER PREFERENCE CLEANUP TECHNOLOGIES

Chapter 173-340-360(4) WAC specifies that cleanup technologies for hazardous substances applied in cleanup actions are to be considered in the following order of decreasing preference:

(1) Reuse or recycling;

(2) Destruction of detoxification;

(3) Separation of volume reduction, followed by reuse, recycling, reduction, or detoxification;

(4) Immobilization;

(5) On-site or off-site disposal at an engineered facility designed to minimize future release of hazardous substances and in accordance with applicable state and federal laws;

(6) Isolation or containment with attendant engineering controls; and

(7) Institutional controls and monitoring.

The components of the proposed cleanup action at the Park that utilize lower preference cleanup technologies are the containment of contaminated soils throughout the Park, and the use of institutional controls and monitoring to address tar-impacted soil and groundwater beneath the western part of the Park and the Harbor Patrol site (sixth and seventh of the seven preferences, respectively). The proposed air sparging and soil vapor extraction components of the proposed cleanup action utilize high-preference technologies (reuse/recycling and destruction/detoxification). The justification for the cleanup technologies applied in the proposed cleanup action is described in Section 14 of the Focused Feasibility (FFS) report.

As discussed in the FFS report, investigations conducted at the Park from the early 1970s to the present indicate that most of the Park was filled with varying thicknesses of materials derived from the former manufactured gas plant operation (including waste debris containing hazardous materials). Most of these soils exceed MTCA Method B soil cleanup levels for the chemicals of concern identified in the FFS report (arsenic and polynuclear aromatic hydrocarbons [PAHs]). The FFS report concluded that cost of removal and off-site disposal of contaminated soils at the Park is substantial and disproportionate to the incremental degree of protection provided by this alternative (per Chapter 173-340-360(5)(vi) WAC), in comparison to the proposed combination containment with a soil cover and by institutional controls.

The FFS report also concluded that tar impacts on soil and shallow groundwater beneath upland areas in the western part of the Park and the adjacent Harbor Patrol property are mitigated by natural attenuation processes and do not result in exceedances of groundwater cleanup action levels at the points where groundwater discharges to Lake Union. The tar-impacted soils above the water table are contained by soil cover or paving. Tar that migrated downward through the shallow groundwater zone has moved along the surface of the low-permeability glacial till to depths below the bottom of Lake Union, such that the tar is isolated from the Lake. The glacial till also prevents the tar from moving downward into deeper groundwater zones. Application of institutional controls to soil and groundwater in the area of the tar impacts will prevent future activities from causing contact of tar-impacted soil or groundwater with humans or the environment.

9. COMPLIANCE WITH APPLICABLE STATE AND FEDERAL LAWS

This section describes the state and federal laws that were determined by the FFS as applicable to the proposed cleanup action selection at the Park. Chapter 173-340-710 (b)(2) WAC specifies that site cleanup actions shall comply with "applicable state and federal laws". This term is interpreted to include legally applicable requirements and those requirements that are relevant and appropriate. Legally applicable requirements include those cleanup standards, standards of control, and other environmental protection requirements, criteria, or limitations promulgated under Federal or State law that specifically address a hazardous substance, contaminant, remedial or cleanup action, location, or other situation at the site. Relevant and appropriate requirements are those promulgated under Federal and State law that are not directly applicable, but still address problems or situations sufficiently similar to those encountered at the site that their use is well suited to the particular site.

Applicable requirements are determined on a case-by-case basis for each cleanup site. Ecology makes the final interpretation as to whether these requirements are correctly identified and are legally applicable or relevant and appropriate. The applicable state and federal laws described in Table 9-1 were considered in the development of cleanup levels for the Park.

Table 9-1. **Summary of state and federal laws potentially applicable to cleanup actions at Gas Works Park.**

Statute/Regulation	Requirements	Discussion
City of Seattle Building Code *Citation* Section 3.06.040 SMC	Local ordinances implement codes and standards for all construction activities.	Plan review and building permit not required, but planned facilities must meet substantive requirements of applicable codes.
Federal Clean Air Act: New Source Performance Standards, National Emission Standards for Hazardous Air Pollutants, National Ambient Air Quality Standards *Citation* 42 USC 7401-7642 40 CFR Subpart 50, 60, 61, 63	Establishes program for source registration and fee payment to restrict emissions, use Best Available Control Technology, and ensure compliance with air quality standards.	Emissions to the atmosphere will comply with substantive requirements of these regulations; however, source registration is not required per MTCA exemption.
Federal Resource Conservation and Recovery Act (RCRA) *Citation* 42 USC 6902 et seq	Requires permits for facilities that treat, store, or dispose of hazardous waste.	Hazardous/dangerous waste generated during Park cleanup will be manifested only to permitted disposal facilities.
Federal Safe Drinking Water Act *Citation* 42 USC 300f et seq 40 CFR 141,143	Defines Maximum Contaminant Levels:	Neither shallow groundwater zone beneath the Park nor Lake Union are usable for water supply.
Federal Water Pollution Control Act (aka Clean Water Act), National Pollutant Discharge Elimination System (NPDES) *Citation* 33 USC Sec. 303, 304 40 CFR Part 122, 125	Establishes State permit program for discharge of pollutants and wastewater to surface waters. Requires all known, available and reasonable methods of treatment (AKART).	No such discharges are planned at the Park.
Federal Water Pollution Control Act (aka Clean Water Act), Surface Water Quality Standards *Citation* 33 USC Sec. 303, 304 40 CFR 131. Qlty Criteria for Water (EPA, 1986, rev. 1987)		Same as above.

Table 9-1. Summary of state and federal laws potentially applicable to cleanup actions at Gas Works Park (continued).

Statute/Regulation	Requirements	Discussion
State Water Pollution Control Act, NPDES Regulations *Citation* RCW 90.48 WAC 1773-220		Same as above.
State Water Pollution Control Act, Water Quality Standards for Surface Water *Citation* RCW 90.48 WAC 173-201		Same as above.
Federal Water Pollution Control Act (aka Clean Water Act) *Citation* 33 USC 1251-1387 33 CFR 320-330 40 CFR 230	Add	Add
State Shoreline Management Act (1971) *Citation* RCW 90.58 WAC 173-27	Establishes permit program for activities performed within 200 ft of shoreline (including wetlands).	Construction activities will comply with substantive requirements of these regulations; however, permit not required per MTCA exemption.
Puget Sound Air Pollution Control Agency (PSAPCA) *Citation* Regulation III		See Federal Clean Air Act.
State Clean Air Laws: Controls for Air Toxics (Air Quality Standards) *Citation* RCW 70.94 WAC 173-460	Air quality standards for toxics:	See Federal Clean Air Act.
State Environmental Policy Act (SEPA) *Citation* RCW 43.21C WAC 197-11	Requires submittal of checklist describing environmental impacts of proposed projects, public notice, and possibly additional project analyses and public involvement.	SEPA checklist is submitted with CAP.

Table 9-1. Summary of state and federal laws potentially applicable to cleanup actions at Gas Works Park (continued).

Statute/Regulation	Requirements	Discussion
State Hazardous Waste Management Act *Citation* RCW 70.105		
Definition/generation of hazardous/dangerous waste *Citation* 40 CFR 261, 262, 264 WAC 173-303-070 through 110	Defines threshold levels and criteria to determine whether materials are hazardous/dangerous wastes.	Dangerous/hazardous waste generated during Park cleanup will comply with these regulations.
Transportation of hazardous/dangerous waste *Citation* 40 CFR 263 29 CFR WAC 446-50	Defines requirements for off-site transportation of waste.	Proper transportation of waste off-site will be conducted.
Disposal Requirements and Land Disposal Restrictions **Solid Waste Disposal Facilities** *Citation* 40 CFR 268 WAC 173-303-140	Defines pre-treatment and land disposal restrictions for certain wastes	Proper disposal of hazardous/dangerous wastes off-site will occur. Wastes probably will not require additional treatment.
State Hydraulics Act *Citation* RCW 75.20 WAC 220-110	Establishes permit program under Dept. of Wildlife/Fisheries for projects that may change natural flow of "waters of the state."	Construction activities will comply with substantive requirements of these regulations; however, permit not required per MTCA exemption.
State Model Toxics Control Act *Citation* RCW 70.105D.090	Defines hazardous waste cleanup policies. Actions conducted under consent decree are exempt from the procedural requirements or RCW 70.94, 70.95, 70.105, 75.20, 90.48, and 90.58 and the procedural requirements of any laws requiring or authorizing government permits or approvals for remedial actions. Action shall comply with substantive requirements adopted pursuant to such laws and shall consult with government agencies charged with implementing such laws.	FFS and CAP for the park were performed under Agreed Order. Cleanup activities will comply with substantive requirements.

Table 9-1. Summary of state and federal laws potentially applicable to cleanup actions at Gas Works Park (continued).

Statute/Regulation	Requirements	Discussion
State Model Toxics Control Act *Citation* RCW 70.105D WAC 173-340-720	Soil and groundwater cleanup levels	Method B cleanup levels applied to the Park
State Water Quality Standards for Groundwaters *Citation* WAC 173-200	Groundwater Quality Standards	Shallow groundwater at the Park is not a current or future source of drinking water.

10. COMPLIANCE WITH MTCA REQUIREMENTS

The cleanup levels will be met at the specified points of compliance by the proposed cleanup actions to be implemented at Gas Works Park, and human health and the environment will be protected. The following discussion relates the analysis and evaluations presented in this Cleanup Action Plan to the requirements for selection of cleanup actions contained in WAC 173-340-360. This discussion is presented in order to show that the minimum requirements of MTCA will be met by the proposed cleanup actions.

10.1 THRESHOLD REQUIREMENTS

The proposed cleanup action must comply with the MTCA threshold requirements (WAC 173-340-360(2)). The four threshold requirements are listed and addressed below:

10.1.1 Protect Human Health and the Environment

Each action proposed for Gas Works Park environmental cleanup has been evaluated for protection of human health and the environment. Ecology has determined that the proposed cleanup actions meet this first threshold requirement.

10.1.2 Comply with Cleanup Standards

The proposed actions comply with the cleanup standards summarized in Section 3 of this CAP.

10.1.3 Comply with State and Federal Laws

Compliance with applicable state and federal laws has been determined for the proposed cleanup actions through the detailed analysis presented in Section 9 of the FFS report and Sections 8 and 9 of this CAP.

10.1.4 Provide Compliance Monitoring

The compliance monitoring program is described in Section 4.2 of this CAP.

10.2 OTHER REQUIREMENTS

The proposed cleanup action must also comply with other requirements listed in WAC 173-340-360(3). The three other requirements are listed and addressed in the following sections.

10.2.1 Use Permanent Solutions

WAC 173-340-360(5)(d) states that "Ecology recognizes that permanent solutions may not practicable for all sites," and proceeds to list seven criteria that should be used to determine whether a cleanup action is "permanent to the maximum extent practicable." The seven criteria are listed and addressed below for the proposed cleanup actions:

1. **Overall protectiveness of human health and the environment.** The proposed cleanup actions will meet the cleanup standards for soils and groundwater over time within a reasonable restoration time-frame.

2. **Long-term effectiveness.** The actions provide a highly effective long-term solution for impacted soil using well-established means of containment. The air sparging/soil vapor extraction system provides an effective long-term solution by reducing benzene levels in groundwater over the operating life of the system.

3. **Short-term effectiveness.** Once installed, the actions provide a highly effective short-term solution for soil using well-established means of containment. During construction, effective controls will be in place to reduce potential for migration of contaminants from the site to air or surface water. The air sparging/soil vapor extraction system will gradually increase the net removal of contaminants and reduce benzene levels over the operating life of the system.

4. **Permanent reduction of toxicity, mobility, and volume of the hazardous substance.** The cleanup actions, especially air sparging and soil vapor extraction, actively remove contamination from the groundwater and soil and prevent or minimize present and future releases of the contaminants.

5. **Ability to be implemented.** All of the technologies used in the proposed cleanup actions are proven and effective means of removal or containment. Offsite treatment and disposal facilities are well established in the northwest for any contaminated materials that need to be removed offsite. The services and materials are readily available in the Seattle area, and the size and complexity of the project are well within the means of area contractors. Construction will cause short-term disruptions to current park activities, but the long-term operation and maintenance of the cleanup activities will be fully compatible with continued park use.

6. **Cleanup costs.** Cleanup costs for the proposed cleanup actions are not substantially greater than costs for the lower-preference cleanup action alternative 2 (soil cover only), are less than costs for alternative 4 (downgradient cut-off wall), and are much less than the costs for contaminant source excavation and off-site disposal.

7. **The degree to which community concerns are addressed.** The cleanup actions address community concerns, especially with regards to prevention of public contact with soil and groundwater contamination, and restoration of the Park for public use after construction of the cleanup action.

Based upon these evaluations and the supporting analysis contained in the FFS, the proposed cleanup actions will meet the requirements of WAC 173-340-360(5)

WAC 173-340-360(5)(e) lists requirements intended to ensure a bias toward permanent solutions. The five requirements are listed and addressed below:

1. **The cleanup action shall prevent or minimize present and future releases and migration of hazardous substances in the environment.** The cleanup actions, especially air sparging and soil vapor extraction, actively remove contamination from the groundwater and soil and prevent or minimize present and future releases of the contaminants. The soil cover greatly minimizes potential exposure of the public to soil and groundwater contaminants.

2. **The cleanup action shall provide for a net reduction in the amount of a hazardous substance being released from the source area**. The cleanup action of air sparging and soil vapor extraction reduces the amount of hazardous substances available for release, and the geomembrane cap over the air sparging system further reduces surface water infiltration and thus groundwater flux from the contaminant source area.

3. **The cleanup action shall not rely primarily on dilution and dispersion of the hazardous substance if active remedial measures are technically possible.** Active remedial measures are being taken to reduce the amount of hazardous substances in the source area and surrounding soils. Thus the cleanup action does not rely on dilution and dispersion.

4. **A cleanup action relying primarily on institutional controls and monitoring shall not be used where it is technically possible to implement a cleanup action alternative that utilizes a higher preference cleanup technology for all or a portion of the site.** The cleanup action does not rely primarily on institutional controls and monitoring.

5. **A cleanup action involving off-site transport and disposal of hazardous substances without treatment shall not be used if a treatment technology or method exists which will attain cleanup standards and is practicable.** Off-site transport and disposal of hazardous substances is minimized. The air sparging and soil vapor extraction system will treat on-site contaminated materials to cleanup standards. Materials that are transported off-site will be treated as appropriate before land disposal at an appropriate landfill (soils) or recycled as supplementary fuel (benzene, etc.).

10.2.2 Provide Reasonable Restoration Time Frame

Factors considered when establishing a reasonable restoration time frame include potential risks posed by the site to human health and the environment; the practicability of achieving a shorter restoration time; current and future use of the site, surrounding areas, and associated resources; availability of alternative water supplies; likely effectiveness and reliability of institutional controls; ability to control and monitor migration of hazardous substances from the site; toxicity of the hazardous substances at the site; and natural processes which reduce concentrations of hazardous substances and have been documented to occur at the site or under similar site conditions. Additionally, a longer period of time may be used for the restoration time frame for a site to achieve cleanup levels at the point of compliance if higher preference cleanup technologies are used. The permanent destruction of contaminants by the air sparging/SVE remedial action is such a higher preference technology.

Modeling shows that, following treatment by air sparging/SVE, surface water criteria will be met within 2 to 27 years. The variation of restoration time frames depends primarily of the oxygen content of the aquifer. This cannot be accurately predicted before implementation of the air sparging/SVE remedial action and must be measured afterwards.

10.2.3 Consider Public Concerns

Concerns expressed by the public to date (preventing contact of soil and groundwater contamination with Park users; restoring the Park to a usable condition after construction of the cleanup action) are addressed by the proposed cleanup action. Additional public concerns presented during the public comment period will be addressed by a responsiveness summary and submitted with the final Park environmental cleanup documents.

11. MANAGEMENT OF HAZARDOUS SUBSTANCES REMAINING ON THE SITE

As described in previous sections of this Cleanup Action Plan, the proposed cleanup action for the Park utilizes containment and institutional controls to protect human health and the environment from hazardous substances that will remain at the site. The hazardous substances in soil and groundwater were summarized in Tables 3-1 and 3-2, which include chemical names, maximum detected concentrations, and applicable cleanup levels. The hazardous substances remaining in place at the Park will be managed by means of the compliance monitoring described in Section 4.2 and the containment measures and institutional controls described in Section 7 of this Cleanup Action Plan, such that migration and contact with these substances will be prevented.

12. REFERENCES

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APPENDIX A

STATE ENVIRONMENTAL POLICY ACT (SEPA) ENVIRONMENTAL CHECKLIST

STATE ENVIRONMENTAL POLICY ACT (SEPA) ENVIRONMENTAL CHECKLIST

A. BACKGROUND

1. Name of proposed project, if applicable:

Gas Works Park Environmental Cleanup

2. Name of applicant:

City of Seattle and Puget Sound Energy

3. Address and phone number of applicant and contact person:

Ms. Robin Kordik
City of Seattle, Department of Parks and Recreation
2911 2nd Avenue, 4th Floor
Seattle, Washington 98121-1079
Telephone: (206) 233-7938

Mr. Steven Secrist, Director of Environmental Services
Puget Sound Energy
815 Mercer Street MER-4
Seattle, Washington 98111
Telephone: (206) 224-2353

4. Date checklist prepared:

October 30, 1998

5. Agency requesting checklist:

Washington State Department of Ecology

6. Proposed timing or schedule (including phasing, if applicable):

Construction is scheduled to occur over a seven-month period in the spring and summer of 2000. Construction will occur in two phases. Installation of the air sparging system will begin around March 1 through and completed before July 4. After installation, the air sparging system will operate continuously until targeted cleanup levels have been achieved, an estimated period of three years. Installation of the soil cover will begin after July 4 and be completed by October 1.

7. Do you have any plans for future additions, expansion, or further activity related to or connected with this proposal? If yes, explain.

There are no plans for future additions, expansions, or activity related to this proposal except for ongoing operations, and environmental and performance monitoring.

8. List any environmental information you know about that has been prepared, or will be prepared, directly related to this proposal.

Gas Works Park Environmental Cleanup, Draft Focused Feasibility Study, October 1998

Gas Works Park Environmental Cleanup, Draft Cleanup Action Plan, October 1998

9. Do you know whether applications are pending for governmental approvals of other proposals directly affecting the property covered by your proposal? If yes, explain.

There are no such applications pending.

10. List any government approvals or permits that will be needed for your proposal, if known.

PSAPCA

Air Contaminant Source Registration/New Source Approval

Washington State Department of Ecology

Temporary Modification of Water Quality Standards Approval

City of Seattle

Clearing and Grading Permit

Shoreline Substantial Development Permit

11. Give brief, complete description of your proposal, including the proposed uses and the size of the project and site. There are several questions later in this checklist that ask you to describe certain aspects of your proposal. You do not need to repeat those answers on this page. (Lead agencies may modify this form to include additional specific information on project description.)

The Gas Works Park site is the former location of a coal and oil gasification plant that operated from 1906 to 1956. Although some of the residues from the gas production process were removed during Park construction, studies conducted in the 1980s indicated that chemicals associated with these residues were present in soils and groundwater beneath the site. The Focused Feasibility

Study (FFS) identified soil and groundwater contaminants at the site in concentrations that exceed cleanup levels specified in the Washington State Model Toxics Control Act (MTCA). These include arsenic and PAHs in existing surface soils, and benzene-contaminated shallow groundwater in the southeast corner of the site.

The proposed project will implement several cleanup technologies to achieve site cleanup. Benzene and other volatile (readily vaporized) and semi-volatile contaminants will be removed from the contaminated shallow groundwater zone using an air sparging and soil vapor extraction system. The air sparging system is a series of vertical wells drilled into the ground that blow air into the saturated soil below the groundwater table. Air bubbling up through the saturated soil will carry benzene and other soil vapors to the unsaturated soil above the water table. The vapors will be collected by the soil vapor extraction (SVE) system. The SVE system consists of a series of horizontal, perforated pipes buried in the ground above the groundwater table and connected to a vacuum system that collects the vapors and draws them into a treatment system. The treatment system has a catalytic oxidizer that uses heat to break down the contaminants to carbon dioxide and water vapor, which are then discharged to the air.

To protect Park users from contact with contaminated soil, a portion of unpaved areas on the site will be covered with a 1-foot-thick layer of clean soil, then reseeded with grass. Any visibly contaminated soil encountered during site preparation will be excavated and removed from the site for appropriate disposal. Refer to the project Cleanup Action Plan (CAP) for more detailed information regarding onsite contamination and the proposed remediation methods.

12. Location of the proposal. Give sufficient information for a person to understand the precise location of your proposed project, including a street address, if any, and section, township, and range, if known. If a proposal would occur over a range of area, provide the range or boundaries of the site(s). Provide a legal description, site plan, vicinity map, and topographic map, if reasonably available. While you should submit any plans required by the agency, you are not required to duplicate maps or detailed plans submitted with any permit applications related to this checklist.

The site is located in central Seattle, between I-5 and Aurora Avenue (Highway 99). The Gas Works Park site street address is: 2000 N. Northlake Way, Seattle, Washington. It is located in Sections 19 and 20, Township 25 North, Range 3 East, City of Seattle, King County, Washington State.

The Park, which covers approximately 20.5 acres, is located on the north shore of Lake Union and is bounded by the following: Northlake Way on the north, Lake Union on the east and south, and City of Seattle Harbor Patrol and Northlake Place on the west.

TO BE COMPLETED BY APPLICANT

B. ENVIRONMENTAL ELEMENTS

1. Earth

a. General description of the site (circle one): Flat, rolling, hilly, steep slopes, mountainous, other __________.

The northern portion of the site is relatively flat, and is separated from the rest of the site by an old railroad grade. Kite Hill is the most prominent topographic feature of the Park, rising about 35 feet above the surrounding land surface. The southeastern part of the site slopes gently toward Lake Union. A large regional upland rises steadily from the Lake Union shoreline to the north, attaining elevations up to 300 ft higher than land surface at the Park.

b. What is the steepest slope on the site (approximate percent slope)?

A maximum slope of 28% occurs on Kite Hill, a 35-foot-high constructed mound of earth located in the southwest portion of the site.

c. What general types of soils are found on the site (for example, clay, sand, gravel, peat, muck)? If you know the classification of agricultural soils, specify them and note any prime farmland.

Exiting near-surface soils and topography on the site are the result of extensive past filling and grading activities. When the gas plant was constructed in the early 1900's, the peninsula upon which it was located was narrower than today. Waste and debris generated during operation of the gas plant were used as fill to extend the plant property more than 100 feet beyond the original shoreline. Additional upland grading and filling occurred during demolition of the gas plant and construction of the Park in the 1960s and 1970s.

Geologic conditions at the site were assessed in detail as part of a cooperative groundwater investigation that was initiated by the USGS and the City in 1986. This investigation involved incorporation of subsurface explorations from the 1970s with data from new monitoring wells and test borings. The geologic framework of the site developed by the USGS indicates that the Park is underlain by the following geologic units:

- A surficial layer of vegetated soil, established after final grading during Park construction; a few inches to a foot thick.
- Soil imported for filling and grading when the Park was constructed; classified as artificial fill; 1 to 5 ft thick, except under Kite Hill, where 50 ft or more may be present.

- A layer of fill and native soil mixed with materials derived from the gas plant operation, including cinders, brick, wood, concrete, lampblack, tar, and various types of oil; classified as the Gas Works deposit; up to 15 ft thick.
- A natural glacial deposit of sand with some clay and gravel, classified as recessional stratified drift; not present under the entire Park, but up to 25 ft thick at some locations.
- A dense, compacted glacial deposit comprised of clay, silt, sand, gravel, and boulders, classified as Vashon till; underlies the entire Park, and was 33 ft thick at the single well location where it was fully penetrated. The till separates the overlying deposits from deeper glacial strata.

d. Are there surface indications or history of unstable soils in the immediate vicinity? If so, describe.

There are no indications or history of unstable soils.

e. Describe the purpose, type, and approximate quantities of any filling or grading proposed. Indicate source of fill.

The air sparging/soil vapor extraction treatment will be installed in the southeast corner of the site (Figure 4-1 of the CAP). To install the treatment system, air sparging wells, constructed of 2-inch diameter steel pipe, will be spaced over the 0.7-acre treatment area. Horizontal trenches will be excavated for installation of the soil vapor collection pipes and backfilled with gravel. An impermeable geomembrane cap will be laid over the entire treatment area to contain soil vapors and promote system efficiency. The area will then be covered with 1 foot of imported soil and seeded with grass. Refer to Section 4.1.1 of the CAP for a more detailed description of air sparging system installation.

To isolate park users from soil contaminants, a soil cover will be placed over the southeast and north central portions of site, with the exception of paved areas, (see Figure 4.1 of the CAP). The area will first be graded to remove the existing lawn cover. The soil cover will consist of a 1-foot-thick layer of imported soil underlain by geotextile fabric. The fabric will provide a barrier for physical migration of underlying materials to the surface and a visual indicator if the soil is later removed (through digging or erosion) and must be replaced. About 5.7 acres will be covered with approximately 9,200 cubic yards of soil. The soil cover will then be seeded with grass.

During grading prior to placement of the soil cover, the potential exists for encountering visibly contaminated soil or waste materials (such as tar). This material will be excavated and hauled offsite for disposal. It is assumed that such incidental "hot spots" will occur over 5% of the area to receive the soil cover, excavated to a depth of 2 feet, and taken offsite. Based on these assumptions, approximately 920 cubic yards of contaminated soil will be removed from the site and replaced with an equal amount of clean fill. Refer to Section 4.1.2 of the CAP for a more detailed description of soil cover installation.

Approximately 10,000 cubic yards of imported soil will be required for the project. The material will be obtained from outside sources. Some soil is currently stockpiled onsite and may be used for the project if determined to be suitable.

f. Could erosion occur as a result of clearing, construction, or use? If so, generally describe.

Approximately 5.7 acres of soil will be exposed during removal of the exiting lawn, excavation and backfilling of "hot spots," and placement of the soil cover. Erosion of exposed soils could occur until vegetative cover is reestablished. Erosion of stockpiled soil also could occur. Excavation and grading of existing contaminated soils has the greatest potential for adverse impacts, particularly because of the site's proximity to Lake Union.

g. About what percent of the site will be covered with impervious surfaces after project construction (for example, asphalt or buildings)?

The project will result in the creation of approximately 2,500 square feet of new impervious surfaces associated with the soil vapor treatment equipment station. All existing impervious surfaces will be retained.

h. Proposed measures to reduce or control erosion, or other impacts to the earth if any:

An erosion and sedimentation plan will be prepared in accordance with City of Seattle standards. Control measures will include:

- Silt fencing to capture construction generated sediments;
- Covering stockpiled material with a waterproof covers;
- Backfilling and seeding excavated and filled areas as soon a possible;
- Combining seed with mulch and tacifier to better retain soil; and
- Completing construction and replanting before October 1.

2. Air

a. What types of emissions to the air would result from the proposal (i.e., dust, automobile, odors, industrial wood smoke) during construction and when the project is completed? If any, generally describe and give approximate quantities if known.

Air quality impacts during the seven-month excavation/construction phase include exhaust emissions and dust generation. Trucks hauling soil to and from the site and construction equipment powered by gasoline and diesel engines will generate carbon monoxide, oxides of nitrogen, and unburned hydrocarbons. Dust will be generated during land clearing, excavation, filling, and grading activities.

Carbon dioxide and water vapor will be emitted from the soil vapor treatment unit during operation of the air sparging/soil vapor extraction system.

No emissions will be generated by the completed project.

b. Are there any off-site sources of emissions or odor that may affect your proposal? If so, generally describe.

There are no off-site emissions or odors that would affect the project.

c. Proposed measures to reduce or control emissions or other impacts to air, if any:

Construction measures:

- Spray exposed soils lightly with water to reduce dust emissions.
- Cover all trucks transporting materials to reduce dust emissions during transportation.
- Provide wheel washers to remove dirt from trucks leaving the site.
- Require appropriate emission-control devices on all construction equipment powered by gasoline or diesel fuel.
- Plant vegetative cover as soon as possible after final grading to reduce windblown particulates in the area.

3. Water

a. Surface

1) Is there any surface water body on or in the immediate vicinity of the site (including year-round and seasonal streams, saltwater, lakes, ponds, wetlands)? If yes, describe type and provide names. If appropriate, state what stream or river it flows into.

No surface water body is located on the site. Surface runoff from the site drains to Lake Union, which forms the southern and eastern boundaries of the site. Lake Union is a freshwater lake that drains to Puget Sound via the Ship Canal and the Hiram Chittenden Locks.

2) Will the project require any work over, in, or adjacent to (within 200 feet) the described waters? If yes, please describe and attach available plans.

Clearing, grading, and filling associated with installation of the air sparging system and installation of the soil cover will occur along approximately 500 feet of Lake Union shoreline (See Figure 4-1 of the CAP).

3) Estimate the amount of fill and dredge material that would be placed in or removed from surface water or wetlands and indicate the area of the site that would be affected. Indicate the source of fill material.

No fill and dredge material will be placed in or removed from surface waters or wetlands.

4) **Will the proposal require surface water withdrawals or diversions? Give general description, purpose, and approximate quantities if known.**

No surface water withdrawals or diversions will be required.

5) **Does the proposal lie within a 100-year floodplain? If so, note location on the site plan.**

The proposed project does not lie within a 100-year floodplain.

6) **Does the proposal involve any discharges of waste materials to surface waters? If so, describe the type of waste and anticipated volume of discharge.**

The proposal does not involve any discharges of waste materials to surface waters.

b. Ground:

1) **Will groundwater be withdrawn, or will water be discharged to groundwater? Give general description, purpose, and approximate quantities if known.**

The proposal does not involve groundwater withdrawal or discharges to groundwater, with the exception of limited groundwater sampling. Less than 500 gallons per year of groundwater would be withdrawn for well purging and sampling.

2) **Describe waste material that will be discharged into the ground from septic tanks or other sources, if any (for example: Domestic sewage; industrial, containing the following chemicals . . .; agricultural; etc.). Describe the general size of the system, the number of such systems, the number of houses to be served (if applicable), or the number of animals or humans the system(s) are expected to serve.**

No waste material will be discharged into the ground.

c. Water Runoff (including storm water):

1) **Describe the source of runoff (including storm water) and method of collection and disposal, if any (include quantities, if known). Where will this water flow? Will this water flow into other waters? If so, describe.**

All runoff from the site is generated by precipitation and drains to Lake Union. The only visible drainage features are a swale between Kite Hill and the cracking towers, and a shallow swale in the southeast section of site near the Play Barn and the picnic shelter. Water flows in these swales only after heavy rains. Storm drains direct runoff from the sundial at the top of Kite Hill, from the parking lot, and from the low grassy area in the northeast corner of the Park.

After completion of the project, site drainage will be similar to existing conditions and will continue to drain to Lake Union. No new stormwater collection facilities will be constructed as a result of the project. Bioswales will be incorporated into the final design to improve stormwater quality.

2) Could waste materials enter ground or surface waters? If so, generally describe.

The project will not cause waste materials to enter ground or surface water. Contaminated soil or groundwater encountered during construction and operation of the project will be contained, tested, and transported off site to a permitted disposal facility.

d. Proposed measures to reduce or control surface, ground, and runoff water impacts, if any:

An Erosion and Sedimentation Plan will be prepared and implemented to control sedimentation impacts to surface water.

4. Plants

a. Check or circle types of vegetation found on the site:

x **deciduous tree: alder, maple, aspen, other**
x **evergreen tree: fir, cedar, pine, other**
x **shrubs**
x **grass**
pasture
crop or grain
x **wet soil plants: cattail, buttercup, bulrush, skunk cabbage, other**
water plants: water lily, eelgrass, milfoil, other
other types of vegetation

b. What kind and amount of vegetation will be removed or altered?

Approximately 5.7 acres of poor quality lawn will be removed for soil cover placement. The area will be reseeded with lawn grasses after final site grading has been completed.

c. List threatened or endangered species known to be on or near the site.

No threatened or endangered plant species are known to be on or near the site (see Section 3.6 and Appendix G of the FFS report).

d. Proposed landscaping, use of native plants, or other measures to preserve or enhance vegetation on the site, if any:

Only lawn areas will be cleared. All existing shrubs and trees on the site will be retained. Willows or other appropriate plants will be planted along the shoreline to stabilize the shore and promote removal of volatile groundwater contaminants via plant transpiration.

5. Animals

a. Circle any birds and animals which have been observed on or near the site or are known to be on or near the site:

birds: hawk, heron, eagle, songbirds, other (Canadian geese, thrushes, waterfowl)
mammals: deer, bear, elk, beaver, other (raccoons, squirrels, possum, mice, rats)
fish: bass, salmon, trout, herring, shellfish, other: (peamouth, northern squawfish, yellow perch, brown bullhead, black crappie, carp)

b. List any threatened or endangered species known to be on or near the site.

Only the Chinook Salmon (listed as a threatened species under the ESA on March 16, 1999) is known to be near the site (see Section 3.6 and Appendix G of the FFS report).

c. Is the site part of a migration route? If so, explain.

This site is adjacent to Lake Union, which is a salmon migration corridor for Chinook and other salmonoid species.

d. Proposed measures to preserve or enhance wildlife, if any:

Willows planted along the shoreline will screen waterfowl on the Lake from park users.

6. Energy and Natural Resources

a. What kinds of energy (electric, natural gas, oil, wood stove, solar) will be used to meet the completed project's energy needs? Describe whether it will be used for heating, manufacturing, etc.

During operation of the air sparging system, the sparging and extraction blowers will be powered by electricity, and the soil vapor treatment unit will be powered by natural gas or propane. Little energy will be required for the completed project.

b. Would your project affect the potential use of solar energy by adjacent properties? If so, generally describe.

The project will not affect the potential use of solar energy by adjacent properties.

c. What kinds of energy conservation features are included in the plans of this proposal? List other proposed measures to reduce or control energy impacts, if any:

The soil vapor treatment system has been designed to use clean hot air exiting the system to preheat cold air entering the system, thereby reducing fuel demand.

7. Environmental Health

a. Are there any environmental health hazards, including exposure to toxic chemicals, risk of fire and explosion, spill, or hazardous waste, that could occur as a result of this proposal? If so, describe.

Work crews could be exposed to potential health risks during excavation of existing contaminated soils. Exposure could occur via inhalation of wind-blown dust containing contaminated soil particles, inhalation of soil gases released during excavation, and direct contact and inadvertent ingestion of contaminated soil. Appropriate personal protective measures will be implemented in accordance with a site-specific Health and Safety Plan.

After completion, the project will result in a reduction in environmental health hazards by preventing exposure of park users to contaminated soils, and reducing the concentration of groundwater contaminants migrating to Lake Union.

1) Describe special emergency services that might be required.

No special emergency services will be required.

2) Proposed measures to reduce or control environmental health hazards, if any:

During installation of the air sparging system, fencing will be installed around the construction area to prevent public access. The park will be closed to the public during excavation of contaminated soils and installation of the soil cover. A site-specific Health and Safety Plan will be implemented to guide construction activities and reduce potential health hazards to work crews. Mitigation measures could include:

- Dust suppression techniques, such as water spray, application of polymer layers, and covering stockpiles with tarps;
- Prompt filling and covering of excavated areas; and

- Monitoring emission levels from soil and air sparging/soil vapor extraction system and implementing appropriate occupational health and safety standards.

b. Noise

1) What types of noise exist in the area which may affect your project (for example: traffic equipment, operation, other)?

The project will not be affected by existing noise.

2) What types and levels of noise would be created by or associated with the project on a short-term or a long-term basis (for example: traffic, construction, operation, other)? Indicate what hours noise would come from the site.

Short-term noise will result from operation of earthmoving and drilling equipment and from trucks hauling material to and from the site. Truck and construction equipment operation during soil cover placement and air sparging system installation will be intermittent over a three-month and four-method period, respectively. Maximum noise levels generated by construction equipment range from about 70 to 100 dBA at a distance of 50 feet from the sound source. Actual noise levels will be less than this maximum because construction equipment will be turned off, idling, or operating at less than full power at any time.

Noise will also be generated during the operation of the air sparging/soil vapor evaporation system. Although the noise level will be relatively low, the noise will be continuous for a period of approximately three years.

No noise will be generated by the completed project.

3) Proposed measures to reduce or control noise impacts, if any:

Temporary noise during construction could be mitigated by one or more of the following measures:

- Limiting construction to normal working hours;
- Installing mufflers on all internal combustion engine-driven equipment and pneumatic tools;
- Turning off idling equipment; and
- Constructing noise barriers or curtains around stationary equipment.

8. Land and Shoreline Use

a. What is the current use of the site and adjacent properties?

The site is a public urban park owned by the City of Seattle. Recreational facilities include picnic areas, play areas, a 35-foot-high hill, and a small system of trails.

The area north of the site is primarily industrial. These properties include two hazardous waste cleanup sites. The moorage for the City of Seattle Harbor Patrol is located to the west of the park.

b. Has the site been used for agriculture? If so, describe.

The site has not been used for agriculture.

c. Describe any structures on the site.

Restroom facilities and a picnic shelter have been constructed on the site. The undeveloped northwest corner of the Park is enclosed by a masonry wall and fence with a locked gate, and was the former location of two large above-ground fuel oil storage tanks associated with the gas plant operations. A number of structures from the former gas plant were retained as part of the Park design. These include gas generators and associated structures (referred to as the cracking towers), a boiler house and pump house (renovated as the Play Barn), seven vertical steel vessels and associated equipment housing, concrete trestles of an abandoned railroad spur, and a concrete barge-unloading platform.

d. Will any structures be demolished? If so, what?

No structures will be demolished.

e. What is the current zoning classification of the site?

The site is zoned Industrial Buffer (IB) by the City of Seattle.

f. What is the current comprehensive plan designation of the site?

The Seattle Comprehensive Plan designation is Parks/Open Space.

g. If applicable, what is the current shoreline master program designation of the site?

The City of Seattle Shoreline Master Plan Designation is Conservancy Management (Cm).

h. Has any part of the site been classified as an "environmentally sensitive" area? If so, specify.

The City of Seattle does not classify the site as environmentally sensitive.

i. Approximately how many people would reside or work in the completed project?

The completed project will not create any new residences or jobs.

j. Approximately how many people would the completed project displace?

No people will be displaced as a result of the project.

k. Proposed measures to avoid or reduce displacement impacts, if any:

N/A

l. Proposed measures to ensure the proposal is compatible with existing and projected land uses and plans, if any:

The proposal will comply with all City of Seattle land use regulations and policies. The proposed cleanup methods were selected, in part, because they will cause minimal disruption to recreational activities on the site. The project will reduce the risk to human health and the environment posed by onsite contaminants and, therefore, improve the suitability of the site for its designated parks/open space land use.

9. Housing

a. Approximately how many units would be provided, if any? Indicate whether high, middle, or low-income housing.

No housing will be provided by the project.

b. Approximately how many units, if any, would be eliminated? Indicate whether high, middle, or low-income housing.

No housing will be eliminated by the project.

c. Proposed measures to reduce or control housing impacts, if any:

N/A

10. Aesthetics

a. What is the tallest height of any proposed structure(s), not including antennas; what is the principal exterior building material(s) proposed?

The soil vapor extraction system will have an exhaust stack approximately 30 feet tall. The above-ground equipment will be contained within a 2,500-square foot area enclosed by fencing.

b. What views in the immediate vicinity would be altered or obstructed?

The soil vapor extraction exhaust stack may be visible to Park users, to motorists and pedestrians traveling on N Northlake Way, and to businesses and residences on the hillslopes facing the Park. No views will be obstructed, however.

c. Proposed measures to reduce or control aesthetic impacts, if any:

Most of the air sparging/soil vapor extraction system equipment will be buried underground and will not be visible to Park users. To minimize impacts to the visual cohesion of the Park, the exhaust stack and equipment staging area may be located next to the cracking towers, which are four vertical tanks that were part of the former gas works operation. The exhaust tower and above ground equipment will be removed after completion of groundwater remediation, approximately three years after initiation.

11. Light and Glare

a. What type of light or glare will the proposal produce? What time of day would it mainly occur?

No light or glare will be produced as a result of the proposal.

b. Could light or glare from the finished project be a safety hazard or interfere with views?

No light or glare will be created.

c. What existing off-site sources of light or glare may affect your proposal?

The project will not be affected by off-site sources.

d. Proposed measures to reduce or control light and glare impacts, if any:

N/A

12. Recreation

a. What designated and informal recreational opportunities are in the immediate vicinity?

The site is a designated public park. Recreational features include a picnic shelter, a lakeside promenade, a system of asphalt and gravel paths, and about eight acres of open area, primarily covered with lawn. The Play Barn, one of the abandoned gas works facilities, has been painted with bright colors and is used as a play area for children. Sand boxes and swings are located next to the

Play Barn. The Prow, a large concrete structure with railings, abuts Lake Union and provides a clear view of downtown Seattle. Another feature is Kite Hill, which is a steep-sloped artificially created hill with trails and a large sundial on top.

The City frequently permits special activities to occur at the site, including concerts, art- and film-related events, and fund-raising activities, such as walk-a-thons. Although access to the shoreline of Lake Union is available at the site, it is not encouraged. Several signs warn park users that lake sediments and water near the park are contaminated.

b. Would the proposed project displace any existing recreational uses? If so, describe.

During installation of the air sparging system, the southeast corner of the site will fenced off and inaccessible to Park users. The remainder of the Park will be open to Park users. The entire Park will be closed for approximately four months during excavation and placement of the soil cover. Afterward, access to some areas of the Park may be restricted until the seeded lawn is established. No recreational uses will be displaced during operation of the air sparging system or after the cleanup is completed.

c. Proposed measures to reduce or control impacts, if any:

The Park is a popular site for viewing Fourth of July fireworks displays. The construction schedule has been designed so the Park can be open during that holiday. The air sparging system was selected as the preferred groundwater cleanup method, in part, because it will cause minimal disruption to park use. After installation, most of the system will be underground and not detectable to park users.

13. Historic and Cultural Preservation

a. Are there any places or objects listed on, or proposed for, national, state, or local preservation registers known to be on or next to the site? If so, generally describe.

Several components of the original gas works facility have been retained and incorporated in the Park design. The City of Seattle considers the structures and their park setting to be a valuable historic resource because they provide a link to the city's industrial history. The site is not listed or proposed for the national or state historic preservation register.

b. Generally describe any landmarks or evidence of historic, archaeological, scientific, or cultural importance known to be on or next to the site.

Several structures associated with the former gas works are present in their original locations throughout the Park. The most significant of these structures are located in the southern and eastern portions of the Park:

- Six original gas generators and associated structures, commonly referred to as the "cracking towers;" surrounded by a locked chain-link fence.

- Structures and equipment associated with the Boiler House and the Pump House, which were modified and preserved in an area of the Park known as the Play Barn.

- Two tall vertical steel vessels (light-oil absorber, gas cooler), a short rectangular structure housing the meters that measured gas output from the plant, and a small brick building (the former Foamite Building), all located southwest of the Play Barn.

- A group of five vertical steel vessels located directly west of the Play Barn. These structures were part of a high-BTU oil gas system that produced a "richer" gas for blending with the lower quality gas from the six oil gas generator sets in the cracking tower area.

- Concrete trestles located northwest of the Play Barn, which formerly supported a railroad spur used for coal unloading.

- The "Prow," a concrete structure located south of the cracking towers on the Lake Union shoreline, which was formerly used for unloading coal from barges.

c. Proposed measures to reduce or control impacts, if any:

The historic structures will not be directly affected by the proposal. The exhaust tower of the soil vapor treatment system will have a temporary, minor visual impact on the setting of these structures. The exhaust tower will be removed upon completion of the site cleanup.

14. Transportation

a. Identify public streets and highways serving the site, and describe proposed access to the existing street system. Show on site plans, if any.

A paved parking lot is located in the north-central portion of the site and has two entrances off N. Northlake Way.

b. Is site currently served by public transit? If not, what is the approximate distance to the nearest transit stop?

The site is served by King County Metro transit. The nearest bus stop is for bus route 26 and is located at the intersection of N. 35th Street and Wallingford Avenue N, about two blocks north of the site.

c. How many parking spaces would the completed project have? How many would the project eliminate?

No parking spaces will be created or eliminated as a result of the project.

d. Will the proposal require any new roads or streets, or improvements to existing roads or streets, not including driveways? If so, generally describe (indicate whether public or private).

No new roads or streets, or improvements to roads or streets, will be required.

e. Will the project use (or occur in immediate vicinity of) water, rail, or air transportation? If so, generally describe.

The project will not use water, rail, or air transportation.

f. How many vehicular trips per day would be generated by the completed project? If known, indicate when peak volumes would occur.

No vehicle trips will be generated by the completed project.

g. Proposed measures to reduce or control transportation impacts, if any:

The selected soil cover cleanup method minimizes the amount of imported fill required for the project, and, therefore, minimizes the number of truck trips to the site. The excavation and removal method considered in the FFS would have generated more truck trips. Installation of geotextile fabric reduces the required thickness of the soil cover.

15. Public Services

a. Would the project result in an increased need for public services (for example: fire protection, police protection, health care, schools, other)? If so, generally describe.

The project will not increase the need for public services.

b. Proposed measures to reduce or control direct impacts on public services, if any.

N/A

16. Utilities

a. Circle utilities currently available at the site: electricity, natural gas, water, refuse service, telephone, sanitary sewer, septic system, other.

b. Describe the utilities that are proposed for the project, the utility providing the service, and the general construction activities on the site or in the immediate vicinity which might be needed.

Electricity will be needed to operate the air sparging/soil vapor extraction equipment for groundwater remediation. The equipment will be connected to existing Seattle City Light electrical lines. No new electrical lines will be required. The soil vapor treatment equipment is powered by natural gas or propane. If powered by natural gas, the system could be connected to existing Puget Power natural gas lines that are located on the site. If powered by propane, an above ground tank would be installed.

C. SIGNATURE

The above answers are true and complete to the best of my knowledge. I understand that the lead agency is relying on them to make its decision.

Signature: Debra V. Kordik

Date Submitted: 10-30-98

APPENDIX B

DETERMINATION OF NON-SIGNIFICANCE (DNS)

SEPA RULES

DETERMINATION OF NONSIGNIFICANCE

Description of proposal: Gas Works Park environmental cleanup (per WAC 173-340).

Proponent: City of Seattle, Department of Parks and Recreation.

Location of proposal, including street address, if any: 2000 N. Northlake Way, Seattle, Washington.

Lead agency: Washington State Department of Ecology

The lead agency for this proposal has determined that it does not have a probable significant adverse impact on the environment. An environmental impact statement (EIS) is not required under RCW 43.21C.030 (2)(c). This decision was made after review of a completed environmental checklist and other information on file with the lead agency. This information is available to the public on request.

__There is no comment period for this DNS.

__This DNS is issued after using the optional DNS process in WAC 197–11–355. There is no further comment period on the DNS.

_X_ This DNS is issued under WAC 197–11–340(2); the lead agency will not act on this proposal for 14 days from the date below. Comments must be submitted by December 31, 1998.

Responsible official: Carol Kraege

Position/title Phone: Section Head, Toxics Cleanup Program (360) 407-7175

Address: Washington Department of Ecology, Toxics Cleanup Program, P.O. Box 47600 Olympia, WA 98054-7600

Date: Wednesday, December 09, 1998

Signature: Carol Kraege

(optional)

_X You may appeal this determination to: Carol Kraege or Charles San Juan, Washington Department of Ecology, Toxics Cleanup Program, P.O. Box 47600 Olympia, WA 98054-7600

Carol Kraege: (360) 407-7175, e-mail: ckra461@ecy.wa.gov
Charles San Juan (360) 407-7191, e-mail: csan461@ecy.wa.gov

at (location): Same as above

no later than (date): December 31, 1998

by (method): phone, fax, or e-mail: any method may be used, phone and e-mail above, fax: (360) 407-7154

You should be prepared to make specific factual objections.

Contact to read or ask about the procedures for SEPA appeals.

__There is no agency appeal.

[Statutory Authority: 1995 c 347 (ESHB 1724) and RCW 43.21C.110. 97–21–030 (Order 95–16), § 197–11–970, filed 10/10/97, effective 11/10/97. Statutory Authority: RCW 43.21C.110. 84–05–020 (Order DE 83–39), § 197–11–970, filed 2/10/84, effective 4/4/84.]

APPENDIX C

MEMORANDUM FROM THERMORETEC TO THE DEPARTMENT OF ECOLOGY DATED APRIL 12, 1999

ThermoRetec Corporation
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Seattle, WA 98134-1162

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MEMORANDUM

TO:	Craig Thompson, Dept. of Ecology	**CLIENT:**	Seattle Department of Parks & Recreation and Puget Sound Energy
FROM:	Dan Baker	**PROJECT:**	Gas Works Park
DATE:	April 12, 1999	**RE:**	Extemely Hazardous Waste

As defined in the Washington Department of Ecology (Ecology) Dangerous Waste Regulations (WAC 173-303-100), solid wastes containing greater than 1% total polycyclic aromatic hydrocarbons (PAH) are considered extremely hazardous waste (EHW). The presence of tar and elevated PAH concentrations in soil at Gas Works Park suggests that some of the soil could potentially classify as EHW if excavated and disposed. Cleanup actions in the Focused Feasibility Study (FFS; Parametrix, pending) are based on risk. Although soil cleanup levels are not governed by Dangerous Waste Regulations, questions have been raised by Ecology and EPA regarding the presence of soils exceeding 1% total PAH. This memorandum attempts to answer the following questions regarding soils at Gas Works Park:

- How much soil at Gas Works Park exceeds the 1% total PAH criterion?
- Where is the soil of concern located?
- Would soil classify as EHW if excavated and characterized for off-site disposal?

An updated cost estimate for excavation to a depth of 15 feet is also provided, which will replace "Alternative 5" in the FFS report and the CAP.

Amount of Soils Exceeding 1% Total PAH: We have reviewed soil analytical data to determine the amount of soils exceeding 1% total PAH. The reason that soil would exceed 1% total PAH is the presence of tar. Pure tar from the Park has exceeded the 1% EHW criterion, based on sampling of seasonal tar seeps that occurred in the past on the north side of Kite Hill. Tar collected from seeps has been characterized as EHW for disposal purposes. All known surficial tar deposits identified by the October 1997 test pit investigation have been removed from the Park.

Existing soil data indicate there are some discrete areas that may exceed 1% total PAH. A review of the historic database indicates that only 3 of 145 samples analyzed for PAH exceeded 1% total PAH. These data are compiled in Table 1 and Table 3-8 of the EPRI report, and sampling locations are shown in Figure 2-4 of the FFS and Figure 2-1 of the EPRI report (attached). It should be noted that there has been bias toward collecting the most heavily impacted soil for characterization in at least some of these sampling programs (i.e., "hot spot" sampling). Of the three samples that exceeded 1% total PAH, two were near surface samples of soils that have been excavated and properly disposed, and the other one was at a depth of 16.5 feet -- beyond a reasonable depth for excavation and below the 15-foot MTCA point of compliance depth. Because all of the surficial areas known to exceed 1% total PAH have been removed, there is no analytical evidence of soils within 15 feet of the ground surface exceeding 1% total PAH.

Sampling programs with the objective of analyzing the most heavily impacted soil, such as the recent EPRI sampling program, suggest that most tarry soils have less than 1% total PAH. Five of the six tarry soil samples submitted in this study did not exceed 1% total PAH and none of the 3 samples collected above 15-foot depth is above the 1% criterion. Data from discrete soil samples suggest it would be reasonable to assume that 2% (3/145) of the soils are greater than 1% total PAH. However, these data are biased as described above. The amount of soil exceeding the 1% criterion is likely much less than 2% of the total soil volume.

Location of Tarry Soils: Investigations have shown that tar occurs in small pockets, lenses, or thin layers. Tar has accumulated in some of the wells in the western park area downgradient of the former American Tar Company tar refinery. Tar has been noted in surface fill material, the Gas Works deposit, and locally in the underlying native stratified drift. All known areas of tar in the surface fill identified by the October 1997 test pit investigation have been excavated. The only area where tar is known to exist in the stratified drift is the western park area where it is mostly below 15-foot depth.

Tarry soils are randomly distributed throughout the Park in the Gas Works deposit. The nature of the Gas Works deposit, consisting of manufactured gas plant residues, is such that all of the Gas Works deposit is potentially tarry. However, a very small percentage of the soil (much less than 2% because of the bias in sampling) is likely to be greater than 1% PAH. The Gas Works deposit is thought to be present beneath most of the Park. Due to the redistribution of soils during park construction and heterogeneous nature of the Gas Works deposit, there are no specific target areas for tarry soils (i.e., no "hot spots"). A schematic diagram depicting the conceptual model of tar occurrence at the park is provided as Figure 1.

Excavated Soil Versus the EHW Criterion: Soils are not a solid waste and could not be classified as an EHW unless excavated and disposed. Based on available data on the concentrations and distribution of tarry soils, soils would not classify as EHW if excavated and characterized for disposal. Only a small percentage of the soil that would be excavated may exceed 1% total PAH. This soil could not be segregated into a separate stockpile based on visual identification because of the random and widely dispersed nature of the tar. Therefore, the concentrations in the soil stockpiles after the excavation activities would be below 1% total PAH. Furthermore, characterization for waste disposal would be based on composite sampling of stockpiled soil. Composite sampling would reflect average soil concentrations which are less than 1% total PAH. For example, samples collected from soil stockpiles during tar removal had concentrations less than 0.1% total PAH and the associated excavation targeted an area of known tarry soils.

Costs for Removing Soils Potentially Exceeding 1% Total PAH: Due to the random distribution of tarry soils in the Gas Works deposit, there are no specific target areas for excavation. However, because the potential exists, the majority of the Park area would need to be excavated to a depth of 15 feet (the MTCA point of compliance) to remove tarry soils possibly exceeding 1% total PAH. Excavation would be difficult due to:

- Excavation beneath the water table
- Proximity to shoreline
- Existence of the Gas Works deposit beneath existing structures

Tables 13-5a through 13-5c present a revised FFS cost estimate developed by Parametrix for excavation of the upper 15 feet of soil that exceeds MTCA Method B soil cleanup levels over the entire Park in the 8.8-acre area assumed for the FFS excavation alternative. This is a larger area than estimated for the soil cover in the FFS (Alternatives 2, 3, and 4) as excavation would presumably be necessary in areas capped with clean fill due to the presence of the underlying Gas Works deposit. The estimated $80 million cost of this alternative includes excavation beneath existing structures such as the cracking towers and Play Barn which are underlain by the Gas Works deposit.

Conclusion: Excavation to a depth of 15 feet to remove all soils exceeding MTCA Method B cleanup levels (including soils potentially exceeding 1% total PAH) would be impracticable due to the random and widespread distribution of tarry soils, existing park conditions, and the shallow water table. Excavation to remove soils exceeding MTCA Method B cleanup levels and 1% total PAH is substantial and disproportionate for the following reasons:

- High cost
- The low percentage of soil exceeding 1% total PAH
- The likely outcome of producing no EHW
- Soil excavation will not provide a greater degree of human health protection as the risk would be managed by the proposed soil cover and air sparging/SVE system presented in the FFS and CAP as Alternative 3.

cc: Steve Secrist, Steve Feller - PSE
Robin Kordik, Peter Hapke - City of Seattle
Harry Grant - Graham & James/Riddell Williams
John Ryan, Jennifer Pilling, File 1-3916 - ThermoRetec

Table 1 PAH Concentrations in Soil—Gas Works Park

Constituent	Site: Sample ID: Date: Depth (ft): Result Type:	84EPA100 148 4/2/84 0.08 Primary	84EPA200 149 4/2/84 0.08 Primary	84EPA300 150 4/2/84 0.08 Primary	84EPA31 142 3/21/84 0.08 Primary	84EPA32 144 3/21/84 0.08 Primary	84EPA33 146 3/21/84 0.08 Primary	84EPA400 151 4/2/84 0.08 Primary	84EPA500 152 4/2/84 0.08 Primary	84EPA600 153 4/2/84 0.08 Primary
Starting Depth	(feet)	0	0	0	0	0	0	0	0	0
Ending Depth	(feet)	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08
Acenaphthene	(mg/kg)	0.34	0.69	NA	0.034	0.27	0.22	0.13	0.1	58
Acenaphthylene	(mg/kg)	5	8.3	5.2	0.13	NA	0.85	0.21	0.1	3000
Fluorene	(mg/kg)	3	3.1	NA	0.098	0.48	0.51	0.1	NA	400
Anthracene	(mg/kg)	2.1	10	3.4	0.29	NA	5.4	0.5	NA	1000
Fluoranthene	(mg/kg)	70	78	17	4.5	3.2	34	6.5	0.4	8000
Phenanthrene	(mg/kg)	110	126	43	3.2	2.8	18	3.3	0.18	14000
Benzo(a)anthracene	(mg/kg)	42	39	9.9	2.1	2.2	12	3.6	0.39	3000
Benzo(b)fluoranthene	(mg/kg)	36	64	11	2	2.9	13	4.9	0.56	4000
Benzo(k)fluoranthene	(mg/kg)	NA	NA	NA	NA	NA	NA	NA	NA	NA
Pyrene	(mg/kg)	120	107	22	4.9	11	40	10	0.8	16000
Chrysene	(mg/kg)	46	80	31	2.7	7.9	18	4.8	0.64	6000
Benzo(a)pyrene	(mg/kg)	44	63	19	0.76	1.2	22	6.9	0.75	10000
Dibenzo(a,h)anthracene	(mg/kg)	52	37	5	1.5	NA	8.9	8.5	NA	2000
Indeno(1,2,3-c,d)pyrene	(mg/kg)	29	130	18	1.8	1.5	13	18	NA	11000
Benzo(g,h,i)perylene	(mg/kg)	38	92	12	2	1.8	18	26	NA	23000
Dibenzo(a,e)pyrene	(mg/kg)	NA	NA	NA	NA	NA	NA	NA	NA	NA
Dibenzo(a,h)pyrene	(mg/kg)	NA	NA	NA	NA	NA	NA	NA	NA	NA
Dibenzo(a,i)pyrene	(mg/kg)	NA	NA	NA	NA	NA	NA	NA	NA	NA
Dibenzo(a,l)pyrene	(mg/kg)	NA	NA	NA	NA	NA	NA	NA	NA	NA
Dibenz(a,j)acridine	(mg/kg)	NA	NA	NA	NA	NA	NA	NA	NA	NA
Total PAHs	(mg/kg)	597.44	838.09	196.5	26.012	35.25	203.88	93.44	3.92	101458
Total PAHs	%	0.059744	0.083809	0.01965	0.0026012	0.003525	0.020388	0.009344	0.000392	**10.1458**

NOTES:

NA - Not Analyzed

For RCL DRF-REQ

Table 1 PAH Concentrations in Soil—Gas Works Park (Continued)

Constituent	Site: / Sample ID: / Date: / Depth (ft): / Result Type:	84EPA700 154 4/2/84 0.08 Primary	95EPA-32 40 1/23/95 0.08 Primary	95EPA-33 210 1/23/95 0.08 Primary	95EPA-35 42 1/23/95 0.08 Primary	B30 44 3/15/85 0.16 Primary	B36 45 3/15/85 0.16 Primary	B6 43 3/15/85 0.16 Primary	C11 46 3/15/85 0.16 Primary	C27 47 3/15/85 0.16 Primary
Starting Depth	(feet)	0	0	0	0	0	0	0	0	0
Ending Depth	(feet)	0.08	0.08	0.08	0.08	0.16	0.16	0.16	0.16	0.16
Acenaphthene	(mg/kg)	27	0.464	1.02	4.38	2	20	20	0.2	2
Acenaphthylene	(mg/kg)	900	2.3	1.07	65.8	1	10	10	0.1	1
Fluorene	(mg/kg)	2000	2.34	0.353	29	0.2	7.4	2	0.02	0.2
Anthracene	(mg/kg)	640	2.74	0.773	66.8	0.18	3.9	0.64	0.002	0.068
Fluoranthene	(mg/kg)	6000	23	3.26	442	2.5	32	15	0.067	1
Phenanthrene	(mg/kg)	9000	9.04	0.943	311	1.4	32	4.4	0.033	0.67
Benzo(a)anthracene	(mg/kg)	3000	8.34	2.29	197	1.6	4.5	8.6	0.03	0.46
Benzo(b)fluoranthene	(mg/kg)	3000	11.1	1.44	213	1.6	12	10	0.047	0.6
Benzo(k)fluoranthene	(mg/kg)	NA	3.65	0.582	61.2	0.7	5.9	4.7	0.022	0.27
Pyrene	(mg/kg)	18000	25.7	5.07	375	4.5	49	28	0.09	1.7
Chrysene	(mg/kg)	4000	11.2	2.37	208	2	21	12	0.048	0.67
Benzo(a)pyrene	(mg/kg)	7000	8.16	1.75	162	2	16	10	0.04	0.7
Dibenzo(a,h)anthracene	(mg/kg)	830	1.37	0.266	34.4	0.4	4	4	0.04	0.4
Indeno(1,2,3-c,d)pyrene	(mg/kg)	1000	8.43	0.781	130	2.5	16	13	0.074	1
Benzo(g,h,i)perylene	(mg/kg)	4000	8.46	0.673	110	2.9	21	16	0.11	1.2
Dibenzo(a,e)pyrene	(mg/kg)	NA	NA	NA	NA	NA	NA	NA	NA	NA
Dibenzo(a,h)pyrene	(mg/kg)	NA	NA	NA	NA	NA	NA	NA	NA	NA
Dibenzo(a,i)pyrene	(mg/kg)	NA	NA	NA	NA	NA	NA	NA	NA	NA
Dibenzo(a,l)pyrene	(mg/kg)	NA	NA	NA	NA	NA	NA	NA	NA	NA
Dibenz(a,j)acridine	(mg/kg)	NA	NA	NA	NA	NA	NA	NA	NA	NA
Total PAHs	(mg/kg)	59397	126.294	22.641	2409.58	25.48	254.7	158.34	0.923	11.938
Total PAHs	%	5.9397	0.0126294	0.0022641	0.240958	0.002548	0.02547	0.015834	0.0000923	0.0011938

NOTES:
NA - Not Analyzed
For RCL DRF-REQ

Table 1 PAH Concentrations in Soil—Gas Works Park (Continued)

Constituent	Site: / Sample ID: / Date: / Depth (ft): / Result Type:	C37 48 3/15/85 0.16 Primary	D32 50 3/15/85 0.16 Primary	D8 49 3/15/85 0.16 Primary	E17 51 3/15/85 0.16 Primary	E25 52 3/15/85 0.16 Primary	EPA1 155 4/17/84 0.5 Primary	EPA1 179 4/17/84 3 Primary	EPA10 164 4/17/84 0.5 Primary	EPA10 188 4/17/84 3 Primary
Starting Depth	(feet)	0	0	0	0	0	0	2.75	0	2.75
Ending Depth	(feet)	0.16	0.16	0.16	0.16	0.16	0.5	3.25	0.5	3.25
Acenaphthene	(mg/kg)	20	20	0.2	2	200	0.044	0.899	0.08	0.476
Acenaphthylene	(mg/kg)	10	10	0.1	1	10	0.31	0.899	0.17	0.283
Fluorene	(mg/kg)	2	2	0.02	0.2	6.4	0.06	0.899	0.2	0.476
Anthracene	(mg/kg)	2	2.3	0.002	0.14	2.3	0.076	0.899	0.2	0.476
Fluoranthene	(mg/kg)	9.2	34	0.01	1.1	20	3	3.876	0.76	0.663
Phenanthrene	(mg/kg)	7.5	11	0.0097	1.1	15	1.3	2.467	0.62	0.048
Benzo(a)anthracene	(mg/kg)	3.3	15	0.01	0.53	12	1.8	2.467	0.2	0.092
Benzo(b)fluoranthene	(mg/kg)	3	11	0.0089	0.65	13	3.4	1.798	2.2	0.952
Benzo(k)fluoranthene	(mg/kg)	1.3	5.4	0.005	0.3	5.7	NA	1.798	NA	0.952
Pyrene	(mg/kg)	12	56	0.02	1.8	38	5.6	6.829	1.4	0.373
Chrysene	(mg/kg)	6.1	18	0.01	0.96	14	1.8	2.511	0.97	0.114
Benzo(a)pyrene	(mg/kg)	3.8	14	0.01	0.75	18	2.7	1.798	0.2	0.952
Dibenzo(a,h)anthracene	(mg/kg)	4	4	0.04	0.4	4	6	1.798	2	0.952
Indeno(1,2,3-c,d)pyrene	(mg/kg)	3.6	13	0.01	1.1	19	2.4	1.798	2	0.952
Benzo(g,h,i)perylene	(mg/kg)	3.3	15	0.02	1.3	22	3.5	1.798	2	0.952
Dibenzo(a,e)pyrene	(mg/kg)	NA	NA	NA	NA	NA	NA	NA	NA	NA
Dibenzo(a,h)pyrene	(mg/kg)	NA	NA	NA	NA	NA	NA	NA	NA	NA
Dibenzo(a,i)pyrene	(mg/kg)	NA	NA	NA	NA	NA	NA	NA	NA	NA
Dibenzo(a,l)pyrene	(mg/kg)	NA	NA	NA	NA	NA	NA	NA	NA	NA
Dibenz(a,j)acridine	(mg/kg)	NA	NA	NA	NA	NA	NA	NA	NA	NA
Total PAHs	(mg/kg)	91.1	230.7	0.4756	13.33	399.4	31.99	32.534	13	8.713
Total PAHs	%	0.00911	0.02307	0.00004756	0.001333	0.03994	0.003199	0.0032534	0.0013	0.0008713

NOTES:
NA - Not Analyzed
For RCL DRF-REQ

Table 1 PAH Concentrations in Soil—Gas Works Park (Continued)

Constituent	Site: Sample ID: Date: Depth (ft): Result Type:	EPA11 165 4/17/84 0.5 Primary	EPA11 189 4/17/84 3 Primary	EPA12 166 4/17/84 0.5 Primary	EPA12 190 4/17/84 3 Primary	EPA13 167 4/17/84 0.5 Primary	EPA13 191 4/17/84 3 Primary	EPA14 168 4/18/84 0.5 Primary	EPA14 192 4/18/84 3 Primary	EPA15 169 4/18/84 0.5 Primary
Starting Depth	(feet)	0	2.75	0	2.75	0	2.75	0	2.75	0
Ending Depth	(feet)	0.5	3.25	0.5	3.25	0.5	3.25	0.5	3.25	0.5
Acenaphthene	(mg/kg)	0.04	0.25	0.14	0.449	0.77	0.58	0.4	0.0114	0.6
Acenaphthylene	(mg/kg)	0.23	0.955	0.53	0.479	5	4.033	0.69	0.0114	0.7
Fluorene	(mg/kg)	0.07	0.386	0.16	0.093	2.4	1.654	0.4	0.0114	0.6
Anthracene	(mg/kg)	0.1	0.454	0.69	0.449	9.3	0.58	2.5	0.0114	2.6
Fluoranthene	(mg/kg)	3.5	3.636	9.7	2.256	5.7	3.04	3.1	0.026	44
Phenanthrene	(mg/kg)	3.1	4.227	5.6	2.075	83	16.662	11	0.0068	8.8
Benzo(a)anthracene	(mg/kg)	3	1.045	3.3	0.436	37	9.188	15	0.0034	22
Benzo(b)fluoranthene	(mg/kg)	3.6	0.614	7.1	0.603	66	1.159	24	0.0227	410
Benzo(k)fluoranthene	(mg/kg)	NA	0.159	NA	0.899	NA	4.907	NA	0.0227	NA
Pyrene	(mg/kg)	4.8	4.363	12	2.628	160	3.21	78	0.0455	110
Chrysene	(mg/kg)	2	1.205	3.5	0.644	63	15.365	25	0.0034	39
Benzo(a)pyrene	(mg/kg)	3.6	0.915	5	0.562	100	3.9	37	0.0227	60
Dibenzo(a,h)anthracene	(mg/kg)	3.1	0.909	11	0.899	6	1.159	23	0.0227	35
Indeno(1,2,3-c,d)pyrene	(mg/kg)	9.2	0.909	3.8	0.899	90	2.298	56	0.0227	90
Benzo(g,h,i)perylene	(mg/kg)	11	0.909	4.9	0.899	220	1.159	83	0.0227	130
Dibenzo(a,e)pyrene	(mg/kg)	NA	NA	NA	NA	NA	NA	NA	NA	NA
Dibenzo(a,h)pyrene	(mg/kg)	NA	NA	NA	NA	NA	NA	NA	NA	NA
Dibenzo(a,i)pyrene	(mg/kg)	NA	NA	NA	NA	NA	NA	NA	NA	NA
Dibenzo(a,l)pyrene	(mg/kg)	NA	NA	NA	NA	NA	NA	NA	NA	NA
Dibenz(a,j)acridine	(mg/kg)	NA	NA	NA	NA	NA	NA	NA	NA	NA
Total PAHs	(mg/kg)	47.34	20.936	67.42	14.27	848.17	68.894	359.09	0.2669	953.3
Total PAHs	%	0.004734	0.0020936	0.006742	0.001427	0.084817	0.0068894	0.035909	0.00002669	0.09533

NOTES:
NA - Not Analyzed
For RCL DRF-REQ

Table 1 PAH Concentrations in Soil—Gas Works Park (Continued)

Constituent	Site: Sample ID: Date: Depth (ft): Result Type:	EPA15 193 4/18/84 3 Primary	EPA16 170 4/18/84 0.5 Primary	EPA16 194 4/18/84 3 Primary	EPA17 171 4/19/84 0.5 Primary	EPA17 195 4/19/84 3 Primary	EPA18 172 4/19/84 0.5 Primary	EPA18 196 4/19/84 3 Primary	EPA19 173 4/19/84 0.5 Primary
Starting Depth	(feet)	2.75	0	2.75	0	2.75	0	2.75	0
Ending Depth	(feet)	3.25	0.5	3.25	0.5	3.25	0.5	3.25	0.5
Acenaphthene	(mg/kg)	0.023	0.02	1.255	0.096	0.0106	0.6	0.022	1.8
Acenaphthylene	(mg/kg)	0.023	0.05	0.765	0.51	0.0106	1.3	0.042	51
Fluorene	(mg/kg)	0.023	0.02	3.1	0.29	0.0106	0.6	0.021	1.8
Anthracene	(mg/kg)	0.023	0.02	0.44	0.91	0.0106	0.6	0.022	15
Fluoranthene	(mg/kg)	0.028	0.34	20.604	4.9	0.0106	11	0.152	48
Phenanthrene	(mg/kg)	0.0186	0.51	9.771	6	0.0106	11	0.091	48
Benzo(a)anthracene	(mg/kg)	0.0105	0.42	16.209	5.6	0.0106	9.8	0.07	42
Benzo(b)fluoranthene	(mg/kg)	0.046	0.43	11.774	9.6	0.0213	27	0.044	92
Benzo(k)fluoranthene	(mg/kg)	0.046	NA	26.137	NA	0.0213	NA	0.044	NA
Pyrene	(mg/kg)	0.0605	0.58	23.901	14	0.0048	50	0.218	110
Chrysene	(mg/kg)	0.0105	0.32	34.674	11	0.0106	22	0.08	100
Benzo(a)pyrene	(mg/kg)	0.046	0.88	62.951	17	0.0213	23	0.044	190
Dibenzo(a,h)anthracene	(mg/kg)	0.046	0.58	0.879	12	0.0213	6	0.044	1.8
Indeno(1,2,3-c,d)pyrene	(mg/kg)	0.046	1.3	0.879	28	0.0213	100	0.044	450
Benzo(g,h,i)perylene	(mg/kg)	0.046	2.2	0.879	38	0.0213	150	0.044	570
Dibenzo(a,e)pyrene	(mg/kg)	NA	NA	NA	NA	NA	NA	NA	NA
Dibenzo(a,h)pyrene	(mg/kg)	NA	NA	NA	NA	NA	NA	NA	NA
Dibenzo(a,i)pyrene	(mg/kg)	NA	NA	NA	NA	NA	NA	NA	NA
Dibenzo(a,l)pyrene	(mg/kg)	NA	NA	NA	NA	NA	NA	NA	NA
Dibenz(a,j)acridine	(mg/kg)	NA	NA	NA	NA	NA	NA	NA	NA
Total PAHs	(mg/kg)	0.4961	7.67	214.218	147.906	0.2174	412.9	0.982	1721.4
Total PAHs	%	0.00004961	0.000767	0.0214218	0.0147906	0.00002174	0.04129	0.0000982	0.17214

NOTES:
NA - Not Analyzed
For RCL DRF-REQ

Table 1 PAH Concentrations in Soil—Gas Works Park (Continued)

Constituent	Site: Sample ID: Date: Depth (ft): Result Type:	EPA19 197 4/19/84 3 Primary	EPA2 156 4/17/84 0.5 Primary	EPA2 180 4/17/84 3 Primary	EPA20 174 4/19/84 0.5 Primary	EPA20 198 4/19/84 3 Primary	EPA21 175 4/19/84 0.5 Primary	EPA21 199 4/19/84 3 Primary	EPA22 176 4/19/84 0.5 Primary
Starting Depth	(feet)	2.75	0	2.75	0	2.75	0	2.75	0
Ending Depth	(feet)	3.25	0.5	3.25	0.5	3.25	0.5	3.25	0.5
Acenaphthene	(mg/kg)	0.0014	1	0.364	0.97	0.021	1.8	0.023	0.55
Acenaphthylene	(mg/kg)	0.0108	0.73	0.014	0.87	0.021	83	0.015	3.5
Fluorene	(mg/kg)	0.0036	1.2	0.0357	1.6	0.021	11	0.023	1.6
Anthracene	(mg/kg)	0.0108	7.8	0.176	3.5	0.021	17	0.023	6.9
Fluoranthene	(mg/kg)	0.29	15	0.506	18	0.054	400	0.045	26
Phenanthrene	(mg/kg)	0.112	29	0.0357	38	0.056	620	0.057	45
Benzo(a)anthracene	(mg/kg)	0.172	18	0.1	9	0.023	61	0.013	17
Benzo(b)fluoranthene	(mg/kg)	0.186	11	0.0714	8.1	0.029	150	0.046	20
Benzo(k)fluoranthene	(mg/kg)	0.048	NA	0.0714	NA	0.042	NA	0.046	NA
Pyrene	(mg/kg)	0.399	35	0.617	30	0.07	460	0.081	56
Chrysene	(mg/kg)	0.217	13	0.069	16	0.021	96	0.0116	26
Benzo(a)pyrene	(mg/kg)	0.127	16	0.0714	20	0.042	150	0.046	46
Dibenzo(a,h)anthracene	(mg/kg)	0.048	22	0.0714	8.8	0.042	12	0.046	16
Indeno(1,2,3-c,d)pyrene	(mg/kg)	0.048	43	0.0714	13	0.042	88	0.046	47
Benzo(g,h,i)perylene	(mg/kg)	0.022	1.6	0.0714	27	0.042	150	0.046	65
Dibenzo(a,e)pyrene	(mg/kg)	NA	NA	NA	NA	NA	NA	NA	NA
Dibenzo(a,h)pyrene	(mg/kg)	NA	NA	NA	NA	NA	NA	NA	NA
Dibenzo(a,i)pyrene	(mg/kg)	NA	NA	NA	NA	NA	NA	NA	NA
Dibenzo(a,l)pyrene	(mg/kg)	NA	NA	NA	NA	NA	NA	NA	NA
Dibenz(a,j)acridine	(mg/kg)	NA	NA	NA	NA	NA	NA	NA	NA
Total PAHs	(mg/kg)	1.6956	214.33	2.3458	194.84	0.547	2299.8	0.5676	376.55
Total PAHs	%	0.00016956	0.021433	0.00023458	0.019484	0.0000547	0.22998	0.00005676	0.037655

NOTES:
NA - Not Analyzed
For RCL DRF-REQ

Table 1 PAH Concentrations in Soil—Gas Works Park (Continued)

Constituent	Site: Sample ID: Date: Depth (ft): Result Type:	EPA22 200 4/19/84 3 Primary	EPA23 177 4/19/84 0.5 Primary	EPA23 201 4/19/84 3 Primary	EPA24 178 4/19/84 0.5 Primary	EPA24 202 4/19/84 3 Primary	EPA3 157 4/17/84 0.5 Primary	EPA3 181 4/17/84 3 Primary	EPA4 158 4/17/84 0.5 Primary	EPA4 182 4/17/84 3 Primary
Starting Depth	(feet)	2.75	0	2.75	0	2.75	0	2.75	0	2.75
Ending Depth	(feet)	3.25	0.5	3.25	0.5	3.25	0.5	3.25	0.5	3.25
Acenaphthene	(mg/kg)	0.024	0.2	1.026	0.6	0.488	0.3	0.952	1.3	0.93
Acenaphthylene	(mg/kg)	0.065	0.77	1.077	2.1	0.415	0.14	0.413	2.8	2.465
Fluorene	(mg/kg)	0.013	0.21	0.244	0.97	0.088	0.21	0.952	4.1	0.419
Anthracene	(mg/kg)	0.024	1.4	1.026	1	0.488	0.44	0.952	12	0.93
Fluoranthene	(mg/kg)	0.108	16	21.59	12	11.158	3.5	4.136	66	5.07
Phenanthrene	(mg/kg)	0.171	14	6.821	11	2.341	4.9	0.964	160	5.349
Benzo(a)anthracene	(mg/kg)	0.045	3.7	17.897	5.2	6.098	4.7	1.517	44	1.302
Benzo(b)fluoranthene	(mg/kg)	0.041	17	8.667	16	3.195	4	5.561	55	1.86
Benzo(k)fluoranthene	(mg/kg)	0.047	NA	46.872	NA	9.463	NA	1.905	NA	1.86
Pyrene	(mg/kg)	0.149	39	29.077	19	15.268	9	7.354	180	7.256
Chrysene	(mg/kg)	0.034	16	38.41	6	13.17	3.5	1.562	72	1.349
Benzo(a)pyrene	(mg/kg)	0.047	30	61.436	10	16.927	5.1	1.905	130	1.86
Dibenzo(a,h)anthracene	(mg/kg)	0.047	20	2.051	12	0.976	2.2	1.905	60	1.86
Indeno(1,2,3-c,d)pyrene	(mg/kg)	0.047	47	37.692	6.6	0.976	9.6	1.905	100	1.86
Benzo(g,h,i)perylene	(mg/kg)	0.047	61	2.051	8.2	0.976	18	1.905	170	1.86
Dibenzo(a,e)pyrene	(mg/kg)	NA	NA	NA	NA	NA	NA	NA	NA	NA
Dibenzo(a,h)pyrene	(mg/kg)	NA	NA	NA	NA	NA	NA	NA	NA	NA
Dibenzo(a,i)pyrene	(mg/kg)	NA	NA	NA	NA	NA	NA	NA	NA	NA
Dibenzo(a,l)pyrene	(mg/kg)	NA	NA	NA	NA	NA	NA	NA	NA	NA
Dibenz(a,j)acridine	(mg/kg)	NA	NA	NA	NA	NA	NA	NA	NA	NA
Total PAHs	(mg/kg)	0.909	266.28	275.937	110.67	82.027	65.59	33.888	1057.2	36.23
Total PAHs	%	0.0000909	0.026628	0.0275937	0.011067	0.0082027	0.006559	0.0033888	0.10572	0.003623

NOTES:
NA - Not Analyzed
For RCL DRF-REQ

Table 1 PAH Concentrations in Soil—Gas Works Park (Continued)

Constituent	Site: Sample ID: Date: Depth (ft): Result Type:	EPA5 159 4/17/84 0.5 Primary	EPA5 183 4/17/84 3 Primary	EPA6 160 4/17/84 0.5 Primary	EPA6 184 4/17/84 3 Primary	EPA7 161 4/17/84 0.5 Primary	EPA7 185 4/17/84 3 Primary	EPA8 162 4/17/84 0.5 Primary	EPA8 186 4/17/84 3 Primary	EPA9 163 4/17/84 0.5 Primary
Starting Depth	(feet)	0	2.75	0	2.75	0	2.75	0	2.75	0
Ending Depth	(feet)	0.5	3.25	0.5	3.25	0.5	3.25	0.5	3.25	0.5
Acenaphthene	(mg/kg)	0.23	0.909	0.6	0.454	0.65	0.023	0.8	0.92	0.1
Acenaphthylene	(mg/kg)	1.1	1.66	1	2.851	5.7	0.008	10	6.069	0.44
Fluorene	(mg/kg)	0.17	0.244	0.6	0.17	0.67	0.023	3.5	0.506	0.15
Anthracene	(mg/kg)	1.8	0.909	0.65	0.454	11	0.023	4.9	0.92	0.84
Fluoranthene	(mg/kg)	8.3	5.509	8.7	14.386	75	0.076	35	6.759	6.9
Phenanthrene	(mg/kg)	9.2	3.295	3.2	2.916	43	0.0425	34	5.655	7.5
Benzo(a)anthracene	(mg/kg)	9.7	3.561	5.6	9.348	51	0.0184	25	1.793	4.4
Benzo(b)fluoranthene	(mg/kg)	20	2.841	14	0.909	83	0.023	41	1.333	7.3
Benzo(k)fluoranthene	(mg/kg)	NA	1.818	NA	0.909	NA	0.046	NA	1.839	NA
Pyrene	(mg/kg)	27	8.523	13	22.041	190	0.13	68	9.609	20
Chrysene	(mg/kg)	18	5.637	7.5	15.909	110	0.015	28	2.667	9
Benzo(a)pyrene	(mg/kg)	43	5.04	17	1.267	180	0.046	36	1.761	15
Dibenzo(a,h)anthracene	(mg/kg)	28	1.818	6	0.909	110	0.046	86	1.839	1.2
Indeno(1,2,3-c,d)pyrene	(mg/kg)	46	1.818	16	0.909	430	0.046	34	1.839	24
Benzo(g,h,i)perylene	(mg/kg)	84	1.818	20	0.909	520	0.046	61	1.839	30
Dibenzo(a,e)pyrene	(mg/kg)	NA	NA	NA	NA	NA	NA	NA	NA	NA
Dibenzo(a,h)pyrene	(mg/kg)	NA	NA	NA	NA	NA	NA	NA	NA	NA
Dibenzo(a,i)pyrene	(mg/kg)	NA	NA	NA	NA	NA	NA	NA	NA	NA
Dibenzo(a,l)pyrene	(mg/kg)	NA	NA	NA	NA	NA	NA	NA	NA	NA
Dibenz(a,j)acridine	(mg/kg)	NA	NA	NA	NA	NA	NA	NA	NA	NA
Total PAHs	(mg/kg)	296.5	45.4	113.85	74.341	1810.02	0.6119	467.2	45.348	126.83
Total PAHs	%	0.02965	0.00454	0.011385	0.0074341	0.181002	0.00006119	0.04672	0.0045348	0.012683

NOTES:
NA - Not Analyzed
For RCL DRF-REQ

Table 1 PAH Concentrations in Soil—Gas Works Park (Continued)

Constituent	Site: Sample ID: Date: Depth (ft): Result Type:	EPA9 187 4/17/84 3 Primary	F10 53 3/15/85 0.16 Primary	F16 54 3/15/85 0.16 Primary	F24 55 3/15/85 0.16 Primary	G19 56 3/15/85 0.16 Primary	G27 57 3/15/85 0.16 Primary	H10 58 3/15/85 0.16 Primary	H22 59 3/15/85 0.16 Primary	H32 60 3/15/85 0.16 Primary
Starting Depth	(feet)	2.75	0	0	0	0	0	0	0	0
Ending Depth	(feet)	3.25	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16
Acenaphthene	(mg/kg)	1.039	2	20	20	2	2	20	2	2
Acenaphthylene	(mg/kg)	2.961	1	1	10	1	1	10	1	1
Fluorene	(mg/kg)	0.571	0.34	1.9	2	0.2	1.3	4.6	0.47	0.2
Anthracene	(mg/kg)	1.039	0.072	0.28	0.91	0.02	0.19	2.2	0.14	0.074
Fluoranthene	(mg/kg)	6.442	1.2	4.7	7.9	0.53	1.8	22	1.6	1.1
Phenanthrene	(mg/kg)	7.688	0.56	1.8	5.2	0.16	1.2	12	0.92	0.7
Benzo(a)anthracene	(mg/kg)	1.61	0.66	2	4.8	0.25	1.1	12	1.2	0.57
Benzo(b)fluoranthene	(mg/kg)	0.779	0.88	2.3	4.5	0.34	1.3	11	1.5	0.53
Benzo(k)fluoranthene	(mg/kg)	2.078	0.38	1	1.8	0.14	0.57	4.5	0.57	0.23
Pyrene	(mg/kg)	8.468	2.2	7.8	15	0.84	3.2	38	3.3	1.9
Chrysene	(mg/kg)	2.286	0.87	2.6	5.9	0.37	1.2	15	1.5	0.79
Benzo(a)pyrene	(mg/kg)	1.234	1.1	2.9	6.2	0.33	1.3	13	1.9	0.59
Dibenzo(a,h)anthracene	(mg/kg)	2.078	0.4	0.48	4	0.4	0.4	4	0.4	0.4
Indeno(1,2,3-c,d)pyrene	(mg/kg)	2.078	1.4	2.6	8	0.43	1.3	14	2.8	1.2
Benzo(g,h,i)perylene	(mg/kg)	2.078	1.9	3.2	10	0.54	2.4	14	2.9	0.91
Dibenzo(a,e)pyrene	(mg/kg)	NA	NA	NA	NA	NA	NA	NA	NA	NA
Dibenzo(a,h)pyrene	(mg/kg)	NA	NA	NA	NA	NA	NA	NA	NA	NA
Dibenzo(a,i)pyrene	(mg/kg)	NA	NA	NA	NA	NA	NA	NA	NA	NA
Dibenzo(a,l)pyrene	(mg/kg)	NA	NA	NA	NA	NA	NA	NA	NA	NA
Dibenz(a,j)acridine	(mg/kg)	NA	NA	NA	NA	NA	NA	NA	NA	NA
Total PAHs	(mg/kg)	42.429	14.962	54.56	106.21	7.55	20.26	196.3	22.2	12.194
Total PAHs	%	0.0042429	0.0014962	0.005456	0.010621	0.000755	0.002026	0.01963	0.00222	0.0012194

NOTES:
NA - Not Analyzed
For RCL DRF-REQ

Table 1 PAH Concentrations in Soil—Gas Works Park (Continued)

Constituent	Site: Sample ID: Date: Depth (ft): Result Type:	I13 61 3/15/85 0.16 Primary	I21 62 3/15/85 0.16 Primary	I29 63 3/15/85 0.16 Primary	J14 64 3/15/85 0.16 Primary	J32 65 3/15/85 0.16 Primary	K17 66 3/15/85 0.16 Primary	K33 67 3/15/85 0.16 Primary	L12 68 3/15/85 0.16 Primary	L20 69 3/15/85 0.16 Primary
Starting Depth	(feet)	0	0	0	0	0	0	0	0	0
Ending Depth	(feet)	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16
Acenaphthene	(mg/kg)	20	20	20	20	20	20	20	20	20
Acenaphthylene	(mg/kg)	10	10	10	10	10	10	10	10	10
Fluorene	(mg/kg)	2	2.9	4.4	4.7	2	2	2	2	20
Anthracene	(mg/kg)	0.81	2.1	3.9	3.4	2.7	0.3	0.2	1.9	10
Fluoranthene	(mg/kg)	10	19	44	27	42	4.4	4.6	2	65
Phenanthrene	(mg/kg)	4.1	14	35	21	9.7	3.2	2.5	11	79
Benzo(a)anthracene	(mg/kg)	5.4	12	19	15	13	1.2	2.7	11	27
Benzo(b)fluoranthene	(mg/kg)	6.4	11	15	12	12	2	3.2	11	17
Benzo(k)fluoranthene	(mg/kg)	2.6	5	6.9	5.3	5.7	0.8	1.2	4.4	8
Pyrene	(mg/kg)	16	34	63	47	56	6.8	6.7	36	100
Chrysene	(mg/kg)	7.1	15	22	17	16	2.8	3.3	14	29
Benzo(a)pyrene	(mg/kg)	7.1	15	19	16	14	2.4	3.3	13	23
Dibenzo(a,h)anthracene	(mg/kg)	4	4	4	4	4	4	4	4	4
Indeno(1,2,3-c,d)pyrene	(mg/kg)	9.1	15	18	15	14	3.4	4.8	16	20
Benzo(g,h,i)perylene	(mg/kg)	9.4	21	24	20	7.3	3.6	4.9	16	18
Dibenzo(a,e)pyrene	(mg/kg)	NA	NA	NA	NA	NA	NA	NA	NA	NA
Dibenzo(a,h)pyrene	(mg/kg)	NA	NA	NA	NA	NA	NA	NA	NA	NA
Dibenzo(a,i)pyrene	(mg/kg)	NA	NA	NA	NA	NA	NA	NA	NA	NA
Dibenzo(a,l)pyrene	(mg/kg)	NA	NA	NA	NA	NA	NA	NA	NA	NA
Dibenz(a,j)acridine	(mg/kg)	NA	NA	NA	NA	NA	NA	NA	NA	NA
Total PAHs	(mg/kg)	114.01	200	308.2	237.4	228.4	66.9	73.4	172.3	450
Total PAHs	%	0.011401	0.02	0.03082	0.02374	0.02284	0.00669	0.00734	0.01723	0.045

NOTES:
NA - Not Analyzed
For RCL DRF-REQ

Table 1 PAH Concentrations in Soil—Gas Works Park (Continued)

Constituent	Site: Sample ID: Date: Depth (ft): Result Type:	L28 70 3/15/85 0.16 Primary	M10 71 3/15/85 0.16 Primary	M17 72 3/15/85 0.16 Primary	M31 73 3/15/85 0.16 Primary	MW1 116 2/11/87 58 Primary	MW10 123 2/11/87 3.4 Primary	MW12 124 2/11/87 3.3 Primary	MW14 125 2/11/87 6 Primary	MW3 117 2/11/87 4.3 Primary
Starting Depth	(feet)	0	0	0	0	57.5	3	3	5.5	4
Ending Depth	(feet)	0.16	0.16	0.16	0.16	58.5	3.5	3.5	6.5	4.5
Acenaphthene	(mg/kg)	20	20	20	20	0.37	0.33	1.1	1.9	0.73
Acenaphthylene	(mg/kg)	1	10	10	1	0.37	0.33	1.4	0.065	0.73
Fluorene	(mg/kg)	2.2	2	2	1.6	0.37	0.33	6.4	0.34	0.73
Anthracene	(mg/kg)	0.21	2.8	1.6	0.36	0.37	0.33	3.4	0.28	0.73
Fluoranthene	(mg/kg)	1.9	57	24	6.8	0.37	0.054	13	0.74	0.73
Phenanthrene	(mg/kg)	1.2	14	9.4	2.2	0.37	0.053	23	0.23	0.73
Benzo(a)anthracene	(mg/kg)	1.1	32	12	3.5	0.37	0.33	5.8	0.037	0.73
Benzo(b)fluoranthene	(mg/kg)	1.3	28	13	3.7	0.37	0.04	10	0.037	0.73
Benzo(k)fluoranthene	(mg/kg)	0.59	13	5.4	1.7	0.37	0.04	10	0.037	0.73
Pyrene	(mg/kg)	3.2	100	41	11	0.37	0.11	20	1.1	0.73
Chrysene	(mg/kg)	1.5	27	16	4.2	0.37	0.033	8	0.051	0.73
Benzo(a)pyrene	(mg/kg)	1.6	35	16	4.7	0.37	0.33	5.3	0.37	0.73
Dibenzo(a,h)anthracene	(mg/kg)	0.4	4	4	3.1	0.37	0.33	1.5	0.37	0.73
Indeno(1,2,3-c,d)pyrene	(mg/kg)	1.9	29	19	5.3	0.37	0.33	5.5	0.37	0.73
Benzo(g,h,i)perylene	(mg/kg)	2.6	27	24	5.6	0.37	0.33	5.6	0.37	0.73
Dibenzo(a,e)pyrene	(mg/kg)	NA	NA	NA	NA	NA	NA	NA	NA	NA
Dibenzo(a,h)pyrene	(mg/kg)	NA	NA	NA	NA	NA	NA	NA	NA	NA
Dibenzo(a,i)pyrene	(mg/kg)	NA	NA	NA	NA	NA	NA	NA	NA	NA
Dibenzo(a,l)pyrene	(mg/kg)	NA	NA	NA	NA	NA	NA	NA	NA	NA
Dibenz(a,j)acridine	(mg/kg)	NA	NA	NA	NA	NA	NA	NA	NA	NA
Total PAHs	(mg/kg)	40.7	400.8	217.4	74.76	5.55	3.3	120	6.297	10.95
Total PAHs	%	0.00407	0.04008	0.02174	0.007476	0.000555	0.00033	0.012	0.0006297	0.001095

NOTES:
NA - Not Analyzed
For RCL DRF-REQ

Table 1 PAH Concentrations in Soil—Gas Works Park (Continued)

Constituent	Site: / Sample ID: / Date: / Depth (ft): / Result Type:	MW4 / 118 / 2/11/87 / 3.7 / Primary	MW6 / 119 / 2/11/87 / 5.8 / Primary	MW7 / 126 / 2/11/87 / 8 / Primary	MW9 / 121 / 2/11/87 / 2.5 / Primary	MW9 / 122 / 2/11/87 / 5.7 / Primary	N18 / 74 / 3/15/85 / 0.16 / Primary	N26 / 75 / 3/15/85 / 0.16 / Primary	P19 / 76 / 3/15/85 / 0.16 / Primary	S-1 / S-1 / 10/23/97 / 0 / Primary
Starting Depth	(feet)	3.5	5.5	7.5	2.25	5.5	0	0	0	0
Ending Depth	(feet)	4	6	8.5	2.75	6	0.16	0.16	0.16	0
Acenaphthene	(mg/kg)	1.1	1.8	0.46	0.33	0.22	20	20	20	<0.2
Acenaphthylene	(mg/kg)	1.6	1.9	0.46	3	0.5	10	10	10	1.97
Fluorene	(mg/kg)	6.5	2.1	0.46	1.3	0.39	2	2	2	0.365
Anthracene	(mg/kg)	1	3.1	0.46	2.4	0.54	0.21	2.8	2.6	1.66
Fluoranthene	(mg/kg)	11	26	0.46	26	4.3	2.8	19	36	13.5
Phenanthrene	(mg/kg)	19	18	0.46	26	3.3	1.5	5.4	15	5.16
Benzo(a)anthracene	(mg/kg)	6.6	8.5	0.46	8.6	3.4	1.4	5.8	11	8.13
Benzo(b)fluoranthene	(mg/kg)	11	16	0.46	19	4.1	2	4.9	12	12.7
Benzo(k)fluoranthene	(mg/kg)	11	16	0.46	19	4.1	0.79	2.1	5.5	3.55
Pyrene	(mg/kg)	19	33	0.46	43	5.9	4.5	26	48	29.8
Chrysene	(mg/kg)	6.2	9.4	0.46	12	2.5	1.8	7.8	14	9.15
Benzo(a)pyrene	(mg/kg)	5.5	13	0.46	15	2.9	1.9	4.2	16	11
Dibenzo(a,h)anthracene	(mg/kg)	1.6	1.8	0.46	2	0.57	4	4	4	1.64
Indeno(1,2,3-c,d)pyrene	(mg/kg)	5.3	12	0.46	13	1.8	3.5	8.4	14	11.3
Benzo(g,h,i)perylene	(mg/kg)	6.1	14	0.46	16	1.9	4.4	10	15	13.4
Dibenzo(a,e)pyrene	(mg/kg)	NA	NA	NA	NA	NA	NA	NA	NA	NA
Dibenzo(a,h)pyrene	(mg/kg)	NA	NA	NA	NA	NA	NA	NA	NA	NA
Dibenzo(a,i)pyrene	(mg/kg)	NA	NA	NA	NA	NA	NA	NA	NA	NA
Dibenzo(a,l)pyrene	(mg/kg)	NA	NA	NA	NA	NA	NA	NA	NA	NA
Dibenz(a,j)acridine	(mg/kg)	NA	NA	NA	NA	NA	NA	NA	NA	NA
Total PAHs	(mg/kg)	112.5	176.6	6.9	206.63	36.42	60.8	132.4	225.1	123.325
Total PAHs	%	0.01125	0.01766	0.00069	0.020663	0.003642	0.00608	0.01324	0.02251	0.0123325

NOTES:
NA - Not Analyzed
For RCL DRF-REQ

Table 1 PAH Concentrations in Soil—Gas Works Park (Continued)

Constituent	Site:	S-10	S-2	S-3	S-4	S-5	S-6	S-7	S-8
	Sample ID:	S-10	S-2	S-3	S-4	S-5	S-6	S-7	S-8
	Date:	10/23/97	10/23/97	10/23/97	10/23/97	10/23/97	10/23/97	10/23/97	10/23/97
	Depth (ft):	0	0	0	0	0	0	0	0
	Result Type:	Primary	Primary	Primary	Primary	Primary	Primary	Primary	Primary
Starting Depth	(feet)	0	0	0	0	0	0	0	0
Ending Depth	(feet)	0	0	0	0	0	0	0	0
Acenaphthene	(mg/kg)	<0.01	<0.2	<0.2	<0.1	<0.5	0.214	0.2	<0.1
Acenaphthylene	(mg/kg)	<0.01	2.74	1.43	0.739	9.46	4.2	4.67	1.02
Fluorene	(mg/kg)	<0.01	0.443	<0.2	0.134	1.98	1.01	0.704	<0.1
Anthracene	(mg/kg)	<0.01	1.76	0.869	0.627	7.11	2.18	2.75	0.566
Fluoranthene	(mg/kg)	0.0508	9.92	5.86	4.13	62.5	7.11	10.4	2.22
Phenanthrene	(mg/kg)	0.0538	6.83	1.91	2.07	37.3	6.29	8.52	0.871
Benzo(a)anthracene	(mg/kg)	0.0254	5.56	3.55	1.87	23.3	5.03	6.51	1.73
Benzo(b)fluoranthene	(mg/kg)	0.0308	9.42	6.18	3.18	35.4	7.45	11.4	3.89
Benzo(k)fluoranthene	(mg/kg)	0.01	2.77	2.14	0.97	12	2.32	3.69	1.11
Pyrene	(mg/kg)	0.0831	17.3	11.2	7.34	102	13.6	20.3	4.65
Chrysene	(mg/kg)	0.0315	7.61	4.36	2.2	27.7	5.93	7.59	2.32
Benzo(a)pyrene	(mg/kg)	0.0269	7.55	5.94	2.71	36	8.67	11.8	4.12
Dibenzo(a,h)anthracene	(mg/kg)	<0.01	1.45	1.11	0.522	5.57	1.58	2.27	0.729
Indeno(1,2,3-c,d)pyrene	(mg/kg)	0.0269	10.5	8.02	3.9	44.4	10.2	16.9	5.72
Benzo(g,h,i)perylene	(mg/kg)	0.0254	11.7	9.05	4.47	53.7	12	20.4	7.08
Dibenzo(a,e)pyrene	(mg/kg)	NA	NA	NA	NA	NA	NA	NA	NA
Dibenzo(a,h)pyrene	(mg/kg)	NA	NA	NA	NA	NA	NA	NA	NA
Dibenzo(a,i)pyrene	(mg/kg)	NA	NA	NA	NA	NA	NA	NA	NA
Dibenzo(a,l)pyrene	(mg/kg)	NA	NA	NA	NA	NA	NA	NA	NA
Dibenz(a,j)acridine	(mg/kg)	NA	NA	NA	NA	NA	NA	NA	NA
Total PAHs	(mg/kg)	0.3646	95.553	61.619	34.862	458.42	87.784	128.104	36.026
Total PAHs	%	0.00003646	0.0095553	0.0061619	0.0034862	0.045842	0.0087784	0.0128104	0.0036026

NOTES:
NA - Not Analyzed
For RCL DRF-REQ

Table 1 PAH Concentrations in Soil—Gas Works Park (Continued)

Constituent	Site: Sample ID: Date: Depth (ft): Result Type:	S-9 S-9 10/23/97 0 Primary	S-9 S-9 10/23/97 0 Duplicate 1	UW1 77 5/24/84 0.08 Primary	UW10 86 5/24/84 0.08 Primary	UW11 87 5/24/84 0.08 Primary	UW12 88 5/24/84 0.08 Primary	UW13 89 5/24/84 0.08 Primary	UW14 90 5/24/84 0.08 Primary	UW15 91 5/24/84 0.08 Primary
Starting Depth	(feet)	0	0	0	0	0	0	0	0	0
Ending Depth	(feet)	0	0	0.08	0.08	0.08	0.08	0.08	0.08	0.08
Acenaphthene	(mg/kg)	3.99	3.88	NA	0.99	NA	0.48	NA	NA	NA
Acenaphthylene	(mg/kg)	7.64	7.76	NA	19.6	NA	2.61	NA	NA	NA
Fluorene	(mg/kg)	7.48	7.87	NA	7.36	NA	0.94	NA	NA	NA
Anthracene	(mg/kg)	10.5	12.1	NA	5.72	NA	1.68	NA	NA	NA
Fluoranthene	(mg/kg)	43.1	48.9	NA	93.1	NA	9.53	NA	NA	NA
Phenanthrene	(mg/kg)	40.5	47.6	NA	79.2	NA	14.8	NA	NA	NA
Benzo(a)anthracene	(mg/kg)	19.3	18.2	NA	51.3	NA	4.84	NA	NA	NA
Benzo(b)fluoranthene	(mg/kg)	29.1	29.6	NA	44.6	NA	6.19	NA	NA	NA
Benzo(k)fluoranthene	(mg/kg)	8.71	9.18	NA	NA	NA	NA	NA	NA	NA
Pyrene	(mg/kg)	74.4	81.2	NA	98.4	NA	17.8	NA	NA	NA
Chrysene	(mg/kg)	22.4	23	NA	59.4	NA	6.21	NA	NA	NA
Benzo(a)pyrene	(mg/kg)	30.9	31.6	0.94	NA	0.034	NA	1.04	0.52	1.64
Dibenzo(a,h)anthracene	(mg/kg)	4.67	5.26	NA	36.7	NA	7.75	NA	NA	NA
Indeno(1,2,3-c,d)pyrene	(mg/kg)	32.8	36.7	NA	31.8	NA	2.82	NA	NA	NA
Benzo(g,h,i)perylene	(mg/kg)	39	42.9	NA	31.5	NA	10	NA	NA	NA
Dibenzo(a,e)pyrene	(mg/kg)	NA	NA	NA	NA	NA	NA	NA	NA	NA
Dibenzo(a,h)pyrene	(mg/kg)	NA	NA	NA	NA	NA	NA	NA	NA	NA
Dibenzo(a,i)pyrene	(mg/kg)	NA	NA	NA	NA	NA	NA	NA	NA	NA
Dibenzo(a,l)pyrene	(mg/kg)	NA	NA	NA	NA	NA	NA	NA	NA	NA
Dibenz(a,j)acridine	(mg/kg)	NA	NA	NA	NA	NA	NA	NA	NA	NA
Total PAHs	(mg/kg)	374.49	405.75	0.94	559.67	0.034	85.65	1.04	0.52	1.64
Total PAHs	%	0.037449	0.040575	0.000094	0.055967	0.0000034	0.008565	0.000104	0.000052	0.000164

NOTES:
NA - Not Analyzed
For RCL DRF-REQ

Table 1 PAH Concentrations in Soil—Gas Works Park (Continued)

Constituent	Site: Sample ID: Date: Depth (ft): Result Type:	UW16 92 5/24/84 0.08 Primary	UW17 93 5/24/84 0.08 Primary	UW18 94 5/24/84 0.08 Primary	UW19 95 5/24/84 0.08 Primary	UW2 78 5/24/84 0.08 Primary	UW20 96 5/24/84 0.08 Primary	UW21 97 5/24/84 0.08 Primary	UW22 98 5/24/84 0.08 Primary	UW24 99 5/24/84 0.08 Primary
Starting Depth	(feet)	0	0	0	0	0	0	0	0	0
Ending Depth	(feet)	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08
Acenaphthene	(mg/kg)	NA	NA	NA	NA	NA	NA	0.1	NA	NA
Acenaphthylene	(mg/kg)	NA	NA	NA	NA	NA	NA	3.79	NA	NA
Fluorene	(mg/kg)	NA	NA	NA	NA	NA	NA	0.26	NA	NA
Anthracene	(mg/kg)	NA	NA	NA	NA	NA	NA	0.8	NA	NA
Fluoranthene	(mg/kg)	NA	NA	NA	NA	NA	NA	14.9	NA	NA
Phenanthrene	(mg/kg)	NA	NA	NA	NA	NA	NA	8.46	NA	NA
Benzo(a)anthracene	(mg/kg)	NA	NA	NA	NA	NA	NA	9.98	NA	NA
Benzo(b)fluoranthene	(mg/kg)	NA	NA	NA	NA	NA	NA	11.9	NA	NA
Benzo(k)fluoranthene	(mg/kg)	NA	NA	NA	NA	NA	NA	NA	NA	NA
Pyrene	(mg/kg)	NA	NA	NA	NA	NA	NA	24.3	NA	NA
Chrysene	(mg/kg)	NA	NA	NA	NA	NA	NA	10.6	NA	NA
Benzo(a)pyrene	(mg/kg)	2.79	7.86	5.68	22.2	0.99	22.2	NA	11.8	14.8
Dibenzo(a,h)anthracene	(mg/kg)	NA	NA	NA	NA	NA	NA	13.6	NA	NA
Indeno(1,2,3-c,d)pyrene	(mg/kg)	NA	NA	NA	NA	NA	NA	3.1	NA	NA
Benzo(g,h,i)perylene	(mg/kg)	NA	NA	NA	NA	NA	NA	17.5	NA	NA
Dibenzo(a,e)pyrene	(mg/kg)	NA	NA	NA	NA	NA	NA	NA	NA	NA
Dibenzo(a,h)pyrene	(mg/kg)	NA	NA	NA	NA	NA	NA	NA	NA	NA
Dibenzo(a,i)pyrene	(mg/kg)	NA	NA	NA	NA	NA	NA	NA	NA	NA
Dibenzo(a,l)pyrene	(mg/kg)	NA	NA	NA	NA	NA	NA	NA	NA	NA
Dibenz(a,j)acridine	(mg/kg)	NA	NA	NA	NA	NA	NA	NA	NA	NA
Total PAHs	(mg/kg)	2.79	7.86	5.68	22.2	0.99	22.2	119.29	11.8	14.8
Total PAHs	%	0.000279	0.000786	0.000568	0.00222	0.000099	0.00222	0.011929	0.00118	0.00148

NOTES:
NA - Not Analyzed
For RCL DRF-REQ

Table 1 PAH Concentrations in Soil—Gas Works Park (Continued)

Constituent	Site:	UW3	UW4	UW5	UW6	UW7	UW8	UW9
	Sample ID:	79	80	81	82	83	84	85
	Date:	5/24/84	5/24/84	5/24/84	5/24/84	5/24/84	5/24/84	5/24/84
	Depth (ft):	0.08	0.08	0.08	0.08	0.08	0.08	0.08
	Result Type:	Primary	Primary	Primary	Primary	Primary	Primary	Primary
Starting Depth	(feet)	0	0	0	0	0	0	0
Ending Depth	(feet)	0.08	0.08	0.08	0.08	0.08	0.08	0.08
Acenaphthene	(mg/kg)	NA	NA	NA	0.79	NA	NA	0.58
Acenaphthylene	(mg/kg)	NA	NA	NA	4.66	NA	NA	5.77
Fluorene	(mg/kg)	NA	NA	NA	1.09	NA	NA	1.28
Anthracene	(mg/kg)	NA	NA	NA	1.94	NA	NA	2.5
Fluoranthene	(mg/kg)	NA	NA	NA	8.4	NA	NA	34.8
Phenanthrene	(mg/kg)	NA	NA	NA	11	NA	NA	23.7
Benzo(a)anthracene	(mg/kg)	NA	NA	NA	8	NA	NA	17.6
Benzo(b)fluoranthene	(mg/kg)	NA	NA	NA	11.8	NA	NA	23.2
Benzo(k)fluoranthene	(mg/kg)	NA	NA	NA	NA	NA	NA	NA
Pyrene	(mg/kg)	NA	NA	NA	14.2	NA	NA	51.6
Chrysene	(mg/kg)	NA	NA	NA	10	NA	NA	28
Benzo(a)pyrene	(mg/kg)	5.23	1.48	18.4	NA	3.22	5.53	NA
Dibenzo(a,h)anthracene	(mg/kg)	NA	NA	NA	11.1	NA	NA	18.6
Indeno(1,2,3-c,d)pyrene	(mg/kg)	NA	NA	NA	3.1	NA	NA	4.12
Benzo(g,h,i)perylene	(mg/kg)	NA	NA	NA	14	NA	NA	17.5
Dibenzo(a,e)pyrene	(mg/kg)	NA	NA	NA	NA	NA	NA	NA
Dibenzo(a,h)pyrene	(mg/kg)	NA	NA	NA	NA	NA	NA	NA
Dibenzo(a,i)pyrene	(mg/kg)	NA	NA	NA	NA	NA	NA	NA
Dibenzo(a,l)pyrene	(mg/kg)	NA	NA	NA	NA	NA	NA	NA
Dibenz(a,j)acridine	(mg/kg)	NA	NA	NA	NA	NA	NA	NA
Total PAHs	(mg/kg)	5.23	1.48	18.4	100.08	3.22	5.53	229.25
Total PAHs	%	0.000523	0.000148	0.00184	0.010008	0.000322	0.000553	0.022925

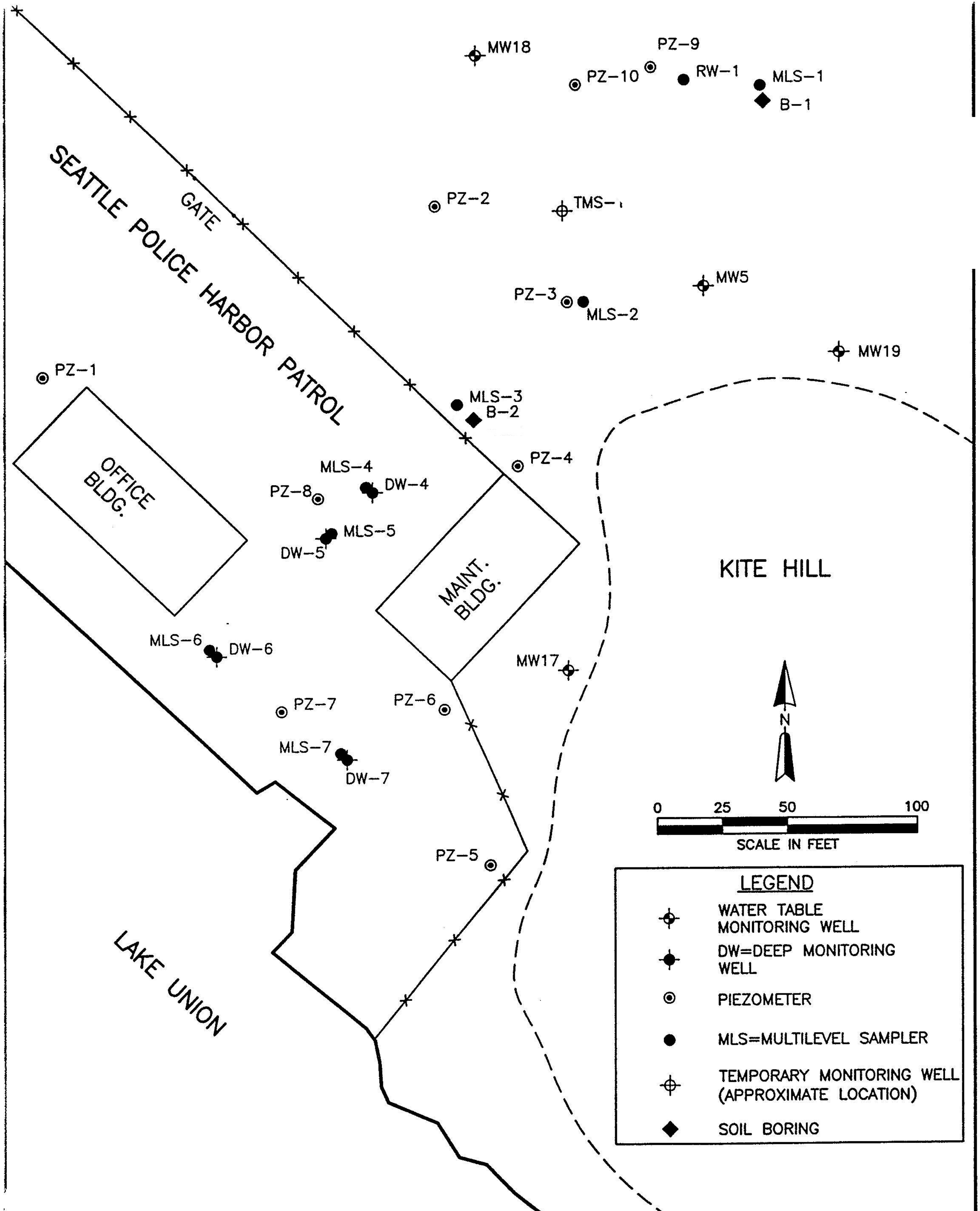
NOTES:
NA - Not Analyzed
For RCL DRF-REQ

Table 3-8 Soil and Aqueous-Phase PAH Concentrations

Location: Depth (ft): Laboratory ID:	B-2 16.5 GW3	DW-5 7 GW5	DW-5 27.5 GW4	DW-7 15 GW6	MW-22 3 GW2	MW-23 3 GW1
Soil Concentrations (mg/kg)						
Naphthalene	6,695	968	1,306	316	164	57
2-Naphthalene	2,896	314	567	160	9	13
1-Naphthalene	1,722	220	327	103	5	7
Acenaphthalene	436	58	105	11	21	28
Acenaphthlene	447	115	76	71	1	5
Fluorene	570	148	122	31	9	13
Phenanthrene	1,550	506	331	90	197	183
Anthracene	409	152	87	23	30	52
Fluoranthene	516	200	112	33	353	577
Pyrene	612	234	133	40	477	773
benz(a)anthracene	194	74	43	13	105	236
Chrysene	175	68	37	10	119	211
Benzo(a)pyrene	146	65	34	8	191	289
Sum	16,369	3,121	3,281	908	1,681	2,445
Aqueous-phase Concentrations (μg/kg)						
Naphthalene	19,809	6,515	13,853	110	1,000	6
2-Naphthalene	2,229	761	1,629	55	10	0.26
1-Naphthalene	1,442	560	1,159	156	10	7
Acenaphthalene	256	81	270	20	15	14
Acenaphthlene	151	170	155	246	3	7
Fluorene	108	109	118	76	5	8
Phenanthrene	102	122	119	120	65	33
Anthracene	24	11	3	21	5	6
Fluoranthene	5	7	7	12	12	21
Pyrene	0.3	7	0.05	11	18	23
benz(a)anthracene	0.1	0.02	0.3	0.4	0.6	0.6
Chrysene	0.03	0.05	0.2	0.1	0.4	0.2
Benzo(a)pyrene	0.01	0.03	0.1	0.04	0.04	0.1
Sum	24,126	8,343	17,314	828	1,144	126

NOTES:

Depths are in feet below ground surface.



RETEC REMEDIATION TECHNOLOGIES INC

GAS WORKS PARK 5-3434-300				WESTERN STUDY AREA MAP	
CURRENT DATE	7/2/98	CADD FILE	3434S035	DRAWING NO.	FIGURE 2-1

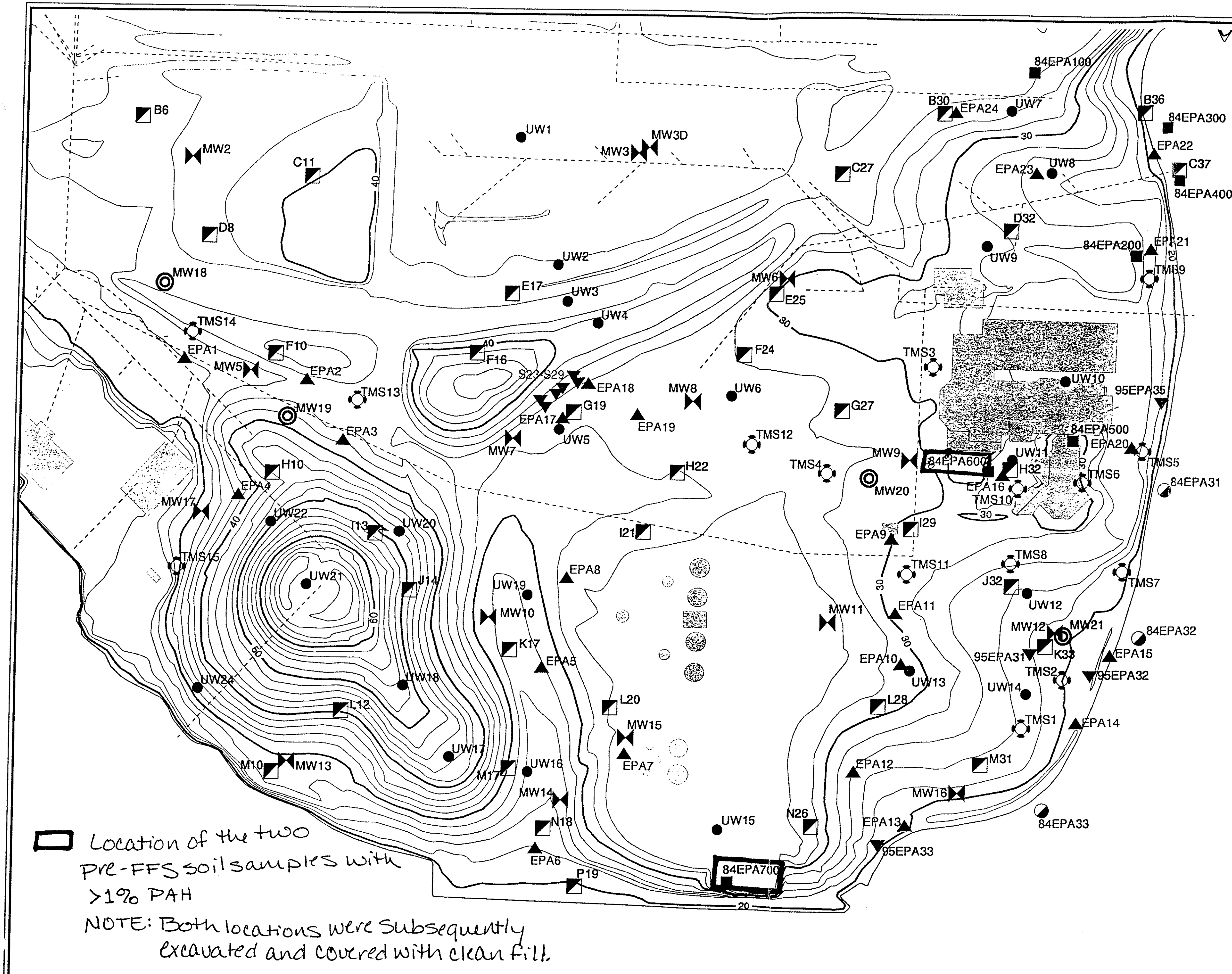


Figure 2-4
Site Map of Gas Works Park Showing Sampling Locations, 1984-1995

- Surface soil sample (EPA 1984)
- Surface soil and water sample (EPA 1984)
- 6 in. and 3 ft. soil sample (Ecology and Environment 1984)
- Surface soil sample (U. of Washington 1984)
- Surface soil sample (Tetra Tech 1985)
- Soil surface sample (HDR 1988)
- Soil and water sample (EPA 1995)
- Groundwater monitoring well (Tetra Tech 1987)
- Temporary groundwater monitoring well (HDR 1988)
- Groundwater monitoring well (HDR 1989)
- Contour interval (10 feet)
- Contour interval (2 feet)
- Sewer/drainage
- Shoreline
- Building

Feet
0 60 120 180

Vertical Datum = NAVD 1988

BASE DATA PROVIDED BY:

Table 13-5a. Life-cycle cost estimate for Alternative 5: excavation of all soils exceeding MTCA Method B Cleanup Lev to the MTCA point of complaince depth of 15 feet.

Item No.	Item Description		Quantity	Units	Unit Price	Extension
1	General Requirements	7%	1	LS	$1,127,600	$1,127,600
2	Mobilization	5%	1	LS	$1,739,500	$1,739,500
3	Demolition/Reconstruction of Play Barn		1	LS	$1,500,000	$1,500,000
4	Demolition of Cracking Towers		1	LS	$500,000	$500,000
5	Soils Excavation/Stockpile		384,780	CY	$20	$7,695,600
6	Soils Handling/Trans./Disp. (Non-DW)		543,411	TON	$45	$24,453,500
7	Soils Handling/Trans./Disp. (DW)		33,759	TON	$250	$8,439,800
8	Soils Handling/Trans./Disp. (EHW)		0	TON	$250	$0
9	Dewatering and Water Treatment		1	LS	$6,105,900	$6,105,900
10	Backfill Material and Placement		384,780	CY	$15.00	$5,771,700
11	Final Grading & Seed Prep.		15.9	AC	$1,000	$15,900
12	Irrigation System		15.9	AC	$30,500	$485,000
13	Hydroseed (seed/mulch/fert.)		15.9	AC	$2,500	$39,800
14	Surface Water Management		20.0	AC	$5,000	$100,000
	SUBTOTAL					**$57,974,300**
15	Contingency (on items 3 through 17)		15%			$8,266,100
16	Engineering (on items 3 through 16)		10%			$5,510,700
17	Construction Eng./Inspection (on items 3 through 16)		10%			$5,510,700
18	Construction Env. Monitoring (on items 3 through 16)		5%			$2,755,400
	TOTAL					**$80,017,200**

Budget Assumptions

General: ***Does not include park redevelopment. Construction estimates are based on complete installation by a private contractor.***

1 Contractor's administrative costs, overhead, and profit (% based on similar projects).
2 Contractor's mobilization and demobilization costs (% based on similar projects).
3 Includes replacement of all contents of the Play Barn and Playground.
4 Assumes structures can be sold as clean scrap and will not be replaced.
5 Soils removed to depth of 15 ft over the acerages shown in Table 13-5b.
6 Estimated cost for non-Dangerous Waste soils handling, transport, and disposal in an eastern WA or OR landfill (without treatment).
7 Estimated cost for Dangerous Waste soils handling, transport, and disposal in an eastern OR landfill (without treatment).
8 Estimated cost for Extremely Hazardous Waste soils handling, transport, and disposal in an eastern OR landfill (without treatment).
9 See Table 13-5c.
10 Locally available, clean, pit-run gravel. Top 1 ft capable of sustaining turf grass and small shrub vegetation.
11 Estimated unit cost for raking and non-amendment soil preparation.
12 Estimated area and unit cost based on Parks Department estimates.
13 Estimated unit cost based on similar Parks Department projects.
14 Estimated unit cost for ditches, bioswales, and control structures. Also includes erosion control during construction.
15 Contingency based on similar clean-up projects with possible unknown limits of contamination.
16 Preparation of construction bid documents (plans, specifications, and engineer's estimate).
17 Third-party construction engineering, inspection, and construction quality assurance.
18 Third-party environmental monitoring during construction (air, water, and soil).

Payment of Washington State sales tax not required for remediation projects.

Table 1: Volume Estimates for Excavation and Disposal of Contaminated Alternative 5.

	Gas Works Park Site Area Designation	Approximate	Estimated Quantities of Soils Exceeding MTCA Method B Cleanup Levels						
		Area	Non-DW		DW		EHW		Total
		(acres)	%	Vol (cu yd)	%	Vol (cu yd)	%	Vol (cu yd)	Vol (cu yd)
	Area North of Old Railroad Grade								
1	NW Area	1.9	95%	43,681	5%	2,299	0%	0	45,980
2	Parking Lot	1.9	0%	0	0%	0	0%	0	0
	Area South of Old Railroad Grade								
3	American Tar Co. (ATCO)	0.6	95%	13,794	5%	726	0%	0	14,520
4	Kite Hill	2.2	0%	0	0%	0	0%	0	0
5	Cracking Towers	1.0	95%	22,990	5%	1,210	0%	0	24,200
6	Play Barn	3.1	95%	71,269	5%	3,751	0%	0	75,020
7	Benzene Source Area	0.3	50%	3,630	50%	3,630	0%	0	7,260
8	Benzene Plume Area (Less Source Area)	1.0	95%	22,990	5%	1,210	0%	0	24,200
9	Concrete Prow	0.2	0%	0	0%	0	0%	0	0
10	Trees/Vegetation	2.0	95%	45,980	5%	2,420	0%	0	48,400
11	All Other Areas	6.0	95%	137,940	5%	7,260	0%	0	145,200
		20.2		362,274		22,506		0	384,780
NOTES									
-	Waste Categories per WAC 173-303: DW = Dangerous Waste; EHW = Extremely Hazardous Waste								
-	Excavation Depth = 15 ft, the soil point of compliance specified by WAC 173-340-740(6)(c)								
1	Relative % of non-DW versus DW is based on characterization of drill cuttings during the FFS and on results in the site soil sampling database.								
2	No soil contamination was indicated in this area, which was north of the gas plant production area.								
3	See Note 1.								
4	Kite Hill is comprised of over 15 ft of clean glacial till fill imported from the Safeco Building excavation.								
5	See Note 1.								
6	See Note 1.								
7	Relative % of non-DW vs DW is based on soil sampling data from the benzene source area of the former Light Oil Plant.								
8	See Note 1.								
9	The Prow is a solid concrete structure with no underlying contaminated soil.								
10	See Note 1.								
11	See Note 1.								

Table 13-5c. Dewatering cost assumptions for Alternative 5.

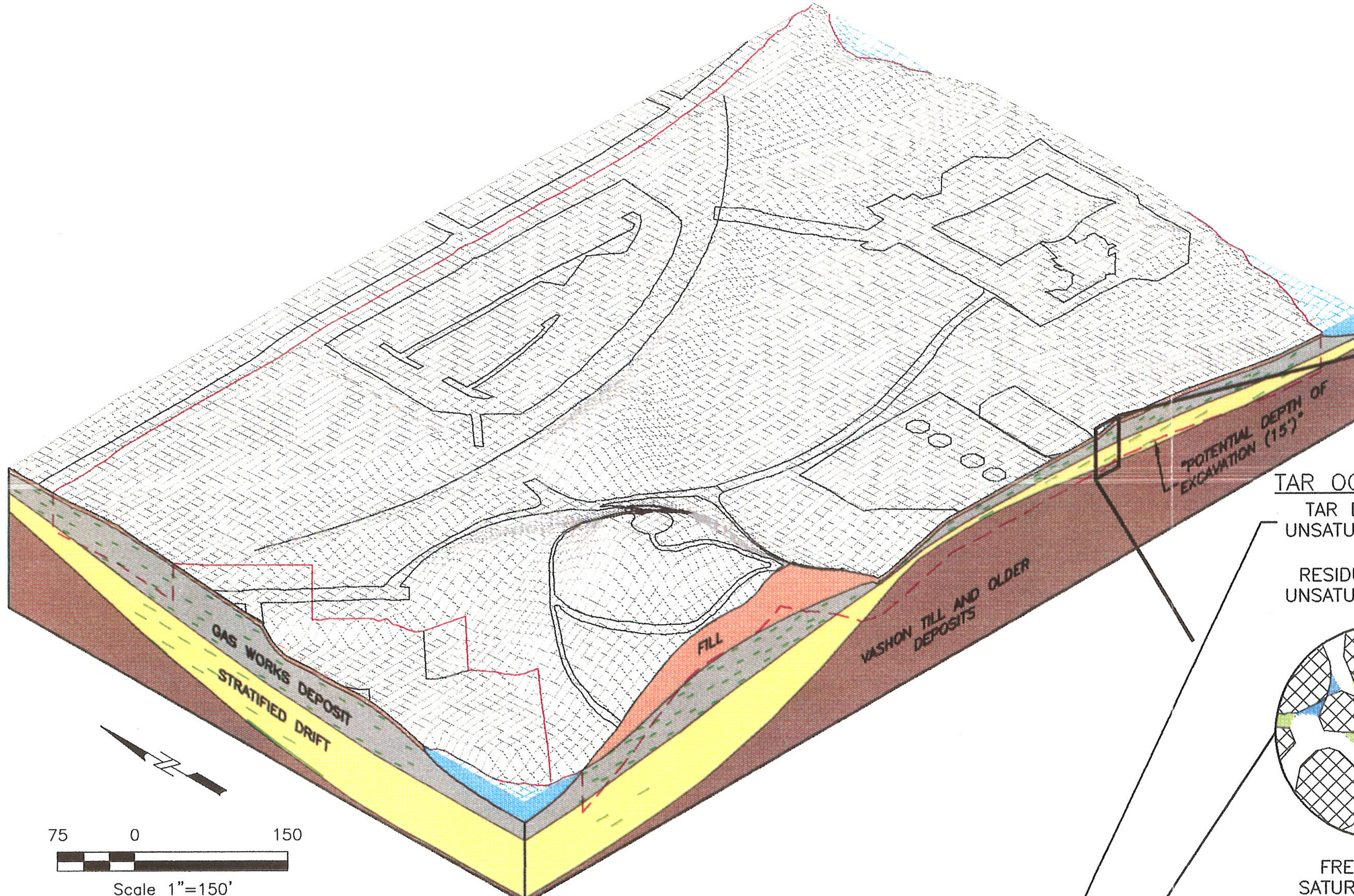
Item No.	Item Description		Quantity	Units	Unit Price	Extension
1	General Requirements	7%	1	LS	$263,800	$263,800
2	Mobilization	5%	1	LS	$188,500	$188,500
3	Upland Sheetpile		84,500	SF	$20	$1,690,000
4	Shoreline Sheetpile		37,800	SF	$25	$945,000
5	Dewatering and Water Treatment		756,000	GAL	$1.50	$1,134,000
	SUBTOTAL					**$4,221,300**
6	Contingency (on items 3 through 17)		25%			$942,300
7	Engineering (on items 3 through 16)		10%			$376,900
8	Construction Eng./Inspection (on items 3 through 16)		10%			$376,900
9	Construction Env. Monitoring (on items 3 through 16)		5%			$188,500
	TOTAL					**$6,105,900**

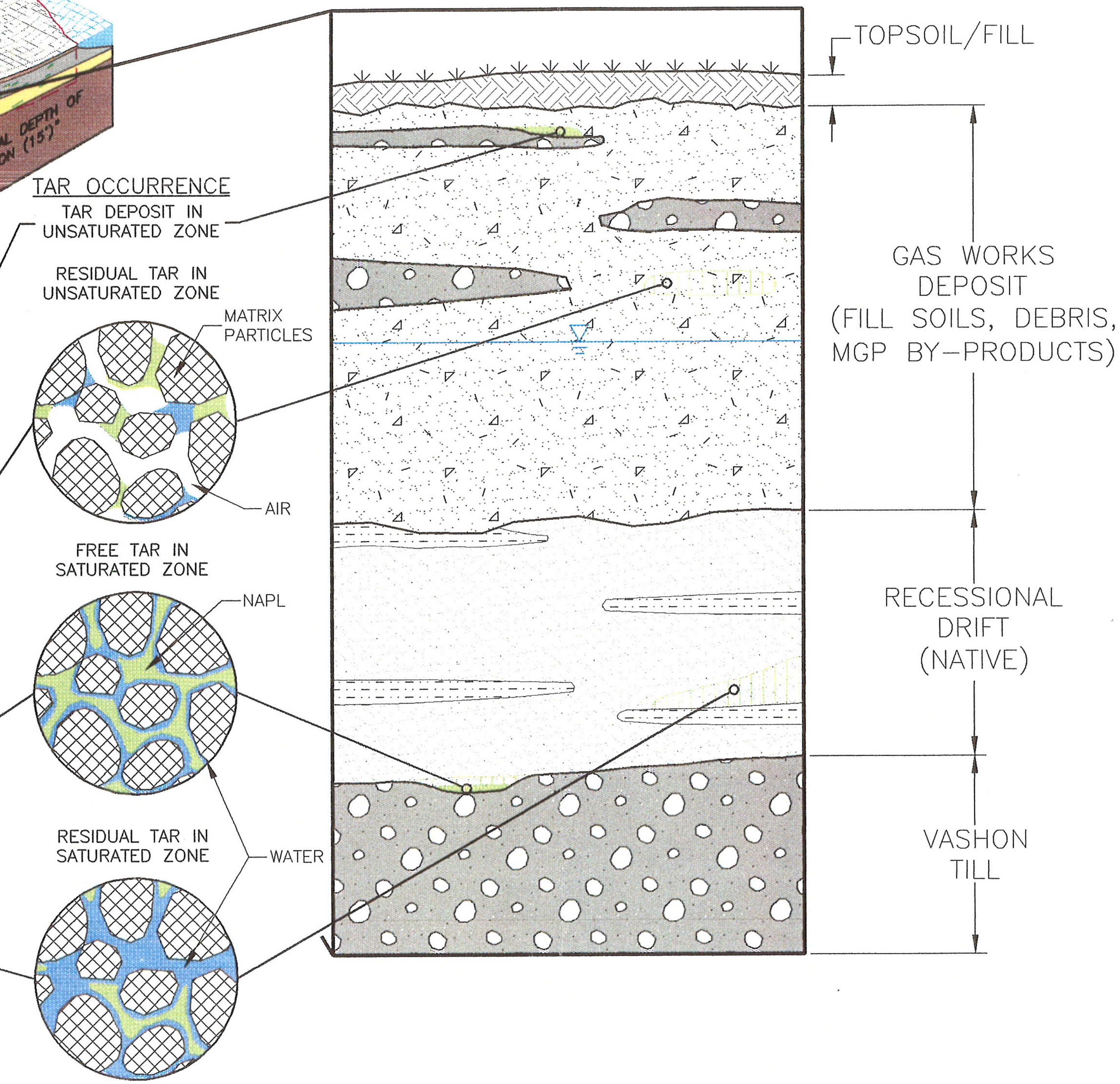
Budget Assumptions

General:* *Does not include park redevelopment. Construction estimates are based on complete installation by a private contractor.

1 Contractor's administrative costs, overhead, and profit (% based on similar projects).
2 Contractor's mobilization and demobilization costs (% based on similar projects).
3 Upland sheetpile to isolate excavation into 4 areas to reduce groundwater infiltration and discharge.
4 Shoreline sheetpile to isolate excavation from lake to reduce groundwater infiltration and discharge.
5 Estimated direct costs for dewatering and water treatment.
6 Contingency based on similar clean-up projects with possible unknown limits of contamination.
7 Preparation of construction bid documents (plans, specifications, and engineer's estimate).
8 Third-party construction engineering, inspection, and construction quality assurance.
9 Third-party environmental monitoring during construction (air, water, and soil).

Payment of Washington State sales tax not required for remediation projects.





DOES TAR/TARRY SOIL EXCEED 1% TOTAL PAH?

TAR DEPOSITS IN UNSATURATED ZONE (E.G. TAR SEEPS) LIKELY EXCEED 1% PAH. ALL TAR AT SURFACE IDENTIFIED BY THE OCTOBER 1997 TEST PIT INVESTIGATION HAS BEEN REMOVED.

AREAS OF RESIDUAL TAR IN UNSATURATED ZONE DO NOT APPEAR TO EXCEED 1% PAH BASED ON TESTING DATA. ALL KNOWN AREAS OF TAR–SATURATED SOIL AT THE SURFACE HAVE BEEN REMOVED.

AREAS OF FREE TAR IN THE SATURATED ZONE MAY EXCEED 1% PAH. FREE TAR OCCURS AS ISOLATED LENSES OR POCKETS.

AREAS OF RESIDUAL TAR IN THE SATURATED ZONE DO NOT APPEAR TO EXCEED 1% PAH BASED ON TESTING DATA.

ThermoRetec

SEATTLE DEPARTMENT OF PARKS AND RECREATION & PUGET SOUND ENERGY 1-3916-900				SCHEMATIC BLOCK DIAGRAM OF TAR OCCURRENCE AT GAS WORKS PARK
CURRENT DATE	4/5/99	CADD FILE	3916s001	FIGURE 1

APPENDIX I

2005 Draft Gas Works Sediment Area Cleanup Standard Determination, Figure 5-2 – GWSA Boundary

0 150 300 Feet

N

Phase 2 and Phase 3 (2002 and 2005)
Surface Sediment Bioassay Sampling Stations

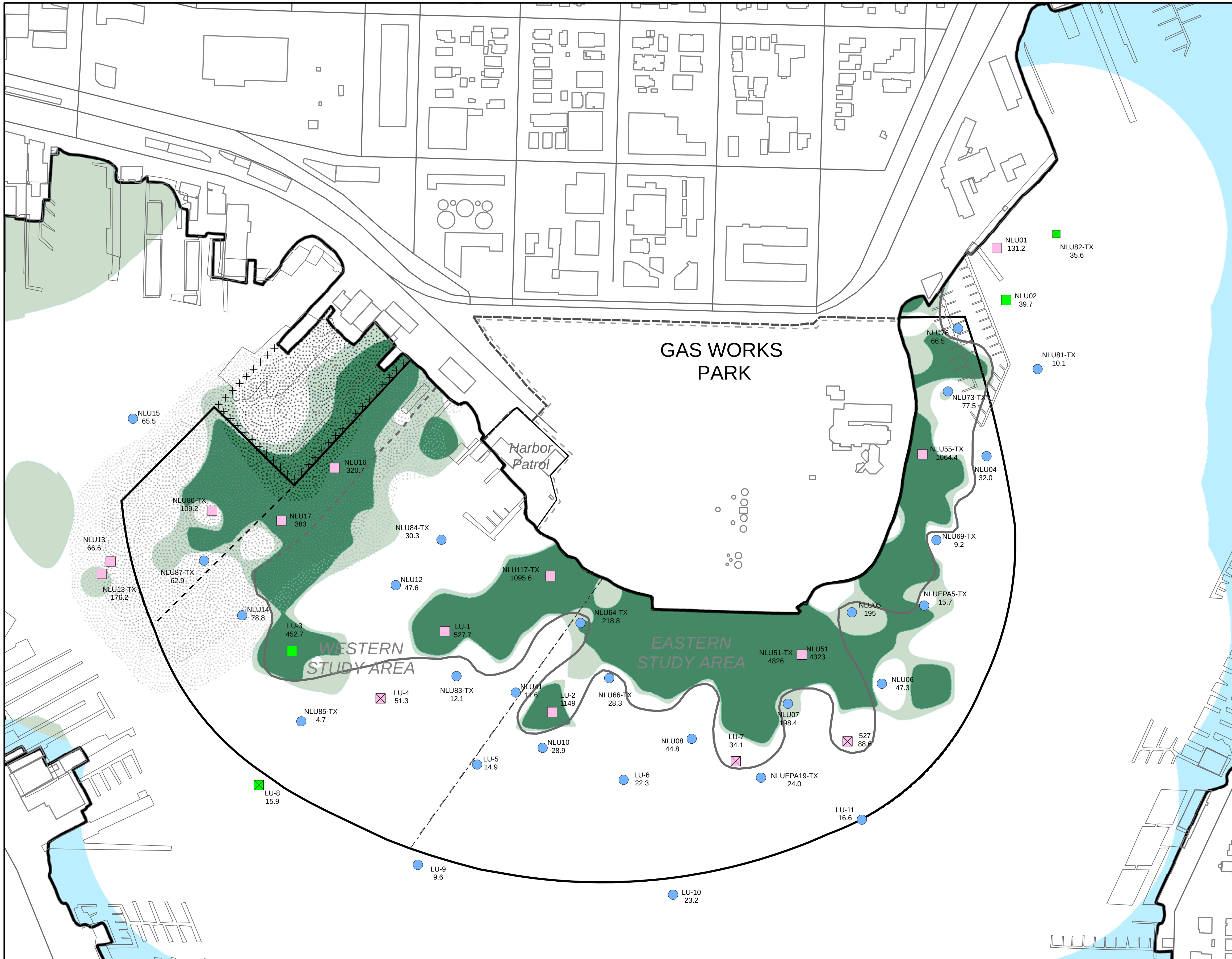
- Pass
- SQS Failure
- Microtox Only SQS Failure
- CSL Failure
- Microtox Only CSL Failure

- GWSA Boundary
- Initial Area of Investigation
- Shipyard Consent Decree Boundary
- Uplands Boundary As Defined By The Consent Decree (December 1999)
- Division Between Eastern And Western Study Areas
- Harbor Patrol Boundary
- Gas Works Park Boundary
- Primary Shipyard Metals Impact

Interpolated TPAH Concentrations (mg/kg dry wt.) *

- < 170
- 170 - 290 (SSQL Area)
- > 290 (SSCL Area)
- No data available, or, if data exists, interpolation not shown

* Western Study Area values are preliminary and not validated



NOTES:

1. Basemap generated in ArcGIS version 8.1 from Seattle Public Utilities Geographic Systems data, 9/28/99. Overwater structure data updated, 12/18/03. Projection in Washington State Plane Coordinates, North Zone, HARN 1983/1991.
2. Concentration contour map generated through interpolation using an Inverse Distance Weighted (IDW) scheme (power = 6) from 2004/05 grab samples and pre-2005 data. Maximum reach from each sampling location is equal to 500 feet. Contoured interval may differ from actual data shown due to influence by neighboring data values.
3. The number given below the sample name is the TPAH concentration (ppm), concentrations represent the total sum of 16 individual PAH compounds. In accordance with Ecology's Sediment Management Standards, individual PAH concentrations below the detection limit (DL) were not included when calculating the sum.
4. Data sets include King County 2000 (527), RETEC March 2002, TAMU July 2002, RETEC October 2002, and RETEC April 2005.
5. Results based on H. *azteca* 10-day mortality H. *azteca* 28-day mortality and growth, C. *tentans* 10-day mortality, C. *Tentans* 20-day mortality and growth, and Microtox bioassay tests. The Microtox data presented for the 5 minute and 15 minute bioluminescence endpoints.
6. Bioassay pass/fail results based on Ecology's proposed freshwater bioassay decision criteria.
7. SQS failure = avg T-R >10 or 15% for mortality endpoint; avg biomass of T/R < 0.75 for growth endpoint; avg decrease T/R <0.85 for luminescence. T = test and R = reference.
8. CSL failure = avg T-R >25% for mortality endpoint; avg biomass of T/R < 0.6 for growth endpoint; avg decrease T/R < 0.75 for luminescence; two SQS failures.
9. The dashed portion of the AB will be further refined as part of the Western Study Area RI/FS process.

FILE: T:/LakeUnion_N83/Projects/NLU/TPAHCleanUp_SD2005/GWSA_AreaBound_5_2.mxd

RETEC

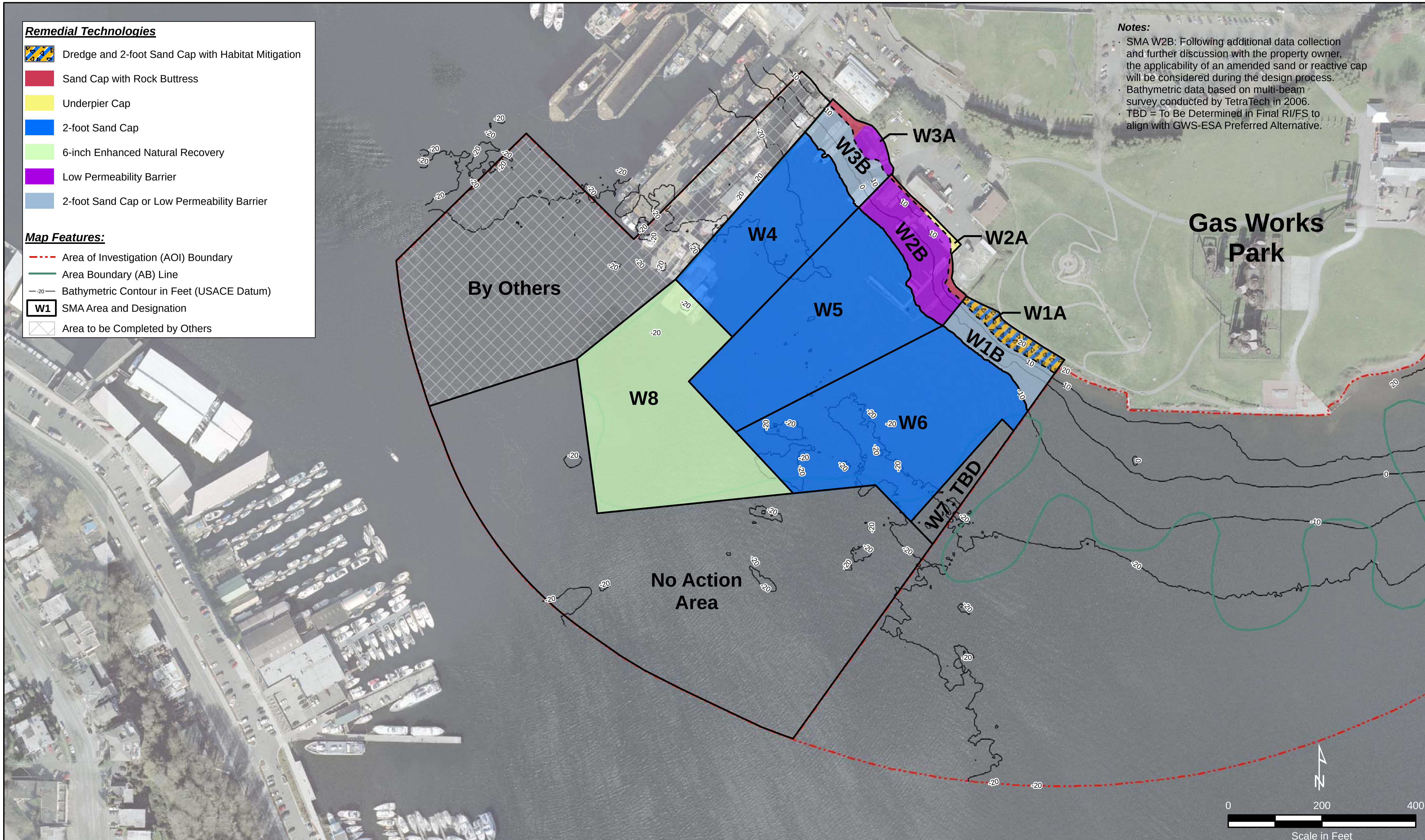
CLEANUP STANDARD DETERMINATION
GAS WORKS SEDIMENT AREA
PSE10-18628-610

GWSA BOUNDARY

DATE: 8/9/05 | DWN. BY: KBL/ftc

FIGURE: 5-2

APPENDIX J
Preferred Alternatives for the Sediment Area



FLOYD | SNIDER
strategy ▪ science ▪ engineering

Remedial Investigation and Feasibility Study
Gas Works Sediment Western Study Area
City of Seattle

DRAFT

Figure 12.4
Remedial Alternative 4

F:\projects\COS-GWSA\GIS\RIFS Report\Figure 12.4 (Remedial Alternative 4).mxd

ECOLOGY REVIEW DRAFT

May 25, 2007

RETEC

GAS WORKS SEDIMENT EASTERN STUDY AREA PSE10-18628-630	PREFERRED REMEDIAL ALTERNATIVE
DATE: 03/31/06 · DRWN: A.S./SEA	FIGURE 14-1

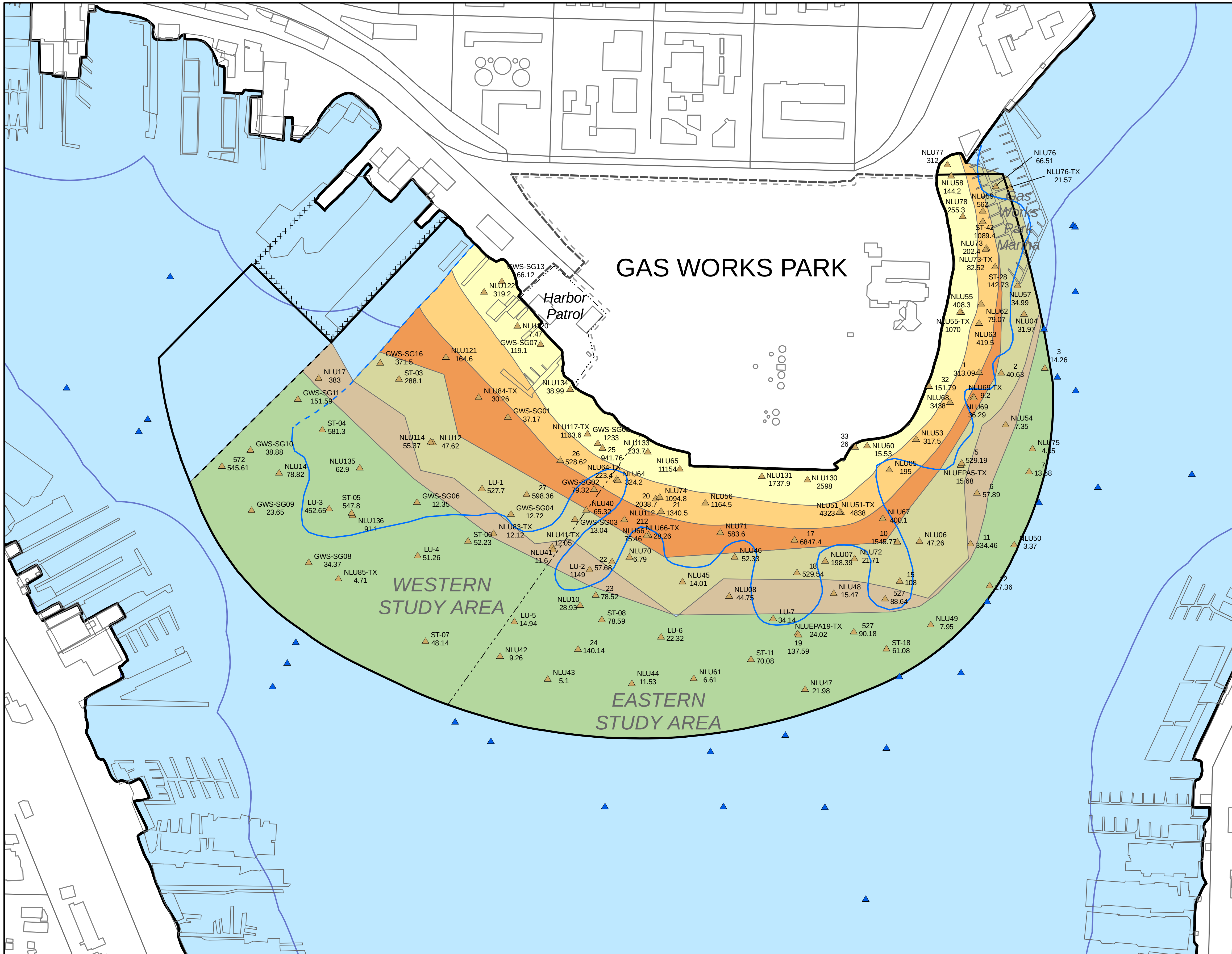
File: H:\18628\18628S022.dwg Layout: ANSI_B1-CP User: seocad Plotted: Apr 10, 2006 - 11:17am Xref's:

APPENDIX K

2012 Gas Works Sediment Area Supplement to the Cleanup Standards Document, Figure 6-2 – Iterative Approach: Estimated Lateral Extent (GWSA Detail) – Indicator COC - TPAH

0 150 300 Feet

N



Surface TPAH Sample Locations

- GWSA Data Set
- Ambient Lake Union Data Set

Statistical Analyses Areas

- Band 1
- Band 2
- Band 3
- Band 4
- Band 5
- No Action
- 300 ft. from shoreline

- Area Boundary
- Area of Investigation (AOI)
- Uplands CD Boundary as depicted on Exibit A to the Consent Decree (December 1999)
- Division between Eastern and Western Study Areas
- Shipyard Consent Decree Boundary
- Harbor Patrol Boundary
- Gas Works Park Boundary

NOTES:

1. Sample dates in ambient lake range from 1986 to 2005; samples dates within GWSA range from 1994 to 2005.
2. GWSA Indicator COCs include benzo(a)pyrene, HPAH, and TPAH.
3. Indicator COCs benzo(a)pyrene and HPAH have essentially identical datasets to TPAH, but different chemical concentrations at any given sample location.

T:\LakeUnion_N83\Projects\NLU\ESA_RI_Revision\Working\Report_SuppCleanupStnds\Fig_6-2_GWSA_Indicators_Detail_ALT.mxd

AECOM

SUPPLEMENT TO THE CLEANUP STANDARDS DOCUMENT GAS WORKS SEDIMENT AREA 60149262	**ITERATIVE APPROACH: ESTIMATED LATERAL EXTENT (GWSA DETAIL) – INDICATOR COC – TPAH**
DATE: 09/06/2011 DRWN: RLB/ftc Revision:5	**FIGURE 6-2**

APPENDIX L

March 22, 2012 Letter from Ecology, Gas Works Park Data Gaps for Remedial Investigation Re-Compilation Report

STATE OF WASHINGTON
DEPARTMENT OF ECOLOGY
Northwest Regional Office • 3190 160th Ave SE • Bellevue, WA 98008-5452 • 425-649-7000
711 for Washington Relay Service • Persons with a speech disability can call 877-833-6341

March 22, 2012

Gas Works Park Data Gaps for Remedial Investigation Re-Compilation Reprt

The purpose of this memorandum is to present data gaps that were identified during compilation of the Gas Works Park Upland Remedial Investigation (RI) report (draft final report prepared for Ecology by Hart Crowser on February 1, 2012). The RI report compiled the findings of numerous environmental investigations and remedial actions that have been completed on the upland portion of the Gas Works Park site. At Ecology's direction, the discussion of upland data gaps and recommendations are included in this separate memorandum.

SUMMARY OF RI CONCLUSIONS

As discussed in the RI report, major findings of these upland site investigations include:

- Fill deposits cover much of the Gas Works Park uplands. Beneath the Fill, the primary hydrostratigraphic unit is low-permeability Till, with higher permeability Glacial Outwash deposits draped along the eastern and western shoreline areas.

- Shallow groundwater beneath the Gas Works Park site flows radially toward Lake Union and is not a current or future source of drinking water. Based on two rounds of pumping tests conducted at the site, the shallow groundwater zone beneath the park is not capable of yielding a sufficient quantity of water to support use as a water supply.

- Elevated concentrations of PAHs, BTEX compounds, and NAPL associated with a former manufactured gas plant and associated historic industrial operations have been encountered in site soil and groundwater.

- In order to address direct contact exposures, clean vegetated soil caps of various thicknesses have been placed over most of the park to prevent park visitors from directly contacting contaminated soil. Exposure to contaminated soil in the Cracking Tower area is prevented by a tall, locked chain-link fence that surrounds it. Several interim actions were completed in 1997 to remove NAPL floating on shallow groundwater and surface/near surface tar occurrences in the Southwest portion of the park. In addition in 1998, an AS/SVE system was installed and operated in the southeastern portion of the park to remove BTEX compounds from soil and groundwater and to prevent impacts to the Lake Union aquatic environment.

IDENTIFICATION OF DATA GAPS

The upland RI included an evaluation of potential risks to human health and the environment posed by residual contamination. In general, implementation of the remedial actions and restrictive covenants conducted under the 1999 Consent Decree (and amended in 2005) has been effective in minimizing risks to human health and the environment. However, several issues should be addressed including:

- Surface and near-surface soil in the northeastern portion of the park contains PAH concentrations well above MTCA Method B direct contact cleanup levels and appear to be affecting surface water runoff quality in the area. In order to evaluate potential direct contact risks to park users, Environ, an international environmental services firm, performed a risk evaluation of the existing soil quality data and concluded that there was not an unacceptable risk to the public. Erosion of PAH-impacted surface soil and particulate transport via surface water runoff appears to be occurring in this area, based on catch basin sampling conducted by the city (Floyd/Snider 2010). The flux of dissolved and particulate-derived PAHs to Lake Union via this runoff pathway has not yet been quantified but would be expected to be relatively small given the low aqueous solubility of PAHs and the limited amount of erosion anticipated from the vegetated surface. Potential mitigation options, including installation of an enhanced vegetated cap in this area, should be evaluated.

- Surface and near-surface soil in the Kite Hill and southwest portion of the park contains PAH concentrations well above MTCA Method B direct contact cleanup levels. In order to evaluate potential direct contact risks to park users, Environ performed a risk evaluation of the existing soil quality data and concluded that there was not an unacceptable risk to the public. Particulate transport via surface water runoff does not appear to be occurring in this area. Additional soil investigations should be conducted to identify the extent of soil contamination. Potential mitigation options, including installation of an enhanced vegetated cap in this area, should be evaluated.

- Benzene concentrations in shallow groundwater in the southeastern section of the park exceed the Consent Decree MTCA Method B surface water protection criteria by direct comparison, but do not currently exceed the remediation level calculated for compliance well OBS-1 using a site-specific dilution attenuation factor. Although benzene concentrations appear to be decreasing over time (likely due to natural attenuation via biodegradation), continued groundwater monitoring and analysis will be needed to ensure that the Lake Union aquatic environment is not being significantly impacted. Additional evaluation of current soil benzene concentrations in the southeastern portion of the Site may also be beneficial to evaluate potential long-term sources to groundwater. This evaluation should be completed as part of the Gas Works Park Uplands Supplemental Feasibility Study.

- Groundwater naphthalene concentrations along the southwestern park shoreline are at or below the Method B surface water protection cleanup level established in the Consent Decree and appear to be decreasing over time. However, Ecology has indicated that Lake Union is classified as being a potential drinking water source, although this scenario is unlikely. If drinking water criteria are applied for protection of Lake Union water quality, additional remedial actions should be evaluated as part of the Gas Works Park Uplands Supplemental Feasibility Study.

- A current comprehensive characterization of contaminant concentrations in groundwater flowing to surface water along the park's waterfront has not been completed and constitutes a data gap. The southeast and southwest perimeter sectors of the park are being monitored for a limited number of contaminants. The groundwater in these sectors needs to be tested for both PAHs and BTEX compounds. Currently, monitoring wells OBS-1, -2, and -3 in the southwest sector of the park are monitored for BTEX but not for PAHs. Monitoring wells CMP-1, MLS 5-3, MLS 5-5, MLS 6-1, and MLS 6-4 along the southeast sector of the park are monitored for PAHs but not for BTEX. Only monitoring wells MW-17 and MW-18, in the southwest sector of the park, are tested for both sets of contaminants. The testing frequency is once every 24 months. Groundwater migrates radially from the area around monitoring well MW-3 in the center area of the park into Lake Union. There are no wells near the eastern shoreline north of OBS-2. Ecology may need to sample the existing shoreline wells and install additional shoreline monitoring wells where needed.

- Soil and groundwater quality within the central portion of the park may not be adequately characterized. Installation of additional soil borings and/or monitoring wells may be required in order to develop a feasibility study for the park. Any additional site characterization work will incorporate the results of recent investigations conducted by the PLPs.

- Heterogeneous occurrences of dense and/or light NAPL are present in various portions of the park uplands including along the park shoreline. NAPL is generally not encountered in Site monitoring wells and there is no direct evidence that NAPL is currently migrating into Lake Union from the park uplands. However, the potential mobility of these NAPL occurrences is being further evaluated by the city and PSE as part of the Gas Works Sediment RI. If NAPL is migrating to the Lake Union aquatic environment, additional remedial actions may be required.

APPENDIX M
January 23, 2013 Letter from Ecology to USEPA Regarding Gas Works Park Status Update

STATE OF WASHINGTON
DEPARTMENT OF ECOLOGY
Northwest Regional Office • 3190 160th Ave SE • Bellevue, WA 98008-5452 • 425-649-7000
711 for Washington Relay Service • Persons with a speech disability can call 877-833-6341

January 23, 2013

Ms. Lynda Priddy
USEPA Region 10
1200 Sixth Avenue
Mail Code: ECL-111
Seattle, WA 98101

Re: Gas Works Park Status Update

Dear Ms. Priddy:

Ecology has continued to work at Gas Works Park. Based on the meeting held on October 23rd, Ecology's main focus has been on addressing EPA's comments and identifying areas where additional work is needed. Responses to comments have been prepared which clarified and helped to define areas where additional work is needed. This letter transmits the responses to comments and concerns raised by both EPA and Ecology regarding the Gas Works Park Site and Gas Works Sediment Area ("the Site"). This response package consists of the comment/response table, a list of defined acronyms used in the comment/response table, Proposed Scope of Work table, and PDFs of referenced EPA and Ecology comment documents.

Attached Table 1 – *Gas Works Park Site/Gas Works Sediment Area Draft Responses to Compiled EPA and Ecology Comments (2004 to 2012)* contains a compilation of written EPA comments pertaining to the site from 2004 to the present. All comments from the following EPA comment documents are compiled and addressed in Table 1:

- June 11, 2009 – Letter from EPA (Priddy) to Ecology (Keeling) – Comments on the Gas Works Park Site Uplands and Sediments. *Table 1 comment numbers 1 – 86.*
- October 1, 2008 – Letter from EPA (Priddy) to Ecology (Keeling) – Comments on the Western Sediment Area RI/FS (May 25, 2007). *Table 1 comment numbers 87 – 91.*
- August 3, 2010 – Letter from EPA (Opalski) to Ecology (Pendowski) – Gas Works Park-Seattle, request for milestone briefing/data gaps. *Table 1 comment numbers 92 – 99.*
- August 24, 2012 – Letter from EPA (Priddy) to Ecology (Keeling) – Comments on Northeast Corner of the Gas Works Uplands 95 Percent Design. *Table 1 comment numbers 100 – 105.*

In addition to comments from the above-listed documents, supplemental comments from the following EPA documents are included if the comments are not redundant with comments listed in the primary documents listed above:

- Undated circa 2004 – Letter from EPA (Eckman) to Ecology (Alexander) – Discussion of the terms of the EPA/Ecology deferral agreement. *Table 1 comment numbers 106 – 108.*
- March 23, 2009 – Email from EPA (Priddy) to Ecology (Keeling) – feedback on EPA/Ecology Gas Works Meetings. *Table 1 comment number 109.*
- October 13, 2010 – Letter from EPA (Opalski) to Ecology (Pendowski) – re: October 5, 2010 briefing. *Table 1 comment number 110.*
- June 6, 2011 – Email from EPA (Priddy) to Ecology (Wang and Keeling) – Questions for EPA/Ecology Briefing on June 9, 2011. *Table 1 comment numbers 111 – 121.*

The comment/response table (Table 1) also includes the data gaps, or "comments," identified by Ecology in their March 22, 2012, data gaps memo. *Table 1 comment numbers 122 – 129.*

The EPA and Ecology comments (129 total) are listed almost verbatim and are categorized and grouped into similar topics (8) and subtopics (34). In order to track comments from multiple comment documents, comments are numbered consecutively from 1 to 129, as shown in the first column of Table 1. The assigned comment number was added in red in the left-hand margins of the comment documents (see PDF attachments) so that table comments can be readily compared to the original document. For further clarification and comparison to the original correspondence, the agency name (EPA or Ecology) and date (and section and number, where appropriate) of each comment within a given document are listed in Table 1.

Table 1 includes the proposed responses to each comment in the Response column. The responses are categorized into status categories, or "buckets." The different category/"bucket" designations are listed in the Status column of the table and are described below.

- *Requires additional investigation.* Indicates additional field work, analysis, and/or reporting is need to fully address comment.
- *Will be addressed in RI/FS.* The comment will be addressed in the Site-wide RI/FS.
- *Work performed to address comment--will be addressed in RI/FS.* Additional work has been completed since the comment was submitted. The new information will be addressed in the Site-wide RI/F.
- *Will be addressed as an interim action.* Work will be addressed by a proposed interim action.
- *Already addressed.* Indicates no additional work is needed. An explanation of work already performed that is responsive to the comment and an explanation of why no additional work is needed is provided in the Response column.

An action plan table, Table 2, was then prepared which includes a description of proposed activities to address comments that have a status of "Requires additional work to address", "Will be addressed in RI/FS", and "Will be addressed as an interim action". The Action Plan Table is intended to provide a summary of proposed actions and becomes the scope of work to be used to modify the Agreed Order. Electronic copies of the attachments will be sent to you via email.

Ecology and the PLPs are in the process of modifying the Agreed Order (AO) to incorporate the tasks identified in Table 2. The reason for the modification is to revise the Statement of Work to address remaining upland tasks required by the AO. Sections II.6-7, III.3, IV.1 of the AO reference the upland areas and impact on sediments. It was our intent for these areas to be addressed. The modification will provide a revised Exhibit B Statement of Work which includes additional tasks to comprehensively address uplands impacts on sediments at Gas Works Park. Exhibit D will also be modified to more clearly present the boundaries of the study area.

As for upcoming work, the PLPs are planning to begin implementation of a supplemental upland field investigation before the 2013 late spring/summer park season. On February 7, 2013 we have scheduled a meeting with you to discuss the proposed work for Spring 2013.. Your input on the proposed field work will be instrumental in defining a comprehensive sampling plan.

I look forward to sitting down with you and discussing what we have accomplished since the October meeting and more importantly our proposed scope of work (Table 2).

Sincerely,

Libby Goldstein

Libby Goldstein
Gas Works Park Site Manager
Washington State Department of Ecology

ecc: Shawn Blocker, (USEPA)
John Rork (PSE)
Pete Rude (City of Seattle)
David Graves (City of Seattle)
Steven Secrist (PSE)
Lorna Luebbe (PSE)
Bob Warren (Ecology)

Attachments:

- Table 1. Gas Works Park Site/Gas Works Sediment Area, Responses to Compiled EPA and Ecology Comments (2004 to 2012)
- Table 2. Gas Works Park Site/Gas Works Sediment Area, Preliminary Scope of Work from Responses to Compiled EPA and Ecology Comments (2004-2012)
- PDFs of Reference EPA and Ecology Comments Documents

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