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

LAW 09746

TABLE OF CONTENTS

Page

TABLE OF CONTENTS (continued)

LAW 09748

LIST OF FIGURES

LIST OF TABLES

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.*

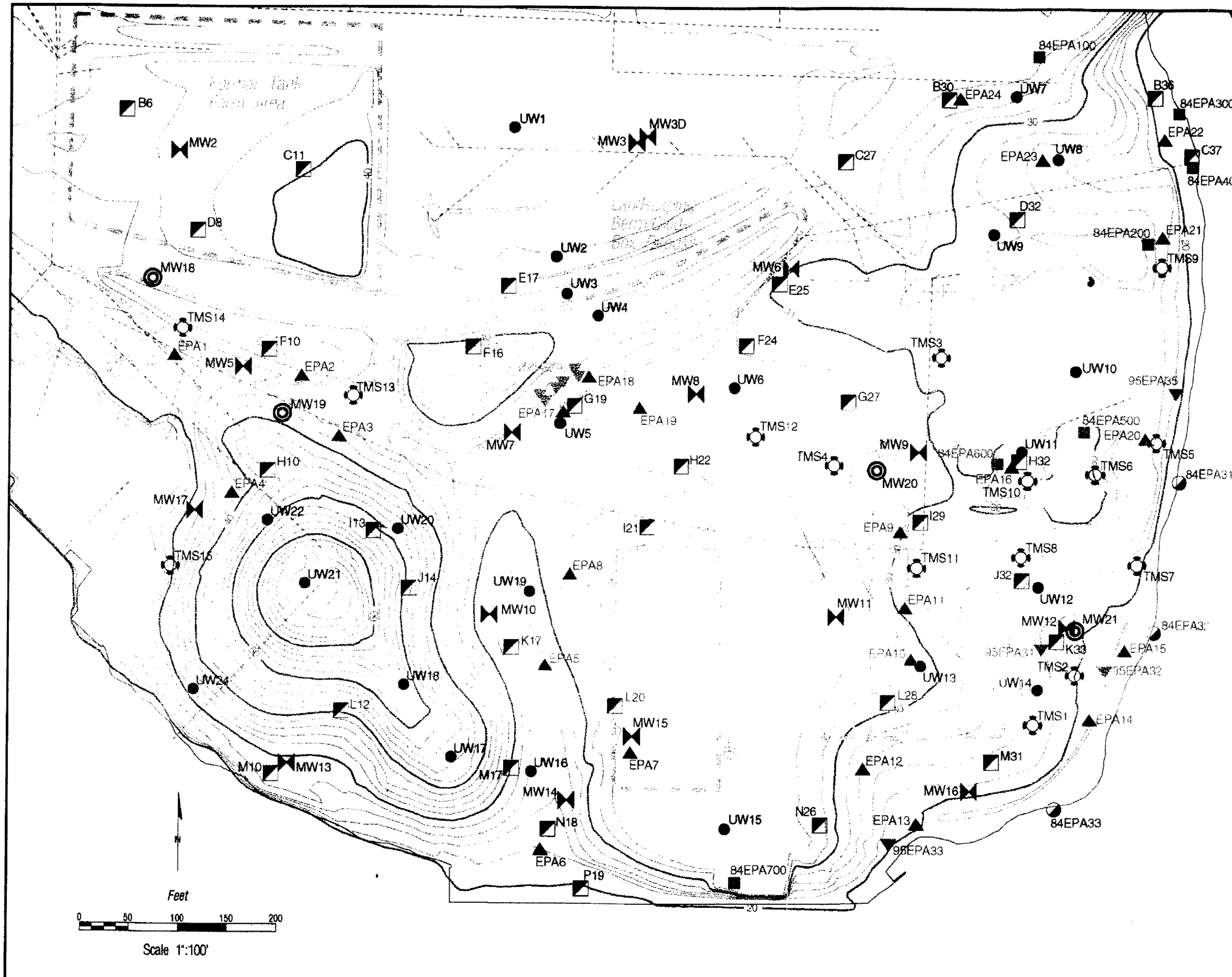


Figure 2-1

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

LAW 09754

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)

LAW 09756

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)

LAW 09757

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

Chemical Name	Number*	Detected Concentrations Maximum (µg/L)	Detected Concentrations Minimum (µg/L)	MTCA B Cleanup Level Groundwater (µg/L)	MTCA B Cleanup Level 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)

LAW 09758

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)

LAW 09761

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

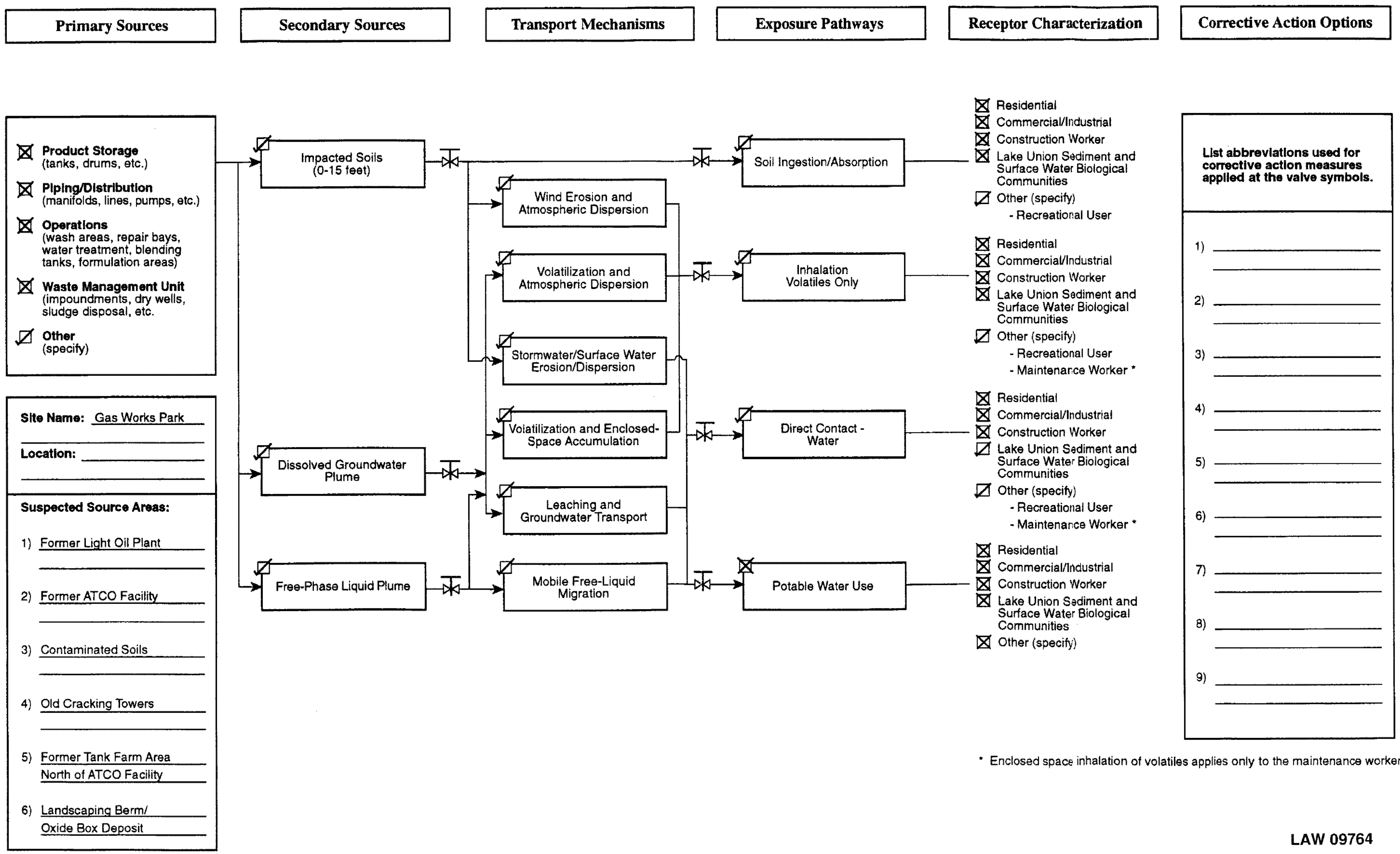
Discussions among representatives of Seattle's Department of Parks and Recreation, Washington Natural Gas, the Department of Ecology, and the Parametrix project team resulted in selection of the Exposure Scenario Flowchart from "Standard Guide for Risk-Based Corrective Action Applied at Petroleum Release 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.



LAW 09764

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

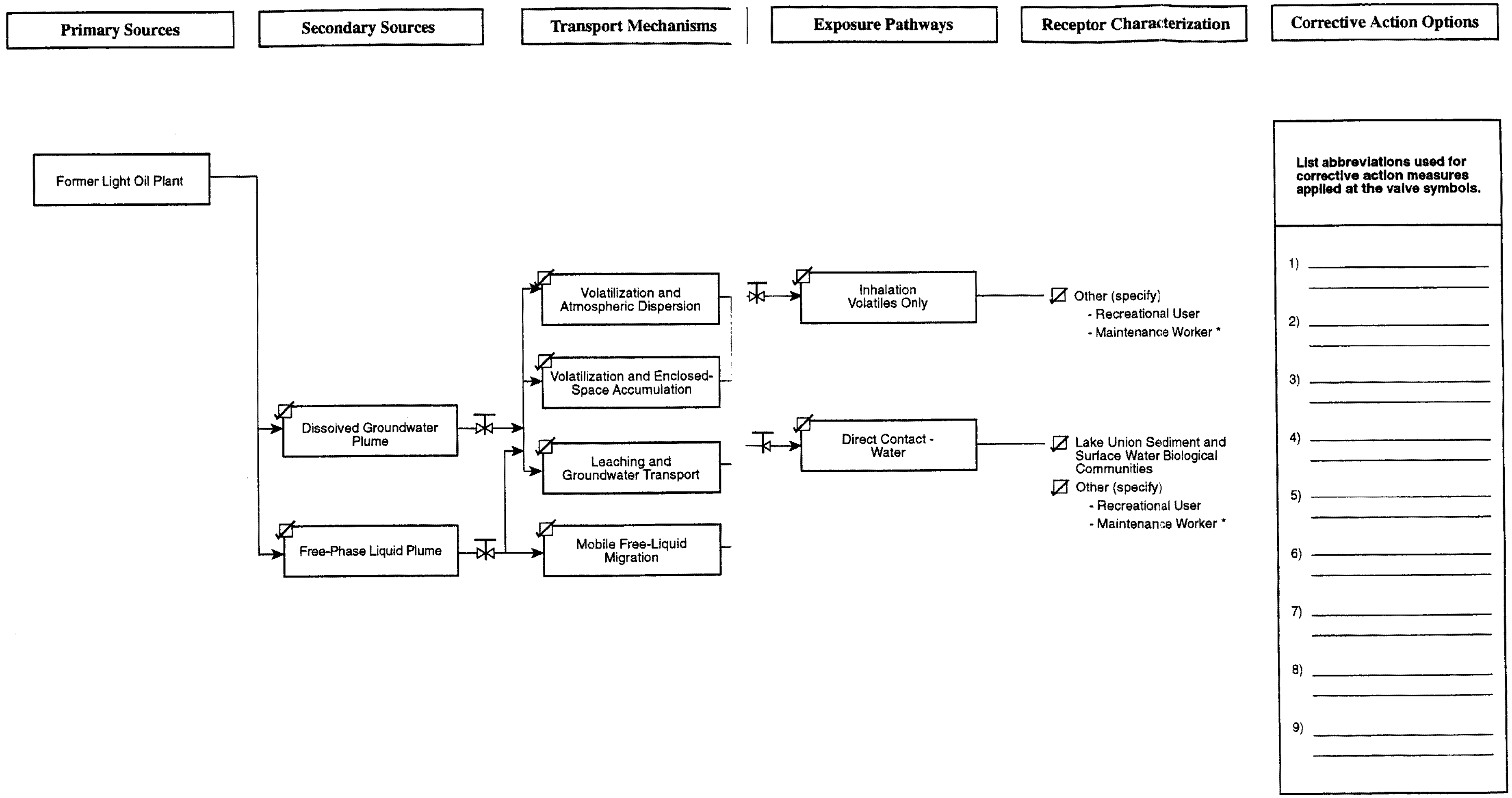
On the basis of known site and regional conditions and discussions with the Department of Ecology, use of groundwater beneath the Gas Works Park site as a potable water supply is not feasible: therefore the "Potential Water Use" box was eliminated.

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

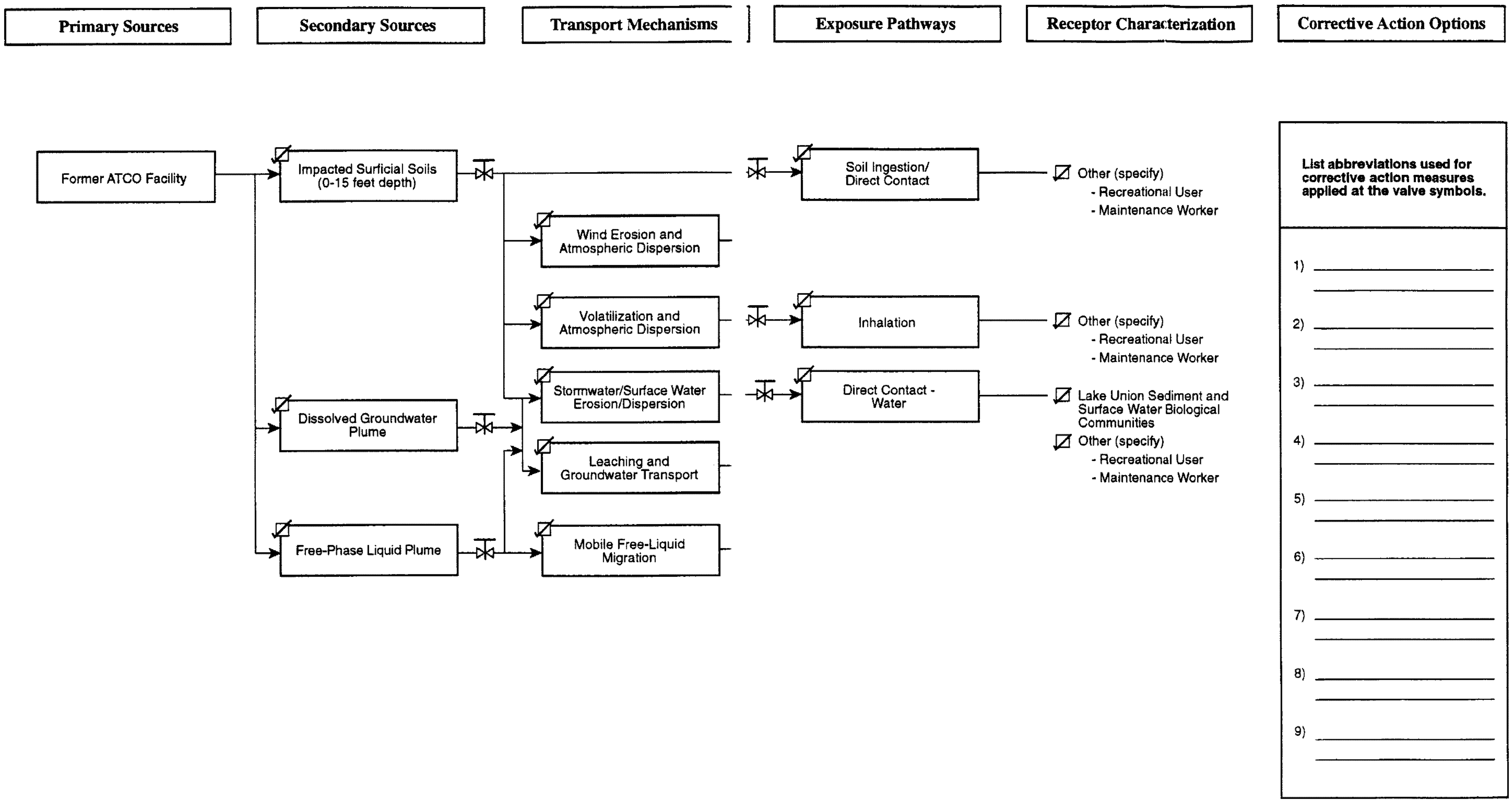
Using the composite conceptual site model (see Figure 3-1) as a guide, conceptual site models were developed for each identified primary source, as shown on Figures 3-2 through 3-7. Only model components (boxes) that pertained to each specific source were retained in each model.



* Enclosed space inhalation of volatiles applies only to the maintenance worker.

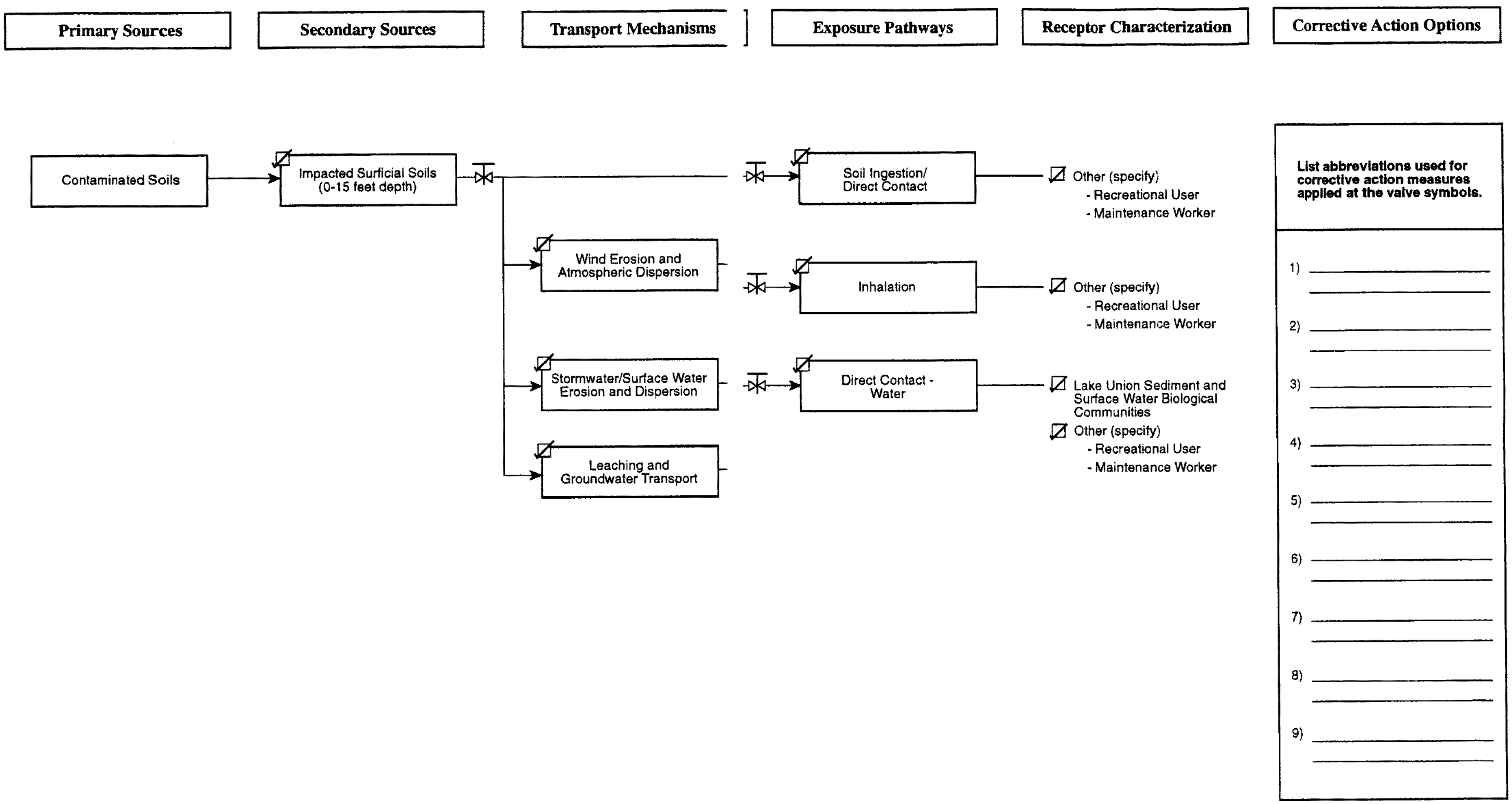
LAW 09767

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



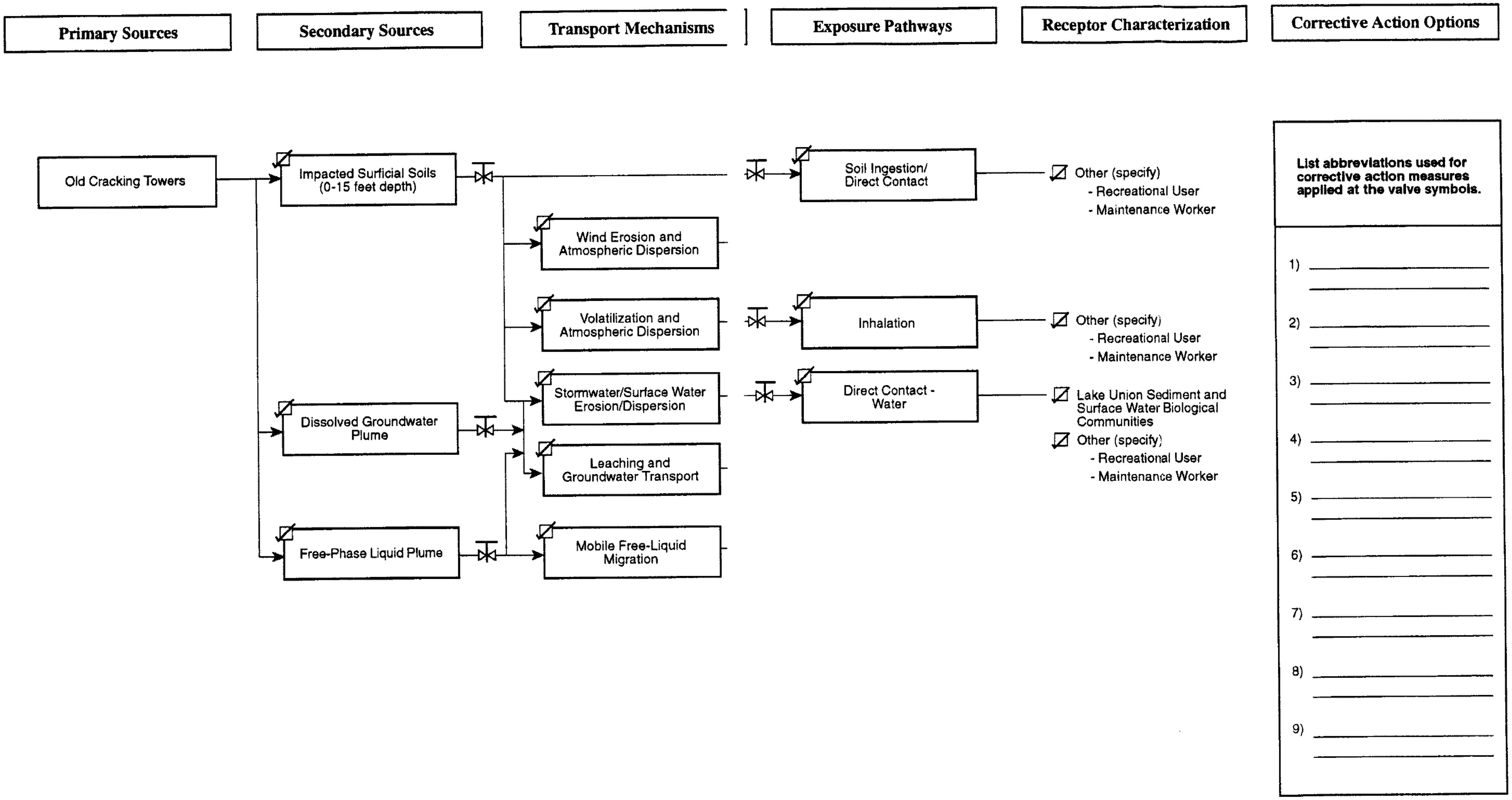
LAW 09768

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



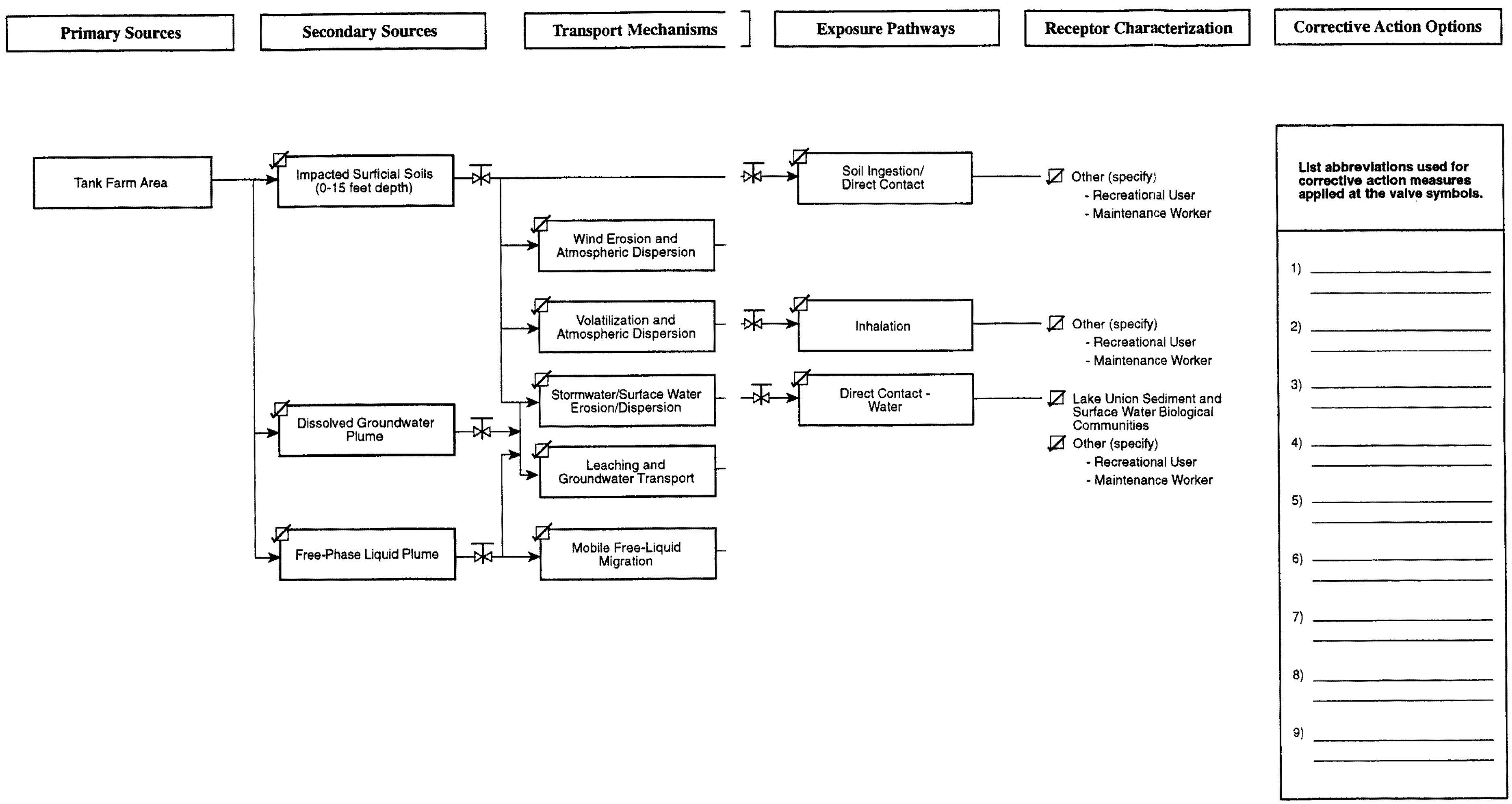
LAW 09769

Figure 3-4. Conceptual Site Model, Contaminated Soils



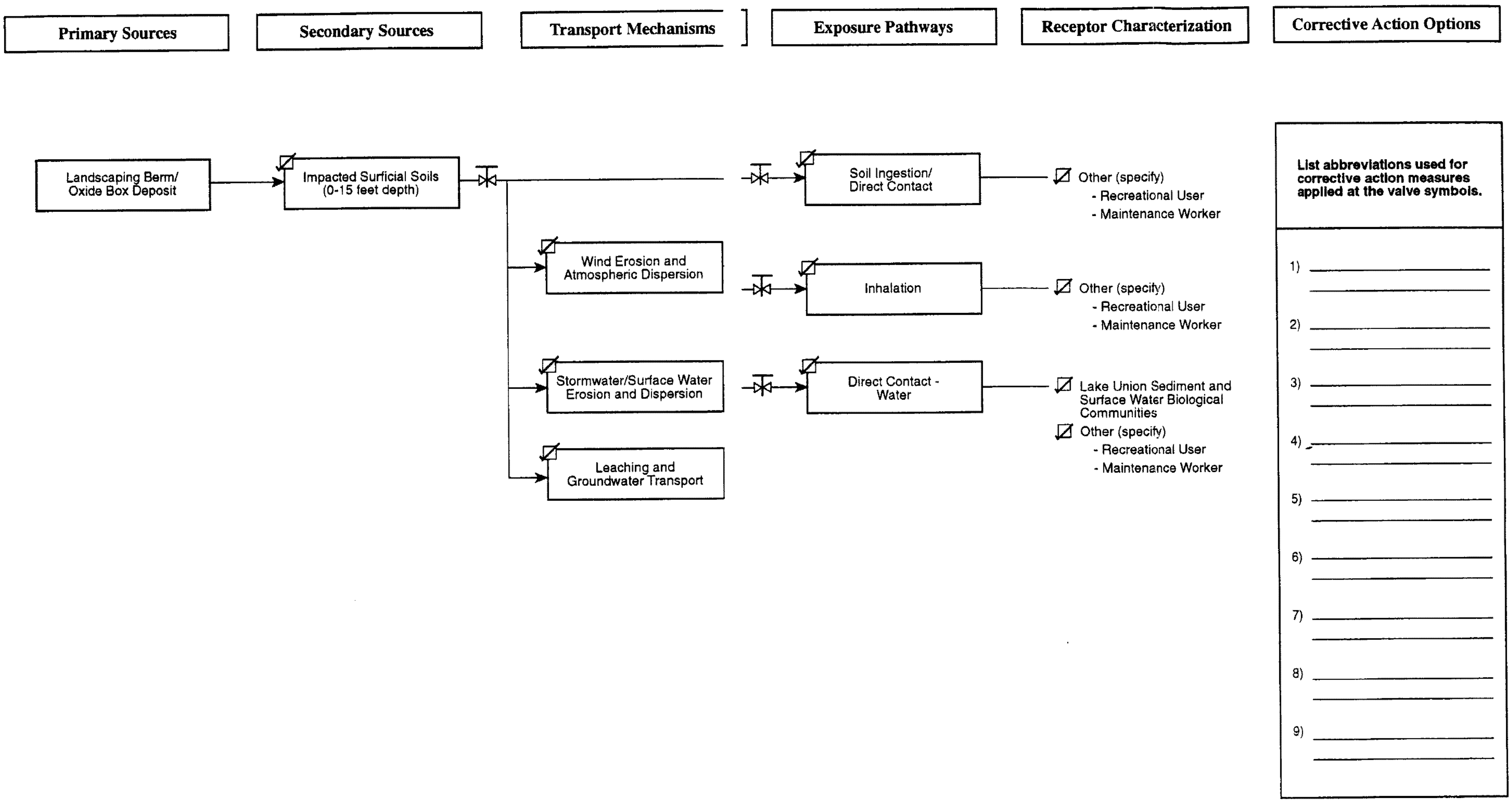
LAW 09770

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



LAW 09771

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



LAW 09772

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.

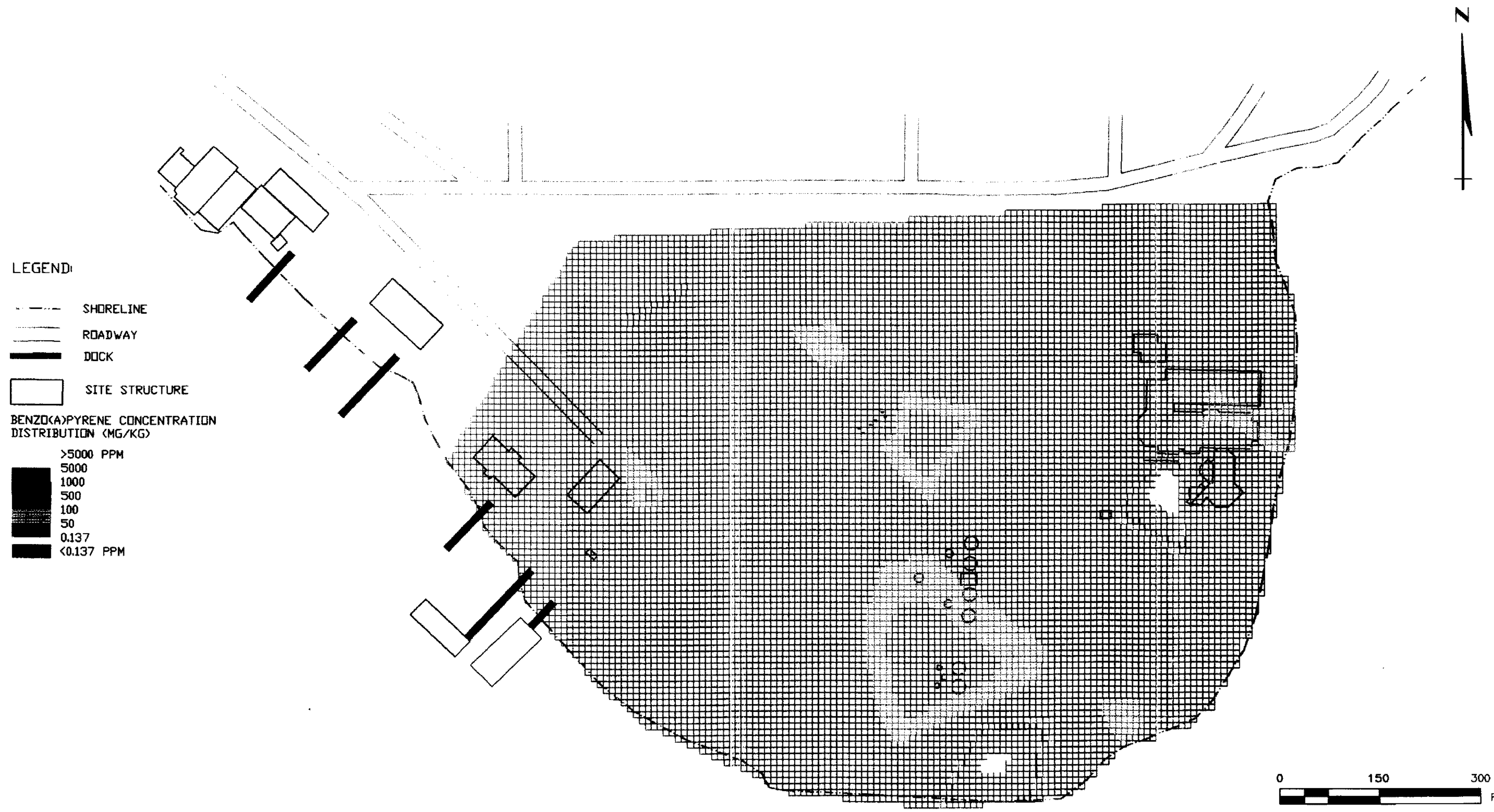
First, the upper end of the areal extent of impacted soil was developed by comparing the site data to the Method B Cleanup Level for benzo(a)pyrene in residential soil. As was shown in Tables 2-1 and 2-2, 99% of the surface soil and 94% of the subsurface samples from the site exceed the Method B cleanup 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

CITY OF SEATTLE
GAS WORKS PARK
SEATTLE, WASHINGTON

DRAWN:	DATE: 5/9/96	KEY ENVIRONMENTAL INCORPORATED
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

KEY ENVIRONMENTAL, INC.

ISSUE DATE:

ROSSLYN FARMS INDUSTRIAL PARK
1200 ARCH ST., SUITE 200
CARNEGIE, PA 15106

NOTES: DATA FOR FIGURE PROVIDED TO KEY ENVIRONMENTAL FROM PARAMETRIX, INC. MAY, 1996. SHORELINE, PARK BOUNDARY, SITE STRUCTURES, DOCKS, AND RAILROAD DIGITIZED BY KEY ENVIRONMENTAL, INC. FROM SEATTLE NORTH 7.5 X 15 MINUTE QUADRANGLE TOPOGRAPHIC MAP, USGS, 1983. DISTRIBUTION OBTAINED BY LINEAR INTERPOLATION OF DATA POINTS.

REV #	DATE	DESCRIPTION	APPD
△			
△			
△			

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.

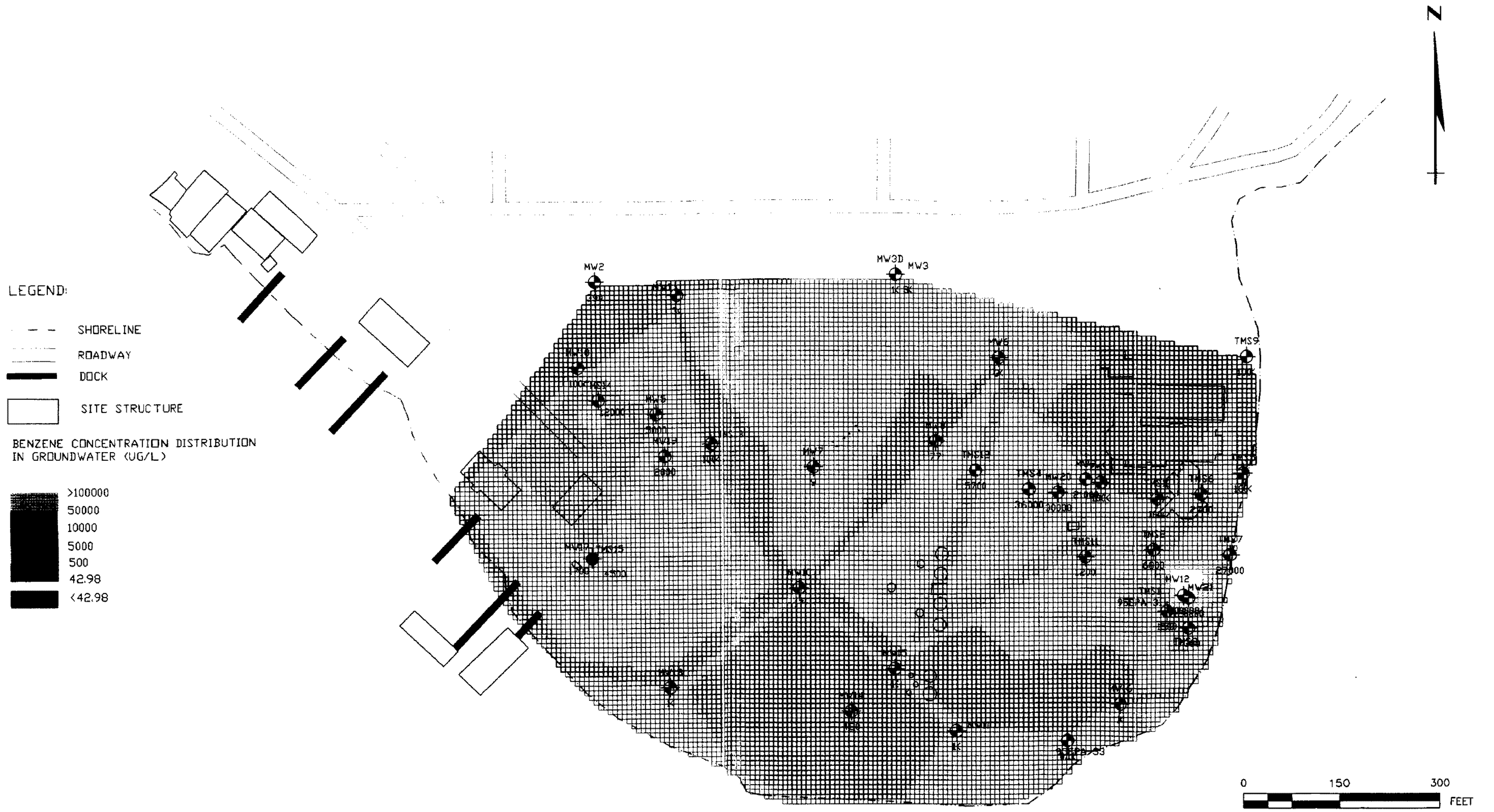
Since this Phase 1 effort is intended to provide input for future planning purposes, it was determined that using a range of reasonable groundwater contaminant concentration values would be most beneficial. This range was developed using two approaches described below.

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

CITY OF SEATTLE GAS WORKS PARK SEATTLE, WASHINGTON	
DRAWN:	DATE: 5/9/96
CHKD:	DATE:
APPD:	DATE:
SCALE:	1"=100'

KEY ENVIRONMENTAL INCORPORATED

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

REMEDIAL ALTERNATIVE SCREENING
PARAMETRIX, INC.

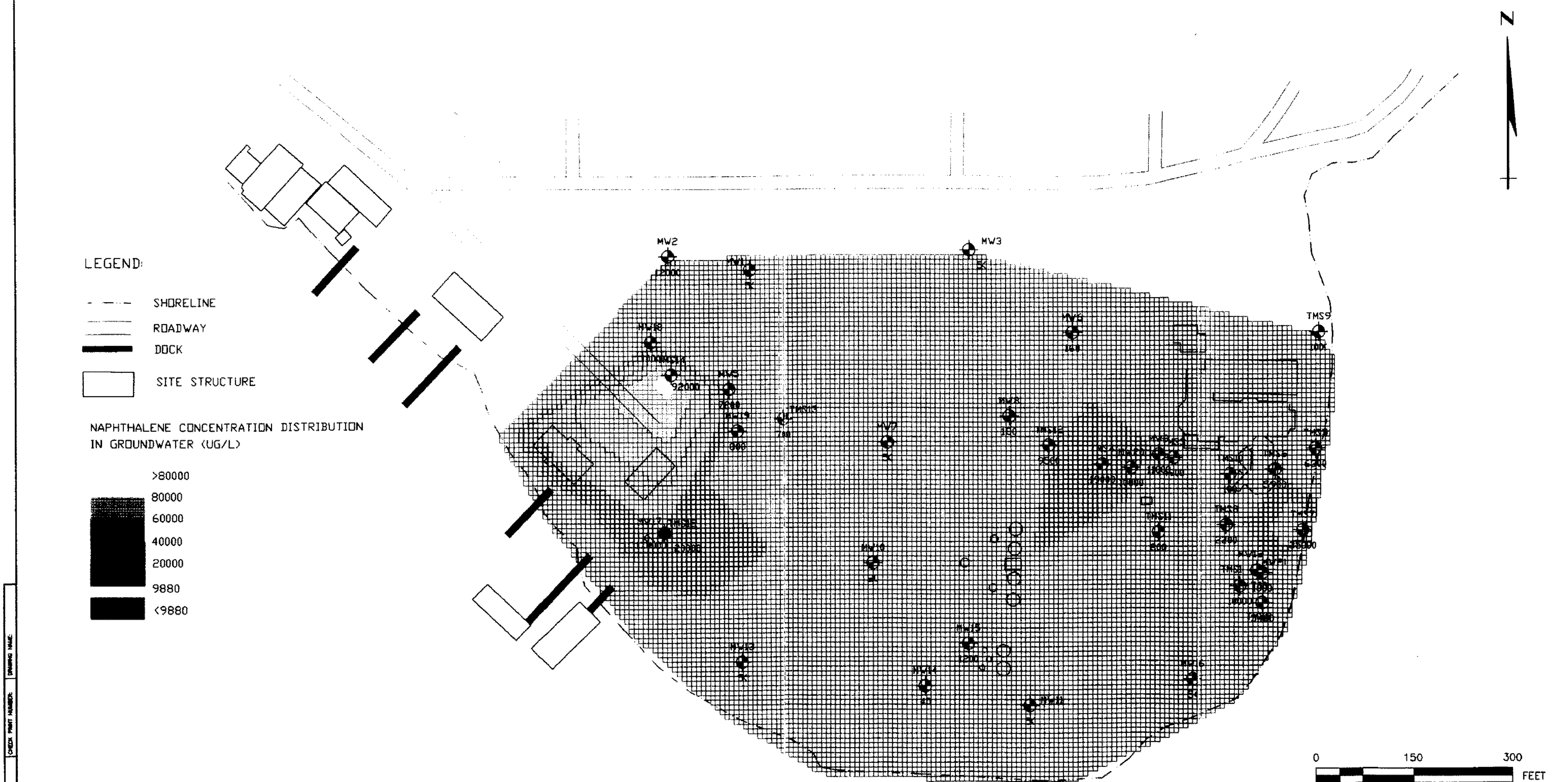
DRAWING NUMBER 96-111
FIGURE 4-2

KEY ENVIRONMENTAL, INC. ISSUE DATE:

ROSSLYN FARMS INDUSTRIAL PARK 1200 ARCH ST., SUITE 200 CARNEGIE, PA 15106

NOTES: DATA FOR FIGURE PROVIDED TO KEY ENVIRONMENTAL FROM PARAMETRIX, INC. MAY, 1988. SHORELINE, PARK BOUNDARY, SITE STRUCTURES, DOCKS, AND RAILROAD DIGITIZED BY KEY ENVIRONMENTAL, INC. FROM SEATTLE NORTH 7.5 x 15 MINUTE QUADRANGLE TOPOGRAPHIC MAP, USGS, 1983. DISTRIBUTION OBTAINED BY LINEAR INTERPOLATION OF DATA POINTS.

REV #	DATE	DESCRIPTION	APPD



LAW 09781

CITY OF SEATTLE
GAS WORKS PARK
SEATTLE, WASHINGTON

DRAWN:	DATE: 5/9/96
CHKD:	DATE:
APPD:	DATE:
SCALE:	1"=100'

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

KEY ENVIRONMENTAL, INC. | ISSUE DATE:

ROSSLYN FARMS INDUSTRIAL PARK 1200 ARCH ST., SUITE 200 CARNEGIE, PA 15106

NOTES: DATA FOR FIGURE PROVIDED TO KEY ENVIRONMENTAL FROM PARAMETRIX, INC. MAY, 1996. SHORELINE, PARK BOUNDARY, SITE STRUCTURES, DOCKS, AND RAILROAD DIGITIZED BY KEY ENVIRONMENTAL, INC. FROM SEATTLE NORTH 7.5 X 15 MINUTE QUADRANGLE TOPOGRAPHIC MAP, USGS, 1983. DISTRIBUTION OBTAINED BY LINEAR INTERPOLATION OF DATA POINTS.

REV #	DATE	DESCRIPTION	APPD

EDITED BY: | DATE: | TIME: | EDITING TIME: | CHECK PRINT NUMBER: | DRAWING NAME:

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 Biodegradation—In Situ or Ex Situ

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 <u>Excavate, Transport, Treat or Dispose Of, Replace with Clean Fill On-Site</u>

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 <u>Cost Summary for Soils Alternatives</u>

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 GROUND-WATER

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 $\mu g/L$ 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

Cole, D.W., and P.S. Machno. December 22, 1971. Myrtle Edwards Park—A Study of the Surface and Subsurface Soil Materials. Submitted to the city of Seattle, Department of Parks and Recreation. 12 pp. + Appendices.

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

HDR Engineering, Inc. April 1988. Environmental Testing for Gas Works Park Play Barn, Investigation Report. Prepared for City of Seattle Department of Parks and Recreation. 17 pp. + Appendices.

HDR Engineering, Inc. June 17, 1988. Health and Safety Plan, Gas Works Park, Seattle, Washington. Prepared for City of Seattle Department of Parks and Recreation.

HDR Engineering, Inc. and EcoChem. June 17, 1988. Quality Assurance Plan, Gas Works Park, Seattle, Washington. Prepared for City of Seattle Department of Parks and Recreation. 13 pp.

HDR Engineering, Inc. June 17, 1988. Sampling Plan, Gas Works Park, Seattle, Washington Prepared for City of Seattle Department of Parks and Recreation. 34 pp. + Appendices.

HDR Engineering, Inc. June 17, 1988. Site Management Plan, Gas Works Park, Seattle, Washington. Prepared for City of Seattle Department of Parks and Recreation. 16 pp. + Appendices.

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 pp. + Appendices.

HDR Engineering. October 1988. Presentation on the Final Report Focused Field Investigation and Irrigation Feasibility Study Gas Works Park.

HDR Engineering, Inc. March 20, 1989 draft. Treatability Study Work Plan for City of Seattle Parks and Recreation Department, Gas Works Park. Prepared for City of Seattle Department of Parks and Recreation. 45 pp. + appendices.

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

Ongerth, J.E. April 4, 1985. Draft Evaluation of Health Risk for Public Use of Gas Works Parks, Department of Environmental Health, University of Washington, The Gas Works Parks Risk Evaluation Panel, appointed by Charles Royer, Mayor, Seattle, Washington.

Parametrix, Inc. and HDR Engineering, Inc. November 1989. Draft Environmental Impact Statement, Gas Works Park Phase II, prepared for the City of Seattle, Department of Parks and Recreation.

Parametrix, Inc. and HDR Engineering, Inc. April 1990. Preliminary Copy, Final Environmental Impact Statement, Gas Works Park Phase II, prepared for the City of Seattle, Department of Parks and Recreation.

Parametrix, Inc. July 31, 1992. Lake Union Capping Feasibility Study. Prepared for City of Seattle Planning Department, funded by Washington Centennial Clean Water Fund Program.

Richard Haag Associates, Inc. April 1971. A Report Substantiating the Master Plan for Myrtle Edwards Park, City of Seattle.

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.

Sabol, M.A, G.L. Turney, and G.N. Ryals. 1988. Evaluation of Available Data on the Geohydrology, Soil Chemistry, and Groundwater Chemistry of Gas Works Park and Surrounding Region, Seattle, Washington. U.S. Geological Survey Water-Resources Investigations Report 87-4045. Prepared in cooperation with the Washington Department of Ecology.

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.

Tetra Tech, Inc. April 1985. Field Operations Plan, Gas Works Park Groundwater Investigation. Prepared for City of Seattle Department of Parks and Recreation. 36 pp.

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 pp.

Tetra Tech, Inc. June 1987. Gas Works Park Groundwater Investigation and Site Evaluation. Prepared for City of Seattle Department of Parks and Recreation.57 pp.

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.

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.

Turney, G.L., and D.F. Goerlitz. 1990. Organic Contamination of Groundwater at Gas Works Park, Seattle, Washington. Groundwater Monitoring Review, Summer 1990.

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

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.

Yake, B., D. Norton, and M. Stinson. October 1986. Application of the Triad Approach to Freshwater Sediment Assessment: An initial Investigation of Sediment Quality near Gas Works Park, Lake Union, Water Quality Investigations Section, Department of Ecology, Olympia, Washington.

Report of Seattle Gas Company to the Public Safety Committee, of the City Council of the City of Seattle on Steps Taken to Comply with Requirements of City Ordinance No. 64,604. June 18, 1935.

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

Gas Works Park, Soils Tests, Information and Related Correspondence, 1970-1977.

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 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

LAW 09824

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	Il-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

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

LAW 09830

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

LAW 09832

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

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

LAW 09834

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

LAW 09835

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

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

LAW 09843

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