Draft Final
Feasibility Study Report

Boeing Renton Facility

Renton, Washington

Prepared for:

The Boeing Company
Seattle, Washington

June 2008

Project No. 8888

Geomatrix

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Prepared by:

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EXECUTIVE SUMMARY

1.0 INTRODUCTION

The Boeing Company (Boeing) Renton Plant (Facility) is located in the City of Renton, Washington (Figure ES-1). In 1941, this property was selected by the U.S. government to be the site of a U.S. Air Force seaplane facility, and construction was initiated on a 95-acre parcel of the property that was originally a marsh. In 1945, a 5,000-foot runway was constructed west of the original 95-acre parcel on adjacent land reclaimed from Lake Washington, which later became the City of Renton Municipal Airport. The U.S. government built aircraft on the property until 1947, when it phased out aircraft production. In 1955, Boeing resumed aircraft production at the Facility. Boeing purchased the original 95 acres from the Air Force in 1962.

On August 8, 1980, Boeing notified the U.S. Environmental Protection Agency (EPA) Region 10 of its dangerous waste management activities, and the EPA assigned the generator identification number WAD009262171 for the Renton Facility. On November 18, 1980, Boeing filed the original Resource Conservation and Recovery Act (RCRA) Part A permit application for the storage of dangerous wastes in a container storage unit (CSU) at Building 4-78 and in dangerous waste tanks at the Facility.

On November 4, 1994, the Washington State Department of Ecology (Ecology) obtained authorization from EPA Region 10 to implement RCRA corrective action requirements using an enforceable order or decree pursuant to the Model Toxics Control Act (MTCA) regulations (specified in Washington Administrative Code [WAC] Chapter 173-340). Boeing and Ecology entered into Agreed Order No. DE 97HZ-N233 (Agreed Order), which became effective on October 10, 1997, and addresses former releases of hazardous substances at the Facility.

Boeing has been working with Ecology to address historic releases of hazardous substances at the Facility for a number of years. Work that has been completed at the Facility includes detailed site characterization, closure of RCRA units, interim cleanup actions, implementation of institutional controls, and quarterly and semiannual monitoring of groundwater. Boeing has completed several requirements of the Agreed Order and has implemented programs to address corrective action requirements at the Facility. This work has included routine reporting, Interim Action Work Plans, the Remedial Investigation (RI) Work Plan, the final RI Report, and the Final Feasibility Study Work Plan (FSWP) required under the Agreed Order. The final FSWP was approved by Ecology on June 18, 2004. This Draft Final Feasibility Study Report is submitted in accordance with the requirements of the Agreed Order.

2.0 FEASIBILITY STUDY APPROACH

The final RI Report for the Facility presents a definitive assessment of historic hazardous substance releases from the Facility. The RI includes an assessment of 37 solid waste management units (SWMUs) and areas of concern (AOCs) identified in the Agreed Order. Based on the RI, 28 SWMUs and AOCs were determined to require no further action, and 9 SWMU and AOC groups were recommended for inclusion in the FS. Subsequent to issuance of the final RI, three additional AOCs were identified that were not included in the Agreed Order. For logistical reasons, one AOC group defined in the RI (AOC-001, -002, and -003), was separated into two sites. One additional AOC (AOC-034/-035) has been added to the FS since the first draft FS Report was submitted. Therefore, 14 different sites (SWMU and AOC groups) are addressed in this Draft Final FS Report (see Table ES-1).

Effective December 1, 2003, the City of Renton rezoned the Facility and some adjacent areas to allow mixed land use. Although the rezoning will allow changes in the use of the Facility property, Boeing will continue to build commercial airplanes there for the foreseeable future. The Facility and the areas adjacent to each of the SWMUs and AOCs addressed in this FS Report are currently used only for industrial purposes and are expected to remain in industrial use. Based on review of the land use and use characteristics on and adjacent to the Facility, it has been determined that the Facility meets the requirements of “zoned for industrial use” of WAC 173-340-745. It is Boeing’s expectation that the changed land use category (UC-N) will meet Ecology’s criteria for being “zoned for industrial use” until Boeing ceases the production of aircraft at the Facility.

The overall remediation objective of this FS is to evaluate appropriate remedial alternatives to reduce the risks to human health and the environment resulting from constituents of concern (COCs) in soil and groundwater and to select the preferred remedial alternative for each of the 14 sites. The active use of the Facility for manufacturing airplanes creates significant constraints for remediation. The preferred remedial alternative for each SWMU or AOC must be compatible with heavy industrial traffic, must not create long-term restrictions for access to the various portions of the property, must avoid impacting the numerous existing structures/buildings/underground utilities on the Facility, and must avoid any detrimental impact to the workers at the Facility. The plans for continued industrial use also facilitate the effective implementation of institutional controls, which will be a key element in remedial alternatives.

As discussed in the FSWP, groundwater beneath the Facility is not used and is not expected to be used beneficially in the future (Geomatrix, 2004c). Facility groundwater discharges to adjacent or nearby surface water bodies and is not used as a resource for any purpose. The final RI Report indicates that groundwater flows from the Facility to these surface water bodies—either the Cedar River Waterway or Lake Washington (Roy F. Weston [Weston], 2001a). Because these surface water bodies are in close proximity to the Facility, remedial alternatives must attain a cleanup standard that is protective of these surface water bodies.

Cleanup standards have been established for each of the 14 sites evaluated in this FS. To be complete, each site-specific cleanup standard must include the cleanup level, point of compliance (POC), and any applicable regulatory requirements. A cleanup standard addressing the above three general requirements has been established for each remedial alternative to ensure that the potential cleanup action would be protective of human health and the environment.

A preliminary screening of remedial technologies was presented in the FSWP. This screening resulted in a list of potentially applicable remedial technologies to be used in a focused FS. The screening process identified technologies compatible with site constituents, ongoing and expected future site use and activity, and the geologic setting for the Facility. Potentially applicable remedial alternatives were developed from the remedial technologies described in the FSWP, and a conceptual design was prepared for each remedial alternative. The alternatives for each SWMU and AOC were then evaluated relative to the criteria specified in the MTCA rules to select the preferred alternative for each site.

3.0 SUMMARY OF FEASIBILITY STUDY RESULTS

This section summarizes the preferred remedial alternative for each of the 14 sites addressed in this FS report. The key issues, preferred remedial alternatives, and estimated cost for the preferred alternatives are presented in Table ES-2. The total estimated net present value (NPV) cost for implementation of all preferred alternatives is about $6.5 million.

3.1 SWMU-168 (BUILDING 5-50)

Data collected for the RI in 1999 indicate that soil at this site was affected by low levels of methylene chloride and groundwater was affected by vinyl chloride (VC) at a concentration just above the cleanup level. Enhanced bioremediation and monitored attenuation (MA) is the preferred alternative for the SWMU-168 site, because it is more effective than the lowest cost remedial alternative considered for the site and the increased costs are not disproportionate to the increased benefits. Under this alternative, affected soils would remain capped by well-maintained pavement or tarmac to prevent potential runoff of affected soil and infiltration of rainfall into the affected area. The groundwater cleanup standard for this alternative will be the groundwater cleanup levels cited in Section 3 and a conditional point of compliance (CPOC) located on leased property downgradient of the source area. An appropriate groundwater monitoring network, as discussed in Section 6, would be implemented to support this remediation approach for SWMU-168. The City of Renton, the owner of the area where the CPOC would be located, has indicated support to allow a CPOC on City property.

3.2 SWMU-172/174 (BUILDING 5-08/5-09)

The site characterization data for this site were collected in 1999 and 2000. The soil COCs identified at this site include chlorinated solvents, benzene, and several metals. Groundwater COCs identified in the RI included chlorinated solvents, degradation products of the solvents, benzene, one semivolatile organic compound (SVOC), and arsenic. Soil vapor extraction (SVE), enhanced bioremediation, and MA is the preferred remedial alternative for the SWMU-172/174 site. Although groundwater modeling indicates that natural attenuation of organic COCs is occurring, natural biodegradation alone would not be sufficient to achieve cleanup levels at the CPOC. SVE would remove organic COCs in the vadose zone, thus resulting in permanent destruction of volatile constituents. Enhanced bioremediation would promote rapid degradation of the organic COCs to nontoxic by-products. SVE in combination with enhanced bioremediation would be effective in attaining the cleanup standard at an on-site CPOC in a reasonable time frame.

3.3 SWMU-179 (BUILDING 4-76)

The SWMU-179 cistern was removed in November 1990. After the buildings restricting the original excavation were demolished in early 2004, additional soil was removed and confirmation sampling was conducted, which confirmed that affected soil exceeding the approved cleanup levels in the FSWP had been removed from the site. Based on the recent cleanup action implemented for this site, no additional cleanup is necessary for SWMU-179, because the soil and groundwater COCs at this site (Total Petroleum Hydrocarbons, Diesel range [TPH-D] and arsenic) meet the approved cleanup levels for soil and groundwater. The standard POC for soil and groundwater has been met at SWMU-179, and the site is currently in compliance with applicable environmental regulations.

3.4 BUILDING 4-78/79 SWMU/AOC GROUP

The COCs identified in the final RI Report for this SWMU and AOC group included trichloroethene (TCE) and its degradation products, 1,1-dichloroethene (1,1-DCE), benzene, and total petroleum hydrocarbons, gasoline range (TPH-G) in groundwater. Although no soil COCs were identified in the final RI Report it has been assumed that soil COCs are the same as groundwater COCs. The preferred cleanup action for the Building 4-78/79 SWMU/AOC group includes SVE, enhanced bioremediation, MA, and monitored natural attenuation (MNA). This alternative would provide a more extensive and rapid remediation than the other alternatives considered. The SVE system would remove COCs from vadose zone soil within both source areas at this site, thus resulting in permanent destruction of the volatile constituents. Enhanced bioremediation for the solvent source area and plume would promote rapid degradation of the solvents to nontoxic by-products. Groundwater modeling conducted for the site indicates that natural attenuation for the benzene plume would degrade the petroleum hydrocarbons present in the plume before the compounds reached the CPOC.

3.5 FORMER FUEL FARM

Site characterization data for the former fuel farm in the final RI Report identified several soil COCs, including benzene, 2-methylnaphthalene, total petroleum hydrocarbons, jet fuel A range (TPH-Jet A), and TPH-D. The groundwater COCs identified for this site in the final RI Report were TPH-D and TPH-Jet A. Monitored natural attenuation is the preferred remedial alternative for the former Fuel Farm. This alternative would provide the greatest benefit at the lowest cost. Groundwater samples collected downgradient from the source areas and upgradient from the Cedar River Waterway show that groundwater COCs have not migrated to the waterway even though the release in the source area occurred many years ago; this indicates that natural attenuation is an active mechanism for this site. Downgradient observations indicate that natural biodegradation is active and that the groundwater cleanup levels would be attained at the CPOC located just west of East Perimeter Road, which is just west of the Cedar River Waterway. Modeling for the site has also indicated that this alternative would attain the cleanup standard at the CPOC. The City of Renton has indicated general agreement to allow a CPOC to be located on City property.

3.6 AOCs-001 and -002 (Building 4-81)

In the final RI Report, AOCs-001 and -002 were combined with AOC-003 as a single AOC group. For the FS, AOCs-001 and -002 have been separated from AOC-003 to facilitate development and evaluation of remedial alternatives. Based on the results presented in the final RI Report and subsequent investigations reported in the FSWP, soil COCs for AOC-001/002 include TCE, degradation products from TCE, and TPH-G. Groundwater COCs for this site include benzene, chlorinated solvents, solvent degradation products, and one SVOC. An interim measure conducted in 2005 included excavation of the source area and enhanced bioremediation within the source area. The preferred alternative for AOC-001/002 includes enhanced bioremediation and MA for the affected groundwater plume for this site. The remediation costs for this alternative are not considered disproportionate, and this alternative would provide a more rapid restoration time frame than the other alternatives considered. Excavation of affected soil exceeding the soil cleanup levels has permanently remediated much of the affected site soil. The cap provided by the existing, well-maintained pavement or tarmac would prevent runoff of affected soil and limit infiltration of surface water. Enhanced bioremediation would rapidly destroy constituents present in groundwater. Site-specific cleanup levels would be attained at an on-site CPOC within a reasonable time frame.

3.7 AOC-003 (Building 4-81)

The soil COC identified for AOC-003 in the final RI Report was TCE. Groundwater COCs identified for this site in the RI included tetrachloroethene (also known as perchloroethylene or PCE) and VC. The preferred remedial alternative for AOC-003 includes enhanced bioremediation and MA. Remediation costs for this alternative are not considered disproportionate, and this alternative would provide more rapid remediation than the other alternative considered. The groundwater cleanup standard for this alternative will be the groundwater cleanup levels for AOC-003 COCs discussed in Section 3 and an on-site CPOC located downgradient of this site and upgradient of AOCs-001 and -002. Given that potential risks from the site COCs in soil and groundwater can be managed through institutional controls until bioremediation and MA attain cleanup levels, no other measures are required to attain remediation objectives and standards.

3.8 AOC-004 (Building 4-21)

Based on the final RI Report, the soil COCs for AOC-004 included several VOCs and TPH-G. The groundwater COCs were benzene, lead, and TPH-G. The preferred alternative for AOC-004 includes enhanced bioremediation and MA. Limited quantities of affected soil would also be removed under this alternative. The remediation costs for this alternative are not considered disproportionate, and this alternative would provide more rapid remediation than the other alternative considered. The groundwater cleanup standard for this alternative is the groundwater cleanup levels discussed in Section 3 at an on-site CPOC located immediately downgradient of this site.

3.9 AOC-034/035 (BUILDING 4-41)

Although site characterization data from the RI indicated that no COCs for this AOC exceeded PCLs, it was added to the FS due to the presence of VC in groundwater that exceeded the cleanup level negotiated with Ecology for CPOCs at the Facility. The preferred remedial alternative for AOC-034/035 includes enhanced bioremediation and MA. Remediation costs for this alternative are not considered disproportionate, and this alternative would provide more rapid remediation than the other alternatives considered. The groundwater cleanup standard for this alternative will be the groundwater cleanup levels discussed in Section 3 and an on-site CPOC located downgradient of this site at the Facility property boundary. Given that potential risks from the site COCs in soil and groundwater can be managed through institutional controls until bioremediation and MA attain cleanup levels, no other measures are required to attain remediation objectives and standards.

3.10 AOC-060 (BUILDING 4-42)

The COCs defined in the final RI Report for AOC-060 included TCE and its degradation products in groundwater. No soil COCs were defined for this site. Monitored natural attenuation was selected as the preferred alternative for AOC-060 because it would provide the greatest benefit at the lowest cost. Substantial evidence was collected during the RI and subsequent quarterly monitoring to demonstrate that natural biodegradation of organic COCs is active at this site. Groundwater samples collected downgradient from the source areas and upgradient from the Cedar River Waterway show that groundwater COCs have migrated off Facility property but have not been detected in wells close to the waterway since 2002. Modeling of natural attenuation at this site agrees with actual monitoring well data and indicates that groundwater cleanup levels would be attained at an off-site CPOC located in the adjacent Cedar River Trail Park within a reasonable time frame. Although groundwater COC concentrations have exceeded cleanup levels in a limited portion of the park, they would present no significant risks to park users.

The City of Renton is the property owner for the Cedar River Trail Park and Nishiwaki Lane (the access road to the park); the City has indicated general agreement to allow a CPOC to be located in the park.

3.11 AOC-090 (BUILDING 4-65)

During the interim action source removal conducted at AOC-090 in 2004, approximately 1,500 cubic yards of contaminated soil was removed from this site. Following soil removal, approximately 17 tons of molasses was added to the excavation area to promote and accelerate degradation of VOCs in soil and groundwater. Evidence collected during the RI and supplemental RI demonstrated that natural biodegradation of organic site COCs is active at this site. Enhanced bioremediation and monitored attenuation would provide the greatest benefit at the lowest cost for AOC-090 and was selected as the preferred remedial alternative.

Soil COCs identified for AOC-090 in the final RI Report and subsequent investigations include several VOCs (including chlorinated solvent degradation products), SVOCs, TPH-G, TPH-D, total petroleum hydrocarbons, motor oil range (TPH-MO), and several metals. Groundwater COCs for this site include VOCs (including chlorinated solvent degradation products), TPH-G, TPH-D, and TPH-MO. Groundwater samples collected downgradient from the source areas and upgradient from the Cedar River Waterway show that groundwater COCs have migrated off Facility property. Separate CPOCs have been proposed for the shallow and intermediate groundwater zones due to different flow paths in the two zones. Groundwater monitoring data indicate that COCs are present at the CPOCs at concentrations exceeding cleanup levels. Boeing has remediated the source area to the extent practicable and is continuing to implement interim measures for groundwater remediation. The preferred alternative is expected to attain cleanup levels at the CPOCs within a reasonable time frame. Groundwater characterization data indicate that the site inorganic COCs are present only in a limited area near the source areas and are not migrating with groundwater.

While the affected soil and the groundwater plume extend beyond the Facility property line, the off-site area is owned by the City of Renton and consists of a public road and the Cedar River Trail Park (also owned by the City). The City of Renton has indicated general agreement to allow a CPOC to be located on City property. A risk assessment presented in the FSWP indicates that the VOCs present in groundwater beneath the park do not create a significant risk to park users.

3.12 AOC-092 (BUILDING 4-20)

The COCs defined for AOC-092 include TPH-G in soil and benzene plus TPH-G in groundwater. The preferred remedial alternative for AOC-092 includes source area excavation, enhanced bioremediation, and MA. The remediation costs for this alternative are not considered disproportionate, and this alternative would provide more rapid remediation than the other alternatives considered. Under this remediation approach, affected soils would be removed from the site to the extent practicable, and groundwater constituents would be actively degraded in situ. Affected soils under the adjacent building would remain beneath the building, which would contain the soils and prevent potential runoff of affected soil and limit infiltration of rainfall to the source area.

3.13 AOC-093 (BUILDING 4-20)

Source Area Excavation and monitored natural attenuation is the preferred remedial alternative selected for AOC-093. Limited excavation and removal of affected soils would be performed; some affected soils would remain covered by the pavement or tarmac, which would prevent potential runoff of affected soil and limit infiltration of rainfall. Given that only TPH-G was detected in soil and no COCs were detected in groundwater, risks from this site can be managed through institutional controls. Cleanup levels would be attained within a reasonable time frame at an on-site CPOC located immediately downgradient from AOC-093. An appropriate groundwater monitoring program would be implemented to ensure that this alternative attains the cleanup standard.

3.14 AOC-094 (BUILDING 5-08)

No remedial action is needed at AOC-094 to achieve compliance with applicable environmental regulations. The only COC identified at this site is TPH-G in soil; measured concentrations exceeded the MTCA Method A soil cleanup level. Site data indicate that groundwater has not been affected by the TPH-G present in soil. Therefore, site-specific data for extractable petroleum hydrocarbons (EPH) and volatile petroleum hydrocarbons (VPH) were used to calculate site-specific soil cleanup levels for this site. The measured TPH-G in soil at this site is below the site-specific MTCA Method B cleanup level. Therefore, the site is currently in compliance with MTCA regulations and no remedial action is necessary. The standard POC for soil and groundwater has been achieved at AOC-094.

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TABLE ES-1

FEASIBILITY STUDY SWMUs[1] AND AOCs[2]

Boeing Renton Facility
Renton, Washington

SWMU/AOC
SWMU-168, Building 5-50
SWMU-172/174, Buildings 5-08 and 5-09
SWMU-179, Building 4-76
Building 4-78/79 SWMU/AOC Group (SWMU 181, AOC-013, -014, -015, -026, -037, and -054)
Former Fuel Farm SWMU/AOC Group (AOC-046, -047, and -048)
AOC-001/002, Building 4-81
AOC-003, Building 4-81
AOC-004, Building 4-21
AOC-034/035, Building 4-41
AOC-060, Building 4-42
AOC-090, Building 4-65 Yard
AOC-092, Building 4-20
AOC-093, north of Building 4-20
AOC-094, west of Building 5-08

Notes:
1. SWMU = solid waste management unit.
2. AOC = area of concern.

TABLE ES-2

PREFERRED REMEDIAL ALTERNATIVES
Boeing Renton Facility
Renton, Washington

Site	Key Issues	Preferred Alternative	Initial Cost[1]	Net Present Value[1]
SWMU-168 (Building 5-50)	Small site on leased property. Soil COCs: methylene chloride (low concentration). Groundwater COCs: VC (low concentration).	**Alternative 3 - Enhanced Bioremediation and Monitored Attenuation:** Injected substrate to address groundwater COCs. Existing cap will stabilize COCs. On-site CPOC near leased property line.	$57,800	$409,000
SWMUs-172/174, (Buildings 5-08 & 5-09)	Moderate size site on leased property. Soil COCs: PCE, TCE, methylene chloride, benzene, metals. Groundwater COCs: PCE, TCE, 1,1-DCE, *cis* -1,2-DCE, methylene chloride, VC, chloromethane, benzene, *bis* -2-ethylhexyl phthalate, metals. Affected soils extend beneath bldg. Groundwater VOC plume extending to lease property line. Strong evidence of active natural biodegradation.	**Alternative 2 - Soil Vapor Extraction, Enhanced Bioremediation, Monitored Attenuation.** SVE addresses source area. Enhanced bioremediation for plume control. On-site CPOC near leased property line.	$354,600	$900,000
SWMU-179 (Building 4-76)	Small site; located on Facility property. Excavation and removal of affected soil completed in 2004. Confirmation sampling for soil and groundwater confirm attainment of cleanup levels.	Cleanup completed. No further action required.	$0	$0
Building 4-78/79 SWMU/AOC Group	Large site on Facility property. Two separate source areas for solvents (former container storage area) and TPH-G/benzene (fuel USTs and piping). Solvent source area beneath Bldg. 4-78. Two offset plumes with slight overlap. Soil COCs: TCE, *cis* -1,1-DCE, *cis* -1,2-DCE, VC, TPH-G, benzene. Groundwater COCs: TCE, 1,2-DCE, VC, TPH-G, benzene. Strong evidence of natural biodegradation.	**Alternative 2 - Soil Vapor Extraction, Enhanced Bioremediation, Monitored Attenuation, and Monitored Natural Attenuation:** SVE addresses both soil source areas. Enhanced bioremediation for solvent source area and plume. MNA for TPH-G/benzene plume. On-site CPOC.	$464,300	$1,140,000

TABLE ES-2

PREFERRED REMEDIAL ALTERNATIVES
Boeing Renton Facility
Renton, Washington

Site	Key Issues	Preferred Alternative	Initial Cost[1]	Net Present Value[1]
Former Fuel Farm	Large site located on leased property. Residual TPH remains at eastern edge of lease property. An air sparge/bioventing interim measure has been operated at site for about 9 years. Soil COCs: TPH-Jet Fuel, TPH-D, benzene, methylnaphthalene. Groundwater COCs: TPH-Jet Fuel, TPH-D. Absence of downgradient plume indicates biodegradation is active.	**Alternative 3 - Monitored Natural Attenuation:** BIOSCREEN modeling shows that MNA would be effective. On-site/Off-site CPOC.	$46,000	$482,000
AOCs-001 and -002 (Building 4-81)	Primary and secondary source areas; site is on Facility property. Soil COCs: TPH-G, *cis*-1,2-DCE, TCE, and VC. GW COCs: TCE, *cis*-1,2 DCE, and VC. Strong evidence of active natural biodegradation.	**Alternative 1 - Enhanced Bioremediation and Monitored Attenuation:** Primary source area to be excavated into shallow water table. Enhanced bioremediation for primary and secondary source areas. On-site CPOC.	$78,900	$524,000
AOC-003 (Building 4-81)	Small site; located on Facility property. Soil COCs: TCE (low concentration). GW COCs: PCE (low concentration) and VC (low concentration). Strong evidence of active natural biodegradation.	**Alternative 2 - Enhanced Bioremediation, and Monitored Attenuation:** Bioremediation for source area and plume. On-site CPOC upgradient of AOCs-001 and -002.	$67,400	$405,000
AOC-004 (Building 21)	Small site; located on Facility property. Soil COCs: benzene, ethylbenzene, toluene, acetone, TPH-G. Groundwater COCs: benzene (low concentrations), TPH-G (low concentrations), lead (low concentrations). Limited plume suggests active natural biodegradation.	**Alternative 2 - Enhanced Bioremediation and Monitored Attenuation:** Excavation of source area soil in vadose zone, enhanced bioremediation for source area groundwater. Monitored attenuation for groundwater plume. On-site CPOC.	$89,400	$382,000

TABLE ES-2

PREFERRED REMEDIAL ALTERNATIVES

Boeing Renton Facility
Renton, Washington

Site	Key Issues	Preferred Alternative	Initial Cost[1]	Net Present Value[1]
AOC-034/035 (Building 4-41)	Small site; located on Facility property. Soil COCs: VC, *cis* -1,2-DCE. Groundwater COCs: VC, cis-1,1-DCE. Limited plume suggests active natural biodegradation.	**Alternative 2 - Enhanced Bioremediation and Monitored Attenuation:** Enhanced bioremediation for source area groundwater. Monitored attenuation for groundwater plume. On-site CPOC.	$61,000	$371,000
AOC-060 (Building 4-42)	Moderate site; source area on Facility property, plume extends off-site. Groundwater COCs: TCE, *cis* -1,2-DCE, VC. Plume presents no unacceptable risks to Cedar River Trail Park users. Strong evidence for natural biodegradation.	**Alternative 1 - Monitored Natural Attenuation:** BIOCHLOR modeling indicates that MNA would be effective in meeting remediation objectives. Off-site CPOC.	$32,300	$521,000
AOC-090	Large site; source area located on Facility property, plume extends off-site. Extensive source area soil excavation completed in 2004; enhanced bioremediation implemented for source area. Soil COCs: chlorinated solvents, petroleum hydrocarbons (gasoline, diesel, motor oil), metals. Groundwater COCs: chlorinated solvents, petroleum hydrocarbons (gasoline, diesel, motor oil). Strong evidence for active natural biodegradation of groundwater COCs.	**Alternative 2 - Enhanced Bioremediation and Monitored Attenuation:** Enhanced bioremediation implemented in Summer 2004 to be continued. Off-site CPOC.	$63,800	$670,000
AOC-092 (Building 4-20)	Small site; located on Facility property. Soil COCs: benzene, TPH-G. Groundwater COCs: benzene, TPH-G. Limited plume length suggests active natural biodegradation.	**Alternative 2 - Source Area Excavation, Enhanced Bioremediation, and Monitored Attenuation:** Excavate source area vadose zone soils. Enhanced bioremediation for source area with monitored attenuation for groundwater plume. On-site CPOC.	$58,200	$364,000

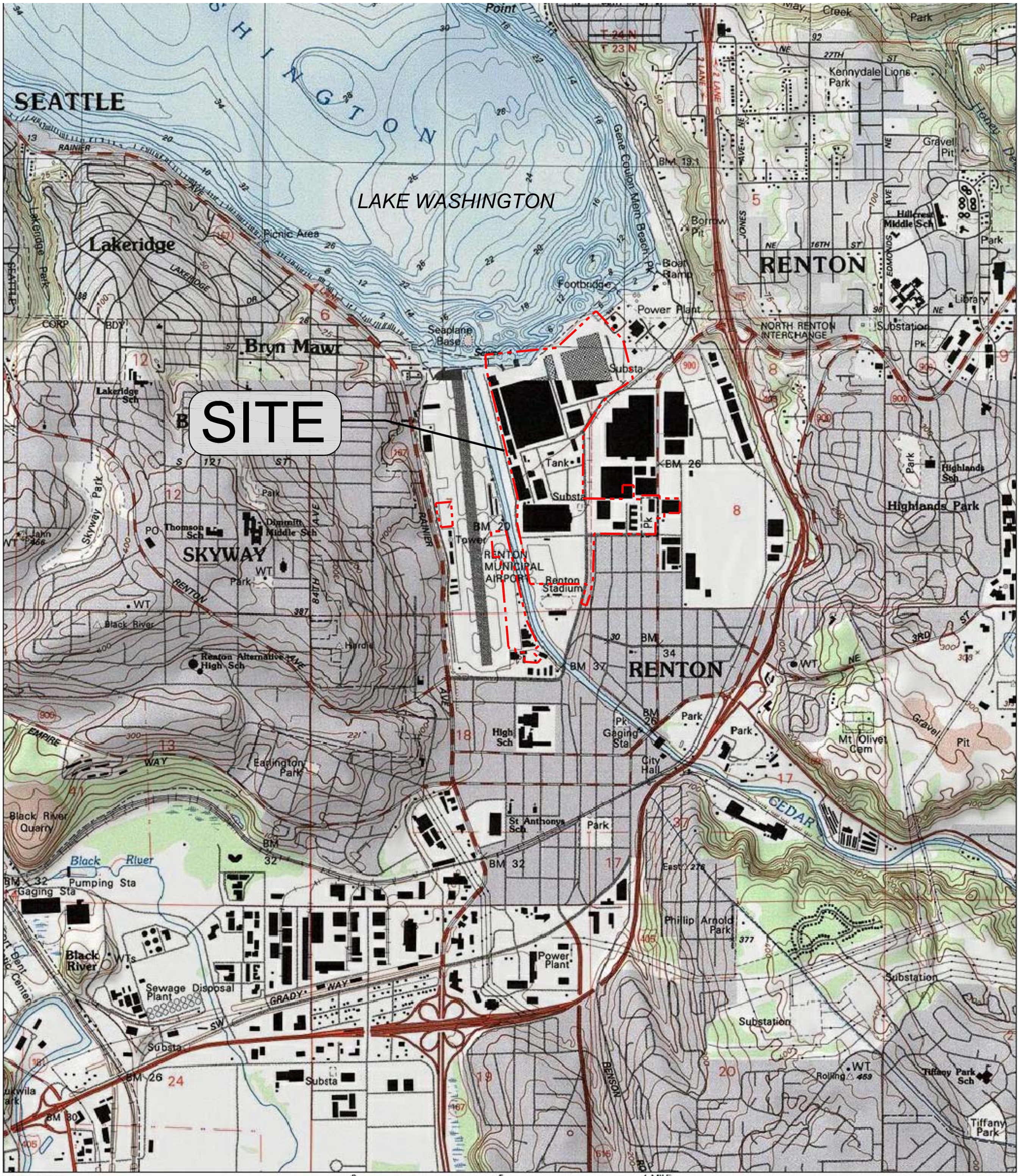
TABLE ES-2

PREFERRED REMEDIAL ALTERNATIVES

Boeing Renton Facility
Renton, Washington

Site	Key Issues	Preferred Alternative	Initial Cost[1]	Net Present Value[1]
AOC-093 (Building 4-20)	Small site located on Facility property. Soil COCs: TPH-G. No groundwater COCs detected. Located within groundwater plume for AOCs-001 and -002. Absence of groundwater COCs indicates active natural biodegradation.	**Alternative 1 - Source Area Excavation and Monitored Natural Attenuation:** Limited excavation and long-term monitoring, with monitoring program for AOCs-001 and -002 to confirm attainment of cleanup standard. On-site CPOC.	$29,700	$286,000
AOC-094	Small site; located on leased property. TPH-G detected in soil; no affected groundwater detected. Soil TPH-G is below cleanup level calculated using EPH/VPH data.	Preliminary assessment of TPH/EPH/VPH data indicate that soil TPH-G is below cleanup level. No remedial action is required.	$0	$0
		TOTAL	**$1,403,400**	**$6,454,000**

Notes:
1. Initial cost is the first year cost for implementation of the preferred alternative. Net Present Value cost is the present worth for full implementation of the alternative over a 15-year life with a 2% inflation rate and 7% discount rate. Details concerning the cost estimate are presented in Appendix B. All costs are in 2007 dollars.



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FACILITY BOUNDARY

SITE LOCATION MAP
Boeing Renton Facility
Renton, Washington

BOEING

By: APS	Date: 05/28/08	Project No. 8888
Geomatrix		Figure ES-1

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APPENDIXES

ACRONYMS & ABBREVIATIONS

Agreed Order	Agreed Order No. DE 97HZ-N233
AOC	Area of Concern
APA	aquifer protection area
ARAR	Applicable or relevant and appropriate requirements
AS	air sparging
bgs	below ground surface
Boeing	Boeing Company
BTEX	benzene, toluene, ethylbenzene, and xylene
CAP	cleanup action plan
cfm	cubic feet per minute
CFR	Code of Federal Regulations
cis-1,2-DCE	*cis*-1,2-dichloroethene
CLARC	Cleanup Levels and Risk Calculation
cm/s	centimeters per second
COC	constituent of concern
CPOC	conditional point of compliance
CSM	conceptual site model
CSU	container storage unit
1,1-DCE	1,1-dichloroethene
DNR	Washington State Department of Natural Resources
Ecology	Washington State Department of Ecology
EIA	Environmental Impact Assessment
EIS	Environmental Impact Statement
EPA	U.S. Environmental Protection Agency
EPH	extractable petroleum hydrocarbons
Facility	Boeing Renton Facility
FS	feasibility study
FSWP	FS Work Plan
GAC	granular-activated carbon
GC/MS	gas chromatography/mass spectrometry
IRIS	Integrated Risk Information System
IWAS	in-well air stripping
HAZWOPER	Hazardous Waste Operations and Emergency Response
HEAST	Health Effects Assessment Summary Table
HI	hazard index
HQ	hazard quotient
ICP	inductively coupled plasma
lbs	pounds
LNAPL	light nonaqueous phase liquid
MA	monitored attenuation
MCL	maximum contaminant level
MEK	methyl ethyl ketone

ACRONYMS & ABBREVIATIONS
(Continued)

mg/kg	milligrams per kilogram
mg/L	milligram per liter
mL	milliliter
µg/kg	micrograms per kilogram
µg/L	micrograms per liter
MNA	monitored natural attenuation
MTCA	Model Toxics Control Act
NAPL	nonaqueous phase liquids
NCEA	National Center for Environmental Assessment
NESHAPS	National Emission Standards for Hazardous Air Pollutants
NPV	net present value
ORC	oxygen-releasing compound
OSHA	Occupational Safety and Health Administration
OSWER	U.S. Environmental Protection Agency Office of Solid Waste and Emergency Response
PCE	tetrachloroethene
PCL	preliminary cleanup level
PEL	Permissible Exposure Limit
POC	point of compliance
PQL	practical quantitation limit
PRG	Preliminary Remediation Goal
PVC	polyvinyl chloride
PSCAA	Puget Sound Clean Air Agency
RCRA	Resource Conservation and Recovery Act
RCW	Revised Code of Washington
RFA	RCRA Facility Assessment
RI	remedial investigation
SAIC	Science Applications International Corporation
scfm	standard cubic feet per minute
SEPA	Washington State Environmental Policy Act
SIM	selected ion monitoring
SVE	soil vapor extraction
SVOC	semivolatile organic compound
SWMU	solid waste management unit
TCE	trichloroethene
TEA	terminal electron acceptor
TOC	total organic carbon
TPH	total petroleum hydrocarbons
TPH-D	TPH-diesel
TPH-G	TPH-gasoline
TPH-Jet	TPH-Jet Fuel A
TPH-MO	TPH-motor oil

ACRONYMS & ABBREVIATIONS
(Continued)

UC-N	Urban Center-North
USACE	U.S. Army Corp of Engineers
USCS	U.S. Soil Conservation Service
UST	underground storage tank
VC	vinyl chloride
VOC	volatile organic compound
VPH	volatile petroleum hydrocarbons
WAC	Washington Administrative Code
Weston	Roy F. Weston, Inc.
WISHA	Washington Industrial Safety and Health Act

Geomatrix

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DRAFT FINAL
FEASIBILITY STUDY REPORT
Boeing Renton Facility
Renton, Washington

1.0 INTRODUCTION

The Boeing Company (Boeing) has been working with the Washington State Department of Ecology (Ecology) to address historic releases of hazardous substances at the Boeing Renton Facility (Facility) located in the City of Renton, Washington. Work that has been completed at this site includes detailed site characterization, closure of Resource Conservation and Recovery Act (RCRA) units, interim cleanup actions, implementation of institutional controls, and quarterly and semiannual monitoring of groundwater. Boeing has entered into Agreed Order No. DE 97HZ-N233 (Agreed Order) with Ecology to address former releases at the Facility. The Agreed Order was issued under the Revised Code of Washington (RCW) 70.105D.050(1) and Washington Administrative Code (WAC) 173-303-646(3)(a), and became effective on October 10, 1997. In accordance with the requirements of the Agreed Order, this Draft Final Feasibility Study (FS) Report has been prepared for the Facility and is being submitted to Ecology.

1.1 BACKGROUND

The location of the Facility is shown on Figure 1-1. In 1941, the Facility property was selected by the U.S. government to be the site of a U.S. Air Force seaplane facility. That year, construction was initiated on a 95-acre parcel of the property that was originally a marsh. A 5,000-foot runway was constructed in 1945 west of the original 95-acre parcel on land reclaimed from Lake Washington, which later became the City of Renton Municipal Airport. The U.S. government built aircraft at the facility until it phased out aircraft production in 1947. In 1955, Boeing resumed aircraft production at the Facility, and in 1962 Boeing purchased the original 95 acres from the Air Force.

On August 8, 1980, Boeing notified the U.S. Environmental Protection Agency (EPA) Region 10 of its dangerous waste management activities, and the EPA assigned the generator identification number WAD009262171 for the Renton Facility. On November 18, 1980, Boeing filed the original RCRA Part A permit application for the storage of dangerous wastes in a container storage unit (CSU) at Building 4-78 and in dangerous waste tanks at the Facility.

In May 1990, Science Applications International Corporation (SAIC) performed a visual site inspection of the Facility on behalf of EPA Region 10 as part of a RCRA Facility Assessment (RFA). Ecology had previously approved closure of all Facility tanks in the original Part A permit application. In December 1997, the above-grade portions of the existing Building 4-78 CSU were closed in accordance with the Ecology-approved closure plan. Currently, hazardous wastes are not stored on the Facility for more than 90 days and no RCRA permit is required.

On November 4, 1994, Ecology obtained authorization from EPA Region 10 to implement RCRA corrective action requirements using an enforceable order or decree pursuant to Model Toxics Control Act (MTCA) regulations (specified in Chapter 173-340 WAC). Boeing and Ecology signed an Agreed Order, which became effective on October 10, 1997.

1.1.1 Land Use and Zoning

The Boeing Company is currently consolidating its commercial airplane operations at the Renton Facility. Consolidation of operations will create opportunities for Boeing to reoccupy or surplus its nonessential properties and buildings, while allowing it to continue to manufacture airplanes at the Facility. Effective December 1, 2003, the City of Renton rezoned the Facility and some adjacent areas to allow mixed land use. Although the zoning will allow changes in the use of the Facility property, Boeing will continue to build commercial airplanes there for the foreseeable future. The Facility and the areas adjacent to each of the solid waste management units (SWMUs) and areas of concern (AOCs) addressed in this FS report are currently used only for industrial purposes, and are expected to remain in industrial use. Based on a review of the land use and use characteristics on and adjacent to the Facility, it has been determined that the Facility meets the requirements of “zoned for industrial use” of WAC 173-340-745. It is Boeing’s expectation that the changed land use category (Urban Center-North [UC-N]) will meet Ecology’s criteria for being “zoned for industrial use” until Boeing ceases aircraft production at the Facility.

Small areas west and south of Renton Municipal Airport are zoned for mixed use commercial and commercial/residential. These parcels are within 0.25 mile of the properties leased by Boeing. Additional small parcels are located within 0.25 mile of the Facility along Park Avenue North. These commercial properties are near Boeing office buildings (such as Building 10-20). Additional small parcels are also located within 1 mile of the of the Facility boundary to the south and east. A parcel northeast that directly borders the Facility was recently rezoned from industrial to commercial.

The closest residential-zoned properties are located south of North 6th Street, which is south of Building 10-20. Residential properties are also located within 0.25 mile west and south of the Renton Municipal Airport. Property located east of Interstate 405 (I-405) (within 0.5 mile of the Facility boundary) is also primarily zoned residential.

Public use areas near the Facility include land reserved for municipal and/or recreational purposes. The largest public use area near the Facility is the Renton Municipal Airport. In addition, Cedar River Trail Park is adjacent to the Facility along the east side of the Cedar River Waterway, and extends north to Lake Washington. Cedar River Park and Liberty Park are at the intersection of I-405 and the Maple Valley Highway, approximately 0.7 mile south-southeast of the Facility boundary. Coulon Beach Park is located approximately 0.25 miles northeast of the Facility boundary, along the shoreline of Lake Washington. Water sport activities on Lake Washington adjacent to the Facility include fishing, boating, and water skiing.

1.1.2 Previous Facility Investigations and Documents

The final Remedial Investigation (RI) report (Roy F. Weston [Weston], 2001a) for the Facility presents a definitive assessment of historic hazardous substance releases from the Facility. The RI included an assessment of 37 SWMUs and AOCs identified in the Agreed Order, plus three new AOCs that were identified at the Facility after the Agreed Order was issued. Preliminary cleanup levels (PCLs) were developed as part of the RI for each constituent of concern (COC) identified in the RI. The PCLs were used to evaluate the results of the soil and groundwater investigation at each of the SWMUs and AOCs and to determine if potential risks were present for either human health or the environment. Based on the results of this evaluation, the final RI Report recommended that nine SWMU and AOC groups (sites) be included in the FS. Four additional sites (AOC-034/035, AOC-092, AOC-093, and AOC-094) were identified after the RI investigation was completed and will also be included in the FS. Due to the physical separation between AOC-001/AOC-002 and AOC-003 and because the groundwater plume from AOC-003 does not extend to AOCs-001 and -002, the AOC group defined as AOC-001/002/003 in the final RI Report has been divided into one AOC group (AOCs-001 and -002) and a separate AOC (AOC-003) for this FS. Thus, 14 different sites (SWMUs, AOCs, and AOC groups) are addressed in this FS report. These sites are based on the final RI Report, sites identified during investigations subsequent to the RI, and the division of one AOC group defined in the RI (see Table 1-1). The location of the SWMUs and AOCs addressed in this FS report are shown on Figure 1-2.

Boeing has completed several requirements of the Agreed Order and has implemented programs to address corrective action requirements at the Facility. This work has included routine reporting, the Interim Action Work Plan, the RI Work Plan, the final RI Report, and the final FS Work Plan (FSWP) required under the Agreed Order. The final FSWP was approved by Ecology on June 18, 2004 (Geomatrix, 2004c).

This FS report was prepared in accordance with the FSWP, and presents the results of the focused FS that was performed to evaluate potential remedial alternatives for the Facility and to select the preferred approach for addressing historical releases at the Facility. Potential remedial alternatives for each of the 14 AOC and/or SWMU sites are identified and evaluated in this FS report. Preferred corrective actions are identified and recommended for implementation to address corrective action issues for these 14 sites within the Facility.

1.2 FEASIBILITY STUDY APPROACH

This FS is based on the findings presented in the final RI Report, supplemental data presented in the final FSWP, and the approach presented in the FSWP. As described in the FSWP, a focused FS was performed for the 14 sites where historic releases exceeded PCLs in soil and/or groundwater. Each of these 14 sites is discussed separately in Sections 6 through 19 of this report. Several elements related to the remediation objectives, cleanup standards, conceptual remedial designs, and evaluation criteria are consistent among the various alternatives developed and considered for the SWMUs and AOCs addressed in this FS. These common elements are presented and discussed in separate sections addressing these topics (Sections 2 through 5) rather than the sections devoted to the individual SWMUs and AOCs (Sections 6 through 19).

The objective of this FS is to evaluate appropriate remediation alternatives and select the preferred remedial alternative for each of the 14 sites listed in Table 1-1. This was accomplished by identifying and evaluating potential remedial alternatives appropriate to address the risks to human health and/or the environment posed at each site. This FS was performed in accordance with the requirements of the Agreed Order, MTCA regulations, and the approved FSWP. Requirements for selecting cleanup actions (WAC 173-340-360) are also addressed in this FS.

The focused FS for the Facility followed the procedures and processes provided in the approved FSWP. Only remedial technologies included in the FSWP were used to develop remedial alternatives for each of the 14 sites. The approved cleanup levels presented in the

FSWP and the methods for establishing cleanup levels described in the FSWP were used to establish remedial objectives and to evaluate points of compliance (POCs). Modeling was performed as specified in the FSWP to assess natural attenuation of COCs, as appropriate for each of the 14 sites, and to establish site-specific soil cleanup levels protective of groundwater. The modeling also supported evaluation of potential conditional POCs (CPOCs).

Individual sections of this FS report present the FS for each of the 14 sites addressed. The general Facility geology, hydrogeology, and environmental setting were fully described in the final RI Report and summarized in the FSWP. These general discussions about the Facility have not been repeated in this FS report. Key factors and issues regarding site-specific geologic, hydrogeologic, and environmental concerns are discussed for each individual SWMU or AOC addressed in this FS. Cleanup levels and POCs specific to each site are also presented in the sections specific to each site.

1.3 REPORT ORGANIZATION

This FS report is organized into the following sections:

- Section 1 – Introduction. This section presents an overview of the Facility and previous work completed in support of the corrective action process and describes the general document organization.
- Section 2 –Remediation Objectives. The potential exposure pathways and remediation objectives applicable to each of the 14 sites addressed in this FS are presented in this section.
- Section 3 – Cleanup Standards. A summary of the approach to establish and evaluate cleanup standards specific to each of the 14 sites is presented in this section.
- Section 4 – Potentially Applicable Remediation Technologies. An overview of the remedial technologies considered in this focused FS is provided in this section.
- Section 5 – Remedial Alternative Evaluation Criteria. This section presents the criteria used to evaluate and compare remedial alternatives for each site and the relevant elements common among the 14 sites addressed in this FS.
- Sections 6 through 19 – Development and Evaluation of Remedial Alternatives. These sections present the results of the FS for each of the 14 sites.
- Section 20 –Summary of Preferred Remedial Alternatives. This section presents the preferred remedial alternative for each site and compares the alternative to regulatory criteria for selection of a cleanup action.

- Section 21 – References. Documents and other resources that were cited in this report are listed in this section.

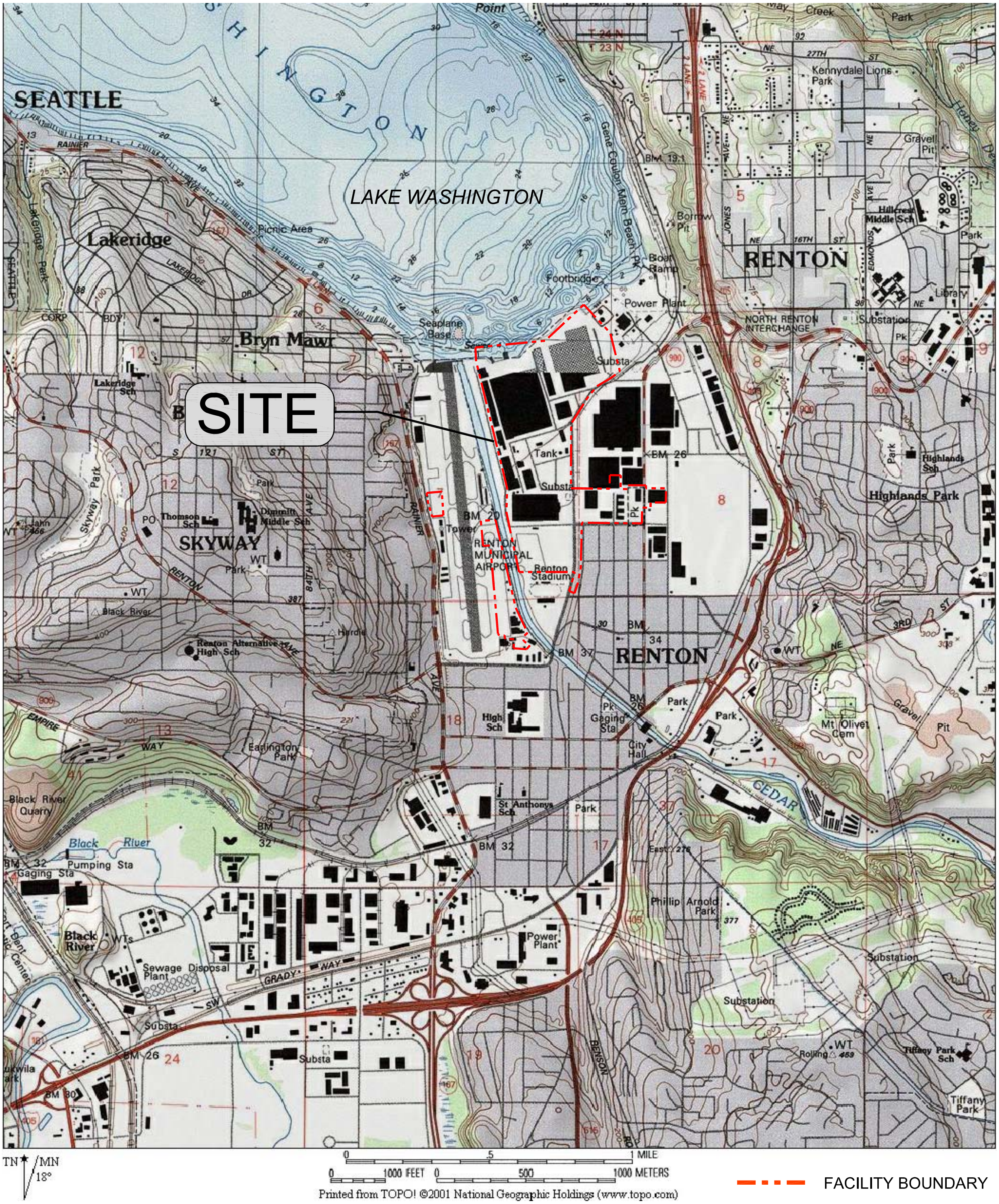
TABLE 1-1

FEASIBILITY STUDY SWMUs[1] AND AOCs[2]

Boeing Renton Facility
Renton, Washington

SWMU/AOC
SWMU-168, Building 5-50
SWMU-172/174, Buildings 5-08 and 5-09
SWMU-179, Building 4-76
Building 4-78/79 SWMU/AOC Group (SWMU 181, AOC-013, -014, -015, -026, -037, and -054)
Former Fuel Farm AOC Group (AOC-046, -047, and -048)
AOC-001/002, Building 4-81
AOC-003, Building 4-81
AOC-004, Building 4-21
AOC-034/035, Building 4-41
AOC-060, Building 4-42
AOC-090, Building 4-65 Yard
AOC-092, Building 4-20
AOC-093, north of Building 4-20
AOC-094, west of Building 5-08

Notes:
1. SWMU = solid waste management unit.
2. AOC = area of concern.



SITE LOCATION MAP
Boeing Renton Facility
Renton, Washington

BOEING

By: APS	Date: 05/28/08	Project No. 8888
Geomatrix		Figure 1-1

Plot Date: 05/28/08 - 9:35am, Plotted by: astenberg
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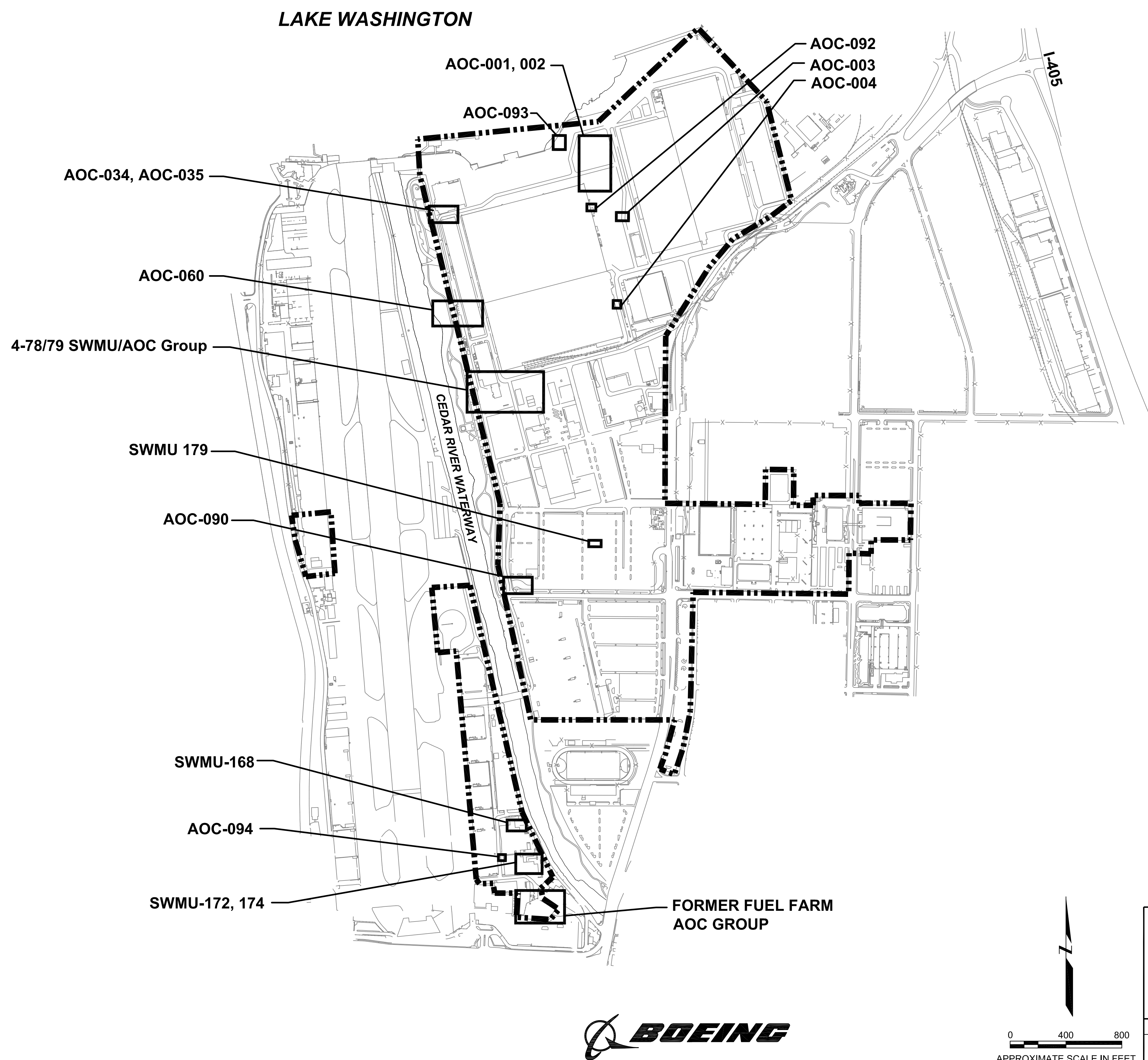

LEGEND

GENERAL LOCATION OF SWMUs AND AOCs

FACILITY BOUNDARY

NOTES

1. BASEMAP COMPILED BY DUANE HARTMAN & ASSOCIATES INC., DECEMBER, 1994

SWMU AND AOC LOCATION MAP
Boeing Renton Facility
Renton, Washington

By: APS	Date: 05/28/08	Project No. 8888
Geomatrix		Figure 1-2

BOEING

Plot Date: 05/28/08 - 9:39am, Plotted by: astenberg
Drawing Path: S:\8888_2006\025_Boeing FS\CAD\, Drawing Name: Figure 1_BoeingRentonSiteMap_012808.dwg

2.0 REMEDIATION OBJECTIVES

The overall remediation objective of this FS is to identify the preferred alternatives to reduce the risks to human health and the environment resulting from COCs in soil and groundwater at the Renton Facility to acceptable levels. All remedial alternatives must address the Conceptual Site Model (CSM) developed in the FSWP and the site migration and exposure pathways of concern described in Section 2.1 below. Furthermore, the remediation considerations and remediation objectives established for the Facility (Sections 2.2 and 2.3) will provide the framework for development of remedial alternatives.

2.1 FACILITY MIGRATION AND EXPOSURE PATHWAYS OF CONCERN

Migration pathways that may result in exposure of human or ecological receptors to site COCs must be addressed by the remedial alternatives. Based on the CSM described in the FSWP, the following migration pathways are of concern for AOCs and SWMUs at the Facility:

- Leaching of contaminants from affected on-site soil to on-site groundwater; and
- Migration of contaminant-affected groundwater from the site to either Lake Washington or the Cedar River Waterway.

The following exposure pathways are of concern for AOCs and SWMUs at the Facility:

- Exposure of temporary construction workers to contaminant-affected soil from direct ingestion, dermal contact, particulate inhalation, or inhalation of volatiles released from affected soil;
- Exposure of temporary construction workers to contaminant-affected groundwater from dermal contact or inhalation of volatile compounds released from affected groundwater;
- Exposure of residential users of publicly supplied potable water drawn from the Cedar River Waterway or Lake Washington due to ingestion, dermal contact, or inhalation of contaminants present in groundwater entering either Lake Washington or the Cedar River Waterway from the Facility;
- Exposure of people harvesting fish from portions of the Cedar River Waterway or Lake Washington that are affected by groundwater entering the waterway or lake from the Facility;
- Exposure of recreational users of the Cedar River Waterway and Lake Washington due to direct dermal contact or ingestion of contaminants present in surface water; and

- Exposure of small aquatic mammals, benthos, fish, piscivorous birds, and/or raptors through ingestion of affected surface water, dermal contact with affected surface water, or ingestion of affected fish or affected aquatic biota.

2.2 FACILITY REMEDIATION CONSIDERATIONS

Several considerations specific to the Facility will affect remediation and the development of remedial alternatives. The current and future classification of the Facility under industrial land use will affect the establishment of cleanup levels and constrain the nature and extent of remedial actions. Two major water bodies are located in the immediate vicinity of the Facility, which will influence cleanup levels and site-specific remedial objectives. The Facility is located within an area where shallow groundwater discharges to surface water, where there is no beneficial use of groundwater either on the Facility or between the Facility and the groundwater discharge areas, and where there is a reliable alternate supply of potable water provided by the City of Renton. These factors define the potential groundwater exposure pathways.

As noted in the final RI Report, the Facility is almost entirely developed with buildings and paved surfaces and is currently being used as an industrial facility. Boeing intends to maintain the Facility as a manufacturing facility for the foreseeable future. The active use of the Facility for manufacturing airplanes creates significant constraints for remediation. The preferred remedial alternative for each SWMU or AOC must be compatible with heavy industrial traffic, must not create long-term restrictions for access to the various portions of the property (including buildings), must avoid impacting the existing structures/buildings/underground utilities on the Facility, and must avoid any detrimental impact to the workers at the Facility. The heavy building development and surface paving on the Facility also effectively limit the potential for constituent migration, because the buildings and pavement or tarmac, which are continually maintained, act as a cap and therefore significantly limit infiltration of surface water into affected areas. The plans for continued industrial use also facilitate the effective implementation of institutional controls, which will be a key element in remedial alternatives.

The eastern portion of the Facility is located adjacent to Nishiwaki Lane and the Cedar River Trail Park, which runs along the eastern shore of the Cedar River Waterway and a portion of the southern shore of Lake Washington. The western portion of the Facility is located within the Renton Municipal Airport west of East Perimeter Road, which borders the western shoreline of the Cedar River Waterway. The final RI Report indicates that groundwater flows from the Facility to these surface water bodies. Because these surface water bodies are in proximity to the Facility, remedial alternatives must attain a cleanup standard that is protective of freshwater aquatic life. Additionally, the remedial alternatives must ensure that state water quality designations are maintained for these two surface water bodies. The remedial alternatives must also effectively limit surface runoff from affected media, both during and after implementing remedial action.

Groundwater beneath and downgradient of the Facility (both east and west of the Cedar River Waterway) is not currently used as a water supply and it is not expected to be used as such in the future. Withdrawal of shallow Facility groundwater may be restricted by Ecology because current flow rates in the Cedar River Waterway are near the minimum rates established in WAC 173-508-060, and groundwater withdrawal would reduce the rate of discharge to the waterway. The result of an extensive search for wells located within a 1-mile radius of the Facility was presented in the final RI Report (Weston, 2001a). The RI concluded that none of the wells within a 1-mile radius would draw groundwater from beneath the Facility. The City of Renton operates water supply wells in locations upgradient from the Facility; however, the Facility is located outside the aquifer protection area (APA) defined by the City of Renton to protect their supply wells (City of Renton Municipal Code, Title IV 4-3-050). These supply wells provide an alternate water supply for industrial, commercial, and residential users in the vicinity of the Facility. Since the Facility property is owned either by Boeing or by the City of Renton, and since the Facility is located very near or adjacent to surface waters receiving groundwater discharge, it is very unlikely that any future supply wells would be located in the vicinity of the Facility.

Existing aquifer conditions would limit beneficial use of groundwater from beneath the Facility. The RI found that groundwater beneath the Facility contains elevated levels of arsenic, iron, and manganese. The RI also demonstrated that upgradient arsenic concentrations are not significantly different from those present at the Facility. The concentrations of iron and manganese exceed Ecology groundwater criteria (WAC 173-200). Detected iron concentrations were more than two orders of magnitude greater than Ecology criteria, and manganese concentrations were more than one order of magnitude greater. As noted in the final RI Report, elevated iron and manganese concentrations have been noted elsewhere in similar depositional environments (Weston, 2001a). Additionally, a significant portion of the Facility is a former wetland that was reclaimed in the 1930s and 1940s by placement of fill. Groundwater within fill areas is not typically used as a water resource. Because the final RI Report states that natural iron and manganese concentrations in Facility groundwater exceed the secondary drinking water maximum contaminant levels (MCLs) established under 40 Code of Federal Regulations (CFR) 143, it is unlikely that Facility groundwater will be used for potable purposes.

In summary, groundwater beneath the Facility is not used beneficially and is not expected to be used beneficially in the future. Facility groundwater discharges to adjacent or nearby surface water bodies and is not used as a resource for any purpose. Existing uses of groundwater in the immediate vicinity of the Facility, including the City of Renton, do not draw from beneath the Facility. The Facility is outside the anticipated future extent of known resource uses because it is outside the Renton APA. Due to the natural chemical composition of groundwater beneath the Facility, it is not expected that the groundwater will be used as a resource in the future, especially since an alternate source of water, the Renton public water system, is readily available to all users. Therefore, remedial alternatives may effectively address potential exposure pathways related to use of groundwater by institutional controls. However, because the Facility is located near surface water bodies classified for potential use as a water supply, it will be necessary for remedial alternatives to address potential exposure to aquatic receptors and to support beneficial use of the surface water, including supply of drinking water.

2.3 FACILITY REMEDIATION OBJECTIVES

Remediation objectives have been established that are applicable to all AOCs and SWMUs at the Facility. Remedial alternatives developed for each of the SWMUs and AOCs must address the remediation considerations in addition to remediation objectives that are necessary to address specific remediation concerns or issues. The remediation objectives are as follows:

- Protect human health and the environment from risks related to the constituents present in soil and groundwater at AOCs and SWMUs;
- Attain a cleanup standard meeting the requirements specified in the MTCA regulations;
- Prevent the release of soil and groundwater constituents from AOCs or SWMUs to Lake Washington or the Cedar River waterway at concentrations that may adversely affect human or ecological receptors;
- Prevent exposure of on-site workers to soil and groundwater constituents at levels that may cause adverse human health impacts;
- Attain soil cleanup levels protective of continued industrial use of the facility;

- Minimize potential disruption of ongoing Facility activities and installations;
- Support continued use of the Facility for industrial purposes; and
- Comply with applicable state and federal regulations for site cleanup, health and safety, and waste management.

The above objectives will be addressed by the remedial alternatives established for each site. Additional objectives specific to the SWMU or AOC being addressed may be established as appropriate.

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3.0 CLEANUP STANDARDS

Cleanup standards have been established for each of the 14 sites evaluated in this FS. To be complete, each site-specific cleanup standard must include the cleanup level, POC, and any applicable regulatory requirements. As noted in Section 6 of the approved FSWP, it is expected that CPOCs will be established for remedial alternatives and that some alternatives may include off-site CPOCs. This is particularly relevant for AOC-060 and AOC-090, where COCs have been detected in off-site groundwater, and for other sites such as SWMU-172/174, where groundwater constituents have been detected near the property line. If an off-site CPOC is considered for a site, groundwater upgradient of the CPOC may exceed cleanup levels. Therefore, it is necessary to assess potential risks to human health and the environment that may be associated with groundwater exceeding cleanup levels upgradient from the CPOC. Appropriate measures, including institutional controls and engineering controls, must be included in remedial alternatives to ensure that remediation objectives are attained.

Remedial alternatives included in this FS must be capable of attaining cleanup standards that meet regulatory requirements. The MTCA regulations (WAC 173-340-200) require that the cleanup standard specify the following:

- Cleanup levels defined in accordance with MTCA regulations;
- The POC established in accordance with MTCA regulations; and
- Additional regulatory requirements that apply to the specific cleanup action and POC.

A cleanup standard addressing the above three general requirements has been established for each remedial alternative to ensure that the potential cleanup action would be protective of human health and the environment.

Cleanup levels for individual hazardous substances are required to be adjusted downward if the total combined excess cancer risk potential (calculated in accordance with MTCA methods) for the carcinogenic substances would exceed one in one hundred thousand (1×10^{-5}), or if the hazard index (HI) calculated in accordance with MTCA methods exceeds 1. The HI is calculated by summing hazard quotients (HQs) for individual COCs. The cleanup levels applicable at the CPOCs must be adjusted to meet these two total risk criteria.

3.1 CLEANUP LEVELS

The proposed cleanup levels used for this FS are based on the FSWP and subsequent negotiations with Ecology. Groundwater beneath each of the SWMUs and AOCs present at the Facility discharge either to the Cedar River Waterway or to Lake Washington. Therefore, under MTCA requirements the groundwater cleanup levels must be protective of surface water. This protection was accomplished by ensuring cleanup levels do not exceed applicable or relevant and appropriate requirements (ARARs) protective of surface water and by conducting groundwater modeling to conservatively establish concentrations at the proposed CPOCs that would attenuate to protective levels before discharge to surface water. The proposed groundwater cleanup levels were also adjusted in accordance with the MTCA regulations considering practical quantitation limits (PQLs) and total risk criteria.

3.1.1 Soil Cleanup Levels

Since the Facility is under industrial land use, most soil cleanup levels for specific COCs will be established in accordance with MTCA Method C requirements, as described in the FSWP. The Method C soil cleanup levels must be protective of human health and the environment and protective of groundwater. Cleanup levels for total petroleum hydrocarbons (TPH) will generally be based on MTCA Method A levels for industrial properties; however, if deemed appropriate, Boeing will work with Ecology to assess extractable petroleum hydrocarbons (EPH) and volatile petroleum hydrocarbons (VPH) data to establish TPH cleanup levels applicable to specific SWMUs or AOCs.

The proposed soil cleanup levels for each SWMU or AOC are summarized on Table 3-1. These are either (1) Industrial Method A cleanup levels for TPH or (2) standard or modified Method C cleanup levels developed in accordance with WAC 173-340-745, as described in the approved FSWP. The modified Method C soil cleanup levels are protective of groundwater at the CPOC established for the specific site. These soil cleanup levels were developed specifically to apply to the designated SWMUs or AOCs. The procedures outlined in the FSWP and subsequently negotiated with Ecology were used to develop these modified Method C soil cleanup levels. The modified Method C soil cleanup levels are based upon partitioning of the COC to groundwater from soil and consider natural attenuation that would occur as the affected groundwater flows to the CPOC. Natural attenuation was modeled using BIOCHLOR or BIOSCREEN, as appropriate for the COCs. The modeling procedures specified in Section 6 of the FSWP were used for the modeling. Partitioning of the COC between soil and groundwater was calculated using the procedures specified in the MTCA regulations and the parameters specified in the FSWP. The modified Method C cleanup level calculated in this manner would be protective of groundwater at the CPOC. Details regarding calculation of the modified Method C soil cleanup levels are presented in Appendix A. Standard Method C soil cleanup levels protective of groundwater (using the Method B groundwater criteria discussed in Section 3.1.2) were used for proposed soil cleanup levels for those constituents for which groundwater cleanup levels protective of groundwater at the CPOC were not established. As shown by the bold entries under the Hazard Quotient/Index and Calculated Cancer Risk Potential headings, the Hazard Index and total risk potential based on the proposed soil cleanup levels are both well below the MTCA thresholds of 1.0 for Hazard Index and 10^{-5} for the total cancer risk potential.

The soil cleanup levels tabulated in Table 3-1 for TPH-Gasoline (TPH-G) (both with and without benzene), TPH-Diesel (TPH-D), and TPH-Motor Oil (TPH-MO) are based on MTCA Method A cleanup levels for industrial properties. These cleanup levels will be applied to those sites with TPH-affected soil. If appropriate, EPH/VPH data may be collected during final design or implementation of a cleanup action to support calculation of cleanup levels for TPH in soil that would be specific to the SWMU or AOC evaluated. If EPH/VPH data are collected for a SWMU or AOC, the soil cleanup levels would be calculated using the methods specified in WAC 173-340-700(8).

3.1.2 Groundwater Cleanup Levels

Cleanup levels for groundwater proposed in this FS have been re-evaluated based on negotiations between Ecology and Boeing, the current Ecology cleanup levels and risk calculation (CLARC) database, and PQLs for the analytical methods to be used for groundwater monitoring. The cleanup levels proposed in the FSWP were also considered in re-evaluating groundwater cleanup levels for the facility.

The re-evaluation of groundwater cleanup levels for each SWMU and AOC is summarized in Table 3-2. Table 3-2 includes the cleanup levels proposed in the approved FSWP, the current Method B cleanup levels obtained from the CLARC database (Ecology, 2007), and the potential CPOC cleanup levels that were used to assess the HI and cumulative cancer risk potential at the CPOC. The potential CPOC cleanup level was determined as follows.

1. The potential CPOC cleanup level was initially set to the Method B cleanup criteria for constituents other than tetrachloroethene (also known as perchloroethylene or

PCE), trichloroethene (TCE), *cis*-1,2-dichloroethene (*cis*-1,2-DCE), and vinyl chloride (VC).

2. For PCE, TCE, cis-1,2-DCE, and VC, the potential CPOC cleanup level was initially set to the lower of the Method B cleanup criteria or the modeled groundwater concentration at the CPOC protective of surface water, based on the modeling presented in Appendix A.

3. The potential CPOC cleanup levels were then adjusted as necessary so that the HI was less than or equal to 1 and so that the cumulative cancer risk potential (calculated in accordance with MTCA) was less than or equal to 10^{-5}.

4. Since cleanup levels cannot be set at levels lower than PQLs, the proposed CPOC cleanup levels listed in Table 3-2 were established as the adjusted potential CPOC cleanup level or the PQL, whichever was higher.

5. For petroleum hydrocarbons, the MTCA Method A cleanup levels were selected for proposed CPOC cleanup levels, as described in the FSWP.

The procedure used for establishing the proposed CPOC cleanup levels in Table 3-2 is consistent with guidance established by Ecology (Ecology, 1993) and with cleanup level negotiations between Ecology and Boeing during preparation of the FS. The Method B Cleanup Levels listed in Table 3-2 were taken from the CLARC website (Ecology, 2007) and are the lowest values reported for the standard Method B formulae (carcinogenic and noncarcinogenic) for groundwater and surface water and for groundwater and surface water ARARs. The adjustments for cumulative HI and cancer risk potential were made in general accordance with Ecology guidance that indicates that the cumulative risk evaluations should be based on risk-based cleanup criteria rather than PQLs. The MTCA regulations [WAC 173-340-720(7)(c)] specify that cleanup levels shall not be set at concentrations lower than PQLs. The PQLs listed in Table 3-2 are the current reporting limits for the project laboratory, Analytical Resources, Inc., as obtained from the laboratory in October 2007. The PQLs for volatile organics are based on either selected ion monitoring (SIM) methods or a 20-milliliter (mL) extraction method. The PQLs for metals are based on graphite furnace or cold vapor atomic absorption spectrophotometry. PQLs for semivolatile organic compounds (SVOCs) are based on the standard 8270 gas chromatography/mass spectrometry (GC/MS) method.

Both Lake Washington and the Cedar River Waterway have been classified as potential sources for public water supply. Therefore, the proposed CPOC groundwater cleanup levels were established to be protective of both human health and ecological receptors. Table 3-2 lists the groundwater COCs for each of the SWMUs/AOCs and the groundwater cleanup levels.

Groundwater meeting these cleanup levels at the CPOC would be protective of surface water use for public water supply and for aquatic life.

3.2 POINTS OF COMPLIANCE

Cleanup levels are applied at the POC to assess compliance with the groundwater cleanup standard, as specified in the MTCA regulations. The standard POC for each of the 14 sites is defined as applying throughout that site. A CPOC is located at a designated location downgradient from the source area and must be established to meet regulatory requirements. If it can be demonstrated in accordance with the MTCA regulations that it is not practicable to meet the groundwater cleanup level at the standard POC within a reasonable time frame, Ecology may approve a CPOC. As noted in the FSWP, many of the SWMUs and AOCs addressed in the FS will likely require a CPOC to comply with MTCA regulations.

According to the provisions of WAC 173-340-720(8), a CPOC must be as close as practicable to the source area and cannot extend outside the property boundary unless the property is near to or abutting surface water or if there is an area-wide groundwater contamination problem. Where the groundwater cleanup level is based on protection of surface water, Ecology may approve a CPOC that is located within the surface water or as close as technically possible to the point or points where groundwater flows into the surface water. The Facility borders Lake Washington and is located near the Cedar River Waterway. Therefore, as noted in the approved FSWP, CPOCs may be proposed at locations between the SWMU/AOC source areas and the Lake Washington shoreline, the shoreline along the Cedar River Trail Park, or along East Perimeter Road east of the Renton Municipal Airport.

The relevant regulatory provisions for establishing CPOCs are presented in WAC 173-340-720(8). These provisions also provide for the establishment of an off-site CPOC beyond the Facility property lines. The specific requirements applicable to the Facility, where groundwater discharges to surface water, are as follows.

- It must be demonstrated through the RI/FS and cleanup action selection/planning process conducted in accordance with WAC 173-340-350 through 173-340-390 that it is not practicable to attain the standard POC within a reasonable time frame.

- All practicable methods of treatment have been used for cleanup of the affected groundwater before it discharges to surface water.

- Affected groundwater will continue to discharge to the surface water after implementation of the cleanup action.
- No surface water mixing zone has been used in attaining cleanup levels at the CPOC.
- The groundwater discharge will not cause violations of sediment quality values specified in WAC 173-204.
- Groundwater and surface water monitoring are conducted as appropriate to assess the long-term performance of the cleanup action, including the potential for bioaccumulation for constituents below detection limits.
- Public notice of the CPOC has been provided to the natural resource trustees, Washington Department of Natural Resources, and the U.S. Army Corps of Engineers.
- If the CPOC is on an off-site property, any property owners located between the source property and the surface water body must agree (in writing) to the CPOC.
- If the CPOC is on an off-site property and the extent of the plume exceeding the cleanup level is known and does not reach the surface water body, the CPOC cannot be located beyond the extent of affected groundwater exceeding the cleanup level at the time the CPOC is approved.

These requirements must be addressed to establish a CPOC. For cleanup alternatives incorporating a CPOC, the regulations in WAC 173-340-720(8)(e) provide for use of upland monitoring wells to demonstrate compliance at the groundwater CPOC. Under these provisions, Ecology must consider that natural attenuation of groundwater constituents may occur between the monitoring wells and the surface water. An estimate of natural attenuation that considers the following can be used to assess attainment of cleanup levels at the CPOC:

- The rate of attenuation,
- The presence of preferential flow pathways, and
- Any effects that changes in water chemistry due to natural attenuation processes may have on attaining surface water or sediment quality standards.

The procedures for establishing CPOCs were presented in Section 6 of the approved FSWP. These procedures include modeling of natural attenuation processes to assess concentrations downgradient from the source area. The procedures specified in the approved FSWP were followed for modeling natural attenuation of COCs for specific sites and for establishing CPOCs downgradient from source areas.

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TABLE 3-1

SOIL CLEANUP LEVELS[1]

Boeing Renton Facility
Renton, Washington

Soil Constituent of Concern	MTCA Method A Industrial Criteria (mg/kg)	Standard MTCA Method C Criteria[2] (mg/kg)	Calculated Soil Concentration Protective of Groundwater at the CPOC (mg/kg)	MTCA Method C Non-Carcinogenic Direct Contact Criteria[3] (mg/kg)	Hazard Quotient/ Index[4]	MTCA Method C Carcinogenic Direct Contact Criteria[3] (mg/kg)	Cancer Risk Potential[5] ($X 10^5$)	Soil Cleanup Level[6] (mg/kg)
SWMU-168					**0.0000001**		**0.000001**	
Methylene Chloride	--	0.024	--	210,000	0.0000001	18,000	0.000001	0.024
SWMU-172/174					**0.002**		**0.00006**	
Tetrachloroethene	--	0.003	0.01	35,000	0.0000003	240	0.00004	0.01
Trichloroethene	--	0.002	0.006	1,100	0.000005	330	0.00002	0.006
Methylene Chloride	--	0.024	--	210,000	0.0000001	18,000	0.000001	0.024
Benzene	--	0.009	--	14,000	0.0000006	2,400	0.000004	0.009
Copper	--	36	--	130,000	0.0003	--	--	36
Thallium	--	0.34	--	250	0.001	--	--	0.34
Zinc	--	39.8	--	1,100,000	0.00004	--	--	39.8
Building 4-78/79 SWMU/AOC Group					**0.001**		**0.009**	
Vinyl Chloride	--	0.0002	0.1	11,000	0.000009	88	0.001	0.1
Trichloroethene	--	0.002	0.1	1,100	0.00009	330	0.0003	0.1
cis -1,2-Dichloroethene	--	0.75	0.3	35,000	0.00001	--	--	0.3
Benzene	--	0.012	19	14,000	0.001	2,400	0.008	19
TPH-Gasoline w/benzene	30	--	14,840	--	--	--	--	30
Former Fuel Farm SWMU/AOC Group					**0.003**		**0.000005**	
TPH-Jet Fuel	2,000	--	68,840	--	--	--	--	2,000
TPH-Diesel	2,000	--	68,840	--	--	--	--	2,000
Benzene	--	0.012	--	14,000	0.0000009	2,400	0.000005	0.012
2-Methylnaphthalene	--	45.8	--	14,000	0.003	--	--	45.8

Geomatrix

TABLE 3-1

SOIL CLEANUP LEVELS[1]

Boeing Renton Facility
Renton, Washington

Soil Constituent of Concern	MTCA Method A Industrial Criteria (mg/kg)	Standard MTCA Method C Criteria[2] (mg/kg)	Calculated Soil Concentration Protective of Groundwater at the CPOC (mg/kg)	MTCA Method C Non-Carcinogenic Direct Contact Criteria[3] (mg/kg)	Hazard Quotient/ Index[4]	MTCA Method C Carcinogenic Direct Contact Criteria[3] (mg/kg)	Cancer Risk Potential[5] (X 10^5)	Soil Cleanup Level[6] (mg/kg)
AOC-001/002					**0.00002**		**0.0003**	
Trichloroethene	--	0.002	0.02	1,100	0.00002	330	0.00006	0.02
cis -1,2-Dichloroethene	--	0.75	0.01	35,000	0.0000003	--	--	0.01
Vinyl Chloride	--	0.0002	0.02	11,000	0.000002	88	0.0002	0.02
TPH-Gasoline w/ benzene	30	--	--	--	--	--	--	30
AOC-003					**0.00008**		**0.0003**	
Trichloroethene	--	0.002	0.09	1,100	0.00008	330	0.0003	0.09
AOC-004					**0.0008**		**0.004**	
Benzene	--	0.012	9.5	14,000	0.000679	2,400	0.004	9.5
Ethylbenzene	--	21.5	--	350,000	0.00006	--	--	21.5
Acetone	--	3.3	--	350,000	0.000009	--	--	3.3
Toluene	--	19	--	280,000	0.00007	--	--	19
TPH-Gasoline w/benzene	30	--	14,840	--	--	--	--	30
AOC-034/035					**0.000005**		**0.0005**	
cis -1,2-Dichloroethene	--	0.75	0.05	35,000	0.000001	--	--	0.05
Vinyl Chloride	--	0.0002	0.04	11,000	0.000004	88	0.0005	0.04
AOC-090					**0.03**		**0.16**	
Benzene	--	0.012	0.7	14,000	0.00005	2,400	0.0003	0.7
Toluene	--	19	--	280,000	0.00007	--	--	19
1,1,2-Trichloroethane	--	0.01	--	14,000	0.0000007	2,300	0.000004	0.01
1,1-Dichloroethene	--	0.001	--	180,000	0.000000006	220	0.000005	0.001
Carbon Tetrachloride	--	0.008	--	2,500	0.000003	1,000	0.000008	0.008
Chloroform	--	0.079	--	35,000	0.000002	22,000	0.000004	0.079

TABLE 3-1

SOIL CLEANUP LEVELS[1]

Boeing Renton Facility
Renton, Washington

Soil Constituent of Concern	MTCA Method A Industrial Criteria (mg/kg)	Standard MTCA Method C Criteria[2] (mg/kg)	Calculated Soil Concentration Protective of Groundwater at the CPOC (mg/kg)	MTCA Method C Non-Carcinogenic Direct Contact Criteria[3] (mg/kg)	Hazard Quotient/ Index[4]	MTCA Method C Carcinogenic Direct Contact Criteria[3] (mg/kg)	Cancer Risk Potential[5] (X 10^5)	Soil Cleanup Level[6] (mg/kg)
AOC-090 (Continued)					**0.02**		**0.08**	
cis -1,2-Dichloroethene	--	0.75	0.006	35,000	0.0000002	--	--	0.006
Methylene Chloride	--	0.027	--	210,000	0.0000001	18,000	0.000002	0.027
Tetrachloroethene	--	0.004	0.03	35,000	0.0000009	240	0.0001	0.03
Trichloroethene	--	0.002	0.01	1,100	0.000009	330	0.00003	0.01
Vinyl Chloride	--	0.0002	0.006	11,000	0.0000005	88	0.00007	0.006
2-Methylnaphthalene	--	45.8	--	14,000	0.003	--	--	45.8
Isophorone	--	0.1	--	700,000	0.0000001	140,000	0.0000007	0.1
Phenanthrene	--	4.928	--	--	--	--	--	0.009
TPH-Gasoline w/benzene	30	--	14,840	--	--	--	--	30
TPH-Diesel	2000	--	68,840	--	--	--	--	2,000
TPH-Motor Oil	2000	--	--	--	--	--	--	2,000
Antimony	--	5.06	--	1,400	0.004	--	--	5.06
Arsenic	--	7	--	1,100	0.006	88	0.08	7
Cadmium	--	1	--	3,500	0.0003	--	--	1
Chromium(III)	--	1,140	--	5,300,000	0.0002	--	--	1,140
Chromium(VI)	--	3.84	--	11,000	0.0003	--	--	3.84
Copper	--	36	--	130,000	0.0003	--	--	36
Mercury	--	0.013	--	1,100	0.00001	--	--	0.013
Selenium	--	0.52	--	18,000	0.00003	--	--	0.52
Silver	--	13.6	--	18,000	0.001	--	--	13.6
AOC-092					**0.00001**		**0.00006**	
Benzene	--	0.012	0.15	14,000	0.00001	2,400	0.00006	0.15
TPH-Gasoline w/benzene	30	--	14,840	--	--	--	--	30

Geomatrix

TABLE 3-1

SOIL CLEANUP LEVELS[1]

Boeing Renton Facility

Renton, Washington

Soil Constituent of Concern	MTCA Method A Industrial Criteria (mg/kg)	Standard MTCA Method C Criteria[2] (mg/kg)	Calculated Soil Concentration Protective of Groundwater at the CPOC (mg/kg)	MTCA Method C Non-Carcinogenic Direct Contact Criteria[3] (mg/kg)	Hazard Quotient/ Index[4]	MTCA Method C Carcinogenic Direct Contact Criteria[3] (mg/kg)	Cancer Risk Potential[5] ($X 10^5$)	Soil Cleanup Level[6] (mg/kg)
AOC-093					**--**		**--**	
TPH-Gasoline w/o benzene	100	--	--	--	--	--	--	100

Notes:

1. The soil cleanup levels listed in this table are used to complete this FS and are not considered final soil cleanup levels for the Renton Facility. Final soil cleanup levels will be established in the Corrective Action Plan.
2. The standard MTCA Method C soil cleanup level established in accordance with WAC 173-340-745. This soil cleanup level is the lower of the direct contact Method C cleanup criteria obtained from the Cleanup Levels and Risk Calculations (CLARC) database (https://fortress.wa.gov/ecy/clarc/Reporting/CLARCReporting.aspx) in March 2008 and the concentration protective of the standard MTCA Method B groundwater cleanup criteria presented in Table 3-2.
3. MTCA Method C soil cleanup criteria for both carcinogenic and non-carcinogenic effects obtained from the Cleanup Levels and Risk Calculations (CLARC) database (https://fortress.wa.gov/ecy/clarc/Reporting/ CLARCReporting.aspx) in March 2008.
4. The Hazard Quotient was calculated by dividing the proposed soil cleanup level (column 9) by the MTCA Method C non-carcinogenic direct criteria (column 5). The bold value for each SWMU or AOC is the Hazard Index calculated by summing the individual Hazard Quotients.
5. The cancer risk potential was calculated by dividing the proposed soil cleanup level (column 9) by the MTCA Method C carcinogenic direct contact criteria. The tabulated values have been multiplied by 10^5. The bold value is the for each SWMU or AOC is the total cancer risk potential calculated by summing the risk potentials for each COC.
6. The cleanup level proposed for application to each SWMU and AOC. The proposed soil cleanup levels are either the calculated soil concentrations protective of groundwater at the CPOC (see Appendix A for calculations), the MTCA Method A industrial criteria for TPH fractions, or the standard MTCA Method C criteria for those constituents for which soil concentrations protective of groundwater at the CPOC were not calculated.

TABLE 3-2

GROUNDWATER CLEANUP LEVELS

Boeing Renton Facility
Renton, Washington

Groundwater Constituent of Concern	Practical Quantitation Limit[1] (µg/L)	FSWP Proposed Cleanup Level[2] (µg/L)	Modeled CPOC Conc.[3] (µg/L)	Method B Cleanup Criteria[4] (µg/L)	Potential CPOC Cleanup Level[5] (µg/L)	Method B Noncancer Std. Formula[6] (µg/L)	Hazard Quotient/Index at CPOC[7]	Method B, Cancer Std. Formula[8] (µg/L)	Calculated Cancer Risk Potential[9] (X 10^6)	Proposed CPOC Cleanup Level[10] (µg/L)
SWMU-168							**0.005**		**3.8**	
Vinyl Chloride	0.02	0.025	0.11	0.025	0.11	24	0.005	0.029	3.8	0.11
SWMU-172/174							**0.27**		**7.3**	
1,1-Dichloroethene	0.02	1	--	0.057	0.057	400	0.0001	0.073	0.78	0.057
Benzene	0.02	1.2	--	0.8	0.8	32	0.025	0.8	1.0	0.80
Chloromethane	0.2	3.37	--	3.40	0.5			3.4	0.15	0.5
cis-1,2-Dichloroethene	0.02	70	0.03	70	0.03	80	0.0004			0.03
Methylene Chloride	0.3	4.7	--	4.6	4.6	480	0.010	5.8	0.79	4.6
Tetrachloroethene	0.02	0.08	0.008	0.081	0.020	80	0.0003	0.081	0.25	0.02
Trichloroethene	0.02	0.11	0.009	0.11	0.020	2.40	0.008	0.11	0.18	0.02
Vinyl Chloride	0.02	0.025	0.11	0.025	0.11	24	0.005	0.029	3.8	0.11
bis (2-ethylhexyl) Phthalate	1	1.8	--	0.8	1.2	320	0.004			1.2
Arsenic	1	1	--	0.018	0.018	4.80	0.004	0.058	0.31	1.0
Chromium, Total, as Cr(III)	5	141.25	--	57	57	24,000	0.002			57
Chromium, Total, as Cr(VI)	10	10	--	10	10	48	0.21			10
Copper	2	8.92	--	3.5	3.5	590	0.006			3.5
Lead	1	1.85	--	0.54	1					1.0
Building 4-78/79 SWMU/AOC Group							**0.14**		**10.0**	
Vinyl Chloride	0.02	0.025	0.26	0.025	0.20	24	0.008	0.029	6.9	0.20
Trichloroethene	0.02	0.11	0.8	0.11	0.23	2.40	0.096	0.11	2.1	0.23
cis-1,2-Dichloroethene	0.02	70	0.9	70	0.90	80	0.011			0.90
Benzene	0.02	1.2	>100,000	0.8	0.8	32	0.025	0.8	1.0	0.80
TPH-Gasoline w/benzene		800	>100,000		800					800
Former Fuel Farm SWMU/AOC Group							**N/A**		**N/A**	
TPH-Jet Fuel		500	>100,000		500					500
TPH-Diesel		500	>100,000		500					500

TABLE 3-2

GROUNDWATER CLEANUP LEVELS

Boeing Renton Facility
Renton, Washington

Groundwater Constituent of Concern	Practical Quantitation Limit[1] (µg/L)	FSWP Proposed Cleanup Level[2] (µg/L)	Modeled CPOC Conc.[3] (µg/L)	Method B Cleanup Criteria[4] (µg/L)	Potential CPOC Cleanup Level[5] (µg/L)	Method B Noncancer Std. Formula[6] (µg/L)	Hazard Quotient/Index at CPOC[7]	Method B, Cancer Std. Formula[8] (µg/L)	Calculated Cancer Risk Potential[9] ($X 10^6$)	Proposed CPOC Cleanup Level[10] (µg/L)
AOC-001/002							**1.00**		**4.5**	
Benzene	0.02	1.2	--	0.8	0.8	32	0.025	0.8	1.0	0.80
Trichloroethene	0.02	0.11	0.002	0.11	0.02	2.40	0.008	0.11	0.18	0.02
cis -1,2- Dichloroethene	0.02	70	0.002	70	0.02	80	0.0003			0.02
trans -1,2- Dichloroethene	0.2	100	--	160	24	160	0.15			24
1,1-Dichloroethene	0.02	1	--	0.057	0.057	400	0.0001	0.073	0.78	0.057
Chloroform	0.2	5.7	--	5.7	5.7	80	0.071	7.2	0.79	5.7
Vinyl Chloride	0.02	0.025	0.05	0.025	0.05	24	0.002	0.029	1.7	0.05
Naphthalene	0.5	160	--	160	119	160	0.74			119
AOC-003							**0.09**		**10.0**	
Tetrachloroethene	0.02	0.08	0.54	0.081	0.02	80	0.0003	0.081	0.25	0.02
Trichloroethene	0.02	0.11	4.0	0.11	0.16	2.40	0.067	0.11	1.5	0.16
Vinyl Chloride	0.02	0.025	4.60	0.025	0.24	24	0.010	0.029	8.3	0.24
cis -1,2- Dichloroethene	0.02	70	0.78	70	0.78	80	0.010			0.78
AOC-004							**0.25**		**10.0**	
Benzene	0.02	1.2	>100,000	0.8	8	32	0.25	0.8	10.0	8.0
Lead	1	1.85	--	0.54	1					1.0
TPH-Gasoline w/benzene		800	>100,000		800					800
AOC-034/035							**0.02**		**10.0**	
Vinyl Chloride	0.02	0.025	80	0.025	0.29	24	0.012	0.029	10.0	0.29
cis -1,2- Dichloroethene	0.02	70	0.65	70	0.65	80	0.008			0.65
AOC-060							**0.02**		**9.2**	
Vinyl Chloride	0.02	0.025	0.26	0.025	0.26	24	0.011	0.029	9.0	0.26
Trichloroethene	0.02	0.11	0.01	0.11	0.02	2.40	0.008	0.11	0.18	0.02
cis- 1,2-Dichloroethene	0.02	70	0.08	70	0.08	80	0.001			0.08

TABLE 3-2

GROUNDWATER CLEANUP LEVELS
Boeing Renton Facility
Renton, Washington

Groundwater Constituent of Concern	Practical Quantitation Limit[1] (µg/L)	FSWP Proposed Cleanup Level[2] (µg/L)	Modeled CPOC Conc.[3] (µg/L)	Method B Cleanup Criteria[4] (µg/L)	Potential CPOC Cleanup Level[5] (µg/L)	Method B Noncancer Std. Formula[6] (µg/L)	Hazard Quotient/Index at CPOC[7]	Method B, Cancer Std. Formula[8] (µg/L)	Calculated Cancer Risk Potential[9] (X 10^6)	Proposed CPOC Cleanup Level[10] (µg/L)
AOC-090 (Shallow and Intermediate)[11]							**1.00**		**10.0**	
1,1-Dichloroethene	0.02	1	--	0.057	0.057	400	0.0001	0.073	0.78	0.057
1,1,2-Trichloroethane	0.2	1	--	0.59	0.2	32	0.006	0.77	0.26	0.20
1,1,2,2-Tetrachloroethane	0.02	1	--	0.17	0.17			0.22	0.77	0.17
Acetone	3	800	--	800	300	800	0.38			300
Benzene	0.02	1.2	61	0.8	0.8	32	0.025	0.8	1.0	0.8
Toluene	0.2	1000	--	640	75	640	0.12			75
Carbon Tetrachloride	0.2	1	--	0.23	0.23	5.60	0.041	0.34	0.68	0.23
Chloroform	0.2	5.7	--	5.7	2	80	0.025	7.2	0.28	2.0
cis-1,2-Dichloroethene	0.02	70	2.4	70	2.4	80	0.030			2.4
trans-1,2-Dichloroethene	0.2	100	--	160	53.9	160	0.34			53.9
Methylene Chloride	0.3	4.7	--	4.6	2	480	0.004	5.8	0.34	2.0
Vinyl Chloride	0.02	0.025	2.1	0.025	0.13	24	0.005	0.029	4.54	0.13
Tetrachloroethene	0.02	0.08	0.11	0.081	0.05	80	0.0006	0.081	0.62	0.05
Trichloroethene	0.02	0.11	0.21	0.11	0.08	2.40	0.033	0.11	0.73	0.08
TPH-Gasoline w/benzene		800	>100,000		800					800
TPH-Diesel		500	>100,000		500					500
TPH-Motor Oil		500	--		500					500
AOC-092							**0.25**		**10.0**	
Benzene	0.02	1.2	>100,000	0.8	8	32	0.25	0.8	10	8.0
TPH-Gasoline w/benzene		800	>100,000		800					800

Geomatrix

TABLE 3-2

GROUNDWATER CLEANUP LEVELS

Boeing Renton Facility
Renton, Washington

Groundwater Constituent of Concern	Practical Quantitation Limit[1] (µg/L)	FSWP Proposed Cleanup Level[2] (µg/L)	Modeled CPOC Conc.[3] (µg/L)	Method B Cleanup Criteria[4] (µg/L)	Potential CPOC Cleanup Level[5] (µg/L)	Method B Noncancer Std. Formula[6] (µg/L)	Hazard Quotient/Index at CPOC[7]	Method B, Cancer Std. Formula[8] (µg/L)	Calculated Cancer Risk Potential[9] (X 10^6)	Proposed CPOC Cleanup Level[10] (µg/L)
AOC-093										
TPH-Gasoline w/o benzene		1,000	--		1,000					1,000

Notes:

1. Laboratory practical quantitation limit (PQL) obtained from Analytical Resources, Inc. (ARI) web site (http://www.arilabs.com/portal/index.php?option=com_remository&Itemid=51&func=selectcat&cat=2) on October 15, 2007. ARI is the project laboratory for the Boeing Renton facility. The PQL is based on using either a 20-mL extraction or selected ion monitoring (SIM) analysis for volatile organics and inductively coupled plasma (ICP) analysis for metals.
2. Groundwater cleanup level listed in Table 5.2 of the FS Work Plan, except for vinyl chloride (VC), trichloroethene (TCE) and tetrachloroethene (PCE), established in late 2006 based on negotiations with Ecology.
3. Conditional point of compliance (CPOC) concentration predicted from modeling, as discussed in Appendix A. This concentration is predicted to be protective of surface water.
4. The cleanup criteria that would be established under the standard MTCA Method B procedures. This is the lowest of the standard formula value and the applicable or relevant and appropriate requirements (ARARs), as obtained from the Cleanup Levels and Risk Calculations (CLARC) database (https://fortress.wa.gov/ecy/clarc/Reporting/CLARCReporting.aspx) in October 2007.
5. Value used at the CPOC to assess the Hazard Index and the Model Toxics Control Act (MTCA) calculation for total cancer risk potential. This value was selected in general accordance with Ecology Implementation Memo No. 3 (Ecology, 1993); values were adjusted as necessary to ensure that the hazard index did not exceed 1 and that the total cancer risk potential did not exceed 1 X 10^{-5}.
6. MTCA Method B standard noncarcinogenic formula value from the CLARC database (https://fortress.wa.gov/ecy/clarc/Reporting/CLARCReporting.aspx) in October 2007.
7. The Hazard Quotient was calculated by dividing the potential CPOC cleanup level (column 6) by the MTCA Method B Noncancer standard formula value (column 7). The bold value for each SWMU or AOC is the Hazard Index for the CPOC calculated by summing the individual Hazard Quotients.
8. MTCA Method B standard carcinogenic formula value from the CLARC database (https://fortress.wa.gov/ecy/clarc/Reporting/CLARCReporting.aspx) in October 2007.
9. Risk potential at the CPOC calculated by dividing the potential CPOC cleanup level by the Method B standard carcinogenic formula value. Tabulated values are multiplied by 10^6. The bold value for each SWMU or AOC is the total cancer risk potential calculated by summing the risk potentials for each COC.
10. The proposed CPOC groundwater cleanup level is the maximum of the potential CPOC cleanup level (which has been adjusted to achieve a hazard index less than or equal to 1 and a total cancer risk potential less than or equal to 1 X 10^{-5}) and the PQL (column 2), to ensure that the applicable cleanup level is not below the PQL.
11. Three CPOCs have been defined for AOC-090; however, only one set of cleanup levels has been established for this AOC. The Modeled CPOC Concentrations listed in this table are the lowest modeling results for the three CPOCs and represent the most conservative case for establishing cleanup levels (see Appendix A). The proposed CPOC Cleanup Levels are lower than the concentrations predicted at the CPOC that would attenuate to the Method B cleanup levels at the point groundwater enters surface water.

4.0 POTENTIALLY APPLICABLE REMEDIATION TECHNOLOGIES

A preliminary screening of remedial technologies was presented in the FSWP. This screening resulted in a list of potentially applicable remedial technologies to be used in a focused FS. The screening process identified technologies compatible with site constituents, ongoing and expected future site use and activity, and the geologic setting for the Facility. The technology screening and resulting list of remedial technologies was approved by Ecology as part of the approved FSWP. The remedial technologies listed in the approved FSWP will be used to develop appropriate remedial alternatives for each of the SWMUs and AOCs addressed by this FS report.

4.1 SOIL REMEDIATION TECHNOLOGIES

The two soil remediation technologies that passed the screening presented in the FSWP and that are potentially applicable to the 14 sites at the Facility are summarized in Table 4-1. These technologies will be incorporated into remedial alternatives considered for each of the SWMUs and AOCs addressed in this FS report. The potentially applicable soil remediation technologies are described below.

4.1.1 Source Removal and Disposal

Application of source removal and disposal technology would result in excavation of affected soils, characterization in accordance with the Dangerous Waste Regulations (WAC 173-303), and disposal at an off-site facility designed and licensed to handle the waste classification. This technology would be very effective at reducing concentrations of all constituents within the site subsurface soils, thereby removing the source for constituents present in the surrounding groundwater. However, this technology would not destroy constituents present in excavated soil unless specific treatment is required prior to soil disposal; site constituents would generally be relocated to another, more secure location.

For most of the sites addressed by this FS report, excavation would be constrained in depth by the shallow water table beneath the site and in areal extent by the presence of buildings, underground utilities, property lines, and other improvements on the property. Because the Facility is actively manufacturing large aircraft, daily operations would also significantly affect the extent and scheduling of excavation. Excavation would create potential risks for the excavation workers, and release of volatile constituents during excavation could affect production workers. Transporting the excavated material to the off-site disposal facility would create risks due to the potential for accidental releases during transport. It is likely that excavated soil affected by volatile organic compounds (VOCs) would require interstate shipment. Although the excavated material would be placed in a secure, permitted landfill, some potential risk would remain for release of constituents present in the soil to the environment. Costs for transportation and disposal would also be very high for soils affected by VOCs.

4.1.2 Soil Vapor Extraction/Bioventing

The use of soil vapor extraction (SVE) and bioventing have a long and successful history for remediation of soils within the vadose zone. SVE is often implemented in conjunction with air sparging (AS) of groundwater as well as with bioventing. SVE has been proven to reduce volatile constituent levels in the subsurface by removal of soil gas, desorption of VOCs from soil and nonaqueous phase liquids (NAPL), and volatilization of constituents from groundwater. Systems for implementing SVE typically consist of several vapor extraction wells installed in the source area vadose zone to collect soil gas. The soil gas is usually drawn from the vapor extraction wells to a manifold using a blower, with the blower discharge typically treated by an oxidizer or adsorber unit.

Implementation of SVE is intrusive in that many wells are typically required. Off-gas collection and treatment are typically included to limit potential exposure of on-site workers and off-site receptors. Air permitting requirements would be extensive for implementation of SVE at the Renton Facility because the Facility is currently classified as a major source under the Clean Air Act. Special design considerations (e.g., below-grade piping) may be required for implementation within the Facility to allow free movement of plant traffic and materials within the area to be remediated. Long-term operation of the SVE system may also be necessary to attain low cleanup levels. Costs for SVE systems are likely to be moderate to high and depend on the number of wells required, permitting requirements, and the type of off-gas treatment utilized.

4.2 GROUNDWATER REMEDIATION TECHNOLOGIES

The groundwater remediation technologies that passed the screening presented in the FSWP and are potentially applicable to the sites are summarized in Table 4-2. These technologies will be incorporated into remedial alternatives considered for each of the SWMUs and AOCs addressed in this FS report. The potentially applicable groundwater remediation technologies are described below.

4.2.1 Biosparging/Air Sparging

Biosparging and AS are based on injection of air into groundwater. For biosparging, the objective is to dissolve oxygen to promote aerobic biodegradation of constituents such as petroleum hydrocarbons or VC. The objective for AS systems is to strip dissolved VOCs from groundwater to the injected air. Sparge or biosparging wells are installed into the saturated zone. Air is delivered to the wells using a compressor or blower. SVE systems are typically installed in conjunction with AS systems and sometimes with biosparging systems to collect volatile components released from groundwater. Biosparging or AS systems can be installed as distributed systems located throughout the source area or affected groundwater plume or as a barrier designed to intercept groundwater flowing from the source area.

Implementation of biosparging or AS systems is intrusive in that many wells are typically required. Off-gas collection and treatment may be needed to limit potential exposure of on-site workers and off-site receptors. Air permitting requirements could be significant if a large quantity of volatilization is generated from the SVE system, because the Renton Facility is currently classified as a major source under the Clean Air Act. Special design considerations (e.g., below-grade piping) may be required for implementation of this technology within the Facility to allow free movement of plant traffic and materials. Long-term operation of a biosparging or AS system may be needed to attain low cleanup levels. Costs for biosparging or AS systems are likely to be moderate to high and depend on the number of wells required, permitting requirements, and whether off-gas treatment is necessary.

4.2.2 Enhanced In Situ Bioremediation

Enhanced in situ bioremediation is a proven remediation technology that increases biodegradation of groundwater constituents by adding electron donors or electron acceptors and necessary nutrients to the affected zone. Aerobic bioremediation accomplished by addition of electron acceptors (such as oxygen) is commonly used on petroleum hydrocarbons. Anaerobic bioremediation accomplished by the addition of electron donors (such as lactate or molasses) is effective to enhance biodegradation of chlorinated solvents. Anaerobic bioremediation accomplished by adding electron acceptors (such as calcium nitrate) has been effective for enhancing degradation of some nonchlorinated constituents. Anaerobic and aerobic bioremediation can also be done sequentially.

Several different approaches have been developed and used for implementing enhanced in situ bioremediation in the United States and elsewhere. The electron donor or electron acceptor has been injected directly into the affected zone using wells or push probes. The electron donor or acceptor material has also been mixed into the soils following excavation, gradually releasing the materials to groundwater. For some applications, groundwater is pumped to the surface to add the electron donor or acceptor and then reinjected to create a recirculation zone with high biological activity. Injection or recirculation systems have also been implemented in a distributed approach, with injection or recirculation occurring over the plume or as a barrier intercepting groundwater flow. Distributed and barrier approaches can also be combined to fully address the source area and downgradient plume.

Enhanced in situ bioremediation can be designed to have minimal impact on existing operations, but special design (e.g., buried lines) may be required for compatibility with Facility activities. Depending on constituent levels, successive chemical applications may be required over time to ensure all affected areas have been effectively treated and cleanup levels attained. Substantial groundwater monitoring is also typically required to confirm the effectiveness of this treatment.

This method works best when combined with selective source removal, as has already been done for many of the SWMUs and AOCs at the Facility. Biofouling of injection wells can occur, which may necessitate periodic maintenance of the injection wells. Also, existing, natural groundwater constituents (such as iron) can adversely affect the use of aerobic bioremediation by creating a high natural oxygen demand. Costs for enhanced bioremediation systems are expected to be moderate. The term "monitored attenuation," or MA, will be used in this document to refer to groundwater monitoring following enhanced in situ bioremediation.

4.2.3 In-Well Air Stripping

In-well air stripping (IWAS) is an in situ technology used to strip VOCs from groundwater within properly designed wells. It is used primarily for VOCs and TPH-G compounds. This technology typically uses wells with two screens appropriately spaced. Compressed air is discharged into the well, thereby reducing the density of the water inside the well and inducing upward flow. As the air bubbles through the water, VOCs are stripped and discharged with the air. The stripped groundwater then re-enters the aquifer through the upper screen, thus creating a recirculation cell with groundwater flowing toward the deeper inlet screen. The air exiting the groundwater is typically treated to control emissions of VOCs. Emissions can be controlled using oxidation or adsorption systems. The IWAS wells also create a zone of oxygenated groundwater that can enhance aerobic biodegradation but that may inhibit anaerobic processes, such as reductive dechlorination. IWAS systems can be implemented by distributing the wells over the affected area or by constructing a barrier to intercept groundwater flowing from the source area. Downgradient monitoring is required to confirm the effectiveness of this technology.

IWAS systems can be designed to have a minimal impact on existing Facility operations. Although a vapor collection manifold is usually required, much of the system could be constructed below grade. Air permitting requirements for the Renton Facility would likely be significant because the Facility is classified as a major source under the Clean Air Act. Fouling of the wells from biological activity or precipitation of natural groundwater constituents such as iron can affect operations and increase maintenance needs. Costs for IWAS would be moderate to high, depending on permitting requirements, emission control requirements, and special design requirements to accommodate ongoing Facility activities.

4.2.4 Monitored Natural Attenuation

Monitored natural attenuation (MNA) is a remedial approach that can lead to permanent destruction of COCs in a noninvasive manner. This approach relies on natural processes, including biodegradation by indigenous organisms and adsorption to soil, to retard and degrade organic compounds and to retard and immobilize metals. It is most effective following source removal, such as has been completed for many of the Facility SWMUs and AOCs. The significant period of time that has passed since source removal was completed supports the use of MNA at many of the SWMUs and AOCs. In addition, the extensive Facility development and activity support the use of noninvasive remedial technologies such as MNA.

This technology is especially appropriate to both solvent and petroleum hydrocarbon plumes at the Facility. The depositional history of the shallow subsurface in the vicinity of the Facility has resulted in a substantial amount of natural organic materials in the subsurface. This organic material supports natural microorganisms that can support natural biodegradation of groundwater constituents. The high organic carbon content of soils beneath the Facility has been confirmed by analytical results presented in the final RI Report (Weston, 2001a) and in the FSWP (Geomatrix, 2004c). The high organic content of site soils is expected to provide a favorable environment for effective natural biodegradation of organic constituents that may be present in affected groundwater. Because this technology does not require installation of equipment or addition of chemicals to the subsurface, it is readily compatible with the ongoing industrial activities at the Facility. Slow degradation rates that may be associated with MNA may lead to a long restoration time frame.

Groundwater monitoring data for chlorinated solvent sites presented in the final RI Report, the final FSWP, and quarterly monitoring reports provide ample evidence that natural biodegradation is active throughout the Facility. All sites where chlorinated solvents have been identified as groundwater constituents have significant concentrations of the products of biodegradation. For sites where PCE or TCE was released in the source area, detectable concentrations of *cis*-1,2-DCE and VC have been observed, both of which are by-products of successive reductive dechlorination of PCE and TCE. For most of these plumes, the extent of affected groundwater is defined by the presence of VC, which is present only due to biodegradation of the solvents. As an example, AOC-060 clearly demonstrates the effectiveness of natural attenuation at the Facility. The source area is located beneath a building, and groundwater flows from the building toward the Cedar River Waterway. Several monitoring wells are present in the plume, and groundwater quality has been monitored for several years. The solvent originally released, TCE, is present only in the immediate vicinity of the source area. The biodegradation products (*cis*-1,2-DCE and VC) define the areal extent of the plume. While the release occurred several years ago, current groundwater monitoring data (2007) indicate that the groundwater COCs are not reaching the waterway at concentrations exceeding the PCLs defined in the final RI Report. Groundwater modeling conducted for this site, as presented in the FSWP and in this report, requires that biodegradation be included to adequately calibrate the model to site data. These lines of evidence clearly indicate that natural attenuation is active at chlorinated solvent sites at the Facility.

Facility monitoring data collected for petroleum hydrocarbon sites also indicate that natural attenuation by biodegradation is active. At the Former Fuel Farm, natural attenuation is limiting the migration of groundwater constituents. This site was used for underground storage of fuels for several years, which resulted in the release of petroleum hydrocarbons. Although a large amount of soil was removed during tank removals, it was not practicable to remove all affected soil from the site. The residual hydrocarbons serve as an ongoing source of hydrocarbons to site groundwater. An interim measure (air sparging and bioventing) has been conducted at this site; however, the interim measure does not fully address the entire hydrocarbon plume at the Former Fuel Farm. Groundwater monitoring indicates that the affected groundwater plume has not reached the Cedar River Waterway, even though the release has likely been present for many years. The limited extent of the plume suggests that attenuation is effectively limiting its migration. Groundwater modeling conducted using BIOSCREEN and MTCATPH requires that active biodegradation be included in the model in order to calibrate it to site data. These lines of evidence indicate that natural attenuation is active for petroleum hydrocarbon sites at the Facility.

A rigorous monitoring network and program are typically associated with this technology to ensure that hazardous constituent degradation is effective and that cleanup levels are attained. The development of a valid remedial approach for MNA requires a monitoring plan designed to verify the existence of and quantify the extent of enhanced and natural attenuation processes. Guidance by Ecology (July 2005) and other recent guidance (Wiedemeier and Haas, 2002; EPA, 2004) provide technical recommendations regarding the types of monitoring parameters and analyses useful for evaluating the effectiveness of MNA and establishing a performance monitoring plan for natural attenuation of VOCs. The EPA guidance builds on EPA Office of Solid Waste and Emergency Response (OSWER) Directive 9200.4-17P (EPA, 1999), which provides guidelines for the use of MNA in RCRA Corrective Actions and establishes general objectives for monitoring programs. Prior to implementation of MNA as a final remedy, a directed investigation, performed in accordance with the Ecology and EPA guidance (Ecology 2005; EPA 1998, 1999), must be completed. Because of the additional study needed to prove that degradation occurs and to monitor the effectiveness of MNA, costs for this technology are expected to be moderate.

4.2.5 Permeable Reactive Barriers

Permeable reactive barriers consist of a reaction barrier placed at a location where it would intercept the plume as it migrates downgradient from the source area. The materials used to construct the reaction barrier would promote degradation of groundwater COCs. Permeable reactive barriers have been constructed of zero-valent iron for chlorinated solvents and some metals and from proprietary materials (e.g., Forager Sponge) to adsorb and immobilize organics and metals. Some barriers may support enhanced biological activity to degrade and destroy organic groundwater constituents. This technology can be effective in destroying or removing groundwater COCs before migration and exposure to a receptor occur. Permeable reactive barriers may be constructed across the affected groundwater flow path or they may be implemented in a “funnel and gate” arrangement, where low-permeability walls are used to direct groundwater flow to the reactive barrier. These barriers are generally passive and require regular monitoring but minimal maintenance.

This technology can be applied successfully to treat chlorinated solvents and petroleum hydrocarbons in groundwater. Based on the site conditions at the Facility, it would be necessary to place the barrier wall to a sufficient depth and width to intercept the full extent of the groundwater plume. Implementing the funnel and gate system at the Facility would be difficult because there is no low-permeability layer present for keying the impermeable wall into so that it would effectively funnel groundwater flow. Because of the site-specific nature of this technology, bench-scale (and possibly pilot-scale) testing would likely be required to confirm its effectiveness. The extensive development and activities at the Facility may limit areas where barrier walls could be located. Downgradient groundwater monitoring is also necessary to prove the effectiveness of this approach. Costs for this technology are expected to be moderate to high.

TABLE 4-1

POTENTIALLY APPLICABLE SOIL REMEDIATION TECHNOLOGIES

Boeing Renton Facility
Renton, Washington

Remedial Technology	Comments	Constituents Addressed[1]
Source Removal/ Disposal	Excavation is effective in removing affected source soils. Geologic conditions of Facility are amenable for removal of shallow soils at many areas. Excavation would be constrained by existing development, Facility activity, property lines, and the high water table.	All constituents
Soil Vapor Extraction/Bioventing	Removes VOCs and would be compatible with Facility geology. Technology would be constrained by existing buildings and may create potential exposure to Facility workers. Permanently destroys volatile constituents through oxidation or activated carbon regeneration.	VOCs and gasoline-range TPH compounds

Notes:
1. TPH = total petroleum hydrocarbons; VOCs = volatile organic compounds.

TABLE 4-2

POTENTIALLY APPLICABLE GROUNDWATER REMEDIATION TECHNOLOGIES

Boeing Renton Facility
Renton, Washington

Remedial Technology	Comments	Constituents Addressed
Biosparging/Air Sparging	Works well for certain petroleum hydrocarbons, aromatics, and VOCs; is relatively easy to implement; and can be done in areas constrained by buildings. Bioventing permanently destroys hydrocarbons through biodegradation. Air sparging permanently destroys VOCs through oxidation or activated carbon regeneration.	VOCs[1] and gasoline-diesel range TPH[2] compounds
Enhanced In Situ Bioremediation	Works well with a variety of COCs[3] and media. Easy to implement and minimal impact on facility operations. Results in permanent destruction of degradable constituents. Can be supplemented to immobilize metals. Difficult to implement in plumes with both chlorinated and nonchlorinated constituents.	TPH, select VOCs, and some metals
In-Well Air Stripping	Removes VOCs and should be effective for Facility geologic conditions. Can be implemented as a distributed system over the source area or as a barrier. Potential problems due to high Fe in groundwater.	VOCs and gasoline-range TPH compounds
Monitored Natural Attenuation	Can be effective for many Facility constituents, provided that proper conditions exist and will be maintained over the time required for remediation. Permanently destroys degradable constituents. Can be implemented in constrained areas. Requires significant study and monitoring.	VOCs, light TPH compounds, and metals
Permeable Reactive Barriers	Zero valent iron barrier walls can be effective for chlorinated constituents present in groundwater, provided that proper hydrogeology and water chemistry conditions are present. Can permanently destroy constituents. Requires pilot testing. Long-term effectiveness is not known.	Chlorinated VOCs, some metals

Notes:
1. VOCs = volatile organic compounds.
2. TPH = total petroleum hydrocarbons.
3. COCs = constituents of concern.

5.0 REMEDIAL ALTERNATIVE EVALUATION CRITERIA

Potentially applicable remedial alternatives will be developed from the remedial technologies described in Section 4. Each of these alternatives will be designed to attain the remedial objectives specific to each SWMU and AOC, as described in later sections of this FS report. A conceptual design will be prepared for each remedial alternative. The alternatives for each SWMU and AOC will then be evaluated relative to the criteria specified in the MTCA rules to select the preferred alternative for that site.

The evaluation for each site will use either a permanent alternative or the most protective alternative as the baseline for the evaluation; all remedial alternatives will be compared to the baseline alternative. The MTCA evaluation criteria are described in more detail in Section 5.1. The basis for selecting a baseline alternative is presented in Section 5.2.

5.1 EVALUATION CRITERIA

The evaluation criteria to be used for this focused FS must address requirements of the MTCA regulations and the Agreed Order, as discussed in the approved FSWP. The evaluation criteria for this FS include the following:

- Protectiveness and Risk Reduction,
- Permanence,
- Cost,
- Long-Term Effectiveness,
- Management of Short-Term Risks,
- Technical and Administrative Implementability,
- Public Concern, and
- Reasonable Restoration Time Frame.

All remedial alternatives considered in this FS will be designed to attain the cleanup standard to the extent practicable. For many alternatives, the cleanup standard will be based on a CPOC. Constraints specific to each SWMU or AOC may limit the capability of attaining cleanup levels at the standard POC. The cleanup standards used for the remedial alternatives will consist of the cleanup levels shown in Tables 3-1 and 3-2 and a POC where the cleanup levels must be attained.

The evaluation criteria are defined and discussed in the following subsections. The criteria are used to evaluate the remedial alternatives as appropriate for each SWMU and AOC in Sections 6 through 19. Since these evaluation criteria are used for each of the remedial alternatives considered in this FS, details regarding application of each criterion are presented in this section and are not repeated in the sections evaluating the alternatives.

5.1.1 Protectiveness and Risk Reduction

This criterion is used to assess the degree to which each remedial alternative protects human health and the environment and reduces potential risks to human or ecological receptors. Protectiveness and risk reduction will address long-term effects rather than short-term effects, which are evaluated under a different criterion. Alternatives that attain the cleanup levels for each alternative will be considered as protective, and alternatives that meet cleanup levels in a shorter time will be considered as providing a higher level of risk reduction. Alternatives that rely on engineering controls or institutional controls to provide protectiveness and risk reduction will generally be considered as ranking lower for this criterion than alternatives that do not rely on these controls.

Factors considered to evaluate this criterion include the following:

- Potential risks of the specific SWMU or AOC to human health and the environment under conditions prior to completion of the alternative. Preremediation risks would be used as a baseline to assess the reduction in risks that would result from the remedial alternative;
- Present and future land use for the SWMU or AOC;
- Present and potential for future use of any water resources either associated with or affected by the SWMU or AOC;
- Potential effectiveness and reliability of institutional controls associated with the alternative;
- The availability of alternative water supplies, as appropriate;
- The ability of the alternative to limit and monitor migration of COCs;
- Toxicity of COCs associated with the SWMU or AOC; and

- Efficacy of any natural processes that may mitigate the impact of COCs associated with the SWMU or AOC.

5.1.2 Permanence

Permanence is the degree to which a remedial alternative attains cleanup objectives by permanently destroying COCs and its capability to reduce the toxicity, mobility, or volume of affected media. Alternatives that actively degrade or destroy COCs would be ranked higher for this criterion than alternatives that rely on on-site or off-site containment. The alternative for each SWMU or AOC with the greatest degree of permanence will be used as the baseline alternative against which other alternatives will be compared.

Factors considered to evaluate this criterion include the following:

- Present and future land use for the SWMU or AOC and nearby properties;
- Present and potential for future use of any water resources either associated with or that may be affected by the SWMU or AOC;
- Potential effectiveness and reliability of institutional controls associated with the alternative;
- The ability of the alternative to limit and monitor migration of COCs; and
- Efficacy of any natural processes that may mitigate the impact of COCs associated with the SWMU or AOC.

5.1.3 Cost

Costs of remedial alternatives include implementation costs, operation and maintenance costs, monitoring costs, and reporting costs. Cost estimates will be prepared for each remedial alternative considered for each of the SWMUs and AOCs. The costs will include future costs for the estimated restoration time of the specific alternative or a maximum life of 15 years, whichever is less. Future costs will be included in the total alternative cost using present net worth analysis.

The costs for implementing an alternative include costs for engineering, permitting, public relations, construction, purchase of facilities and equipment, building demolition or utility relocation, transportation and disposal, building restoration, and site restoration. Implementation costs typically occur at the beginning of the remediation program but may also include costs that occur later in the remediation program, such as replacement of key remedial system components. Details regarding cost estimates for each of the sites are presented in Appendix B.

Costs for operations, maintenance, monitoring, and reporting generally occur annually after construction has been completed. Operation and maintenance costs include longer term expenses associated with multiyear remediation activities. Reporting costs are incurred to document monitoring and operations activities and provide regulatory information to Ecology. These ongoing costs usually include labor, power, analyses, subcontractors, and consumed materials. Future recurring costs for operations and maintenance, monitoring, and reporting will be combined with initial implementation costs into a single net present value (NPV) cost for each remedial alternative. The NPV calculations consider future annual inflation (assumed to be 2%) and an annual discount rate (assumed to be 7%) that addresses the time value of money. The discount rate is typically described as the interest rate that could be obtained from a prudent investment. This NPV cost, including initial implementation costs and future recurring costs, will be used to assess the cost criterion and compare the cost of the remedial alternatives.

For the purpose of this FS, a standard period of 15 years has been used for future recurring costs for all remedial alternatives evaluated. This period has been based on an assumed long-term groundwater monitoring period. In general practice, monitoring is conducted for a few years after remediation has been completed to ensure that cleanup standards have been attained. The time required to achieve remediation objectives cannot be accurately predicted in the absence of site-specific monitoring or testing data. The actual monitoring period would likely be different for a specific alternative; monitoring periods may be longer than 15 years for some alternatives and shorter than 15 years for other alternatives. It is difficult to accurately anticipate the monitoring time frame before reviewing the results of laboratory or pilot studies that would probably be conducted prior to final design and full-scale implementation. Additionally, monitoring programs can be terminated earlier than expected (or extended longer than expected) based on actual monitoring data collected. Longer monitoring periods would have minimal impact on the NPV cost estimate because the discount rate would reduce their present value. Monitoring periods shorter than 15 years would have a more significant effect on the NPV cost than longer periods because the effect of the discount rate would be lower. The standard monitoring period of 15 years is considered reasonable for the conceptual evaluation of remedial alternatives and comparison of remediation cost.

5.1.4 Long-Term Effectiveness

For this criterion, the capability of a remedial alternative to reliably maintain its effectiveness over a long period of time is assessed. In addition, the production of residues is assessed; alternatives that do not generate hazardous substance residues would have a greater long-term effectiveness than alternatives that do produce such a residue. Many COCs have a very slow degradation rate under natural conditions, and some COCs, such as metals, do not degrade. Permanent alternatives that result in destruction of COCs would provide better long-term effectiveness than alternatives relying on containment using engineering controls.

To evaluate this criterion, both positive and negative long-term environmental consequences are assessed. Positive consequences of remedial alternatives other than those associated with reductions in exposure concentrations of COCs include enhancements to the environment that may result from remediation (such as improved habitat) or not causing a disturbance to the existing environment (such as not altering natural groundwater flow patterns). Negative long-term consequences include factors such as changes that may reduce environmental value (such as destroying habitat) or the introduction of new, persistent constituents to the environment as a result of remediation. The incremental benefit accrued for an alternative will be compared to the negative consequences to assess disproportionality in long-term benefits and effectiveness.

Factors considered to evaluate this criterion include the following:

- Efficacy of any natural processes that may mitigate the long-term impact of COCs associated with the SWMU or AOC;
- Present and potential for future use of any water resources either associated with or that may be affected by the SWMU or AOC;
- Potential effectiveness and reliability of institutional controls;
- The ability of the alternative to limit long-term migration of COCs; and
- Present and future land use for the SWMU or AOC, including any constraints land use may have on the alternative.

5.1.5 Management of Short-Term Risks

Short-term risks associated with remedial alternatives include potential releases of material, water, particulates, or vapors containing COCs that could occur during implementation of the alternative. These types of losses could occur as a result of dust generation during excavation or handling of excavated materials, loss of affected soil or affected groundwater during treatment, or accidental releases during transport of affected media to a permanent disposal or treatment facility. Alternatives with minimal potential risks requiring management, such as MNA, would rank higher for this criterion than alternatives such as excavation and off-site disposal, which would have significant potential short-term risks.

5.1.6 Technical and Administrative Implementability

The technical and administrative implementability criterion involves the capability to effectively implement the alternative. Technical implementability involves technical and physical factors, such as the presence of existing buildings, that may affect implementation of an alternative or the need to have very specialized equipment for implementation. Administrative implementability assesses factors such as permitting requirements or regulatory approvals needed for implementation. Administrative factors would most likely affect the implementation schedule, whereas technical factors could make an alternative ineffective. Simple, nonintrusive alternatives would rank high for technical implementability. Alternatives with minimal permitting requirements and that are readily accepted by regulatory agencies would rank high for administrative implementability.

Factors considered to evaluate this criterion include the following:

- The size and complexity of the remedial alternative;
- The degree to which the remedial alternative can be integrated with existing plant operations and activities;
- Regulatory requirements, including permitting;
- Present and future land use for the SWMU or AOC, including any constraints land use may have on the alternative;
- Present and potential for future use of any water resources either associated with or that may be affected by the SWMU or AOC; and
- Potential effectiveness and reliability of institutional controls associated with the alternative.

5.1.7 Public Concern

For this criterion, the potential for creating concern among the general public, adjacent facilities, and the community if the alternative were to be implemented is assessed. Alternatives likely to be readily accepted by the public would rank higher than alternatives that may create issues that must be addressed. Potential public concerns include factors such as increased truck traffic, noise, dust, odors, release of vapors, and effects on property values. The Cedar River Trail Park is located just west of several SWMUs and AOCs in the main portion of the Facility, which could lead to potential public concern related to potential impacts to the park or to users of the park. Impacts on Lake Washington or the Cedar River Waterway may also create public concern over water quality or potential effects on aquatic biota. The public potentially affected by the Facility includes users of the Cedar River Trail Park and lessees/users/owners of nearby facilities or the Renton Municipal Airport. The potentially affected landowner is the City of Renton.

5.1.8 Reasonable Restoration Time Frame

The restoration time frame is the time required for an alternative to attain remedial objectives. In assessing this criterion, the practicability of attaining the shortest restoration time is assessed. Additional consideration is given to several factors, including the following:

- Existing risks to human health and the environment;
- Site use;
- Potential future site use;
- Availability of alternative water supplies; and
- Reliance on institutional controls.

These factors are assessed as a whole and determine the urgency of achieving the remedial objectives for a specific site. Alternatives that achieve remediation objectives in a shorter time would rank higher for this criterion than alternatives requiring a longer time. This criterion involves the practicality and necessity of implementing an alternative within a shorter time and the potential effectiveness and reliability of any institutional controls associated with the alternatives.

5.2 BASELINE REMEDIAL ALTERNATIVES

The baseline remedial alternative must be a cleanup alternative that provides the highest degree of permanence. The MTCA regulations (WAC 173-340-200) define a “permanent solution” or a “permanent cleanup action” as:

> "…a cleanup action in which the cleanup standards of WAC 173-340-700 through 173-340-760 can be met without further action being required at the site being cleaned up or any other site involved with the cleanup action, other than the approved disposal of any residue from the treatment of hazardous substances."

The MTCA regulations in WAC 173-340-700 through 173-340-760 define the requirements for establishing cleanup levels and POCs, which together comprise the cleanup standard that must be met by the selected cleanup action. Cleanup levels established in accordance with these regulations were proposed in the FSWP and recently negotiated with Ecology. Points of compliance are defined for each remedial alternative considered in this FS.

Each remedial alternative is evaluated relative to attainment of the cleanup standard. As previously noted, all alternatives considered for each site would be capable of attaining the cleanup standard and are, therefore, permanent alternatives. For each site evaluated in this FS, the "most permanent" alternative is defined as the baseline alternative.

The factors considered in defining the baseline alternative include the following:

- Attaining the standard POC for soil and groundwater;
- Establishing a CPOC as close to the source area as possible;
- The degree to which COCs are destroyed with no toxic residual. Alternatives with a greater degree of COC destruction will be favored over alternatives with a lesser degree; and
- For most COCs that are not destroyed by alternatives, the degree to which COCs are removed from the site. Alternatives that remove COCs would be favored over alternatives that immobilize or contain the COCs.

The baseline alternatives considered for each SWMU and AOC in this FS were selected based on a consideration of these factors.

6.0 DEVELOPMENT AND EVALUATION OF REMEDIAL ALTERNATIVES, SWMU-168

In this section we discuss remediation objectives, identify and evaluate remedial alternatives, and describe the preferred remedial alternative for SWMU-168.

6.1 SITE CHARACTERIZATION SUMMARY

SWMU-168 (referred to as “the site” in this section) is located near the northeast corner of Building 5-50 near the Renton Municipal Airport and consists of the area around a former underground storage tank (UST) designated URE-31 (for underground tank Renton, number 31) (see Figure 1-2). Former UST URE-31 was a 1,000-gallon concrete tank that was installed in 1979 and removed in September 1985. This UST was used for the storage of solvent waste generated in Building 5-50. There is no documented information regarding releases from this SWMU. Section 5.4 of the final RI Report presents the complete site characterization results for this SWMU (Weston, 2001a). The results of the RI and additional data collection are summarized below.

6.1.1 Historical, Present, and Future Site Use

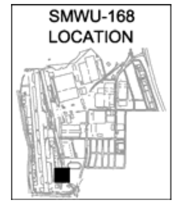
The type of solvent waste that was stored in URE-31 is not known. Building 5-50 is currently used by Boeing to support airplane manufacturing activities conducted at the Renton Facility. This building is owned by Boeing and the land is leased to Boeing by the City of Renton. This building and the adjacent buildings and areas are currently used for industrial purposes and are expected to remain in industrial use for the foreseeable future.

6.1.2 Previous Site Remedial Actions

The UST URE-31 was removed in 1985, and there was no documented soil removal at the time the tank was removed.

6.1.3 Site Hydrogeology

The general stratigraphy beneath SWMU-168 consists of an upper layer of fill material that extends to depths ranging from approximately 5 to 7 feet below ground surface (bgs) throughout most of the SWMU-168 site. In the immediate vicinity of the former UST, the fill material extends to depths of approximately 10 to 14 feet bgs. This fill material consists of fine- to medium-grained reddish- to greenish-brown sand with silt and gravel. The alluvium below the fill, which is present throughout the SWMU-168 area, consists of interbedded greenish-gray clayey silt with gravelly and silty sand.



A sheet pile wall is located adjacent to the Cedar River Waterway, downgradient from the site. In 1999, the U.S. Army Corp of Engineers (USACE) constructed floodwalls and earthen levees for flood control along both the east and west sides of the Cedar River Waterway from the Logan Avenue North bridge to the mouth of the waterway. The concrete floodwalls (maximum height of approximately 10 feet above grade) were constructed above interlocking steel sheet piles that were driven to a minimum depth of 21 feet bgs. The sheet piling runs along the entire western bank of the waterway, from Logan Avenue to Lake Washington. According to the final RI Report, the sheet piling is not keyed into a low-permeability soil unit and functions as a “hanging barrier wall.” It is expected that the sheet pile wall affects groundwater flow, likely causing groundwater to flow beneath the piling as it approaches the waterway.

Depth to groundwater at SWMU-168 was approximately 5 feet during the RI. The general direction of groundwater flow is to the northeast toward the Cedar River. A groundwater hydraulic gradient of 0.001 to 0.006 was measured for this SWMU. The hydraulic conductivity of the shallow aquifer in the SWMU-168 area ranges from 4.6×10^{-5} to 4.2×10^{-3} centimeters per second (cm/s).

Based on a geologic cross-section presented in the final RI Report, the predominant soil type in the vadose zone is silty sand with gravel, and the soil type dominating groundwater flow is also silty sand with gravel. Therefore, the dominant Unified Soil Classification System (USCS) soil classification for both the vadose and saturated zones is SM; soil characteristics for SM soil will be used for relevant calculations in this FS.

6.1.4 Nature and Extent of Affected Soil

The 1999 sampling results from the RI (summarized on Figure 6-1) indicated that SWMU-168 soils contained VOCs above the respective PCL as defined in the final RI Report (Weston, 2001a). Methylene chloride was the VOC detected exceeding the soil cleanup level at that time; it was detected in 1999 at only two sample locations: PP001 (at 2 feet bgs) and PP002 (at 5 feet bgs). Methylene chloride was detected in a soil sample from PP001 at a concentration of 73 micrograms per kilogram (µg/kg) and in a soil sample from PP002 at a concentration of 30 µg/kg. None of the remaining soil samples collected during the RI contained methylene chloride at concentrations that exceeded the methylene chloride PCL of 27 µg/kg. TCE and *cis*-1,2-DCE were also detected in soil samples, but none of the concentrations exceeded the PCLs.

6.1.5 Nature and Extent of Affected Groundwater

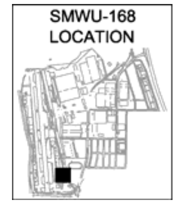
VC was detected at concentrations exceeding the VC groundwater cleanup level in one groundwater sample collected in 1999 from push probe PP003 at SWMU-168. VC was detected at a concentration of 2.1 micrograms per liter (µg/L), which is just above the groundwater PCL of 2.0 µg/L for VC. Analytical results from the groundwater investigation at the site are also summarized on Figure 6-1. The extent of VC-affected groundwater was limited to PP003. VC was not detected in any of the remaining push probe groundwater samples. No other VOCs were detected above the PCLs in groundwater samples collected from the remaining push probes.

6.2 CONCEPTUAL SITE MODEL

A preliminary conceptual model for migration of constituents present in affected soil and groundwater at the Facility is shown in Figure 2-6 of the FSWP (Geomatrix, 2004c). Based on the conceptual model and considerations presented in the FSWP plus information specific to this site, a site-specific conceptual site model is described below. This site-specific conceptual site model identifies the media and exposure pathways that must be addressed for remedial alternatives potentially applicable to this site.

Methylene chloride was present in soil within the source area for SWMU-168. As shown in the Facility conceptual model presented in the FSWP, methylene chloride can migrate from the source areas via groundwater or vapor pathways. Migration via a vapor pathway may have already occurred, and remaining concentrations of methylene chloride may be below the applicable cleanup level. It is also possible that methylene chloride has migrated through the vadose zone to groundwater, although it was not detected in groundwater samples collected at the same push probe locations at the time. Constituent transport via groundwater at this site is affected by soil/groundwater interactions, biodegradation, and by the presence of the sheet pile wall in the downgradient groundwater flow path. As groundwater flows through methylene chloride-affected soil in the source area, adsorbed methylene chloride may dissolve into groundwater. Any dissolved methylene chloride will move with groundwater but at a different velocity because of continuing solute-soil interactions. This movement may create a plume extending downgradient from the source areas; however, no such plume was detected in the adjacent push probes.

The extent of groundwater affected by dissolved VC was limited to a small area near PP003. The source of the VC is likely the shallow soils at the site, which contain low concentrations of



TCE and *cis*-1,2-DCE, but at concentrations below the soil cleanup levels. The VC-affected groundwater is migrating to the northeast from the source area toward the discharge area along the Cedar River Waterway. However, the low concentration of VC in the groundwater will likely degrade into ethene and chloride salts before it reaches the waterway. Volatilization of constituents from groundwater is not significant for most workers at this site, as noted in the conceptual model presented in the FSWP.

6.3 SITE REMEDIATION OBJECTIVES AND CLEANUP STANDARDS

The remediation objectives for the Renton Facility were presented in Section 2 of this report. Cleanup levels applicable to the Facility were proposed in the FSWP and were subsequently negotiated with Ecology. The remedial alternatives developed and evaluated for this site will be capable of attaining the remediation objectives and cleanup standards presented in this section. As defined in the MTCA regulations, the cleanup standard consists of the cleanup level and the location or POC at which the cleanup level must be met. The remedial alternatives for this site, presented below in Section 6.4, may have different points of compliance while fully addressing remediation objectives and meeting cleanup levels.

The groundwater and soil COCs exceeding the PCLs established in the final RI Report for SWMU-168 were identified in FSWP Tables 5-1 and 5-3, respectively. These constituents were identified by comparing detected constituent concentrations to the PCLs identified in the final RI Report; if a constituent concentration measured in any sample exceeded the PCL, the constituent was listed as a COC that must be addressed in the FS. Cleanup levels for both soil and groundwater meeting MTCA requirements were presented in the FSWP (Tables 5-6 and 5-2, respectively) and subsequently negotiated with Ecology.

The soil and groundwater cleanup levels for the SWMU-168 site COCs are listed in Tables 3-1 and 3-2, respectively. The soil cleanup levels in Table 3-1 were established using MTCA Method A or Method C and are applicable anywhere within the site up to and including the CPOC. The groundwater cleanup levels listed in Table 3-2 were developed as described in Section 3 and in accordance with recent negotiations with Ecology. The cleanup levels in Table 3-2 are protective of surface water, human health, and the environment.

6.4 DESCRIPTION OF SITE REMEDIAL ALTERNATIVES

SWMU-168 is located near the northeast corner of Building 5-50 near the Renton Municipal Airport and consists of the area around former UST URE-31. This area is leased from the City

of Renton, and the nearby buildings will continue to be used to support airplane manufacturing activities for the main plant area across the Cedar River Waterway for the foreseeable future.

MTCA requires that remedial alternatives selected for a site meet the MTCA threshold requirements for cleanup actions. The minimum threshold requirements specify that cleanup actions shall (1) protect human health and the environment, (2) comply with cleanup standards, (3) comply with applicable state and federal law, and (4) provide for compliance monitoring. In order to be considered as a potential remedial alternative for the site, the technologies considered had to pass the screening evaluation of the remedial technologies described in Section 4. In addition, the alternatives had to meet the minimum threshold requirements established by MTCA and had to be consistent with overall site conditions.

Based on the screening evaluation, MTCA minimum threshold requirements, and the site considerations discussed above, three remedial alternatives addressing groundwater COCs were developed for SWMU-168:

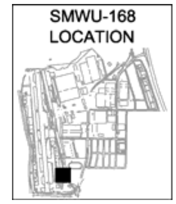
- Alternative 1: Monitored Natural Attenuation
- Alternative 2: Soil Vapor Extraction and Monitored Attenuation
- Alternative 3: Enhanced Bioremediation and Monitored Attenuation

6.4.1 Alternative 1: Monitored Natural Attenuation

Alternative 1 consists of three primary elements: confirmation sampling, followed by institutional controls and MNA, if necessary. The groundwater cleanup standard for this alternative will be the groundwater cleanup level for the SWMU-168 COC discussed in Section 6.3 and a CPOC downgradient of the Facility, as shown on Figure 6-1. The soil cleanup standard will be the general soil cleanup level discussed in Section 6.3 and shown in Table 3-1. The detected concentrations of methylene chloride in soil at PP001 and PP002 and VC in groundwater at PP003 are the only COCs exceeding the soil and groundwater cleanup levels at SWMU-168. Alternative 1 uses institutional controls and MNA to address these COCs.

6.4.1.1 Confirmation Sampling

Because the COCs at this site are VOCs and were detected more than 5 years ago, it is possible that natural attenuation has already resulted in concentrations below the cleanup levels. To confirm that these VOCs in soil and groundwater still exist, a confirmation sampling program



would be conducted, and soil and groundwater samples would be collected as they were in 1999 at the PP001, PP002, and PP003 locations shown on Figure 6-1. If concentrations in soil or groundwater continue to exceed cleanup levels, the subsequent steps of this alternative, institutional controls and MNA, would be implemented. If the soil and groundwater concentrations were found to be below cleanup levels, no additional remedial action would be taken.

6.4.1.2 Institutional Controls

The following institutional controls are included to reduce the risk of human exposure to impacted soil or groundwater:

- Continued engineering controls, protocols, and monitoring previously established by Boeing to ensure that industrial workers inside buildings are protected and indoor air concentrations meet Permissible Exposure Limits (PELs) established by the Washington Department of Labor and Industry;
- Continued engineering controls, protocols, and monitoring to ensure that temporary construction workers adhere to WAC 296-62-300, applicable Washington Labor and Industry standards, and Occupational Safety and Health Administration (OSHA) Hazardous Waste Operation and Emergency Response (HAZWOPER) regulations (29 CFR 1919.120) for all construction work conducted in exposed areas of affected soil and groundwater; and
- Deed restrictions to limit development and use of the site.

It is anticipated that deed restrictions would be established to limit future unrestricted land use without additional actions to attain compliance with appropriate soil and groundwater cleanup levels. It is further assumed that a CPOC would be established for this alternative with permission granted by the landowner, the City of Renton. In conjunction with permission for a CPOC, it is anticipated that the City of Renton would formalize internal restrictions and institutional controls for temporary construction or maintenance workers in areas off of the Boeing lease property.

6.4.1.3 Monitored Natural Attenuation

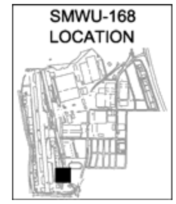
Groundwater monitoring data collected at the Renton Facility (as discussed in Section 4.2.4) indicate that natural processes are at work degrading and retarding the migration of COCs at other SWMUs and AOCs (as discussed in Section 4.2.4), so it is expected that these same processes will also address the low concentrations of methylene chloride and VC at SWMU-168.

In accordance with the current guidance and the approach discussed in Section 4.2.4, the conceptual monitoring program for SWMU-168 is designed to:

- Demonstrate that natural attenuation is occurring according to expectations;
- Identify any potentially toxic and/or mobile transformation products;
- Verify that the plume is not expanding beyond the CPOC;
- Verify that cleanup levels are attained at the CPOC;
- Verify that there is no unacceptable impact to downgradient receptors;
- Detect new releases of COCs that could impact the effectiveness of the natural attenuation remedy;
- Demonstrate the efficacy of institutional controls put in place to protect potential receptors; and
- Verify attainment of remediation objectives.

The conceptual monitoring program for Alternative 1 at SWMU-168 assumes that if this remedy were selected, a detailed MNA Validation and Long-Term Sampling Work Plan would be developed to guide the process. This work plan would identify additional monitoring wells and monitoring analytes that would be required for both characterization/validation sampling and long-term groundwater monitoring. Characterization/validation sampling would be used to demonstrate the effectiveness of MNA with respect to contaminant mass reduction, attenuation rates, and temporal trends. Long-term groundwater monitoring would be used after characterization/validation monitoring to confirm that the contaminant plume is progressing toward containment or achievement of numerical cleanup goals.

For this conceptual design, it is assumed that characterization/validation sampling would consist of quarterly monitoring of four monitoring wells for a minimum of 1 year. Four new monitoring wells (three shallow monitoring wells and one intermediate depth monitoring well) are assumed to be required to monitor plume migration (Figure 6-1). Monitoring parameters and analytes would consist of VOCs (contaminants and daughter products), as well as the full suite of MNA geochemical parameters [dissolved oxygen, nitrate, Fe(II), sulfate, methane, temperature, pH, specific conductance, alkalinity, oxidation/reduction potential, chloride, ethane, and total organic carbon (TOC)]. It is assumed that reporting for characterization/validation sampling would follow each quarterly event.



It is further assumed that long-term groundwater monitoring would follow for an additional 13 to 14 years (15 total years of monitoring) and include semiannual monitoring of the four monitoring wells for VOCs (contaminants and daughter products) and a limited suite of geochemical parameters (dissolved oxygen, oxidation/reduction potential, temperature, and pH). To ensure plume control, all four wells would be sampled once every 5 years for the entire characterization/validation list of analytes. It is assumed that annual reporting would be required for long-term groundwater monitoring.

6.4.2 Alternative 2: Soil Vapor Extraction and Monitored Natural Attenuation

Alternative 2 consists of four primary elements: confirmation sampling, followed by institutional controls, SVE, and MNA, if necessary. The groundwater cleanup standard for this alternative will be the groundwater cleanup levels for SWMU-168 COCs discussed in Section 6.3 and a CPOC as shown on Figure 6-1. The soil cleanup standard will be the general soil cleanup level discussed in Section 6.3 and presented in Table 3-1. The detected concentrations of methylene chloride in soil at PP001 and PP002, and VC in groundwater at PP003, are the only COCs that exceed soil and groundwater cleanup levels at SWMU-168. Alternative 2 uses institutional controls, SVE, and MNA to address the soil and groundwater COCs. Given that other risks from the VOCs in soils can be managed through institutional controls (discussed below) and that the soils are confined by the existing tarmac or pavement, no other active measures are required to remediate soils.

6.4.2.1 Confirmation Sampling

Confirmation sampling for Alternative 2 would be performed as discussed in Section 6.4.1.1 for Alternative 1.

6.4.2.2 Institutional Controls

Institutional controls for Alternative 2 would be as discussed in Section 6.4.1.2 for Alternative 1.

6.4.2.3 Soil Vapor Extraction

A single SVE well would be used to extract soil affected by methylene chloride at SWMU-168. The well would be installed near PP001 (Figure 6-1). SVE is compatible with the current site use and would be effective at addressing the affected soil at this SWMU. VOCs removed from the soil would be collected and treated using potassium permanganate and granular-activated carbon (GAC) beds operated in series to control emissions. Subsequent to the completion of

SVE system operation, soil confirmation sampling would be performed to confirm that the unsaturated zone soil at this SWMU had met the soil cleanup level for methylene chloride.

6.4.2.4 Monitored Natural Attenuation

Monitored natural attenuation for this alternative is intended to be a final "polishing" mechanism, following the soil vapor extraction, to ensure that cleanup levels for all COCs are met at the CPOC. With this alternative, it is assumed that MNA would follow SVE and consist of long-term groundwater monitoring for three shallow wells and one intermediate well, as described in Section 6.4.1.3 for Alternative 1.

6.4.3 Alternative 3: Enhanced Bioremediation and Monitored Attenuation

Alternative 3 consists of four primary elements: confirmation sampling, followed by institutional controls, enhanced biodegradation, and MA. The groundwater cleanup standard for this alternative will be the groundwater cleanup levels for SWMU-168 COCs discussed in Section 6.3 and a CPOC as shown on Figure 6-1. The soil cleanup standard would be the general soil cleanup level discussed in Section 6.3 and presented in Table 3-1. The detected concentrations of methylene chloride in soil at PP001 and PP002, and VC in groundwater at PP003, are the only COCs exceeding the soil and groundwater cleanup levels at SWMU-168. Alternative 3 uses institutional controls, enhanced biodegradation, and MA to address the soil and groundwater COCs. Given that other risks from the VOCs in soils can be managed through institutional controls and that the soils are confined by the existing pavement or tarmac, no other active measures are required to remediate soils.

6.4.3.1 Confirmation Sampling

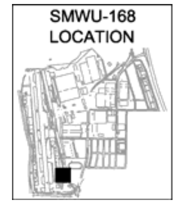
Confirmation sampling for Alternative 3 would be conducted as described in Section 6.4.1.1 for Alternative 1.

6.4.3.2 Institutional Controls

Institutional controls for Alternative 3 would be conducted as described in Section 6.4.1.2 for Alternative 1.

6.4.3.3 Enhanced Bioremediation

Enhanced bioremediation for SWMU-168 would consist of increasing the reductive capacity of the subsurface aqueous system by providing additional growth substrates for microbial activity. The conceptual design of enhanced bioremediation for Alternative 3 employs a series of four



injection push probes in an injection zone surrounding the apparent source area (Figure 6-1). The push probes would be driven to approximately 15 feet bgs, and growth substrate would be injected through the probes into the impacted aquifer at a depth between 11 and 15 feet bgs. The growth substrate injected would be emulsified vegetable oil or similar substrates. For costing purposes, it is assumed that 250 gallons of 2% emulsified vegetable oil would be injected into the four push probes in approximately equal portions. It is also assumed that a single application would be sufficient to effectively treat the aquifer.

6.4.3.4 Monitored Attenuation

Monitored attenuation for this alternative is intended to be a final "polishing" mechanism, following the active enhanced bioremediation, to ensure that cleanup levels for all COCs are met at the CPOC. With this alternative, it is assumed that MA would follow enhanced bioremediation and consist of the long-term groundwater monitoring for three shallow wells and one intermediate well, as described in Section 6.4.1.3 for Alternative 1.

6.5 EVALUATION OF SITE REMEDIAL ALTERNATIVES

As previously discussed, all three alternatives developed for SWMU-168 meet the MTCA minimum requirements for cleanup actions. This section compares and evaluates the alternatives based on the MTCA criteria described in Section 5.1. Analyses of all three alternatives with respect to the evaluation criteria are summarized in Table 6-1 and discussed below.

6.5.1 Protectiveness and Risk Reduction Evaluation

Protectiveness and risk reduction are gauged primarily by the time required for the alternative to reduce risk and meet cleanup levels. Because they employ active technologies, Alternatives 2 and 3 are expected to more quickly reduce COCs in soil and groundwater to attain cleanup levels and are rated highest for this criterion.

6.5.2 Permanence

Permanence refers to the ability to reduce the toxicity, mobility, or volume of hazardous substances, including the permanent destruction of hazardous substances. All three alternatives provide permanent destruction of COCs. Alternative 2 is rated highest for this criterion because the destruction is more controlled in both soil and groundwater and is expected to occur at a faster rate.

6.5.3 Cost

The cost evaluation includes all costs related to implementation of an alternative, including initial design and construction costs, operation and maintenance costs, monitoring costs, and reporting costs. The annual costs for operation, maintenance, monitoring, and reporting are recurring costs that occur in the future. The cost evaluation considers initial implementation costs and future recurring costs using NPV analysis. For NPV calculation, recurring costs were inflated 2% annually and a discount rate of 7% was used. Details regarding the cost estimates for the three alternatives are presented in Appendix B. The NPV costs for the three alternatives, in 2007 dollars, are summarized below:

Alternative	Net Present Value
1: Monitored Natural Attenuation	$367,000
2: Soil Vapor Extraction and Monitored Attenuation	$572,000
3: Enhanced Bioremediation and Monitored Attenuation	$409,000

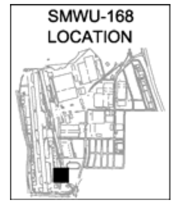
As shown by these costs, Alternative 2 has the highest NPV cost, while Alternative 1 has the lowest. Therefore, Alternative 1 ranks highest for cost and Alternative 2 ranks lowest, with Alternative 3 having nearly the same cost as Alternative 1.

6.5.4 Long-Term Effectiveness

Long-term effectiveness includes the degree of certainty and reliability of the alternative and whether treatment residue remains from the alternative that will require management. All three alternatives are proven technologies. Alternatives 1 and 3 would produce no residual waste. The SVE treatment system for Alternative 2 would produce residual wastes requiring off-site handling.

6.5.5 Management of Short-Term Risks

Short-term risk refers to the risk to human health and the environment during implementation of the alternative. Because Alternative 1 would be the simplest to implement and not require construction of a treatment or injection system, it is rated highest for this criterion.



6.5.6 Technical and Administrative Implementability

This criterion refers to whether the alternative is technically possible relative to complexity, administrative/regulatory requirements, size, access, and integration with existing operations. Given that Alternative 1 is a small, simple system that integrates well with the Facility operations, it is rated highest, whereas Alternative 2 rates lowest.

6.5.7 Public Concerns

This criterion considers potential community concerns with the alternative. Because all three of these alternatives deal with an industrial site with limited public access, they are rated the same.

6.5.8 Reasonable Restoration Time Frame

Restoration time frame involves the practicability of a shorter restoration time frame with consideration given to a number of factors, including site risks, site use and potential use, availability of alternative water supply, effectiveness and reliability of institutional controls, and toxicity of hazardous substances at the site. As a whole, these factors are a measure of the urgency of reducing risk and achieving cleanup goals for the site. Given that the site is industrial, has limited public access, and the risk to the public is low, all three of these alternatives are ranked medium low.

6.6 Selection of the Preferred Site Remedial Alternative

Selection of a preferred alternative under MTCA requires that a preference be given to alternatives that use permanent solutions (to the maximum extent practicable), alternatives that provide for a reasonable restoration time frame, and alternatives that consider public concerns. The analysis below compares the baseline alternative (the alternative that provides the greatest degree of permanence) to the other alternatives based on degree of permanence, reasonable restoration time frame, and public concerns. According to MTCA (WAC 173-340-200), a permanent solution or permanent cleanup action means a cleanup action in which cleanup standards can be met without further action being required at the site involved, other than the approved disposal of any residue from the treatment of hazardous substances.

6.6.1 Baseline Remedial Alternative

The baseline remedial alternative for SWMU-168 is Alternative 2. Although all three alternatives could be considered to be permanent cleanup actions in the sense that cleanup standards would be met, this alternative is considered to have a higher degree of permanence

because it relies on permanent destruction of hazardous substances in both soil and groundwater and would likely provide for a shorter restoration time frame than Alternatives 1 and 3.

The evaluation of all three remedial alternatives for this site is summarized in Table 6-1. None of the alternatives is capable of attaining the standard POC at this site. However, all alternatives are capable of meeting the CPOC located on the leased property and less than 60 feet from PP003.

6.6.2 Comparison to Baseline Alternative

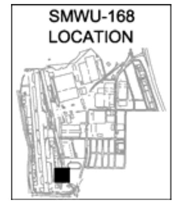
As noted above, Alternative 2 has been defined as the baseline remedial alternative for this site. Alternatives 1 and 3 will be compared to the baseline alternative below for selection of the preferred alternative. The purpose of this comparison is to assess the benefits and costs for Alternative 2 relative to Alternatives 1 and 3. The evaluation criteria presented above and in Table 6-1 were established in accordance with the MTCA requirements cited in WAC 173-340(3)(f). Costs for the alternatives will be based on the NPV, which reflects the total cost associated with each alternative over the 15-year time period evaluated. The evaluation of benefits will be qualitative.

The benefits to be assessed in this comparison and the relative rating for the alternatives are presented in Table 6-2. The rationale for this comparison is presented below.

- **Reduced risk to on-site worker health.** All three alternatives are equal in reducing risk to site workers because they are all equally protective. Although the baseline alternative would remove volatile COCs within a few years, potential risks to on-site workers would not be changed substantially by the other alternatives. The institutional controls included in each of the alternatives have been proven effective in protecting worker health and would continue to be protective.

- **Reduced risk to off-site human health.** All three alternatives were rated high for this benefit. All three would attain the cleanup level at the CPOC, which is protective of human health and the environment. The institutional controls included in the alternatives that have proven to be protective of worker health on site would also be protective of human health in off-site areas located upgradient of the CPOC.

- **Reduced risk to the environment.** All three alternatives were rated high for this benefit. All three alternatives would be protective of the aquatic environment because they would attain the cleanup levels at the CPOC.



- **Minimal adverse impact on Facility operations.** The baseline alternative was rated moderate for this benefit because it would impact Facility operations during installation and maintenance of the SVE system. A high rating was given to Alternative 1, which relies on passive degradation of site COCs and would have the least impact on Facility operations.

- **Minimal restrictions on Facility traffic and access.** The baseline alternative was rated moderate for this benefit because it would impact Facility traffic and access during installation and maintenance of the SVE system, and during operation. Alternative 3 was also rated moderate for similar reasons as the baseline alternative. Alternative 1 was given a high rating because it would affect traffic only during installation of monitoring wells, resulting in the least impact on Facility traffic and access.

- **Minimal adverse impact on Facility structures and utilities.** All three alternatives were rated high for minimizing adverse impacts on facility structures and utilities. None of these alternatives would potentially affect the integrity of site improvements.

The potential benefit evaluation for the alternatives shows that Alternative 1, Monitored Natural Attenuation, would provide the greatest benefit. The baseline alternative (Alternative 2) and Alternative 3 would provide the next highest benefits.

The NPV costs for all three alternatives were presented in Section 6.5.3. Alternative 2 ranks first among the alternatives and would have the highest cost (approximately 56% higher than the cost for Alternative 1, and 40% higher than the cost for Alternative 3).

6.6.3 Preferred Remedial Alternative

Alternative 3, Enhanced Bioremediation and Monitored Attenuation, is the preferred remedial alternative for the SWMU-168 site. Under Alternative 3, affected soils would remain capped by maintained pavement or tarmac to prevent potential runoff and infiltration of rainfall. Groundwater in the area is not used for any purpose, and potable water is readily available from the Renton public water system. The institutional controls included in Alternative 3 have been implemented and proven by Boeing, who would continue to maintain overall responsibility for this site and ensure that the institutional controls are properly enforced. Alternative 2, as the baseline and the most permanent potential remedy, does not provide more benefits than the other two alternatives. Alternative 3, Enhanced Bioremediation and Monitored Attenuation, is the preferred alternative for the SWMU-168 site because it is nearly as effective as the baseline alternative, but at a lower cost. Furthermore, the additional cost of Alternative 3 over Alternative 1 is not disproportionate to the more rapid restoration time frame.

Enhanced bioremediation and monitored attenuation for this site would achieve the expectations for cleanup actions cited in the MTCA regulations at WAC 173-340-370 (1) – (8). The relevant expectations are addressed as follows.

- **Implement Treatment at Sites with Liquid Wastes, High Contaminant Concentrations, Highly Mobile Materials, or Discrete Areas of Contamination.** Ecology expects that treatment will be emphasized for sites meeting these general criteria. The remaining COC levels at this site are low in concentration, and there is no evidence of liquid wastes at the site. The source area is not discrete preventing ready access for removal or treatment. Enhanced bioremediation and MA will degrade or "treat" organic COCs over the long term using natural processes that result in nontoxic degradation products.

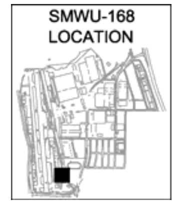
- **Destroy, Detoxify, or Remove Hazardous Substances.** Ecology expects that hazardous substances will be destroyed, detoxified, or removed to below cleanup levels. Enhanced bioremediation and MA will ultimately destroy COCs resulting in nontoxic degradation products and meeting cleanup levels at the CPOC.

- **Implement Engineering Controls for Low Contaminant Concentrations.** Ecology recognizes the need for containment for low concentrations of contaminants where treatment is impracticable. This alternative uses containment by the pavement or tarmac to limit migration from soil to groundwater.

- **Prevent Runoff of Hazardous Substances.** Ecology expects that cleanup actions will include active measures to prevent precipitation from creating runoff that contains affected soil. This expectation would be met by the preferred alternative, because the source area is entirely covered by pavement or tarmac. This pavement and tarmac are integral to Boeing's activities at the site and are well maintained. In addition to preventing runoff from contacting hazardous substances, the pavement/tarmac minimizes surface water infiltration, thus resulting in decreased groundwater flow rates and increased time for groundwater to flow from the source area to the waterway.

- **Consolidate On-Site Contaminants Exceeding Cleanup Levels.** Ecology expects that when contaminants are left on site exceeding cleanup levels that they will be consolidated to the extent practicable. At this site, due to the location of the contaminants, it is not practicable to consolidate contaminants.

- **Prevent Runoff and Groundwater Discharge to Surface Water.** Ecology expects that the cleanup action would include active measures to prevent or minimize releases to adjacent surface water bodies via runoff or groundwater



discharge, and that dilution will not be the sole method for attaining cleanup levels. Available groundwater monitoring data indicate that biodegradation of organic COCs is active and significant at this site. The cleanup alternative also includes a groundwater monitoring network and program that would confirm that cleanup levels are attained in groundwater less than 60 feet downgradient of the SWMU and before groundwater can reach the Cedar River Waterway.

- **Ensure Appropriateness of Attenuation.** Ecology expects that natural attenuation may be appropriate if source control has been conducted to the maximum extent practicable; contaminants remaining on site do not pose unacceptable risks to human health and the environment; evidence indicates that degradation is occurring and will continue to occur at a reasonable rate; and appropriate monitoring is conducted. These expectations would all be achieved by Alternative 3. Although affected soil and groundwater have been present at the site for a long time, Boeing has implemented effective institutional controls that have proven effective in protecting human health and the environment at this site. Groundwater monitoring data indicate that biodegradation of organic COCs is active at the Facility; coupled with the high organic fraction in site soil, site conditions are favorable to continued active biodegradation, and the enhanced bioremediation included under Alternative 3 would further support biodegradation. Alternative 3 also includes a robust groundwater monitoring program. The monitoring system included in the preferred alternative would confirm that cleanup levels are attained prior to groundwater discharging to the Cedar River Waterway.

The preferred remedial alternative would be designed to comply with applicable regulations. Potentially applicable regulations are listed in Table 6-3. These regulations govern the design, installation, and operation of remediation systems. For the preferred alternative at SWMU-168, regulatory requirements are expected to be minimal. Construction for the preferred alternative would be limited to injection of substrate through four push probes and installation of new monitoring wells, some within 200 feet of the shoreline along the Cedar River Waterway.

The primary regulations governing the preferred alternative would be the MTCA regulations, the Washington well drilling regulations for monitoring wells, the solid waste disposal regulations, the dangerous waste regulations, the transportation regulations, underground injection control regulations, and the Department of Labor and Industries health and safety regulations. Well drilling rules specify well design and drilling requirements. The solid and dangerous waste regulations specify waste characterization, manifesting, and disposal requirements for soil from drilling operations. Transportation regulations specify labeling and shipping requirements for wastes generated from implementation of the alternative. Underground injection control regulations must be addressed for injection of substrate for enhanced bioremediation. MTCA regulations specify the remediation requirements and the

cleanup standards to be attained. The alternative would require environmental analysis and public notice in accordance with MTCA and the Washington State Environmental Policy Act (SEPA) requirements. The preferred alternative would be designed and implemented to comply with these regulations.

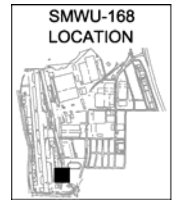


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TABLE 6-1

COMPARISON OF REMEDIAL ALTERNATIVES, SWMU-168[1]

Boeing Renton Facility
Renton, Washington

Standards/Criteria		Alternatives: 1 - Monitored Natural Attenuation	2 - SVE, Monitored Attenuation	3 - Enhanced Bioremediation, Monitored Attenuation
Protectiveness and Risk Reduction	Pros	Destroys COCs.	Destroys COCs.	Destroys COCs.
	Cons	Slow to achieve cleanup.	Requires off-site waste management.	
	Rating	ML	MH	MH
Permanence	Pros	Natural carbon promotes MNA; Destroys COCs; No residuals.	Destroys COCs; Reasonably rapid cleanup.	Destroys COCs; No residuals; Reasonably rapid cleanup.
	Cons	Slow degradation rates.		
	Rating	MH	H	MH
Cost	Pros	Lowest total cost		Good cost/benefit ratio
	Cons		High total cost.	
	Rating	MH	ML	MH
Long-Term Effectiveness	Pros	Destroys COCs; Passive, natural process.	Removes/Destroys COCs.	Removes/Destroys COCs.
	Cons		Requires vapor treatment for SVE off-gas, and off-site waste management.	
	Rating	MH	MH	MH
Management of Short-Term Risks	Pros	Simplest implementation; No residuals.		Fairly simple implementation.
	Cons		Requires periodic maintenance; potential risk due to SVE emissions and residuals.	
	Rating	H	MH	M
Technical and Administrative Implementability	Pros	Simple system.	Simple system.	Simple system.
	Cons		Requires air permitting; GAC requires periodic replacement.	Injection permit required.
	Rating	H	ML	MH
Public Concerns	Pros	Industrial site.	Industrial site.	Industrial site
	Cons	Requires City of Renton approval.	Requires City of Renton approval.	Requires City of Renton approval.
	Rating	ML	ML	ML
Restoration Time Frame	Pros	Industrial site; Proven institutional controls; Alternative water available; Practicability of shorter time frame limited by facility operations.	Industrial site; Proven institutional controls; Alternative water available; Practicability of shorter time frame limited by facility operations.	Industrial site; Proven institutional controls; Alternative water available; Practicability of shorter time frame limited by facility operations.
	Cons			
	Rating	ML	ML	ML

Notes:
1. Comparison Ratings: H = Highest (if the decision were based solely on one criterion, an H score would indicate the alternative is the preferred alternative);
MH = Medium High;
ML = Medium Low;
L = Low.

TABLE 6-2

COMPARISON OF BENEFITS FOR SWMU-168[1]

Boeing Renton Facility
Renton, Washington

Benefit	Alternative 1: Monitored Natural Attenuation	Alternative 2: SVE and Monitored Attenuation	Alternative 3: Enhanced Bioremediation and Monitored Attenuation
Reduced risk to on-site worker health	High	High	High
Reduced risk to off-site human health	High	High	High
Reduced risk to the environment	High	High	High
Minimal adverse impact on Facility operations	High	Moderate	Moderate
Minimal restrictions on Facility traffic and access	High	Moderate	Moderate
Minimal adverse impact on Facility structures and utilities	High	High	High

Notes:
1. Benefits for each remedial alternative are rated as follows:
   High = high benefit;
   Moderate = moderate benefit;
   Low = low benefit.

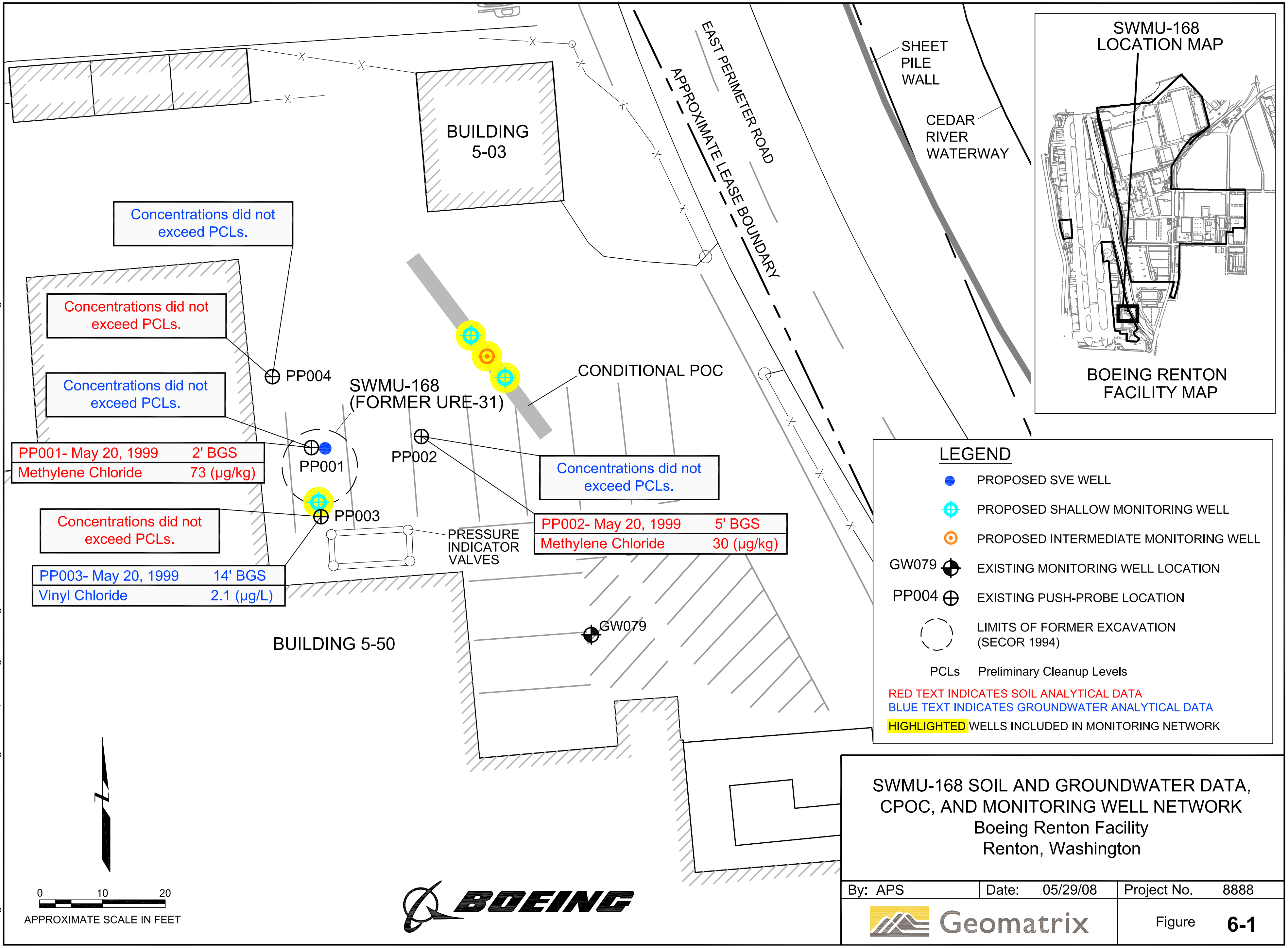
TABLE 6-3

POTENTIALLY APPLICABLE REGULATIONS
SWMU-168 PREFERRED REMEDIAL ALTERNATIVE

Boeing Renton Facility
Renton, Washington

Law/Regulation	Citation	Applicability
Chemical-Specific Laws and Regulations		
Washington Dangerous Waste Regulations	WAC 173-303	Waste management, permitting requirements
Washington Model Toxics Control Act Regulations	WAC 173-340	Establishment of cleanup levels and POCs
Action-Specific Laws and Regulations		
Washington State Environmental Policy Act Regulations	WAC 197-11	Permitting, EIA/EIS[1] requirements
Washington Industrial Safety and Health Act Regulations	WAC 296-24	Occupational health and safety
Transportation regulations	49 CFR Parts 100 & 177, WAC 446-50	Transportation for wastes and materials
Washington well drilling regulations	WAC 173-160 & -162	Well design and installation standards
Washington underground injection control regulations	WAC 713-218	Underground injection permitting
Washington solid waste disposal regulations	WAC 173-304	Disposal of nondangerous waste
Location-Specific Regulations		
Shoreline Management Act	RCW 90.58	Standards for construction within 200 ft of shoreline

Notes:
1. EIA = Environmental Impact Assessment; EIS = Environmental Impact Statement.



SWMU-168 SOIL AND GROUNDWATER DATA, CPOC, AND MONITORING WELL NETWORK
Boeing Renton Facility
Renton, Washington

By: APS	Date: 05/29/08	Project No. 8888
Geomatrix		Figure 6-1

Plot Date: 05/29/08 - 5:11pm, Plotted by: astenberg
Drawing Path: S:\8888_2006\025_Boeing FS\CAD\, Drawing Name: Figure 6-1_SWMU-168_Soil and GW Conc Above PCLs_101207.dwg

7.0 DEVELOPMENT AND EVALUATION OF REMEDIAL ALTERNATIVES, SWMU-172/174 (BUILDINGS 5-08 AND 5-09)

In this section we discuss remediation objectives, identify and evaluate remedial alternatives, and describe the preferred remedial alternative for SWMU-172/174.

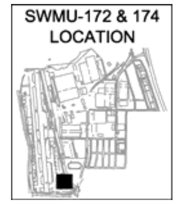
7.1 SITE CHARACTERIZATION SUMMARY

SWMUs 172 and 174, collectively referred to in this section as the site, are located on the west side of the Cedar River Waterway, near the Renton Municipal Airport (Figure 7-1). Both SWMU-172 and SWMU-174 are the locations of former wastewater USTs located adjacent to Buildings 5-09 and 5-08, respectively. SWMU-172 is associated with former UST URE-66, and SWMU-174 is associated with former UST URE-73. URE-66 was a 155-gallon concrete tank installed in 1963, and URE-73 was a 120-gallon concrete tank installed in 1957. Both USTs were used for the collection and temporary storage of steam-cleaning wastewater. URE-73 was deactivated in 1980; the deactivation date for URE-66 was not documented, indicating that it occurred prior to 1980. Both USTs were removed in 1987. Section 5.5 of the final RI Report presents the complete site characterization results for these units (Weston, 2001a). Additional site characterization data are presented in Section 3.2.2 of the FSWP (Geomatrix, 2004c). The results of the RI and additional data collection are summarized below.

7.1.1 Historical, Present, and Future Site Use

Steam-cleaning wastewater was stored in the former USTs at SWMU-172 and SWMU-174. Based on the site investigation results presented in the final RI Report, wastewater containing VOCs appears to have been released from the former USTs, apparently affecting soil and groundwater. The constituents identified for this site include PCE, TCE, *cis*-1,2-DCE, VC, and benzene. Both *cis*-1,2-DCE and VC are biodegradation products from chlorinated solvents such as PCE and TCE. The presence of these compounds indicates that biodegradation is active in this area.

Buildings 5-08 and 5-09 are currently used by Boeing to support airplane manufacturing activities at the Renton Facility. These buildings are owned by Boeing and the land is leased to Boeing by the City of Renton. These buildings and adjacent buildings and areas are currently used for industrial purposes and are expected to remain in industrial use for the foreseeable future.



7.1.2 Previous Site Remedial Actions

During the UST removal activities conducted in 1987 for both SWMUs, approximately 29 cubic yards of affected soil was removed from SWMU-172 and approximately 8 cubic yards of affected soil was removed from SWMU-174. The excavations were backfilled with clean, imported fill. Excavated areas have been repaved with asphalt and returned to active use.

7.1.3 Site Hydrogeology

Several monitoring wells and push probes have been placed both upgradient and downgradient of these SWMUs to assess the shallow stratigraphy and hydrogeology for this site. The general stratigraphy beneath SWMU-172/174 consists of an upper layer of sand and gravel fill material underlain by predominantly fine-grained alluvial deposits. The fill material consists mostly of sand and gravel with isolated pockets of debris (glass, paper, and bricks) that extend to a depth of approximately 10 to 15 feet bgs at SWMU-174, and to a depth of approximately 15 feet bgs at SWMU-172. The underlying alluvial deposits consist of interbedded greenish-gray silty clay, clayey silt, and fine- to medium-grained silty sand with occasional gravelly lenses.

A sheet pile wall is located adjacent to the Cedar River Waterway, downgradient from the site. In 1999, the USACE constructed floodwalls and earthen levees for flood control along both the east and west sides of the Cedar River Waterway from the Logan Avenue North bridge to the mouth of the Cedar River Waterway. The concrete floodwalls (maximum height of approximately 10 feet above grade) were constructed above interlocking steel sheet piles that were driven to a minimum depth of 21 feet bgs. The sheet piling runs along the entire western bank of the waterway, from Logan Avenue to Lake Washington. According to the final RI Report, the sheet piling is not keyed into a low-permeability soil unit and functions as a “hanging barrier wall.” It is expected that the sheet pile wall affects groundwater flow, likely causing groundwater to flow beneath the piling as it approaches the Cedar River Waterway from the west.

The depth to groundwater in this area ranges from approximately 8 to 11 feet bgs, with groundwater generally extending into the lower portion of the fill material. Results from the final RI Report indicate that shallow groundwater generally flows to the northeast, toward the Cedar River Waterway, with a hydraulic gradient ranging from 0.003 to 0.006. The calculated hydraulic conductivity of the shallow aquifer in the vicinity of SWMU-172/174 ranges from 4.6×10^{-5} to 4.2×10^{-3} cm/s. Based on a geologic cross-section presented in the final RI Report, the predominant soil type in the vadose zone is sand with gravel, and the soil type

dominating groundwater flow is also sand with gravel. Therefore, the dominant USCS soil classification for both the vadose and saturated zones is SP/SW; soil characteristics for this soil type will be used for relevant calculations in this FS.

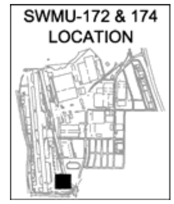
7.1.4 Nature and Extent of Affected Soil

The results of the RI indicate that SWMU-172/174 soils contain concentrations of VOCs and some metals above the respective PCLs defined in the final RI Report. The analytical results from soil investigations conducted at this site are summarized on Figure 7-1. The VOCs exceeding PCLs include PCE, TCE, benzene, and methylene chloride. The most prevalent VOC found in site soil was PCE, which was detected above the PCL of 48 µg/kg in eight soil samples collected from six locations. The detected PCE concentrations ranged from 70 µg/kg to 5,900 µg/kg. VOC-affected soil appears limited to the upper 15 feet of soil at both SWMUs. VOC-affected soil in SWMU-172 was detected above PCLs in an area extending at least 45 feet to the east, 15 feet to the north, 70 feet to the southeast, and 10 feet to the southwest of the former location of the UST. Affected soil in SWMU-174 exceeding the PCLs did not extend more than about 10 feet from the former UST location.

Antimony, copper, selenium, thallium, and zinc were detected above their respective PCLs in soil samples collected for SWMU-172/174. The highest concentrations of these metals were typically found in the samples collected from the fill materials. Metals-affected soils were found to extend laterally north, east, and southwest from SWMU-172. The lateral extent of metals above the PCLs was not defined to the north and east from SWMU-174, but the final RI Report concluded that the extent was likely limited due to the generally low metals concentrations detected within these units. The vertical extent of soil affected by metals is approximately 15 feet bgs at both SWMUs.

7.1.5 Nature and Extent of Affected Groundwater

VOCs, bis(2-ethylhexyl) phthalate, and metals were detected at concentrations exceeding the respective PCLs defined in the final RI Report in the vicinity of SWMU-172/174 in some groundwater samples collected. The analytical results from groundwater investigations conducted at the site are summarized on Figure 7-2. It should be noted that site characterization data described below are several years old; the most recent sampling event occurred in August 2000, over 7 years ago. Groundwater conditions may have changed since the last sampling event.



Results from the final RI Report indicate that soil layers composed of sand with gravel or silty sand predominate in the saturated zone at this site. Therefore, the saturated zone soils will be characterized as SP/SW sand for assessing soil properties.

Based on results from the RI, VOCs exceeding PCLs included 1,1-dichloroethene (1,1-DCE), benzene, chloromethane, *cis*-1,2-DCE, methylene chloride, PCE, TCE, and VC. These VOCs were detected in groundwater samples collected from both monitoring wells and push probes. PCE and its breakdown products were detected at the highest concentrations in push probe PP061, which was installed just downgradient of SWMU-172, in the shallow groundwater at 12 feet bgs. Based on the RI data, the extent of affected groundwater exceeding the PCLs appears to be defined by monitoring wells GW171 to the south, GW084 to the west, and GW080/GW081 to the north. The downgradient extent of the dissolved VOCs extending eastward toward the Cedar River Waterway was not fully defined during the RI. However, VOCs in groundwater samples collected as part of investigations performed subsequent to the final RI Report and reported in the FSWP from three push probes (PP086, PP087, and PP088) placed downgradient from the former UST locations were well below the PCLs established in the final RI Report, defining the eastern extent of affected groundwater at this site.

The SVOC bis(2-ethylhexyl) phthalate was detected above the PCL of 1.8 µg/L in groundwater samples collected from well GW152 and push probes PP005 and PP007. No other SVOCs have been detected in site groundwater at concentrations exceeding the PCLs.

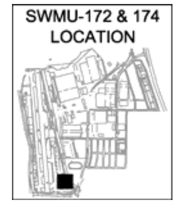
Metals detected in site groundwater samples at concentrations above the PCLs included arsenic, chromium, copper, and lead. All of these constituents were found in a sample collected in June 1999 from well GW152; arsenic was detected in a sample collected from GW153. Dissolved metals concentrations in push probe groundwater samples were below the PCLs, except for arsenic detected in samples collected near the former location of the USTs (PP006 for SWMU-172 and PP007 for SWMU-174). These results indicate that metals other than arsenic appear to be related to the presence of suspended sediment in the water sample rather than from site activities and will not be addressed further in this FS. Arsenic was detected in groundwater at concentrations exceeding the PCLs only in samples collected within the source areas. The extent of groundwater affected by arsenic appears to be limited to the source areas where the USTs were located, and arsenic does not appear to be migrating from the source areas.

7.2 CONCEPTUAL SITE MODEL

A preliminary conceptual model for migration of constituents present in affected soil and groundwater at the Renton Facility was shown in Figure 2-6 of the FSWP (Geomatrix, 2004c). Based upon the conceptual model, considerations presented in the FSWP, plus information specific to this site, a site-specific conceptual site model is described below. This site-specific conceptual site model identifies the media and exposure pathways that must be addressed for remedial alternatives potentially applicable to this site. Additional details regarding migration and exposure pathways addressed by remedial measures for this site were presented in Section 2.

VOCs and metals are present in soil within the source areas for SWMU-172/174. As shown in the Facility conceptual model presented in the FSWP, these soil constituents can migrate from the source areas via groundwater or vapor pathways. For this site, migration via groundwater is the most significant pathway. Constituent transport via groundwater at this site is affected by soil/groundwater interactions, biodegradation, and the presence of the sheet pile wall in the downgradient groundwater flow path. As groundwater flows through the VOC-affected soil in the two source areas, adsorbed VOCs dissolve into groundwater. These dissolved constituents move with groundwater but at a different velocity because of continuing solute-soil interactions. This movement has created a plume extending downgradient from the source areas. The VOCs at this site also undergo natural biodegradation that destroys the constituents originally released (PCE, TCE) and generates biodegradation products (*cis*-1,2-DCE, VC). These degradation products will also biodegrade, ultimately producing ethene and chloride salts.

The extent of groundwater affected by dissolved VOCs extends to the north, south, and east of the source areas where the USTs were located. The affected groundwater is migrating to the northeast from the source areas toward the discharge area along the Cedar River Waterway. Although no data have been collected to confirm the exact groundwater flow path adjacent to the waterway, it is expected that the sheet pile wall affects the flow path. The sheet pile wall, which is located between East Perimeter Road and the waterway, extends to a minimum depth of 21 feet bgs. The sheet pile wall functions as a low-permeability barrier and diverts groundwater flow through more permeable pathways. Groundwater is expected to flow downward as it approaches the sheet pile wall and pass beneath the sheet piles and into the lower depths of the waterway. Site constituents, if present in the groundwater at this location, would enter the waterway along with groundwater.



Volatilization of constituents from groundwater is not significant for most workers at this site, as noted in the conceptual model presented in the FSWP. However, the release of volatile groundwater constituents to receptors may occur after affected groundwater enters the Cedar River Waterway.

7.3 SITE REMEDIATION OBJECTIVES AND CLEANUP STANDARDS

The remediation objectives applicable to SWMU-172/174 were presented in Section 2 of this report. The selected remedial alternative considered for potential implementation at the site will be capable of achieving remediation objectives and cleanup standards for the site.

The COCs for groundwater and soil were identified in FSWP Tables 5-1 and 5-3, respectively. These COCs were identified by comparing detected constituent concentrations to the PCLs defined in the final RI Report; if a constituent concentration measured in any sample exceeded the PCL, the constituent was listed as a COC that must be addressed in the FS. Cleanup levels for both soil and groundwater meeting MTCA requirements were presented in the FSWP (Tables 5-6 and 5-2, respectively) and subsequently negotiated with Ecology. To confirm that the COCs listed in the FSWP included all constituents detected at concentrations exceeding the approved cleanup levels, the RI soil and groundwater data were compared to the approved cleanup levels listed in the FSWP. If concentrations for constituents that were not identified as COCs exceeded cleanup levels, it would be necessary to include them as COCs. If concentrations for previously identified COCs were below the approved cleanup levels, the constituent should be removed as a COC. No new constituents were identified as COCs for this site, and one COC identified in the final RI Report (thallium) was removed as a result of this comparison.

The soil and groundwater cleanup levels for the site COCs are listed in Tables 3-1 and 3-2, respectively. The soil cleanup levels are either MTCA Method A cleanup levels or site-specific MTCA Method C cleanup levels that are protective of groundwater at the CPOC and were calculated in accordance with the procedures described in the FSWP or in accordance with recent negotiations with Ecology. The groundwater cleanup levels listed in Table 3-2 were developed as described in Section 3 and in accordance with recent negotiations with Ecology. The cleanup levels are protective of surface water, human health, and the environment.

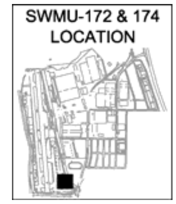
7.4 SITE REMEDIAL ALTERNATIVES

Remedial alternatives that incorporate remedial technologies presented in Section 4 have been identified and developed for SWMU-172/174. The alternatives specifically address site conditions, the site remediation objectives, and the soil and groundwater cleanup levels for SWMU-172/174. The remedial alternatives to be evaluated for this site are described below. These alternatives are evaluated against the evaluation criteria in Section 7.5.

SWMU-172/174 is located on leased property on the eastern portion of the Renton Municipal Airport. As noted previously, the site and adjacent areas are used for industrial purposes and are expected to remain under industrial use. Industrial buildings are located adjacent to the former locations of the USTs. Water level contours presented in the final RI Report indicate that groundwater beneath this site generally flows to the northeast toward the Cedar River Waterway. Groundwater flows from the source areas toward the leased property boundary, which is about 80 to 140 feet to the northeast of the two source areas. Outside the property boundary, groundwater flows beneath East Perimeter Road, beneath the sheet pile wall, and into the Cedar River Waterway. A concrete retaining wall extends about 8 feet above grade along the sheet pile wall. There is unrestricted public access to East Perimeter Road and the embankment along the Cedar River Waterway.

The buildings adjacent to the former USTs will constrain remedial activities for this site. Although affected soil was excavated at the time the former USTs were removed from the two source areas, additional excavation would be limited because of the potential for undermining the buildings or causing settlement that would damage the buildings. The buildings immediately upgradient of the two source areas would also limit access for conducting remediation activities upgradient of the source areas. Access for remediation and/or monitoring is also constrained outside the lease boundary line because of the adjacent public roadway and the retaining wall. Remediation approaches considered for the two site groundwater plumes must address the effects the sheet pile wall has on the groundwater flow path.

The soil COCs for this site include several metals, PCE, TCE, methylene chloride, and benzene. With the exception of selenium, all soil samples reported in the final RI Report with metals exceeding PCLs were collected from depths less than 9 feet bgs (see Figure 7-1). Concentrations of selenium near the laboratory reporting limit were found at greater depths. Additionally, all soil samples exceeding PCLs for metals were located within about 20 feet of



the former UST locations; samples collected outside this range were below PCLs. With the exception of samples collected from PP061 and PP062, soil samples exceeding PCLs for PCE, TCE, methylene chloride, and benzene were also located within about 20 feet of the former UST locations. Based on the results from the final RI Report, it appears that soil affected with both metals and VOCs is located near the two former USTs, and soil affected only by VOCs is in another area in the vicinity of PP061 and PP062.

Selenium was identified as a soil COC for this site; it was not identified as a groundwater COC because groundwater sampling results indicated selenium was below the PCL in all samples collected for the RI. The RI results indicated that 8 of the 16 samples analyzed for metals contained detectable levels of selenium at sampling depths up to 15 feet bgs. Data presented in the final RI Report indicate that the depth to groundwater varies from about 8 to 11 feet bgs. Some samples that exceeded the soil PCL were collected within the saturated zone. Although soil exceeding the selenium PCL is present in the saturated zone, selenium in groundwater did not exceed its PCL. All samples with reported selenium concentrations were collected near the two former USTs. Although present in site soil, selenium was not used in production processes at the Boeing Renton Plant. No other site COCs exceeding PCLs were present at the depth where selenium was detected.

The detected selenium concentrations in soil (7 to 8 milligrams per kilogram [mg/kg]) were only slightly greater than the PCL for selenium (5.2 mg/kg) and just slightly above the laboratory reporting limit (5 to 10 mg/kg). The laboratory reporting limits were somewhat greater than the PCL because the analytical results were converted to dry weight for reporting. The selenium quantitation limit is 5 mg/kg; this limit was achieved by the analysis, but the reporting limit was raised by converting the 5 mg/kg to dry weight. Selenium concentrations in groundwater samples collected downgradient from the locations where selenium was detected in soil were below reporting limits, which indicates that the selenium present in site soil, including in the saturated zone, is not migrating via groundwater.

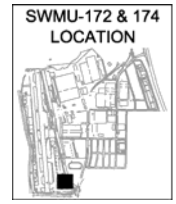
The soil PCL of 5.2 mg/kg is a Method C cleanup level calculated using the MTCA partitioning model for protection of groundwater. Although the measured soil concentrations slightly exceed the concentration calculated for protection of groundwater, site data indicate that existing concentrations are protective of groundwater (all groundwater samples were below the groundwater PCL for selenium). Actual site data indicate that the calculated MTCA

Method C cleanup level for the site is conservative, and that the higher concentrations present at the site are protective of groundwater.

The Method C Cleanup Level listed in CLARC 3.1 tables for direct ingestion is 17,500 mg/kg; the EPA Region 9 Preliminary Remediation Goal (PRG) for residential soil is 390 mg/kg. Both of these alternate health-based standards are substantially greater than the concentrations detected at the site. Therefore, while selenium was identified in the final RI Report as a COC for soil at this site, it is not a COC for groundwater, existing soil concentrations are protective of groundwater, and existing soil concentrations are well below levels posing a risk to human health. Given these considerations, selenium will not be considered as a soil COC for remediation of this site.

Antimony was identified as a soil COC for this site; it was not identified as a groundwater COC because groundwater sampling results indicated that antimony was below the PCL in all samples collected during the RI. The RI results indicated that only 3 of the 11 soil samples analyzed contained detectable antimony, with all hits reported at depths less than 9 feet bgs. Antimony was detected only in samples collected near SWMU-174. The water table varies from about 8 to 11 feet bgs at the site, indicating that the soil samples containing antimony extend to the capillary fringe above the water table. As such, soils with the measured antimony concentrations are in intimate contact with site groundwater. In the three samples with reportable concentrations of antimony, all were only slightly above the reporting limit of 5 to 7 mg/kg, and all three were reported as “J” values, which indicate that the constituent was detected but that the quantification is approximate.

The approved MTCA Method C soil cleanup level for antimony listed in the FSWP is 5.786 mg/kg. This cleanup level was calculated using the MTCA partitioning model for protection of groundwater. The antimony concentrations in groundwater samples collected downgradient from SWMU-174 were all below the PCL and are all below the groundwater cleanup level listed in the FSWP. Since the measured soil antimony concentrations are above the calculated cleanup level and groundwater antimony is below the cleanup level, site data indicate that existing antimony concentrations in soil are protective of groundwater. These data also indicate that the MTCA partitioning model yields a conservative cleanup level. The Method C Cleanup Level listed in the CLARC 3.1 tables for protection of workers is 1,400 mg/kg and the EPA Region 9 PRG for residential soil is 31 mg/kg, both of which are substantially greater than the concentrations detected at the site. Therefore, while antimony



was identified in the final RI Report as a COC for soil at this site, it is a minor constituent, it is not mobile, existing concentrations are protective of groundwater, and antimony is below levels that may pose a risk to human health. Based on these considerations, antimony will not be considered as a soil COC for remediation of this site.

Thallium was defined as a soil COC based on one sample exceeding the PCL. The detected thallium concentration (6 mg/kg in the borehole for GW152) exceeds the PCL of 5 mg/kg, but it is below the cleanup level for thallium of 71.2 mg/kg in the approved FSWP. This cleanup level is based on protection of groundwater. Since the detected thallium concentration at this site is below the cleanup level, thallium is not addressed as a COC in this FS report.

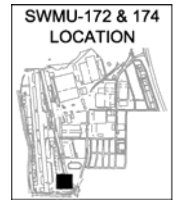
Copper was defined as a soil COC but it was not identified as a groundwater COC. Three of the 16 samples analyzed for copper exceeded the PCL, which is based on the background concentration assigned by Ecology. These results indicate that about 19% of the samples exceeded the background concentration, which is based on the 90th percentile. Given the basis for the Ecology background concentration, it is expected that 10% of uncontaminated soil samples would exceed the established background threshold. Although the soil samples exceeding the copper PCL were all collected in or adjacent to the former UST locations, copper concentrations in all downgradient groundwater samples were below groundwater PCLs. The only exceedance for copper in groundwater was for total metals in one well (GW-152) located adjacent to a former UST location; the dissolved copper in the same sample was below the cleanup level, indicating that the exceedance was due to suspended sediment. A subsequent sample from the same well did not exceed the PCL for copper. These data indicate that copper present in site soil is not mobile and is not affecting groundwater. Therefore, while copper is a soil COC at this site, it is a minor constituent and is not mobile. Residual levels of copper that may remain in site soil after implementation of a remedial measure will not pose a risk to human health and will not be considered significant. Residual levels of copper will be addressed by deed recordation and institutional controls.

The groundwater COCs for this site include several metals, chlorinated solvents, benzene, and one semivolatile compound (see Table 3-2). Groundwater analytical results exceeding PCLs are shown on Figure 7-2. All sample results with metals concentrations exceeding PCLs were collected in the immediate vicinity of the former UST locations. Groundwater samples collected downgradient and cross-gradient from the former UST locations were all below PCLs, indicating that metals in groundwater are limited to the source areas.

The highest concentrations detected for VOCs in groundwater were in PP061, which is approximately 40 feet downgradient from SWMU-172. The affected groundwater plume extends laterally from the source areas, from just south of wells GW080 and GW081 to south of PP062, covering a lateral span of approximately 240 feet. Groundwater samples collected downgradient from the source areas indicate that biodegradation is active within the downgradient plume, which likely extends beyond the lease boundary line but not to the Cedar River Waterway. Downgradient groundwater samples show significant concentrations of the reductive dechlorination by-products of PCE and TCE. The rapid disappearance of the primary compounds (PCE and TCE) coupled with the rapid rise of the degradation products clearly confirms that natural biodegradation is active at this site and is destroying the COCs originally released. The substantial decrease in concentration seen in a short distance indicates that this transformation is occurring at a significant rate. The rapid degradation of the toxic COCs to nontoxic by-products is also demonstrated by the limited extent of affected groundwater downgradient from the source areas; groundwater COCs have not migrated to the shoreline of the waterway, as demonstrated by groundwater sampling.

The groundwater metals exceeding PCLs for this site (arsenic, total chromium, copper, and lead) were detected only in groundwater samples collected less than about 20 feet from the former USTs. All groundwater samples collected further downgradient from the source areas were below the PCLs for theses metals. The metals other than arsenic appear to be due to the presence of suspended soil in the samples, since analyses for dissolved metals were below the PCLs. These data indicate that the metals present in site groundwater are much less mobile than the VOCs, which were detected in samples well downgradient from the two source areas. These data also indicate that the only metal exceeding PCLs in filtered samples, arsenic, rapidly attenuates at the site. The site data also show that several metals present in soil at low concentrations are not mobile and do not pose a significant risk to human health and the environment. The single soluble metal exceeding PCLs in groundwater, arsenic, has not migrated significantly from the source areas and meets cleanup levels in all downgradient monitoring wells.

Based on these considerations, the remedial alternatives developed for this site must address VOCs in source area soil and in groundwater. Site characterization data show that VOCs in soil and groundwater can pose a risk to construction workers and that migration within groundwater is occurring. Site characterization data also show that migration has not reached the downgradient receptor, the Cedar River Waterway.



MTCA requires that remedial alternatives selected for a site meet the MTCA threshold requirements for cleanup actions. The minimum threshold requirements specify that cleanup actions shall (1) protect human health and the environment, (2) comply with cleanup standards, (3) comply with applicable state and federal law, and (4) provide for compliance monitoring. To be considered as a potential remedial alternative for the site, the technologies considered had to pass the screening evaluation of the remedial technologies described in Section 4. In addition, the alternatives had to meet the minimum threshold requirements established by MTCA and had to be consistent with Facility conditions.

Based on the screening evaluation, MTCA minimum threshold requirements, and the site considerations discussed above, the following three remedial alternatives that could be used to address COCs on the SWMU-172/174 site were developed:

- Alternative 1: Source Area Excavation, Enhanced Bioremediation, and MA
- Alternative 2: Soil Vapor Extraction and Enhanced Bioremediation
- Alternative 3: Monitored Natural Attenuation

7.4.1 Alternative 1: Source Area Excavation, Enhanced Bioremediation, and Monitored Attenuation

Remediation Alternative 1 would involve excavating the source areas at SWMU-172/174 to remove affected soil in the vicinity of the source areas. This alternative also includes enhanced bioremediation and MA to address the groundwater plume downgradient from the source areas. The specific elements of this remediation alternative are:

- Excavation of source area soil in the vicinity of the two former USTs and push probes PP061 and PP062; the extent of excavation would be guided by soil verification sampling to confirm removal of affected soil exceeding cleanup levels for soil COCs to the extent practicable;
- Enhanced anaerobic bioremediation for chlorinated VOCs by adding electron donor and nutrients within the source areas;
- MA for groundwater constituents using both existing and new monitoring wells located appropriately to intersect the plume at the CPOC;
- Institutional Controls:
  - Deed recordation noting the location and nature of historical waste management at the site;

  - Covenants and deed restrictions to address potential risks to human health that may remain as a result of residual soil constituents and affected groundwater within the plume area;

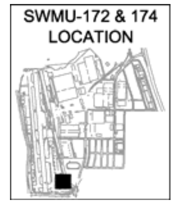
- An on-site CPOC near the lease boundary line to provide ready access for installation and sampling of the downgradient monitoring wells.

Additional soil from the vadose zone that exceeds soil cleanup levels for chlorinated solvents and metals would be excavated and removed. Biodegradation of chlorinated VOCs present within the downgradient plume would destroy these constituents prior to the point where groundwater enters the Cedar River Waterway. The institutional controls would continue to protect human health, as has been done routinely at the site by the existing institutional controls. For this remedial alternative, a CPOC would likely be used. The CPOC for groundwater would be located along the lease boundary west of East Perimeter Road (Figure 7-3). The approximate extent of soil excavation, the expected location of the CPOC, and the downgradient monitoring wells are shown on Figure 7-3.

7.4.1.1 Source Area Excavation

With Remedial Alternative 1, affected soils in the two source areas would be excavated for off-site disposal. Soil exceeding cleanup levels would be removed from the vadose zone. The approximate extent of the soil excavations is shown in Figure 7-3. The maximum depth of excavation would be to the water table, approximately 8 to 11 feet bgs, to minimize potential sidewall stability issues. The lateral westward extent of the excavation would be limited by Buildings 5-08 and 5-09 to avoid undermining the building foundations and causing settlement. The extent of the excavations to the north, east, and south would generally be based on verification sample results.

For the conceptual design developed for this FS, it was estimated that approximately 1,200 cubic yards of soil would be removed from the site for off-site treatment and disposal. Excavated soil would be characterized in accordance with dangerous waste regulations and disposed of, as appropriate, in permitted, off-site RCRA Subtitle C or solid waste landfills. The excavated soil would be treated if required to meet RCRA requirements for landfill disposal. Verification soil sampling would be conducted to confirm the removal of soil exceeding cleanup levels or to characterize soil that could not be excavated due to physical constraints such as buildings.



It is expected that, unless constrained by physical structures, excavation would remove soil exceeding the soil cleanup levels listed in Table 3-1. For those soil COCs for which cleanup levels have not been established, the general cleanup levels would be used for comparison to verify sample results. Buildings 5-08 and 5-09 would likely prevent removal of all soil exceeding cleanup levels because the affected soil may extend beneath the buildings. To the extent practicable, soil exceeding soil cleanup levels (as appropriate for constituents other than selenium) would be removed from the site. As indicated above, existing selenium levels in soil are protective of groundwater and selenium is not a COC for remediation of this site. To the extent practicable, this alternative would provide a permanent remedial solution for affected soil at this site.

7.4.1.2 Enhanced Bioremediation and Monitored Attenuation

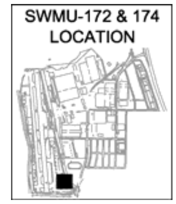
With remedial Alternative 1, the reductive dechlorination processes that are active at this site would be enhanced by the addition of an electron donor and nutrients to site groundwater, as appropriate. By increasing the concentration of electron donor and any nutrients that may be deficient, biological activity would be enhanced and the rate of biodegradation would increase, thereby destroying the chlorinated solvents present in groundwater. An electron donor (such as molasses, lactate, or emulsified vegetable oil) would be injected into affected groundwater at the locations shown on Figure 7-3. For the purposes of this FS, it was assumed that this would be accomplished using a line of injection wells traversing the groundwater plume near the source areas and/or through existing monitoring wells. The assumed spacing for the injection wells is 25 feet; actual spacing would be defined in the detailed design for implementation of this alternative. New injection wells would be installed to an approximate depth of 15 feet bgs and would be screened through the entire saturated zone above the silty clay layer identified beneath the site. The electron donor injected into these wells would cover the width of the plume and move downgradient as the groundwater moves, eventually addressing the affected groundwater area. Based on this conceptual design, up to 12 electron donor injection wells would be used. It has been assumed that four injection events occurring over a 2-year period would be sufficient to achieve full degradation of groundwater COCs. Although the electron donor has not been selected for this site, for the conceptual design it was assumed that emulsified vegetable oil would be used. A different electron donor may be used if this approach is selected for implementation. For costing purposes, it was estimated that 200 gallons of 2% emulsified vegetable oil per well (approximately 2,400 gallons total) would be injected during each event.

Monitored attenuation would be conducted to confirm the effectiveness of enhanced bioremediation and attainment of the cleanup standard. A network of groundwater monitoring wells would be required at the CPOC to assess the effectiveness of enhanced bioremediation and to confirm that the cleanup standard is met for groundwater. In accordance with the MNA guidance discussed in Section 4.2.4, the conceptual monitoring program for SWMU-172/174 has been designed to:

- Demonstrate that biodegradation is occurring according to expectations for site COCs;
- Identify any potentially toxic and/or mobile transformation products;
- Verify that the plumes are not expanding beyond the CPOC;
- Verify that there is no unacceptable impact to potential downgradient receptors;
- Verify that cleanup levels are attained at the CPOC;
- Detect new releases of COCs that could impact the effectiveness of the remedy;
- Demonstrate the efficacy of the institutional controls to protect potential receptors; and
- Verify attainment of remediation objectives.

For this remedial alternative, a detailed MA plan would be developed to document the monitoring program. This plan would identify existing and additional monitoring wells and analytes that would be required for both characterization/validation sampling and long-term groundwater monitoring. Characterization/validation sampling would be done during the initial implementation to demonstrate the effectiveness of enhanced bioremediation with respect to COC mass reduction, attenuation rates, and temporal trends. Long-term groundwater monitoring would be used after the characterization/validation sampling program was completed to confirm that the COC plume is progressing toward and eventually attaining numerical cleanup goals.

For this alternative, an on-site CPOC would be required; the assumed location is along the downgradient lease boundary on the west side of the East Perimeter Road wall (Figure 7-3). It has been assumed that three new shallow monitoring wells would be located along the CPOC (see Figure 7-3). Two of the shallow CPOC monitoring wells would be nested with intermediate depth wells to monitor the deeper sand unit underlying the shallow, affected zone,



for a total of five new wells located along the CPOC. Due to the installation of new wells along the CPOC, existing wells GW152 and GW153 would be abandoned in accordance with Ecology regulations. The new shallow wells would be completed in the upper portion of the saturated zone at a depth of about 15 feet bgs. The two intermediate wells would be completed beneath the silty-clay layer at a depth of about 25 feet bgs. The five new monitoring wells would be fitted with 5-foot-long screens.

It has been assumed that the five new CPOC monitoring wells, plus six existing source area monitoring wells (GW081, GW082, GW084, GW171, GW172, and GW173), would be included in the monitoring well network for a total of 11 monitoring wells. For this conceptual program, it was assumed that characterization/validation sampling would consist of quarterly monitoring of the 11 monitoring wells for a minimum of 1 year. Monitoring parameters and analytes for each of these wells would include groundwater COCs listed in Table 3-2 and the appropriate MNA geochemical parameters [e.g., dissolved oxygen, nitrate, Fe(II), sulfate, methane, temperature, pH, specific conductance, alkalinity, oxidation/reduction potential, chloride, ethane, and TOC]. For the conceptual design, it was also assumed that data reporting for characterization/validation sampling would follow each quarterly sampling event and an annual report would be prepared that evaluates and discusses the monitoring data.

Long-term groundwater monitoring would follow the initial characterization/validation sampling program. The long-term monitoring would be conducted for an additional 13 to 14 years (15 years of monitoring total), with semiannual sampling of five shallow wells for groundwater COCs and a limited suite of geochemical parameters (dissolved oxygen, oxidation/reduction potential, temperature, and pH). It was assumed that the intermediate wells would be dropped from the monitoring program after 2 years of quarterly monitoring. To monitor overall plume control, all 11 wells would be analyzed once every 5 years for the full list of characterization/validation analytes. For the conceptual design of this alternative, it was assumed that long-term groundwater monitoring results would be reported to Ecology annually.

7.4.1.3 Institutional Controls

Institutional controls would be incorporated into this remedial alternative to ensure it is fully protective of human health and the environment. Institutional controls are necessary because it is expected that some COCs may remain beneath existing buildings and because enhanced biodegradation of groundwater constituents would require time to fully degrade the COCs. In general, the institutional controls that would be incorporated into this remedial alternative

would be a continuation of the controls that have been implemented at the Renton Facility and that have been proven effective. These institutional controls would be established such that they are legally enforceable for current and future landowners.

The nature and location (including depth) of the former USTs at SWMU-172/174 would be recorded on the deed to the property. This recordation would identify the nature of the releases and inform any future landowners of potential human health or ecological issues related to the release.

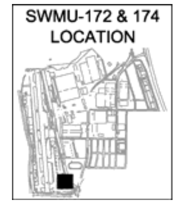
An institutional control restricting the recovery and use of groundwater beneath and downgradient of the site would be implemented. This control would apply to the leased property where the SWMUs are located and the area downgradient, extending to the Cedar River Waterway. This institutional control would require cooperation from the City of Renton because the City is responsible for the property being leased by Boeing and for the downgradient area outside the lease boundaries. Recovery of groundwater in this area for any purpose other than construction dewatering would be prohibited.

Institutional controls requiring implementation of specific and appropriate health and safety procedures would be implemented for conducting any subsurface work in the immediate vicinity of the source areas and in the downgradient area where affected groundwater occurs. In the portions of the source areas where all COCs would not be removed, these controls would cover all subsurface work, including excavation and installation or maintenance of underground utilities. In the downgradient plume area, where only affected groundwater is present, the institutional controls would require appropriate health and safety procedures for any work (such as excavation below the water table) where direct contact with affected groundwater or inhalation of vapors released from groundwater may occur.

It was assumed that deed restrictions would be established to limit future unrestricted land use without additional actions to attain compliance with appropriate soil and groundwater cleanup levels.

7.4.2 Alternative 2: Soil Vapor Extraction, Enhanced Bioremediation, and Monitored Attenuation

Remediation Alternative 2 includes SVE within the source area to remove volatile COCs from affected soil in the vicinity of the source areas and enhanced bioremediation with MA to address the groundwater plume downgradient from the source areas. Nonvolatile COCs would



remain within site soils under this alternative. The specific elements included in this remediation alternative are:

- Installation and operation of a SVE system in the vicinity of the two former USTs and push probes PP061 and PP062. VOCs removed from the soil would be collected and treated prior to discharge of soil gas to the atmosphere;
- Soil verification sampling to confirm attainment of cleanup levels for volatile soil COCs;
- Enhanced anaerobic bioremediation of chlorinated VOCs by the addition of electron donor and nutrients to site groundwater;
- MA for groundwater constituents using both existing and new monitoring wells located appropriately to intersect the plume at the CPOC;
- Institutional Controls:
    - Deed recordation noting the location and nature of historical waste management at the site;
    - Covenants and deed restrictions to address potential risks to human health that may remain as a result of residual soil constituents and affected groundwater within the plume;
- Points of Compliance: On-site CPOC along the downgradient lease boundary to provide ready access for installation and sampling of the monitoring wells.

The SVE system would be installed to remove volatile soil COCs from the vadose zone within the source areas. This technology would be capable of removing volatile constituents that are present beneath the existing buildings without adversely affecting the buildings or facility operations. Biodegradation of the groundwater constituents would destroy VOCs present within groundwater prior to its entering the Cedar River Waterway.

Metals present in site soil would remain with this alternative. As discussed above, residual metals are not mobile and do not present a significant risk to human health or the environment. Attenuation of these metals through soil-groundwater interactions would continue to limit their migration. The institutional controls included in Alternative 2 would adequately address issues related to these metals and continue to protect human health, as has been done routinely at the site by the existing institutional controls. The CPOC for this alternative would be located along the downgradient lease boundary on the west side of East Perimeter Road (see Figure 7-4).

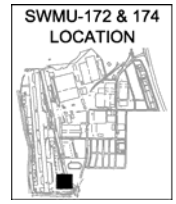
The approximate locations for the SVE system, the enhanced bioremediation injection wells, and the downgradient monitoring wells are shown on Figure 7-4.

7.4.2.1 Soil Vapor Extraction

For this remedial alternative, soils in the two source areas affected by volatile COCs would be remediated by an SVE system. The approximate locations of the SVE wells are shown in Figure 7-4. Due to the nature of this process, it is expected that volatile COCs present beneath the existing buildings west of the former USTs would be effectively removed. The SVE system would address essentially all source area soils above the water table. For conceptual design of the SVE system, three vapor extraction wells have been assumed (see Figure 7-4). One well would be placed in each of the former UST locations, and one well would be placed in the area east of Building 5-09. A blower with a capacity of approximately 100 cubic feet per minute (cfm) would be used to draw soil gas from the vapor extraction wells. The extracted soil gas would be treated using a permanganate oxidation bed and activated carbon adsorption to prevent the release of VOCs and to permanently destroy COCs during off-site regeneration. Air permitting may be required to address the site remediation National Emission Standards for Hazardous Air Pollutants (NESHAPS) regulations. Field testing would be required to determine site-specific design parameters for implementation of SVE at the site.

Verification sampling of soils within the area treated by SVE would be conducted after monitoring data indicate that the SVE system has removed recoverable VOCs. It has been assumed that this would be accomplished in 2 years. The verification samples would be compared to soil cleanup levels to confirm attainment of remediation objectives. The verification samples would also be analyzed for nonvolatile COCs to confirm previous sampling results and to confirm the delineation of soil affected by the nonvolatile COCs. It should be noted that verification sampling may not be possible in all treated areas due to access restrictions related to the site buildings and activities.

It is expected that the SVE system would substantially remove soil VOCs throughout the affected area, including the area beneath buildings. Residual concentrations of soil COCs would be addressed by institutional controls. This alternative would provide a permanent remedial solution for most of the soil affected by VOCs at this site.



7.4.2.2 Enhanced Bioremediation

The enhanced bioremediation approach for Alternative 2 would be essentially the same as that described in Section 7.4.1.2 for Alternative 1. The SVE system included in this alternative would create an aerated zone within unsaturated soils above the water table. It is expected that this aerobic soil zone would not adversely affect the anaerobic reductive dechlorination process in the groundwater. The addition of electron donor would ensure that reducing conditions would be maintained to support reductive dechlorination processes. The SVE system may create a slight increase in the demand for electron donor material. For this alternative, a slightly higher dose of electron donor has been included in the conceptual design. The enhanced bioremediation system for this alternative would include 12 injection wells designed as described for Alternative 1 and spaced about 25 feet apart. For costing purposes, it was estimated that 250 gallons of 2% emulsified vegetable oil per well (approximately 3,000 gallons total) would be injected during each event. It has also been assumed that four injection events occurring over a 2-year period would be sufficient to achieve full degradation of groundwater COCs. The conceptual layout for the injection system for this alternative is shown on Figure 7-4.

An MA program would be included for Alternative 2 similar to that described in Section 7.4.1.2 for Alternative 1. The CPOC for groundwater would be located on site along the lease boundary on the west side of East Perimeter Road (see Figure 7-4). The network of groundwater monitoring wells for Alternative 2 would include all of the wells as presented above for Alternative 1, plus two additional existing monitoring wells for a total of 13 wells. The monitoring well network included in this alternative is shown on Figure 7-4. Monitored attenuation would be conducted as described for Alternative 1; quarterly sampling and reporting would be conducted for the first 1 to 2 years, followed by 13 to 14 years of semiannual monitoring and annual reporting.

7.4.2.3 Institutional Controls

The institutional controls for Alternative 2 would be nearly the same as those described above in Section 7.4.1.3 for Alternative 1. This alternative would remove the majority of soil affected by VOCs beneath the building, but the metals present in soils would remain unaffected. This would be reflected in the deed recordation and in health and safety procedures required for subsurface work in the source area. The institutional controls for the groundwater plume would be the same as those for Alternative 1.

7.4.3 Alternative 3: Monitored Natural Attenuation

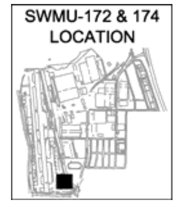
Alternative 3 is based on biodegradation of organic constituents by MNA and on institutional controls to limit the potential for exposure to site constituents that may remain in site soil. The cleanup standard for this alternative would be attained through permanent destruction of organic constituents by the ongoing natural processes and immobilization of the nonbiodegradable COCs. The specific elements included in this alternative are:

- Groundwater monitoring using both existing and new monitoring wells located appropriately to intersect the plume at the CPOC;
- Institutional Controls:
  - Deed recordation noting the location and nature of historical waste management at the site and location where residual COCs exceed cleanup levels;
  - Covenants and deed restrictions to address potential risks to human health that may remain as a result of residual soil constituents and affected groundwater within the plume area;
- Points of Compliance: An on-site CPOC to provide for ready access to install and sample monitoring wells.

For this alternative, the CPOC would be along the eastern lease boundary, as shown in Figure 7-5.

7.4.3.1 Monitored Natural Attenuation

For this alternative, MNA would be used to attain the groundwater cleanup levels at the CPOC. The groundwater monitoring data for this site presented in the final RI Report and the data collected during the supplemental investigation and presented in the FSWP indicate that natural processes are effectively degrading and retarding the migration of both organic and inorganic COCs. Groundwater sampling data within the source areas and in the downgradient plume show the products of biodegradation for the chlorinated solvents released in the source areas. The data also show that although chlorinated COCs are present near the lease boundary, they have not reached the area east of East Perimeter Road. Available monitoring data indicate that groundwater COCs have not migrated to the lease boundary; the front of the plume lies between the most downgradient monitoring wells (GW081, GW173, and GW172) and the downgradient push probes PP086 and PP087. The groundwater sampling data also show that metals are only present in samples collected immediately adjacent to the source areas, which indicates that the metals COCs are not mobile. The single SVOC detected at the site [bis-(2-



ethylhexyl) phthalate] is also only present within the source area and was not found in any downgradient groundwater samples collected during the RI. These data demonstrate that natural attenuation is an active process for this site.

Based on the highly conservative modeling approach presented in Section 6 of the FSWP, fate and transport groundwater modeling using BIOCHLOR was conducted to evaluate the potential efficacy of MNA as a final remedy for this site. The modeling followed the conservative protocol established in the FSWP using the approved model input parameters presented in the FSWP. The BIOCHLOR model was calibrated using groundwater data for SWMU-172. Calibration required that degradation rates be included in the model, further supporting that natural attenuation is active at this site. The modeling parameters specified in the FSWP result in a very conservative evaluation of natural attenuation. Modeling results with these very conservative parameters indicate that natural attenuation may not attain the cleanup levels for chlorinated COCs prior to reaching the Cedar River Waterway. Details regarding the modeling are presented in Appendix A.

In accordance with current MNA guidance and the approach discussed in Section 4.2.4, the conceptual monitoring program for SWMU-172/174 is designed to:

- Demonstrate that natural attenuation is occurring according to expectations and regulatory requirements for both organic and inorganic COCs;
- Identify any potentially toxic and/or mobile transformation products;
- Verify that the plume is not expanding beyond the CPOC;
- Verify that cleanup levels are attained at the CPOC;
- Verify that there is no unacceptable impact to potential downgradient receptors;
- Detect new releases of COCs that could impact the effectiveness of the natural attenuation remedy;
- Demonstrate the efficacy of the institutional controls to protect potential receptors; and
- Verify attainment of remediation objectives.

For this alternative, a detailed MNA monitoring plan would be developed. This plan would identify existing and additional monitoring wells and analytes that would be required for both

characterization/validation sampling and long-term groundwater monitoring. Characterization/validation sampling would be used to demonstrate the effectiveness of MNA with respect to COC mass reduction, attenuation rates, and temporal trends. Long-term groundwater monitoring would be used after the characterization/validation sampling program was completed to confirm that the COC plume is progressing toward achievement of numerical cleanup goals.

For this conceptual design it was assumed that the groundwater monitoring program for MNA would be the same as the monitoring program described in Section 7.4.2.2 for Alternative 2. Quarterly sampling for the groundwater COCs listed in Table 3-2 would be conducted for 2 years, followed by 13 to 14 years of semiannual sampling. As described previously, more rigorous monitoring would be conducted every 5 years, for a total of 15 years of monitoring, for the geochemical and monitoring parameters identified in Section 7.4.1.2.

7.4.3.2 Institutional Controls

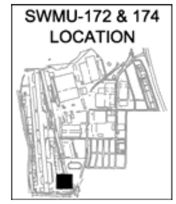
Institutional controls would be incorporated into this Alternative, as described in Section 7.4.1.3 for Alternative 1.

7.5 EVALUATION OF SITE REMEDIAL ALTERNATIVES

As previously discussed, all three remedial alternatives developed for SWMU-172/174 meet the MTCA minimum requirements for cleanup actions. This section compares and evaluates the alternatives based on the MTCA criteria of protectiveness and risk reduction, permanence, cost, long-term effectiveness, management of short-term risks, technical and administrative implementability, public concerns, and restoration time frame. An evaluation of each alternative with respect to these evaluation criteria is summarized in Table 7-1 and discussed below.

7.5.1 Protectiveness and Risk Reduction Evaluation

Protectiveness and risk reduction are gauged primarily on the time required for the remedial alternative to reduce risk associated with the site and to meet cleanup levels. Alternatives 1 and 2 would provide protectiveness and risk reduction and are expected to attain cleanup levels for organic constituents. Alternative 2 is rated higher than the others because it would provide the most complete and rapid removal of soil COCs from the site. Enhanced bioremediation, which has been included in Alternative 2, would also provide the most rapid destruction of groundwater COCs.



7.5.2 Permanence

Permanence refers to the ability to reduce the toxicity, mobility, or volume of hazardous substances, including the permanent destruction of hazardous substances. For this site, Alternatives 1 and 2 would provide a greater degree of permanence than Alternative 3, which was ranked lowest. Under Alternatives 1 and 3, organic constituents would remain in soils beneath buildings. Alternative 2 was ranked highest for permanence because it would provide the most rapid and complete destruction of site COCs in soil and groundwater.

7.5.3 Cost

The cost evaluation includes all costs related to implementation of an alternative, including initial design and construction costs, operation and maintenance costs, monitoring costs, and reporting costs. The annual costs for operation, maintenance, monitoring, and reporting are recurring costs that occur in the future. The cost evaluation considers initial implementation costs and future recurring costs using NPV analysis. For NPV calculation, recurring costs were inflated 2% annually, and a discount rate of 7% was used. Details regarding the cost estimates for the three alternatives are presented in Appendix B. The present value costs for the three alternatives, in 2007 dollars, are summarized below:

Alternative	Net Present Value
1: Source Area Excavation, Enhanced Bioremediation, and Monitored Attenuation	$1,416,000
2: Soil Vapor Extraction, Enhanced Bioremediation, and Monitored Attenuation	$ 900,000
3: Monitored Natural Attenuation	$ 492,000

As shown by these costs, Alternative 1 has the highest NPV cost, while Alternative 3 has the lowest. Therefore, Alternative 1 ranks lowest for cost, Alternative 3 ranks highest, and Alternative 2 is intermediate.

7.5.4 Long-Term Effectiveness

Long-term effectiveness includes the degree of certainty and reliability of the alternative and whether treatment residue remains from the alternative that will require management. Alternative 2 was ranked highest for this criterion because it would remove soil and groundwater COCs to the greatest extent and accomplish this in the shortest time. Alternative 3 was ranked lowest for this criterion because it would lead to the slowest destruction of site

COCs. Alternative 1 was ranked intermediate because excavation would not remove all affected soil beneath buildings. All the alternatives would use proven technologies and have good long-term effectiveness. Alternative 1 would produce a residual waste that would require long-term management at an off-site facility. The three alternatives would all rely on in situ biological processes to destroy soil and groundwater COCs; however, Alternative 3 would have the slowest rate of degradation. Alternative 2, which includes SVE and enhanced bioremediation, would require active operation to achieve faster remediation, while Alternative 3, which relies solely on natural attenuation, is a passive process with no active operating requirements. Alternative 2 was ranked highest for long-term effectiveness because it would attain cleanup objectives faster than Alternative 1, which was ranked intermediate.

7.5.5 Management of Short-Term Risks

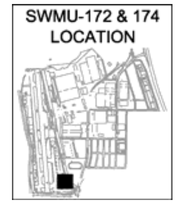
Short-term risk refers to the risk to human health and the environment during implementation of the alternative. Since Alternative 1 would require excavation of affected soil, it would create potential short-term risks because of the open excavation and off-site transport of affected soil and groundwater. Alternative 3 would create minimal short-term risks because it relies on passive, in situ processes. Alternative 3 was ranked highest for this criterion, with Alternative 1 ranked lowest.

7.5.6 Technical and Administrative Implementability

This criterion is evaluated based on whether the alternative is technically possible relative to complexity, administrative/regulatory requirements, size, access, and integration with existing operations. Alternative 1 would require invasive construction to excavate affected soil, thus significantly affecting site activities and facilities. Alternatives 1 and 2 would both require permitting and waste manifesting. Alternative 3 was ranked highest for this criterion and Alternative 1 was ranked lowest.

7.5.7 Public Concerns

This criterion involves potential community concerns with implementation of the alternative. All three alternatives deal only with an industrial site, which minimizes the potential for public concern. However, all three alternatives include an on-site CPOC located along the downgradient lease boundary. Alternative 1 was ranked lowest for public concern due to the potential for creating odors during excavation and the need to transport significant quantities of waste for off-site disposal. Both Alternatives 2 and 3 were ranked equal for this criterion.



7.5.8 Reasonable Restoration Time Frame

Restoration time frame involves the practicability of a shorter restoration time frame with consideration given to a number of factors, including site risks, site use and potential use, availability of alternative water supply, effectiveness and reliability of institutional controls, and toxicity of hazardous substances at the site. As a whole, these factors are a measure of the urgency of reducing risk and achieving cleanup goals for the site. Given that the site is an industrial facility and that no imminent risks have been identified, only Alternatives 1 and 2 would achieve a reasonable restoration time frame. Alternative 3, monitored natural attenuation, would not be able to meet the restoration time frame for PCE and TCE.

7.6 SELECTION OF PREFERRED SITE REMEDIAL ALTERNATIVE

Selection of a preferred alternative under MTCA requires that preference be given to alternatives that use permanent solutions (to the maximum extent practicable), provide for a reasonable restoration time frame, and consider public concerns. The analysis below defines the baseline alternative for SWMU-172/174 and compares the other alternatives to the baseline alternative based on the degree of permanence, reasonable restoration time frame, and the degree to which it addresses potential public concerns. Based on this comparison, the preferred remedial alternative is identified and proposed for selection as the cleanup action to be implemented for the site.

7.6.1 Baseline Remedial Alternative

The comparison of the three remedial alternatives for this site is summarized in Table 7-1. None of the alternatives is capable of attaining the standard POC at this site. Buildings 5-08 and 5-09 are located adjacent to the source areas, and affected soil and groundwater extend beneath the buildings. These buildings are actively used to support manufacturing operations at the Facility and cannot be demolished. Therefore, it is not technically possible to remediate affected soil and groundwater beneath the buildings without creating the potential for damaging the buildings.

Based on the remedial alternative evaluation presented above and summarized on Table 7-1, the three remedial alternatives are ranked as follows for permanence:

1. Alternative 2: Soil Vapor Extraction, Enhanced Bioremediation, and MA
2. Alternative 1: Source Area Excavation, Enhanced Bioremediation, and MA

3. Alternative 3: Monitored Natural Attenuation

Based on this ranking, Alternative 2, Soil Vapor Extraction, Enhanced Bioremediation, and MA, is defined as the baseline remedial alternative. This alternative would provide the greatest degree of removal and destruction for site COCs and accomplish this removal in the shortest time. Alternative 2 would provide for permanent destruction of volatile organic COCs through the SVE system and biodegradation. During initial SVE operations, VOCs present in extracted soil vapor would be adsorbed or oxidized by on-site equipment; adsorbed VOCs would be destroyed during regeneration of the adsorbers at an off-site facility. Thus, the alternative would lead to permanent destruction of the volatile organic constituents.

7.6.2 Comparison to Baseline Alternative

As noted above, Alternative 2 has been defined as the baseline remedial alternative for this site. Alternatives 1 and 3 will be compared to the baseline alternative in this section for selection of the preferred alternative. The purpose of this comparison is to assess the benefits and costs for Alternatives 1 and 3 relative to Alternative 2. The evaluation criteria presented above and in Table 7-1 were established in accordance with the MTCA requirements cited in WAC 173-340(3)(f). Costs for the alternatives will be based on the NPV, which reflects the total cost associated with each alternative over the 15-year time period evaluated. The evaluation of benefits will be qualitative.

The benefits to be assessed in this comparison and the relative rating for the alternatives are presented in Table 7-2. The rationale for this comparison is presented below.

- **Reduced risk to on-site worker health.** All three alternatives are equal in reducing future risk to site workers because they are all equally protective. Alternative 1 would pose some risk to site workers during remedial construction. Although the baseline alternative would remove volatile COCs within a few years, potential risks to on-site workers would not be changed substantially by the other two alternatives. The institutional controls included in each of the alternatives have been proven effective in protecting worker health and would continue to be protective.

- **Reduced risk to off-site human health.** All three alternatives were rated moderate for reducing risks to off-site human health. The baseline alternative and Alternative 1 would attain the cleanup level at the CPOC, which is protective of human health and the environment. Alternative 3 would not attain the cleanup level at the CPOC. The baseline alternative actively withdraws volatile COCs from the subsurface, which creates the potential for emissions that may impact off-site receptors. For Alternative 1, volatile COCs exposed during excavation could be released to the atmosphere and migrate to off-site receptors.

- **Reduced risk to the environment.** Alternative 3 was ranked lower than the baseline alternative and Alternative 1 for reducing potential risks to the environment, since it may not attain the cleanup level at the CPOC. The active removal of volatile COCs using SVE that would result from the baseline alternative creates the potential for emissions to the atmosphere, which could migrate to off-site ecological receptors. The excavation for Alternative 1 could also release VOCs that could migrate to ecological receptors. The baseline alternative and Alternative 1 would be protective of the aquatic environment because they would all attain the cleanup levels prior to discharge of the groundwater to the Cedar River Waterway.

- **Minimal adverse impact on Facility operations.** The baseline alternative was rated moderate for this benefit because it would impact Facility operations during installation of the SVE system and require long-term operation and periodic replacement of SVE system components. Alternative 1 was rated low because the excavation would substantially disrupt activities at the site. A high rating was given to Alternative 3, which relies on passive degradation of site COCs and would have the least impact on Facility operations.

- **Minimal restrictions on Facility traffic and access.** The baseline alternative was rated moderate for this benefit because it would impact Facility traffic and access during installation and operation of the SVE system. Additional impact would occur during periodic replacement or maintenance of SVE system components. Alternative 1 was rated low because the excavation would substantially disrupt site traffic and access during construction. Alternative 3 was given a high rating because it would affect traffic only during installation of monitoring wells, resulting in the least impact on Facility traffic and access.

- **Minimal adverse impact on Facility structures and utilities.** The baseline alternative and Alternative 3 were both rated high for minimizing adverse impacts on facility structures and utilities. Neither of these two alternatives would potentially affect the integrity of site improvements. Alternative 1, which relies on excavation to remove COCs from the source areas, could cause damage to buildings or underground utilities, and was rated low for this benefit.

The potential benefit evaluation for the three alternatives shows that the baseline alternative (Alternative 2 – SVE, Enhanced Bioremediation, and Monitored Attenuation) would provide the greatest benefit. MNA (Alternative 3) would provide the next highest benefit, and Alternative 1 ranks lowest for benefits.

The NPV costs for the three alternatives were presented in Section 7.5.3. The baseline alternative ranks second among the three alternatives, with an intermediate cost. Alternative 3

would have the lowest net present value cost (approximately 54% of the estimated cost for the baseline alternative). Alternative 1 would have the highest cost (approximately 1.6 times the cost for the baseline alternative). Alternative 3 is ranked highest for cost because it has the lowest NPV.

7.6.3 Preferred Remedial Alternative

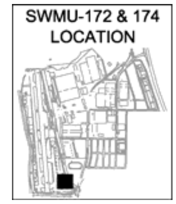
The preferred remedial alternative for SWMU-172/174 is the baseline alternative, Alternative 2, Soil Vapor Extraction, Enhanced Bioremediation, and Monitored Attenuation. This alternative would address the elevated COC concentrations remaining in the soil. PCE exceeds the soil cleanup level that is protective of groundwater at the CPOC. PCE and TCE concentrations in the source area groundwater also exceed the cleanup level that is protective of groundwater at the projected CPOC.

Groundwater fate and transport modeling conducted using very conservative assumptions indicates that groundwater COCs would attain cleanup levels at an on-site CPOC located upgradient of the Cedar River Waterway. The presence of East Perimeter Road and the retaining wall along the western shoreline of the waterway precludes development and minimizes the potential for exposure to groundwater downgradient from the CPOC.

Groundwater in the vicinity of the site is not used for any purpose, and potable water is readily available from the Renton public water system. The institutional controls included in Alternative 2 have been implemented and proven by Boeing, who would continue to maintain overall responsibility for this site and ensure that the institutional controls are properly enforced.

SVE and enhanced bioremediation for this site would achieve the expectations for cleanup actions cited in the MTCA regulations at WAC 173-340-370 (1) – (8). Only those expectations relevant to large, complex sites are considered relevant to SWMU-172/174. The relevant expectations are addressed as follows.

- **Implement Treatment at Sites with Liquid Wastes, High Contaminant Concentrations, Highly Mobile Materials, or Discrete Areas of Contamination.** Ecology expects that treatment will be emphasized for sites meeting these general criteria. Boeing has completed removal of affected soils within the source areas to the extent practicable without adversely affecting building foundations. While remaining COC levels are significant, they are not high, and there is no evidence of liquid wastes at the site. The source areas are not discrete and extend beneath



buildings, preventing ready access for removal or treatment. SVE and enhanced bioremediation will address the source areas to the extent practicable given site constraints.

- **Destroy, Detoxify, or Remove Hazardous Substances.** Ecology expects that hazardous substances will be destroyed, detoxified, or removed to below cleanup levels. SVE and enhanced bioremediation will result in the ultimate destruction of COCs.

- **Implement Engineering Controls for Low Contaminant Concentrations.** The buildings and extensive surface pavement or tarmac covering the site serve as a cap to provide containment for affected soil and groundwater over the source areas and much of the plume. The cap will remain over the site while SVE and enhanced bioremediation treat the site COCs.

- **Prevent Runoff of Hazardous Substances.** Ecology expects that cleanup actions will include active measures to prevent precipitation from creating runoff that contains affected soil. This expectation would be met because the installation of the SVE system and implementation of enhanced bioremediation would not materially alter the buildings, tarmac or pavement at the site. The buildings, tarmac, and pavement are integral to Boeing's activities at the site and are well maintained. In addition to preventing runoff from contacting hazardous substances, the buildings, tarmac, and pavement minimize surface water infiltration, thus resulting in decreased groundwater flow rates and increased time for groundwater to flow from the source area to the waterway.

- **Prevent Runoff and Groundwater Discharge to Surface Water.** Ecology expects that the cleanup action would include active measures to prevent or minimize releases to adjacent surface water bodies via runoff or groundwater discharge, and that dilution will not be the sole method for attaining cleanup levels. SVE and enhanced bioremediation would attain cleanup levels by removing and destroying COCs or promoting their enhanced bioremediation. The cleanup alternative also includes a groundwater monitoring network and program that would confirm that cleanup levels are attained in groundwater upstream from the waterway.

The preferred remedial alternative would be designed to comply with applicable regulations. Potentially applicable regulations are listed in Table 7-3. These regulations govern the design, installation, and operation of remediation systems. Construction for the preferred alternative would include installation of the SVE wells, the bioremediation injection wells, and the new monitoring wells, some of which are within 200 feet of the shoreline along the Cedar River Waterway. To establish baseline groundwater conditions at the proposed CPOC, these groundwater monitoring wells may be installed as an interim action prior to completion of the

Cleanup Action Plan (CAP). Results from installation and water quality testing at the CPOC may be used during the CAP process to ensure that this preferred alternative is optimal for this SWMU and continues to meet site objectives. If appropriate, based on the initial monitoring results for the CPOC wells, the remedial design may be revised as part of the CAP to ensure the remedial design is optimal for this SWMU.

The primary regulations governing the preferred alternative would be the MTCA regulations, the Puget Sound Clean Air Agency (PSCAA) regulations, federal NESHAPS, Washington well drilling regulations for monitoring wells, solid waste disposal regulations, dangerous waste regulations, transportation regulations, underground injection control regulations, and Department of Labor and Industries health and safety regulations. Well drilling rules specify well design and drilling requirements. The solid and dangerous waste regulations specify waste characterization, manifesting, and disposal requirements for drilling wastes and spent media from controlling emissions. Transportation regulations specify labeling and shipping requirements for wastes and spent media generated from implementation of the alternative. The PSCAA and NESHAPS regulations govern design and permitting for emissions from the SVE system. MTCA regulations specify remediation requirements and the cleanup standards to be attained. The preferred alternative would be designed, implemented, and monitored to comply with these regulations

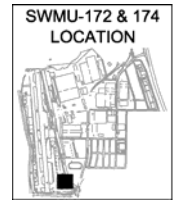


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TABLE 7-1

COMPARISON OF REMEDIAL ALTERNATIVES, SWMU-172/174[1]

Boeing Renton Facility

Renton, Washington

Standards/Criteria		Alternatives		
		1 -Source Area Excavation/Enhanced Bioremediation/MA	**2 - Soil Vapor Extraction/Enhanced Bioremediation/MA**	**3 - Monitored Natural Attenuation**
Protectiveness and Risk Reduction	Pros	Removes or destroys soil COCs, including metals. Soil COCs addressed quickly. Destroys or immobilizes groundwater COCs.	Removes volatile soil COCs. Destroys or immobilizes groundwater COCs. Removes VOCs beneath buildings.	Destroys organic groundwater COCs. Immobilizes metals.
	Cons	Slow to achieve cleanup for groundwater. Cannot remediate area beneath buildings. Off-site waste management required.	Cannot remove nonvolatile soil COCs.	Metals remain at site. Long remediation time.
	Rating	MH	H	ML
Permanence	Pros	Most soil COCs, including metals, are removed from site. Organic groundwater COCs are destroyed.	Volatile soil and groundwater COCs are destroyed.	Natural carbon in site soils promotes MNA. COCs are destroyed, no toxic residuals.
	Cons	COCs beneath building remain at site. Metals remain in site soil. Residuals managed at off-site facility. Off-site CPOC.	Nonvolatile soil COCs remain at site. Metals remain in site soil. Residuals managed at off-site facility. Off-site CPOC.	Metals remain in site soil. Slow degradation rates; Off-site CPOC.
	Rating	MH	H	ML
Cost	Pros	Long-term costs minimized.		Lowest total cost. Minimal impact on site activities.
	Cons	Affects site activities. May damage facilities. High initial cost.		Long-term monitoring costs incurred.
	Rating	ML	MH	H
Long-Term Effectiveness	Pros	Removes or destroys accessible soil COCs. Groundwater organic COCs destroyed.	Removes or destroys volatile soil COCs. Organic groundwater COCs destroyed.	Destroys COCs; Passive, natural process.
	Cons	Soil COCs remain beneath buildings. Requires institutional controls. Off-site waste management.	Requires periodic injections. Metals remain in site soils. Requires institutional controls. Off-site waste management.	Requires institutional controls.
	Rating	MH	H	ML
Management of Short-Term Risks	Pros	In situ management of affected groundwater.	In situ management of affected groundwater.	Simplest implementation. Minimal potential for exposure to site COCs.
	Cons	Exposure of affected soil, potential emission of dust and volatiles. Waste transportation. Requires periodic electron donor injection.	Requires periodic electron donor injection. Volatile COCs are extracted, potential for emissions.	
	Rating	L	ML	H
Technical and Administrative Implementability	Pros	Off-site landowner has indicated general acceptance for CPOC.	Moderate impact on site activities. Off-site landowner has indicated general acceptance for CPOC.	Simple system, minimal impact on ongoing activities. No permits needed. Off-site landowner has indicated general acceptance for CPOC.
	Cons	Requires excavation and backfill permits, waste manifests, coordination with site manufacturing activities. Potential for damaging facilities. Periodic electron donor injection. Injection permit required. Off-site landowner permission needed for CPOC.	Requires periodic electron donor injection. Injection and emission permitting. Off-site landowner permission for CPOC.	Off-site landowner permission for CPOC.
	Rating	L	MH	H
Public Concerns	Pros	Industrial site.	Industrial site.	Industrial site.
	Cons	Requires City of Renton approval for CPOC. Potential odor issues.	Requires City of Renton approval for CPOC.	Requires City of Renton approval for CPOC.
	Rating	ML	MH	MH
Restoration Time Frame	Pros	Industrial site; Proven institutional controls; Alternative water available; Most rapid removal of soil COCs.	Industrial site; Proven institutional controls. Alternative water available. Fair to moderate cleanup time frame.	Industrial site; Proven institutional controls; Alternative water available.
	Cons	Does not address COCs beneath building. Practicability of shorter time frame limited by facility operations	Practicability of shorter time frame limited by facility operations. Metals remain in site soil.	Longest cleanup time. Metals remain in site soil. Practicability of shorter time frame limited by facility operations.
	Rating	ML	ML	L

Notes:

1. Comparison Ratings: H = Highest (if the decision were based solely on one criterion, an H score would indicate the alternative is the preferred alternative);
   MH = Medium High;
   ML = Medium Low;
   L = Low.

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TABLE 7-2

COMPARISON OF BENEFITS FOR SWMU-172/174[1]

Boeing Renton Facility
Renton, Washington

Benefit	Alternative 1: Soil Excavation/Enhanced Bioremediation/Monitored Attenuation	Alternative 2: SVE/Enhanced Bioremediation/Monitored Attenuation	Alternative 3: Monitored Natural Attenuation
Reduced risk to on-site worker health	High	High	High
Reduced risk to off-site human health	Moderate	Moderate	Moderate
Reduced risk to the environment	Moderate	Moderate	Low
Minimal adverse impact on Facility operations	Low	Moderate	High
Minimal restrictions on Facility traffic and access	Low	Moderate	High
Minimal adverse impact on Facility structures and utilities	Low	High	High

Notes:
1. Benefits for each remedial alternative are rated as follows:
    High = high benefit;
    Moderate = moderate benefit;
    Low = low benefit.

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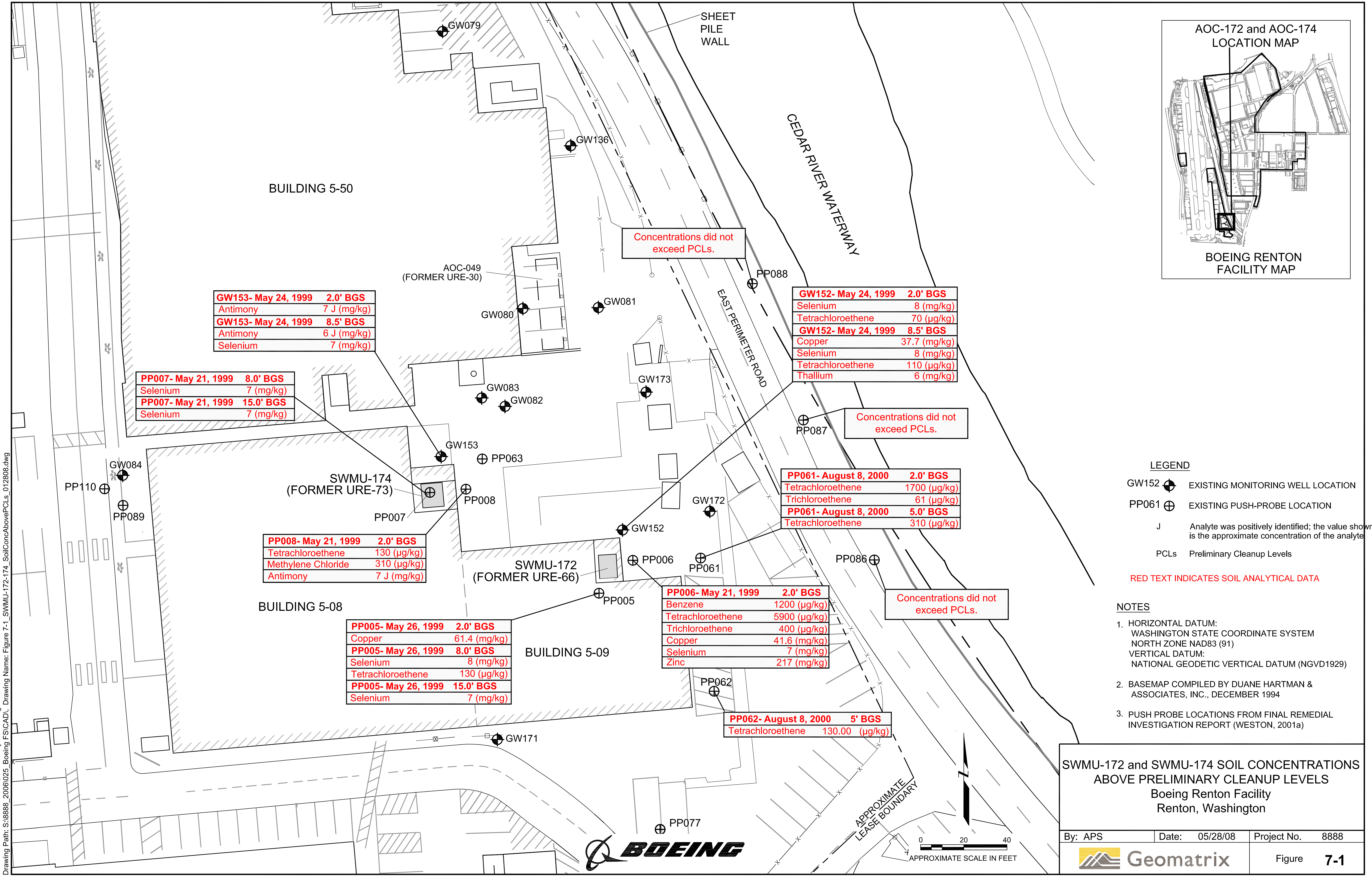
TABLE 7-3

POTENTIALLY APPLICABLE REGULATIONS
SWMU-172/174 PREFERRED REMEDIAL ALTERNATIVE

Boeing Renton Facility
Renton, Washington

Law/Regulation	Citation	Applicability
Chemical-Specific Laws and Regulations		
Washington Clean Air Act/Puget Sound Clean Air Agency Regulations	WAC 173-400	Permitting, air quality impacts
National Emission Standards for Hazardous Air Pollutants	40 CFR Part 61	Emission control requirements, permitting
Washington Dangerous Waste Regulations	WAC 173-303	Waste management, permitting requirements
Washington Model Toxics Control Act Regulations	WAC 173-340	Establishment of cleanup levels and POCs
Action-Specific Laws and Regulations		
Washington State Environmental Policy Act Regulations	WAC 197-11	Permitting, EIA/EIS[1] requirements
Washington Industrial Safety and Health Act Regulations	WAC 296-24	Occupational health and safety
Transportation regulations	49 CFR Parts 100 & 177, WAC 446-50	Transportation for wastes and materials
Washington well drilling regulations	WAC 173-160 & -162	Well design and installation standards
Washington Underground Injection Control Regulations	WAC 173-218	Underground injection permitting
Washington solid waste disposal regulations	WAC 173-304	Disposal of nondangerous waste
Location-Specific Laws and Regulations		
Shoreline Management Act	RCW 90.58	Standards for construction within 200 ft of shoreline

Notes:
1. EIA = Environmental Impact Analysis; EIS = Environmental Impact Statement.



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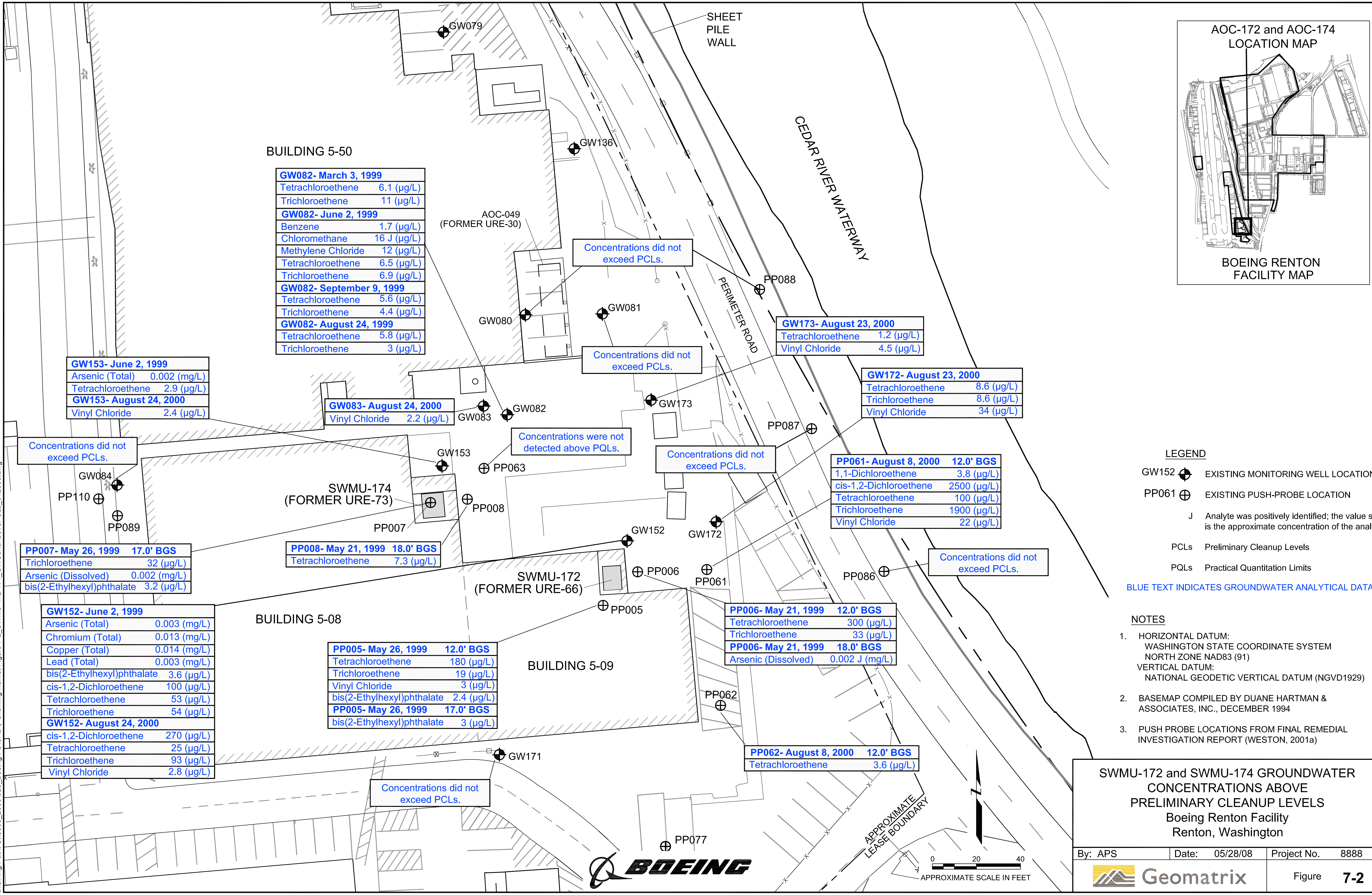

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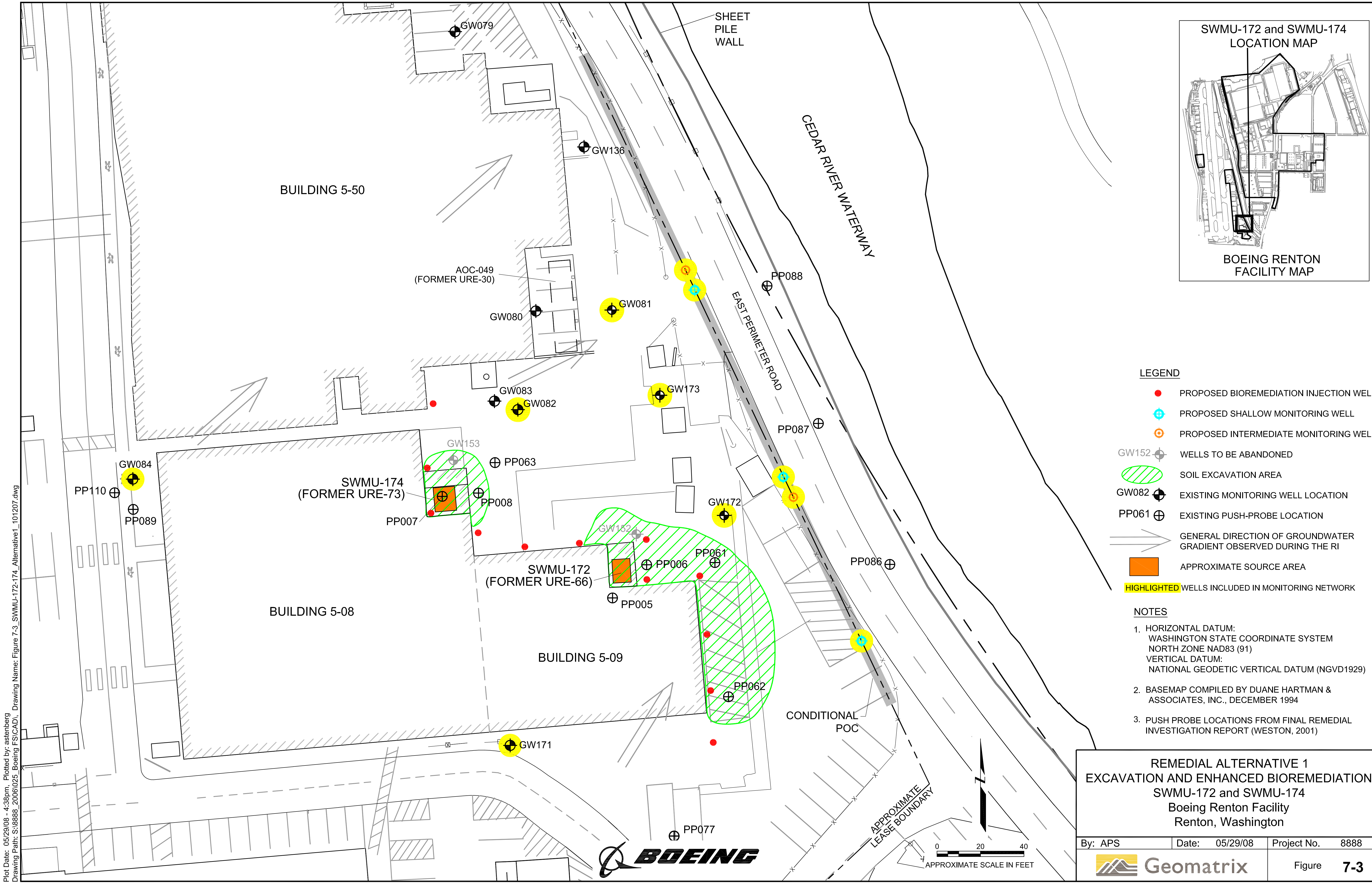
SWMU-172 and SWMU-174
LOCATION MAP
BOEING RENTON
FACILITY MAP
SHEET PILE WALL
CEDAR RIVER WATERWAY
EAST PERIMETER ROAD
BUILDING 5-50
BUILDING 5-08
BUILDING 5-09
AOC-049
(FORMER URE-30)
SWMU-174
(FORMER URE-73)
SWMU-172
(FORMER URE-66)
CONDITIONAL POC
APPROXIMATE LEASE BOUNDARY
GW079
GW136
GW080
GW081
GW083
GW082
GW173
GW084
GW153
GW152
GW172
GW171
PP088
PP087
PP086
PP110
PP089
PP063
PP008
PP007
PP006
PP061
PP005
PP062
PP077
LEGEND
PROPOSED BIOREMEDIATION INJECTION WELL
PROPOSED SHALLOW MONITORING WELL
PROPOSED INTERMEDIATE MONITORING WELL
GW152 WELLS TO BE ABANDONED
SOIL EXCAVATION AREA
GW082 EXISTING MONITORING WELL LOCATION
PP061 EXISTING PUSH-PROBE LOCATION
GENERAL DIRECTION OF GROUNDWATER GRADIENT OBSERVED DURING THE RI
APPROXIMATE SOURCE AREA
HIGHLIGHTED WELLS INCLUDED IN MONITORING NETWORK
NOTES
1. HORIZONTAL DATUM:
WASHINGTON STATE COORDINATE SYSTEM
NORTH ZONE NAD83 (91)
VERTICAL DATUM:
NATIONAL GEODETIC VERTICAL DATUM (NGVD1929)
2. BASEMAP COMPILED BY DUANE HARTMAN & ASSOCIATES, INC., DECEMBER 1994
3. PUSH PROBE LOCATIONS FROM FINAL REMEDIAL INVESTIGATION REPORT (WESTON, 2001)
0 20 40
APPROXIMATE SCALE IN FEET
BOEING
REMEDIAL ALTERNATIVE 1
EXCAVATION AND ENHANCED BIOREMEDIATION
SWMU-172 and SWMU-174
Boeing Renton Facility
Renton, Washington
By: APS
Date: 05/29/08
Project No. 8888
Geomatrix
Figure 7-3
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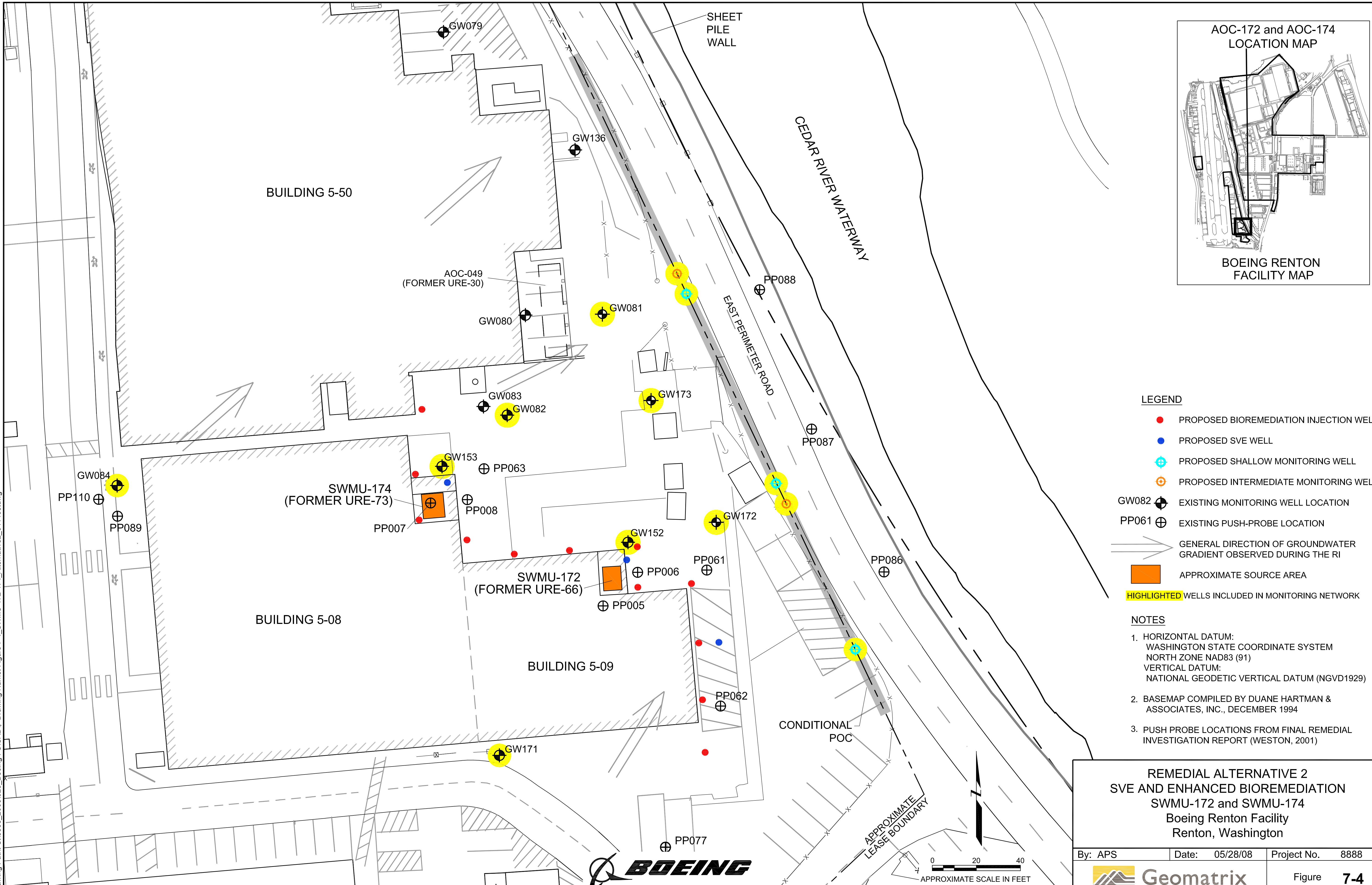

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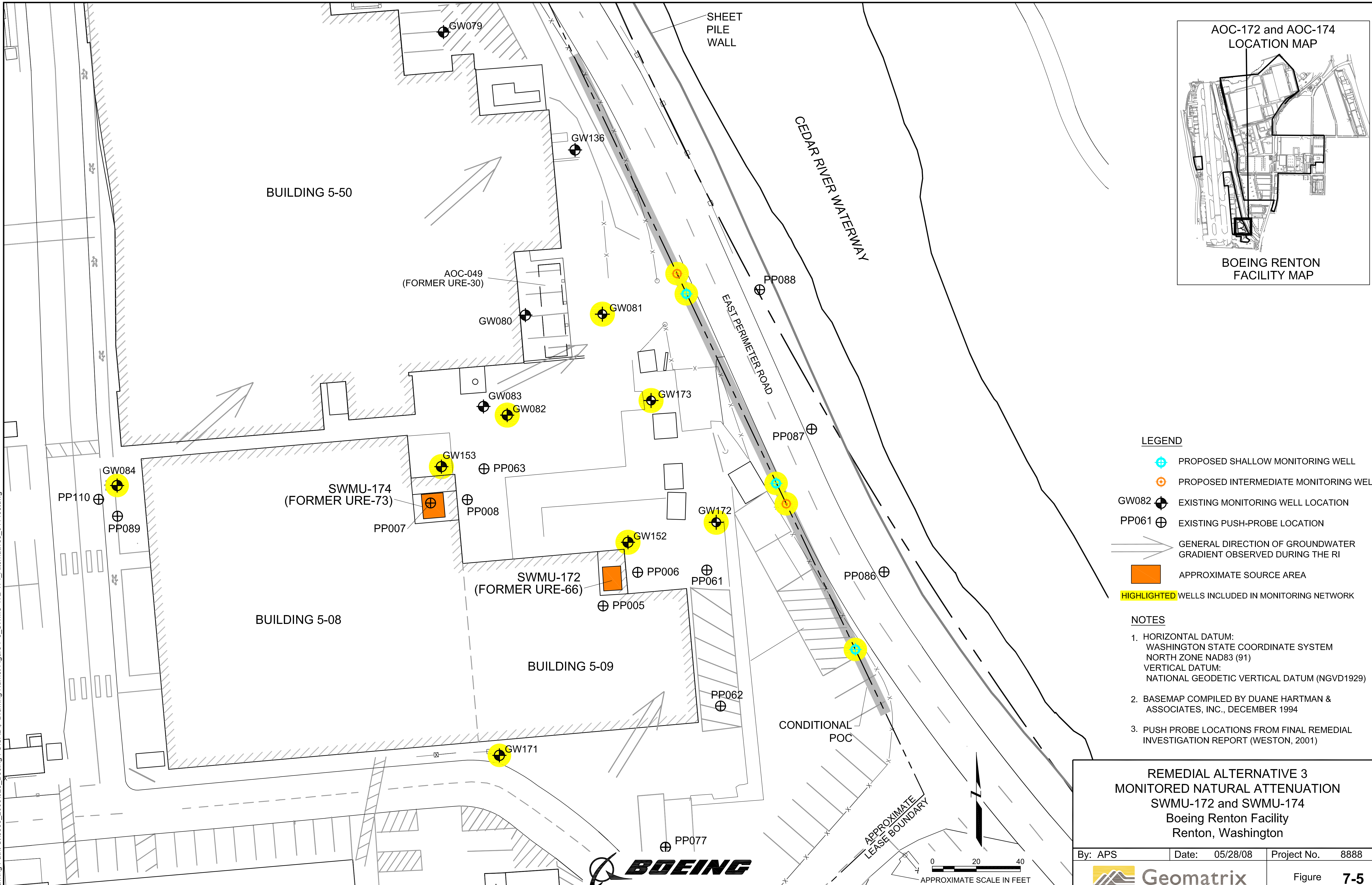

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8.0 DEVELOPMENT AND EVALUATION OF REMEDIAL ALTERNATIVES, SWMU-179

In this section we describe existing conditions and document the status of SWMU-179.

8.1 SITE CHARACTERIZATION AND REMEDIAL ACTION SUMMARY

SWMU-179 is located at the site of a former cistern in Building 4-76 (see Figure 1-2) that received air compressor condensate blowdown that contained low concentrations of oil. The sump was initially constructed with concrete walls and a gravel floor; the installation date is not known. This SWMU was identified as an area to be investigated in the RFA (SAIC, 1991).

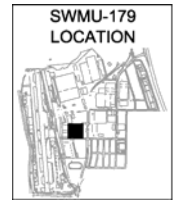
The original sump was removed and replaced in 1990 with a steel-lined concrete sump that provided proper containment. Soil and groundwater in the vicinity of SWMU-179 were investigated under the RI.

8.1.1 Historical, Present, and Future Site Use

The former sump in former Building 4-76 received blowdown condensate from an air compressor that contained low concentrations of oil. The former Building 4-76 was used for logistical support of airplane manufacturing, and the compressed air was used in the machine shop in the adjacent building (former Building 4-63). Earlier excavations at SWMU-179 had been hampered by the presence of building foundations near the former cistern location. Both buildings were demolished and all foundations removed in early 2004 as Boeing relocated some manufacturing operations to the northern portions of the Renton Facility. The SWMU-179 area will be paved and landscaped and used as a parking lot for the foreseeable future.

8.1.2 Site Hydrogeology

Fill observed in this area consists of greenish-brown fine- to medium-grained sand with silt and gravel ranging to 2.5 to 5 feet bgs. Alluvium encountered below the fill consists of light brown clayey silt with fine-grained sand grading into greenish-brown fine-grained sand with silt. Depth to groundwater measured at GW157, the nearest shallow well to SWMU-179, has ranged between 7.09 to 7.49 feet bgs, with seasonal variations of less than 0.4 foot bgs. Groundwater in the area of the SWMU generally flows to the west-northwest toward the Cedar River Waterway. The hydraulic gradient has been fairly constant at approximately 0.004.



8.1.3 Nature and Extent of Affected Soil

The sump walls were removed in November 1990, and soil was excavated to a depth of approximately 5 feet. Approximately 0.5 cubic yard of soil was removed from the excavation. Confirmatory soil samples collected from the walls and floor of the excavation contained TPH ranging from 840 to 9,900 mg/kg, which is above the PCLs defined in the final RI Report (Weston, 2001a). Nickel was also detected in soil samples collected from the excavation after soil removal. Soil was removed to the extent practicable; no additional soil could be removed because of the potential for damaging the foundation and floor slab of adjacent buildings.

Further investigation of soil in the area of SWMU-179 was conducted as part of the RI to determine if significant residual concentrations of previously detected constituents were present. Six soil samples were collected and analyzed from three locations (GW157, PP009, and PP010) within 10 feet of the former sump area. Only copper, chromium, and selenium were detected in soil at concentrations slightly above the PCLs (see Figure 8-1). Table 5-4A from the final RI Report shows the concentrations in soil samples from the RI investigation of SWMU-179, and PCL exceedances are shown on Figure 5-4F from the final RI Report.

8.1.4 Nature and Extent of Affected Groundwater

A groundwater sample from a well point driven in the base of the sump prior to removal was analyzed for TPH; no detectable TPH was present in the groundwater sample. Further investigation of groundwater in the area of SWMU-179 was conducted as part of the RI. One groundwater sample was collected at each of the three locations (GW157, PP009, and PP010). TPH-D and arsenic were the only compounds detected in groundwater above the PCLs defined in the final RI Report (see Figure 8-2). TPH-D was detected below the PCL at GW157 (0.30 milligram per liter [mg/L]) and above the PCL at PP009 (1.00 mg/L). However, TPH appears to be limited to the immediate vicinity of the cistern based on the results from adjacent push probe PP010, which was placed on the opposite side of the load-bearing wall that precluded additional soil excavation in 1990. In this probe (located approximately 5 feet west of the SWMU), TPH was not detected.

8.2 ATTAINMENT OF THE CLEANUP STANDARD

This section documents attainment of cleanup standards at SWMU-179.

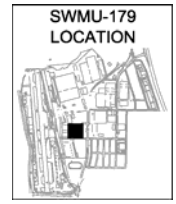
8.2.1 Interim Remedial Actions

The walls of the SWMU-179 cistern were removed in November 1990. Approximately 0.5 cubic yard of soil was removed from the excavation, which extended to approximately 5 feet bgs. The soil samples from the walls and floor of the excavation contained residual TPH and nickel at concentrations above screening levels as determined during the RI Work Plan (Weston, 1998). Additional soil was not removed at the time of the excavation because of the potential for damaging the adjacent Building 4-63 foundation and floor slab.

Buildings 4-76 and 4-63 at the Facility were demolished in December 2003. Monitoring well GW157 was sampled and then decommissioned in November 2003 just prior to the demolition work. In January 2004, an interim action soil removal was performed at SWMU-179 in accordance with the Final SWMU-179 Remedial Action Work Plan (Geomatrix, 2003b). Affected soil was removed from an excavation that extended 8 feet to the south, 10 feet to the north, 10 feet to the west, and 6 feet to the east of the former cistern, as shown on Figure 8-3. The excavation extended to the capillary fringe, and approximately 98 tons of soil were removed from the area of the former cistern. Confirmation samples were taken from the floor and walls of the excavation. All soil confirmation sample results were below the cleanup/comparison levels described in the Final SWMU-179 Remedial Action Work Plan. With the exception of arsenic, all final groundwater sampling results were below the applicable cleanup/comparison levels. Prior to decommissioning, a groundwater sample from GW157 contained dissolved arsenic at 0.010 mg/L. As described in the final RI Report, samples of groundwater upgradient of the Facility have contained arsenic at concentrations up to 0.035 mg/L, which is representative of ambient dissolved arsenic concentrations in the Puget Sound region (Weston, 2001a).

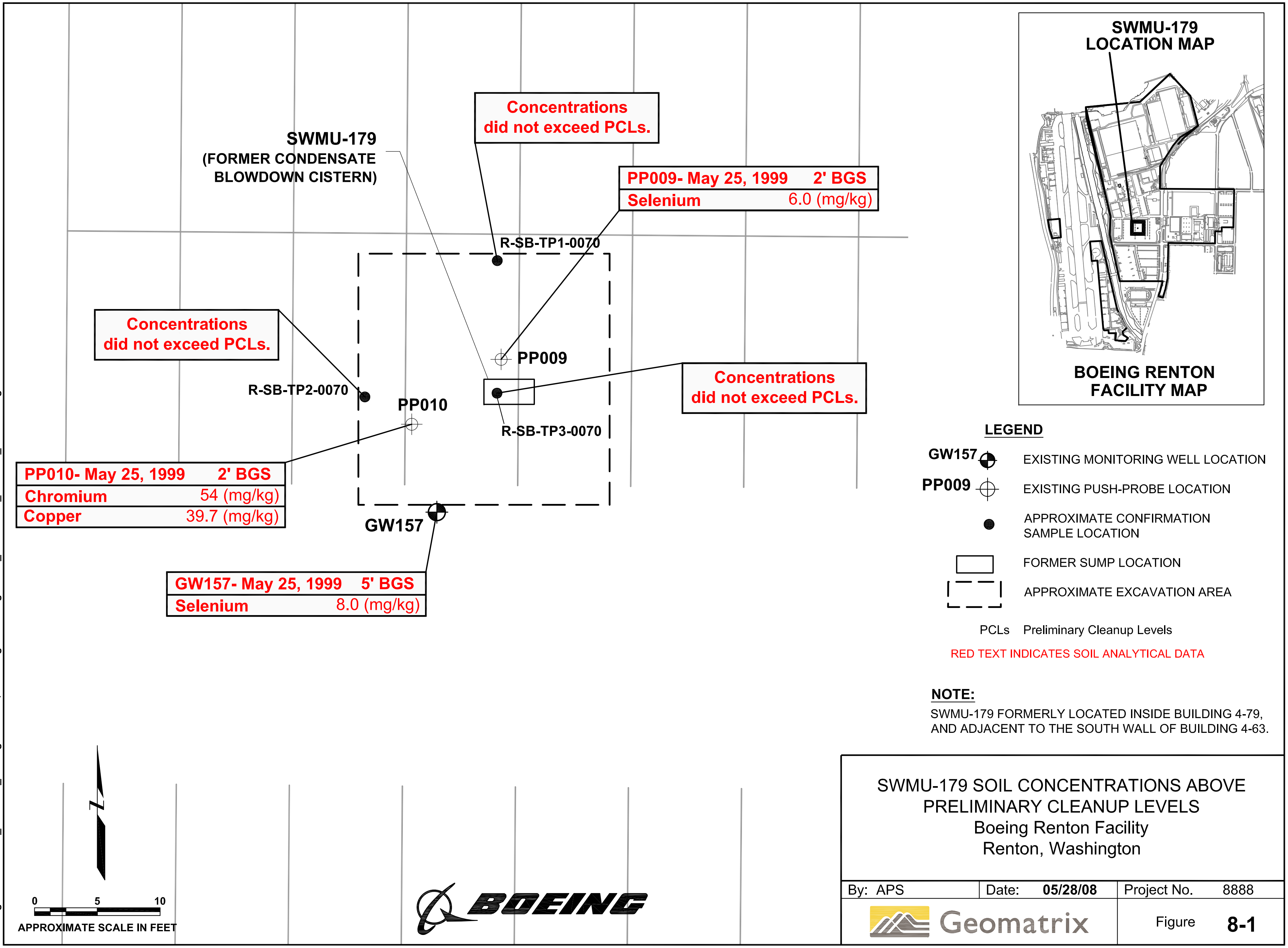
Following excavation, 60 pounds (lbs) of oxygen-releasing compound (ORC) was added to the base of the excavation prior to backfilling with clean imported fill materials. The purpose of the ORC was to enhance degradation of any remaining petroleum hydrocarbon compounds that may have existed in soil or groundwater.

Three months later, in April 2004, a push probe groundwater sample (R-GW-PP-0-7) was obtained from the location of the previous monitoring well GW157. The groundwater sample did not contain any COCs above the PCLs or groundwater cleanup levels (Geomatrix, 2004e). The affected soils have been removed from SWMU-179, and the groundwater under the former cistern location is no longer affected by COCs.



8.2.2 No Further Action Recommendation

No further additional cleanup actions are necessary for SWMU-179 because the soils and the groundwater at SWMU-179 meet the FS cleanup levels for soil and groundwater. The standard POC for soil and groundwater has been met at SWMU-179. SWMU-179 will not be further evaluated during the FS.



NOTE:
SWMU-179 FORMERLY LOCATED INSIDE BUILDING 4-79, AND ADJACENT TO THE SOUTH WALL OF BUILDING 4-63.

SWMU-179 SOIL CONCENTRATIONS ABOVE
PRELIMINARY CLEANUP LEVELS
Boeing Renton Facility
Renton, Washington

By: APS	Date: 05/28/08	Project No. 8888
Geomatrix		Figure 8-1

Plot Date: 05/28/08 - 9:46am, Plotted by: astenberg
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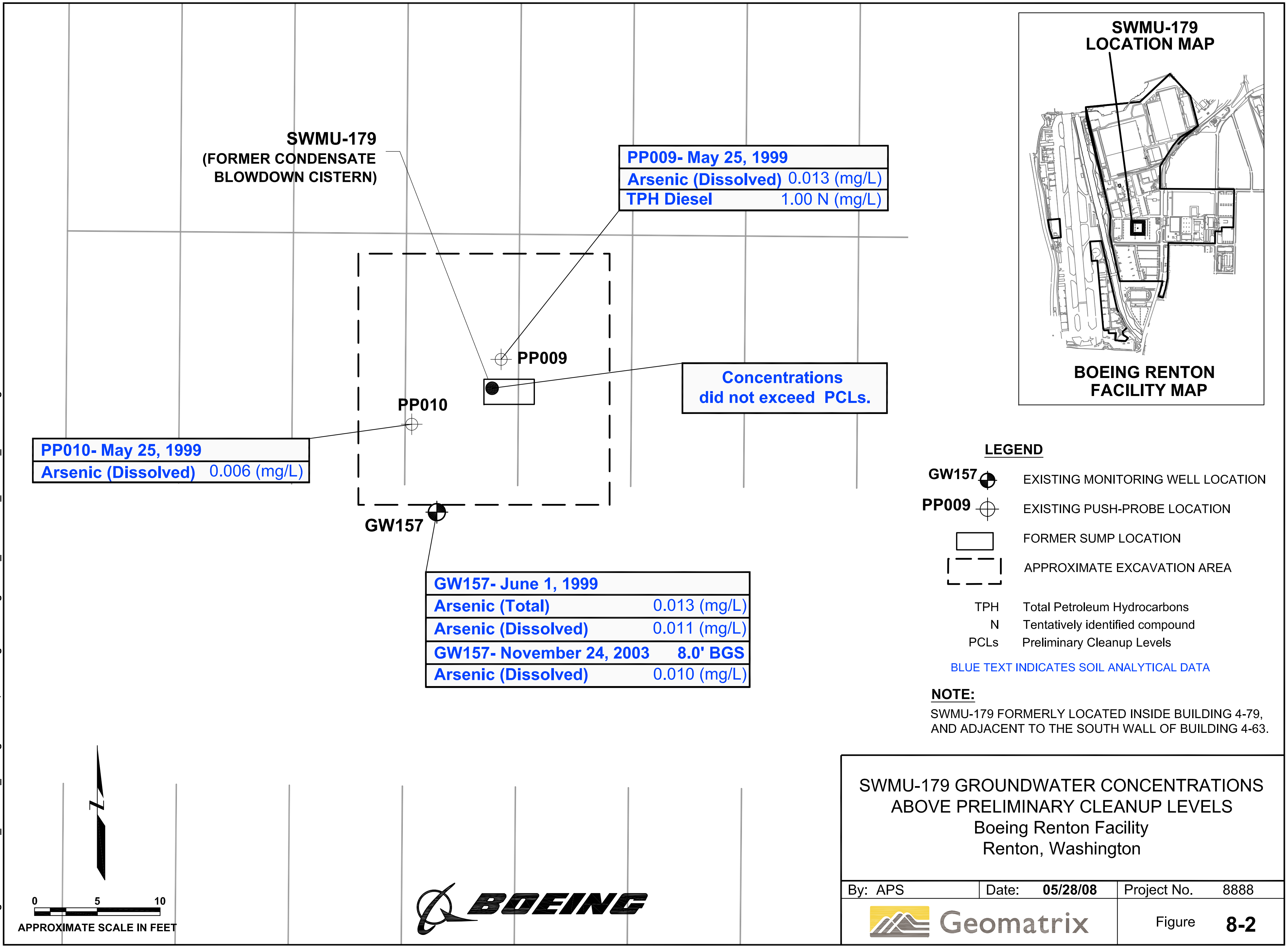

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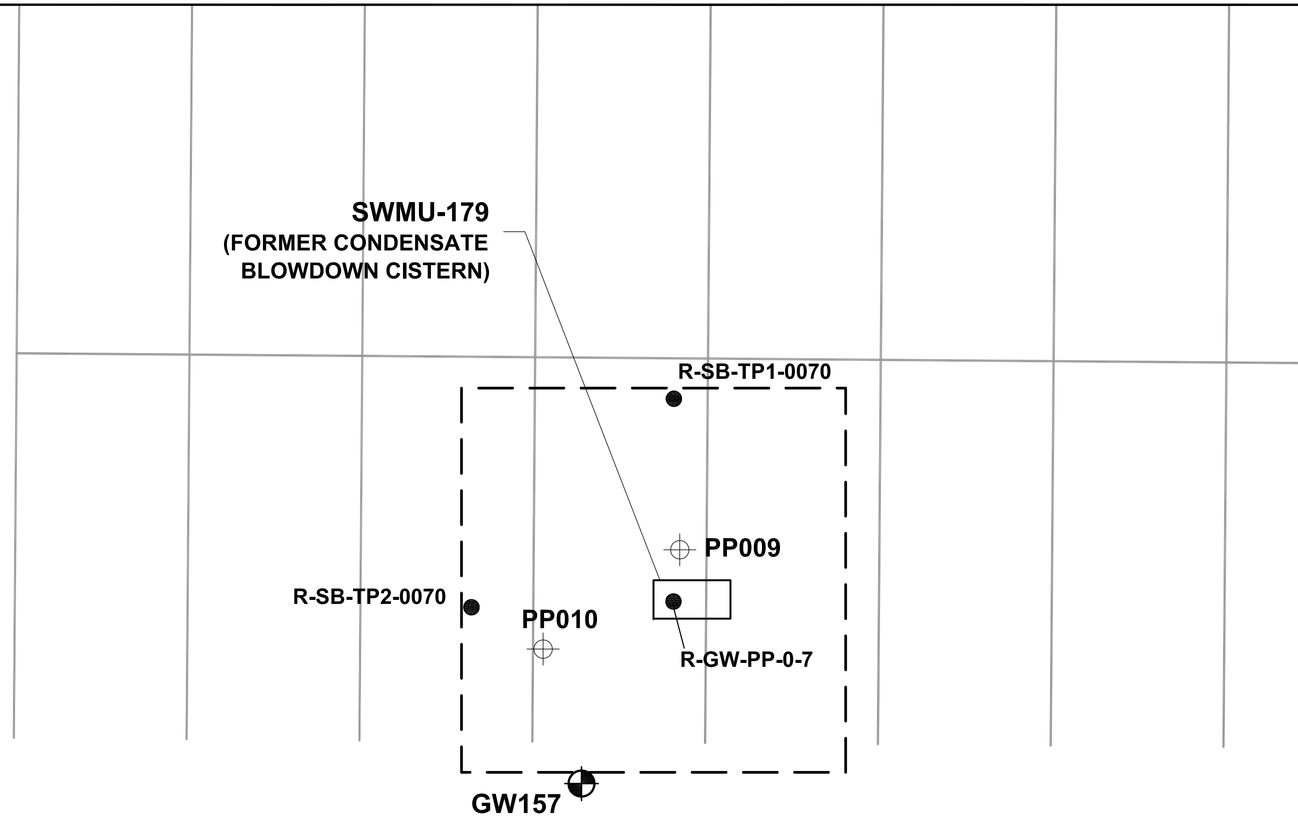

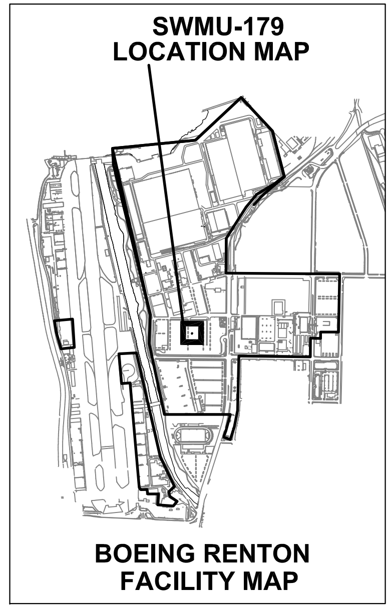

LEGEND

- GW157 — EXISTING MONITORING WELL LOCATION
- PP009 — EXISTING PUSH-PROBE LOCATION
- APPROXIMATE CONFIRMATION SAMPLE LOCATION
- FORMER SUMP LOCATION
- APPROXIMATE EXCAVATION AREA

NOTE:
SWMU-179 FORMERLY LOCATED INSIDE BUILDING 4-79, AND ADJACENT TO THE SOUTH WALL OF BUILDING 4-63.

0 5 10
APPROXIMATE SCALE IN FEET

BOEING

SWMU-179 REMEDIATION AREA
Boeing Renton Facility
Renton, Washington

By: APS	Date: **05/28/08**	Project No. 8888
Geomatrix		Figure **8-3**

Plot Date: 05/28/08 - 9:48am, Plotted by: astenberg
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9.0 DEVELOPMENT AND EVALUATION OF REMEDIAL ALTERNATIVES, BUILDING 4-78/79 SWMU/AOC GROUP

In this section we discuss remediation objectives, identify and evaluate remedial alternatives, and describe the preferred remedial alternative for the Building 4-78/79 SWMU/AOC Group.

9.1 SITE CHARACTERIZATION SUMMARY

The Building 4-78/79 SWMU/AOC group includes a former dangerous waste storage area (SWMU-181), four former gasoline USTs (UREs-17, -23, -24 and -54), and two former methyl ethyl ketone (MEK) USTs (UREs-18 and -25). The location for this site is shown on Figure 1-2, and the general site layout is shown on Figure 9-1. A general description of each unit is provided below:

- **SWMU-181: Building 4-78 Former Dangerous Waste Storage Area—**This SWMU was used for the accumulation of dangerous wastes brought from other areas of the Facility. Wastes typically stored at SWMU-181 included solvents, spent petroleum products, and sludges. As documented in the final RI Report, historical data from investigations indicate that releases of VOCs, SVOCs, and TPH to groundwater from this SWMU have occurred.

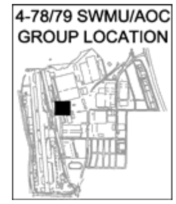
- **AOC-013: Former URE-17—**This 1,000-gallon steel tank was used to store gasoline. Soil and groundwater samples collected in the vicinity of this former UST in 1989 had detectable concentrations of VOCs and TPH.

- **AOC-14: Former URE-18—**This 10,000-gallon steel tank was used to store MEK. VOCs, MEK, and TPH were detected in groundwater samples from the vicinity. These constituents were not detected in soil samples collected near the former tank.

- **AOC-015: Former URE-24—**This 4,000-gallon steel tank was used to store gasoline. The tank was removed in September 1985. Benzene, toluene, ethylbenzene, and xylene (BTEX); TPH; MEK; and VOCs were detected in groundwater samples in the vicinity. Soil samples collected near the former tank were analyzed for BTEX, TPH, and MEK. None of the analytes was detected.

- **AOC-026: Former URE-54—**This 1,000-gallon steel tank was used to store gasoline. It was removed in 1985. Dissolved-phase benzene was detected in groundwater samples adjacent to this former UST. TCE, benzene, and VC were detected in groundwater samples collected in the vicinity of this AOC.

- **AOC-037: URE-25—**This 500-gallon steel tank was used to store MEK. URE-25 was removed in September 1987. Laboratory analyses of soil verification samples collected in 1993 were below RCRA Subpart S action limits. TCE, benzene, and VC were detected in groundwater samples collected in the vicinity of this AOC.



- **AOC-054: URE-23—**This 10,000-gallon steel tank was used to store gasoline until it was removed in April 1989. Analysis of soil and groundwater samples identified detectable concentrations of BTEX, TPH, and VOCs.

Section 5.7 of the final RI Report presents the site characterization results for these units (Weston, 2001a). Groundwater monitoring is being conducted on a quarterly basis at this SWMU/AOC group, and these results are reported to Ecology quarterly. The results of the RI and the most recent quarterly groundwater monitoring reports are summarized below.

9.1.1 Historical, Present, and Future Site Use

The former USTs at the site were used to store gasoline and MEK. In addition, the fuel from these tanks was piped to a fuel dispenser located on the east side of Building 4-79. The gasoline pump dispenser island and associated piping were removed from this area as well. Buildings 4-61 and 4-73 were demolished in early 2004 and converted to parking facilities. Building 4-78 is still being used for temporary storage of hazardous wastes. Building 4-79 is still used for painting of aircraft parts to support airplane manufacturing activities conducted at the Renton Facility. These two buildings and adjacent buildings and areas are currently used for industrial purposes and are expected to remain in industrial use for the foreseeable future.

9.1.2 Previous Site Remedial Actions

Previous site cleanup actions in this area have been related to removal of structures or USTs, and implementation of an interim action. The following paragraphs summarize the site cleanup actions at the SWMU and AOCs that comprise this group.

- **SWMU-181: Former Dangerous Waste Storage Area—**This SWMU became inactive in December 1989. The original container storage pad and canopy were removed in 1993 and replaced by Building 4-78, which was placed into operation as a CSU. The CSU was initially operated as a permitted dangerous waste storage facility. A closure plan for the CSU was approved by Ecology on November 6, 1997, and implemented later in 1997. A closure certification report was submitted to Ecology that documented closure in accordance with the approved closure plan. The CSU is currently used for storage of containers for less than 90 days and is no longer permitted. Releases to the subsurface from the former SWMU are being addressed by this FS.

- **AOC-13: Building 4-62 Former UST URE-17—**This gasoline storage UST was removed in September 1985, and 50 gallons of gasoline was reported to have been removed from the tank excavation. No soil was documented as having been removed from the excavation.

- **AOC-14: Building 4-61 Former UST URE-18—**This former UST contained MEK and was removed in March 1987. During the tank removal, approximately 290 cubic yards of soil was removed from the excavation for off-site disposal.

- **AOC-15: Building 4-61 Former UST URE-24—**This gasoline storage UST was removed in September 1985, and approximately 50 gallons of gasoline was reportedly recovered from the excavation.

- **AOC-26: Building 4-61 Former UST URE-54—**This gasoline storage UST was removed in September 1985, and holes were noted in the bottom of the tank. An unspecified amount of contaminated soil was removed from the excavation, and an unknown quantity of floating hydrocarbon was extracted from the excavation.

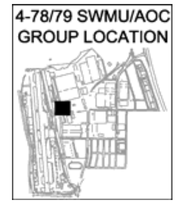
- **AOC-037: Building 4-79 Former UST URE-25—**This UST, which stored MEK, was removed in September 1987 in accordance with Subtitle I. No soil was documented to have been removed during the excavation. Soil verification samples collected in 1993 were below RCRA Subpart S action limits. TCE, benzene, and VC were detected in groundwater in the vicinity of this AOC.

- **AOC-054: Building 4-78 Former UST URE-23—**This 10,000-gallon steel tank was used to store gasoline. During removal of URE-23 in April 1989, gasoline was observed in the soil and on groundwater samples. Approximately 200 cubic yards of soil was excavated. Soil and groundwater sampling revealed detectable concentrations of BTEX, TPH, and VOCs.

All of these units are located within the capture zone for the interim action groundwater hydraulic containment system that was installed at this site in 1991. The hydraulic containment system consists of two extraction wells, an air stripper, and a monitoring well network. The groundwater hydraulic containment system was shut down in November 2003 to allow site hydrogeologic conditions to recover to static conditions and support evaluation of potential remedial alternatives during this focused FS. Monitoring data have been collected to evaluate the hydraulic and hydrogeologic conditions in the absence of pumping. Groundwater monitoring for this site is being conducted quarterly while the hydraulic containment system is shut down. The groundwater extraction and treatment equipment is being maintained in operable condition to ensure that it can be restarted easily and with minimal complications if it becomes necessary to restore hydraulic containment for this site.

9.1.3 Site Hydrogeology

The general stratigraphy beneath this site consists of hydraulic fill and alluvium. Hydraulic fill materials consist of brown sandy gravel to brown fine- to medium-grained sand with silt and gravel. Alluvium consists of interbedded greenish-gray silt, greenish-gray silty clay, grayish-



green sand, and grayish-green sandy gravel. The contact between hydraulic fill materials and alluvium ranges from 2 to 5 feet bgs.

Groundwater elevations as measured in monitoring wells ranged between 3.79 and 6.56 feet bgs. Seasonal variations in the groundwater elevations varied less than 1 foot. Contour maps developed for the area during operation of the hydraulic containment system indicate a cone of depression from extraction wells GW042 and GW151. The effects from operation of the extraction system were seen throughout the area and extended as far as 600 feet in a cross-gradient direction. The extensive cone of depression created by the system wells prevented groundwater in the source area from migrating toward the Cedar River Waterway.

Based on the geologic cross-section presented in the final RI Report, the predominant soil type in the vadose zone is silty sand and the soil type dominating groundwater flow is also silty sand. Therefore, the dominant USCS soil classification for soils in both the vadose and saturated zones is SM; soil characteristics for SM soil are used for relevant calculations in this FS. The results of slug tests at this SWMU/AOC group indicate that the hydraulic conductivity of aquifer material in this area ranges from 7.3×10^{-5} to 1.8×10^{-2} cm/s.

9.1.4 Nature and Extent of Affected Soil

The data presented in the final RI Report suggest that soils affected by TPH-G may be present near the former location of the USTs that were used for gasoline storage. The final RI reported that gasoline-affected soils were left in place near the former tank cavities, and floating gasoline had been present on the groundwater surface within some tank excavations. These observations suggest that TPH-G has affected the shallow soils near the former UST locations. The extent of contamination near the former USTs cannot be determined from the final RI Report because no analytical data for soil were reported. Based on information available in the final RI Report, it appears that affected soil is limited to the source area in the vicinity of the former USTs and the CSU (Building 4-78).

9.1.5 Nature and Extent of Affected Groundwater

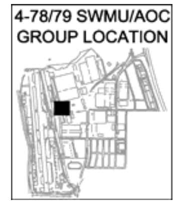
Groundwater data presented in the final RI Report and in quarterly groundwater monitoring reports for the Building 4-78/79 SWMU/AOC group indicate that there are two groundwater plumes present at this site. One plume, designated as the benzene plume, consists of groundwater affected by TPH-G and benzene and lies to the east, west, and south of Building 4-79. The second plume, designated as the solvent plume, consists of groundwater

affected by TCE breakdown products and is located generally east of the benzene plume. Recent monitoring data indicate that the solvent plume lies entirely west of Building 4-78 (Figure 9-1), although historical data in the final RI Report indicate that the plume was previously present just to the east of Building 4-78 as well.

Both VOCs and TPH-G have affected the groundwater at this site. The chlorinated VOC plume and the gasoline-related VOC plume slightly overlap each other at this site. Benzene, TPH, TCE, and chlorinated biodegradation products (e.g., *cis*-1,2-DCE and VC) have been found in site groundwater at concentrations exceeding the PCLs defined in the final RI Report. Figure 9-1 shows recent groundwater monitoring data for the Building 4-78/79 SWMU/AOC group (Geomatrix, 2007a).

Quarterly groundwater monitoring data collected since shutdown of the hydraulic containment system in November 2003 show that concentrations of several VOCs, including benzene, *cis*-1,2-DCE, and VC, have rebounded in several groundwater monitoring wells. Groundwater samples from groundwater monitoring wells GW031, GW033, and GW034 have shown increases in *cis*-1,2-DCE and VC concentrations during recent groundwater monitoring events. Groundwater samples from well GW033 have shown the highest concentrations of VC and *cis*-1,2-DCE. As documented in the final RI Report, historic releases of VOCs, SVOCs, and TPH to groundwater occurred from SWMU-181. Moreover, the extent of chlorinated VOCs in groundwater is defined to the north, east, south, and west of these three monitoring wells (Figure 9-1). All other groundwater samples collected for this site have been below PCLs for chlorinated solvents and degradation products. These findings indicate that the area beneath and just west of Building 4-78 is the source area for the solvent plume

Benzene and TPH-G concentrations exceeding the PCL have also been observed in GW031, GW033, and GW040. As documented in the final RI Report, the TPH-G and benzene concentrations in these three wells are attributable to TPH-G-affected soils located near the former USTs. The TPH-G/benzene detected at GW031 and GW033 is assumed to be attributed to TPH-G-affected soils associated with the former fuel dispenser and its former piping system, as well as a former UST east of GW033 (former UST URE-23; Figure 9-1). The extent of TPH-G/benzene-affected groundwater has been defined to the north, east, south, and west of these groundwater monitoring wells (Figure 9-1). All other groundwater samples collected for this site have been below the PCLs for petroleum hydrocarbons and benzene.



9.2 CONCEPTUAL SITE MODEL

A preliminary conceptual model for migration of constituents present in affected soil and groundwater at the Renton Facility was presented in Figure 2-6 of the FSWP (Geomatrix, 2004c). Based on the conceptual model, considerations presented in the FSWP, and information specific to this site, a site-specific conceptual site model is described below. This site-specific conceptual site model identifies the affected media and exposure pathways that must be addressed for remedial alternatives potentially applicable to this site.

VOCs and TPH-G are present in soil within the Building 4-78/79 source areas. As shown in the general facility conceptual model presented in the FSWP, VOCs and TPH-G can migrate from the source areas via groundwater or vapor pathways. For this site, migration via groundwater is the most significant and is affected by soil/groundwater interactions and biodegradation. As groundwater flows through VOC- and TPH-affected soil in the source areas, adsorbed VOCs may dissolve into groundwater. Dissolved VOCs and TPH-G will move with groundwater but at a different velocity due to continuing solute-soil interactions. This movement creates a plume extending downgradient from the source areas as the natural groundwater flow direction is reestablished. Aromatic VOCs, VC, and TPH-G are likely to readily biodegrade under aerobic conditions and, except for VC, are less readily biodegradable under anaerobic conditions; chlorinated VOCs are generally more likely to biodegrade under anaerobic conditions.

The primary source of the VOCs in groundwater is soil in the respective source areas that have been affected by releases from the USTs or the SWMU. Based on the groundwater recovery observed to date, chlorinated VOC-affected groundwater from the SWMU-181 source area will flow west toward the Cedar River Waterway. As this chlorinated VOC plume migrates from the source area, the COCs undergo biodegradation, with TCE degrading to *cis*-1,2-DCE, which subsequently degrades to VC. Biodegradation is shown by the prevalence of these two breakdown products in well GW033 and the low concentrations of TCE in groundwater samples collected at this site. The chlorinated VOC-affected groundwater is generally located to the east of the TPH-affected groundwater and is expected to flow westward toward the TPH-G/benzene source area.

Based on the observed groundwater recovery at this site and the observed hydraulic conditions at nearby AOC-060, it is assumed the TPH-G/benzene plume will migrate from the source area in the vicinity of the former UST and dispenser locations westward toward the Cedar River

Waterway. It is expected that this plume will attenuate as a result of natural biodegradation processes. The benzene and TPH-G constituents in this plume will support reductive dechlorination of any chlorinated VOCs that may commingle with the TPH-G/benzene plume. When the natural hydraulic conditions have reestablished, it is likely that the TPH-G/benzene and VOC plumes will overlap to a greater extent than observed now.

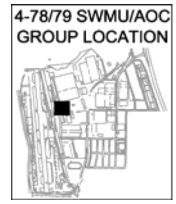
Volatilization of constituents from groundwater is not significant for most workers at this site, as noted in the conceptual model presented in the FSWP. However, release of volatile groundwater constituents to receptors may occur if affected groundwater enters the Cedar River Waterway.

9.3 SITE REMEDIATION OBJECTIVES AND CLEANUP STANDARDS

The remediation objectives applicable to the Building 4-78/79 SWMU/AOC group were presented in Section 2. The remedial alternatives considered for potential implementation at the site will be capable of achieving the remediation objectives and cleanup standards for the site.

The COCs for groundwater at this site were identified in Table 5-1 of the FSWP and subsequently negotiated with Ecology. As noted in the FSWP, only groundwater constituents are of concern; no soil COCs were identified in the final RI Report. These COCs were identified by comparing detected constituent concentrations to the PCLs identified in the final RI Report; if a constituent concentration measured in any sample exceeded the PCL, the constituent was listed as a COC that must be addressed in the FS. Although 1,1-DCE was listed as a COC in the FSWP, it has been detected in GW033 only in the June 1999 sampling event; subsequent samples collected from GW033 in December 1999 and January 2000 had nondetectable levels of 1,1-DCE. Additionally, this constituent was not detected in any groundwater samples collected at the site through 2004. Therefore, 1,1-DCE is no longer considered a COC for this site.

To confirm that the COCs other than 1,1-DCE listed in the FSWP included all constituents detected at concentrations exceeding the approved cleanup levels, the RI soil and groundwater data and routine monitoring data were compared to the approved cleanup levels listed in Table 5-2 of the FSWP. If detected concentrations for constituents that were not identified as COCs exceeded cleanup levels, it would be necessary to include them as COCs. If concentrations for previously identified COCs were below the approved cleanup levels, the



constituent should be removed as a COC. No new constituents were identified as COCs for this site, and no previously identified COCs were removed as a result of this comparison.

Although no soil COCs were identified in the final RI Report or the FSWP, information presented in the final RI Report indicates that affected soil is likely present at this site. Given that soil is generally the source of constituents observed in affected groundwater, for this FS it has been assumed that the soil COCs for the site are the same as the groundwater COCs.

The soil and groundwater cleanup levels for the site COCs are listed in Tables 3-1 and 3-2, respectively. The soil cleanup levels are either MTCA Method A cleanup levels or site-specific MTCA Method C cleanup levels that are protective of groundwater at the CPOC and were calculated in accordance with the procedures described in the FSWP or in accordance with recent negotiations with Ecology. The groundwater cleanup levels listed in Table 3-2 were developed as described in Section 3 and in accordance with recent negotiations with Ecology. The cleanup levels are protective of surface water, human health, and the environment. These cleanup levels have been used to develop and evaluate remedial alternatives. An on-site CPOC will be used for each of the alternatives for this site.

9.4 SITE REMEDIAL ALTERNATIVES

Remedial alternatives identified and developed for the Building 4-78/79 SWMU/AOC group incorporate the remedial technologies presented in Section 4. The alternatives specifically address site conditions, the site remedial objectives, and the approved soil and groundwater cleanup levels for the Building 4-78/79 SWMU/AOC group. Three remedial alternatives have been considered for this site:

- Alternative 1: Source Area Excavation, Enhanced Bioremediation, MA, and MNA
- Alternative 2: Soil Vapor Extraction, Enhanced Bioremediation, MA, and MNA
- Alternative 3: Source Area Excavation and MNA

The Building 4-78/79 SWMU/AOC group is located on the western portion of the Renton Facility. Former Building 4-61, which was demolished in 2003-2004, was located between the Building 4-78/79 SWMU/AOC group and the Boeing property line. Nishiwaki Lane and the Cedar River Trail Park are between the Boeing property line and the Cedar River Waterway. All property adjacent to the Building 4-78/79 SWMU/AOC Group is owned by Boeing and used for industrial purposes. The site is expected to remain under industrial use for the

foreseeable future. Industrial buildings are located adjacent to some of the former UST locations.

Remediation alternatives considered for this site must be compatible with the two different source areas and groundwater plumes; remediation approaches considered for one plume must have no adverse effects on the other plume.

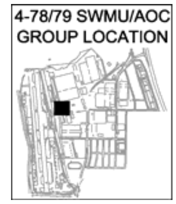
Water level contours presented in the final RI Report indicate hydraulic containment has resulted from operation of the pump and treat system that has been installed and operated as an interim action for the site. The pump and treat system was shut down in November 2003 to allow groundwater to recover so that natural gradients can be assessed for the site. Groundwater levels at the site appear to have recovered from the operation of the containment system. The groundwater in the vicinity of this site flows towards the west-northwest. Given the increase in dissolved-phase benzene and VOCs in several wells (e.g., GW033), it would appear that the plumes may be moving toward the CPOC (shown in Figures 9-2 and 9-3).

The presence of the buildings adjacent to some of the former USTs will constrain remedial activities for this site. Although affected soil was excavated when most of the USTs were removed from the TPH/benzene source area, any additional excavation would be limited because of the potential for undermining buildings or causing settlement that would damage buildings. The buildings would also limit access for conducting other remediation activities such as installing wells. Remediation approaches considered for groundwater plumes must accommodate the existing buildings and site activities.

The remedial alternatives to be evaluated for this site are described below. These alternatives are evaluated against the evaluation criteria in Section 9.5.

9.4.1 Alternative 1: Source Area Excavation, Enhanced Bioremediation, Monitored Attenuation, and Monitored Natural Attenuation

Remedial Alternative 1 for the Building 4-78/79 SWMU/AOC group includes excavation of the presumed TPH/benzene soil source area to remove affected soil, enhanced bioremediation with MA to address the chlorinated solvents in the solvent plume, and monitored natural attenuation to address TPH-G and benzene in the benzene plume. The following specific elements are included in this alternative:



- Excavation of TPH/benzene source area soil that likely exists in the vicinity of the former USTs where releases were identified during tank removal (URE-17, -18, -23, -24, and -54) and in the area where the underground lines supplying fuel to the dispenser island were located; source areas and the approximate excavation area are shown on Figure 9-2;
  - Soil verification sampling to confirm removal of affected soil exceeding soil cleanup levels for TPH-G and benzene;
- Enhanced anaerobic bioremediation with MA for chlorinated VOCs in the solvent plume by adding electron donor and nutrients within the source area;
  - Groundwater monitoring using both existing and new monitoring wells located appropriately to intersect solvent plume at the CPOC;
- MNA to ensure that TPH-G and benzene plume COCs attain cleanup levels at the CPOC;
- Institutional Controls:
  - Deed recordation noting the location and nature of historical USTs and waste management units at the site;
  - Covenants and deed restrictions to address potential risks to human health that may remain as a result of residual soil constituents and affected groundwater;
- Points of Compliance: An on-site CPOC located along the downgradient property line for both the benzene and solvent plumes to allow biodegradation reactions to proceed to completion.

Additional soil that exceeds soil cleanup levels for TPH-G and benzene in the vicinity of the former USTs, dispenser island, and underground piping would be excavated and removed from the vadose zone. Enhanced biodegradation of chlorinated VOCs within the solvent plume would permanently destroy these constituents through biodegradation. Natural attenuation of the petroleum hydrocarbons present in the benzene plume would permanently destroy these constituents prior to discharge of the groundwater to the Cedar River Waterway. The institutional controls would continue to protect human health, as has been done routinely at the site by the existing institutional controls. For this remedial alternative, an on-site CPOC for both the benzene and solvent plumes would likely be located along the western property line bordering Nishiwaki Lane. The approximate extent of soil excavation, the locations of electron donor injection wells, and the CPOC are shown on Figure 9-2.

9.4.1.1 Soil Excavation

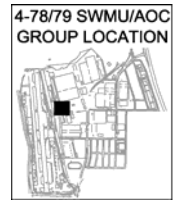
For this remedial alternative, affected soils in the TPH source area would be excavated for off-site disposal. Vadose zone soil exceeding the soil cleanup levels for TPH-G and benzene would be removed from the site. The approximate extent of the soil excavation is shown in Figure 9-2. For the conceptual design of this alternative, it was estimated that 1,150 cubic yards of affected soil would be removed from the site. To minimize potential sidewall stability issues, the maximum depth of the excavation would be the water table. To avoid undermining the building foundation and causing settlement, the lateral extent of the excavation to the north would be limited by proximity to Building 4-79. The extent of the excavations to the west, east, and south would generally be based on verification sample results. Excavated soil would be characterized in accordance with dangerous waste regulations and disposed of as appropriate in a permitted, off-site landfill. It is expected that this soil would not be a dangerous waste because it would be affected by petroleum hydrocarbons. The excavated soil may be treated if required to meet requirements for landfill disposal. Verification soil sampling would be conducted to confirm removal of soil that exceeds soil cleanup levels for TPH-G and benzene and to characterize soil that could not be excavated because of physical constraints such as buildings or underground utilities.

It is expected that, unless constrained by physical structures, excavation would remove soil that exceeds cleanup levels. To the extent practicable, this approach would provide a permanent remedial solution for TPH-G-affected soil at this site.

9.4.1.2 Enhanced Bioremediation

Enhanced bioremediation has been included in this remedial alternative to address the solvent plume downgradient from Building 4-78. The reductive dechlorination processes that are active at this site would be enhanced by addition of an electron donor and nutrients to the solvent plume groundwater, as appropriate. By increasing the concentration of electron donor and any nutrients that may be deficient, biological activity would be enhanced and the rate of biodegradation would increase, thus destroying the chlorinated solvents present in groundwater. An electron donor (such as molasses, lactate, or emulsified vegetable oil) would be injected just upgradient of groundwater affected by solvents using the injection wells shown on Figure 9-2.

For the purposes of this FS, it was assumed that electron donor injection would be accomplished using a line of injection wells located west of Building 4-78 just upgradient of the solvent plume source area. The assumed spacing for the injection wells is 25 feet. These



wells would be installed to a depth of approximately 30 feet bgs and screened through the entire saturated zone above the silty clay layer identified beneath the site. A mobile system consisting of tank, mixers, and pumps would be used to inject electron donor and nutrients as needed into each injection well. Electron donor injected into these wells would cover the width of the plume and move downgradient as the groundwater moves, eventually covering the affected groundwater area.

Based on this conceptual design, a total of seven injection wells would be installed. It has been assumed that four injection events over a 2-year period would be sufficient to achieve full degradation of groundwater COCs. For costing purposes, it was estimated that about 250 gallons of 2% emulsified vegetable oil per well (2,000 gallons total) would be injected during each event. For actual implementation, an alternate electron donor may be used, as determined in the final design.

A network of groundwater monitoring wells would be required at the CPOC to assess the effectiveness of enhanced bioremediation and to confirm that the cleanup standard is met for groundwater. The CPOC would apply to both the benzene and solvent plumes. The approximate location for the CPOC for this alternative is shown on Figure 9-2. Because of the similarities between enhanced bioremediation and natural attenuation, the conceptual design for the MA groundwater monitoring program has been designed to address recent EPA guidance for monitored natural attenuation programs, and the same monitoring program would be used to assess natural attenuation of the benzene plume, as discussed in Section 9.4.1.3.

For this conceptual program, it was assumed that characterization/validation sampling would consist of quarterly monitoring of 14 monitoring wells for a minimum of 1 year. It was assumed that 9 new monitoring wells would be required (in addition to 5 existing wells) to monitor plume migration. The wells would include nested monitoring wells with shallow wells (approximately 15 feet bgs), intermediate wells completed just above the underlying silt layer (about 25 feet bgs), and deep wells completed just below the silt layer (approximately 35 feet bgs). Monitoring parameters and analytes for each of these wells would include TPH-G, benzene, the COCs listed in Table 3-2 (TCE, *cis*-1,2-DCE, and VC), and the full suite of MNA geochemical parameters for TPH and chlorinated solvents in groundwater [dissolved oxygen, nitrate, Fe(II), sulfate, chloride, methane, ethene, temperature, pH, specific conductance, alkalinity, oxidation/reduction potential, and TOC]. For the conceptual design, it was assumed that data reporting for characterization/validation sampling would follow each quarterly

sampling event and an annual report would be prepared evaluating and discussing the monitoring data.

Long-term groundwater monitoring would follow the initial characterization/validation sampling program. The long-term monitoring would be conducted for an additional 13 to 14 years (15 years of monitoring total), with semiannual sampling of the three shallow wells installed along the CPOC for groundwater COCs in both the benzene and solvents plumes and a limited suite of geochemical parameters (dissolved oxygen, oxidation/reduction potential, temperature, and pH). For purposes of estimating the monitoring costs for this alternative, it was assumed that the intermediate and deep wells would be dropped from the monitoring program after 2 years of quarterly monitoring. To monitor overall plume control, all 14 wells would be analyzed once every 5 years for the full list of characterization/validation analytes. For the conceptual design of this alternative, it was assumed that long-term groundwater monitoring results would be reported to Ecology annually.

9.4.1.3 Monitored Natural Attenuation

Under Alternative 1, MNA would be implemented to address the benzene plume in groundwater. It is expected that MNA would attain the cleanup standard for hydrocarbon constituents present in this plume. Based on the POC approach presented in Section 6 of the FSWP, highly conservative fate and transport groundwater modeling using BIOSCREEN was conducted to evaluate the potential efficacy of MNA as a final remedy for the solvent plume at this site. The modeling followed the protocol established in the FSWP using the highly conservative model input parameters that were specified in the FSWP and the present hydraulic conditions at the site. The pump and treat system was shut down in 2003 to allow natural groundwater flow conditions to recover. The current groundwater gradient at the site was used in the modeling of MNA. The BIOSCREEN model was calibrated using groundwater data for the Building 4-78/79 SWMU/AOC group. The highly conservative modeling results indicate that natural attenuation can attain the cleanup levels for both TPH-G and benzene prior to reaching the CPOC located along the downgradient property line shown in Figure 9-1. Details regarding the modeling are presented in Appendix A.

The MNA monitoring program would be conducted using the monitoring system described in Section 9.4.1.2. The monitoring program has been designed to verify the effectiveness of attenuation and to quantify the areal extent of natural attenuation processes. The monitoring

approach for this alternative has been designed in general accordance with the requirements specified in recent guidance for MNA, as discussed in Section 4.2.4, and is designed to:

- Demonstrate that natural attenuation is occurring according to expectations;
- Identify any potentially toxic and/or mobile transformation products;
- Verify that the plume is not expanding beyond the CPOC;
- Verify that cleanup levels are attained at the CPOC;
- Verify that there is no unacceptable impact to downgradient receptors;
- Detect new releases of COCs that could impact the effectiveness of the natural attenuation remedy;
- Demonstrate the efficacy of institutional controls put in place to protect potential receptors; and
- Verify attainment of remediation objectives.

9.4.1.4 Institutional Controls

Institutional controls would be incorporated into Alternative 1 to ensure it is fully protective of human health and the environment. Institutional controls are necessary because it is expected that some COCs may remain beneath existing buildings, and biodegradation of groundwater constituents would require time to fully degrade groundwater COCs. In general, the institutional controls that would be incorporated into this remedial alternative would be a continuation of the controls that have been implemented and proven effective at the Renton Facility. These institutional controls would be established such that they are legally enforceable for current and future landowners.

The nature and location (including depth) of the former USTs and SWMU-181 would be recorded on the deed to the property. This recordation would identify the nature of the releases from these units and inform any future landowners of potential human health or ecological issues related to the release.

An institutional control restricting the recovery and use of groundwater beneath the site would be implemented. This control would apply to the area surrounding the Building 4-78/79

SWMU/AOC group and extend to the downgradient property line. Recovery of groundwater in this area for any purpose other than construction dewatering would be prohibited.

Institutional controls requiring implementation of specific and appropriate health and safety procedures would be implemented for conducting any subsurface work in the immediate vicinity of the source areas and in the area downgradient of affected groundwater. These controls would be a continuation of institutional controls already in place at the Facility. In any portion of the source areas where soil COCs may remain, these controls would cover all subsurface work, including excavation and installation or maintenance of underground utilities. In the downgradient plume areas where only affected groundwater is present, the institutional controls would require appropriate health and safety procedures for subsurface work, such as excavation below the water table, where direct contact with affected groundwater or inhalation of vapors released from groundwater may occur.

This alternative would also include deed restrictions. These deed restrictions would limit future nonindustrial land use of the site without implementing additional, specific remedial actions to demonstrate compliance with soil and groundwater cleanup levels appropriate for unrestricted site use.

9.4.2 Alternative 2: Soil Vapor Extraction, Enhanced Bioremediation, Monitored Attenuation, and Monitored Natural Attenuation

Alternative 2 includes SVE within both source areas to remove volatile soil COCs in the vicinity of the source areas, enhanced bioremediation with MA to address the solvent plume downgradient from the source area, and MNA to address the downgradient benzene plume. Because all site COCs are volatile, this alternative would address all source area COCs. The specific elements included in this remedial alternative are:

- Installation and operation of a SVE system in the source areas for both the benzene and solvent plumes; VOCs removed with the soil gas would be collected and treated prior to discharge of soil gas to the atmosphere;
- Soil verification sampling within the source areas to confirm attainment of soil cleanup levels for TPH-G, benzene, and the other soil COCs listed in Table 3-1, as appropriate;
- Enhanced anaerobic bioremediation with MA for chlorinated VOCs in the solvent plume source area by addition of electron donor and nutrients to site groundwater;


4-78/79 SWMU/AOC GROUP LOCATION

- Groundwater monitoring using both existing and new monitoring wells located appropriately to intersect the plume at the CPOC;

- MNA for benzene plume COCs;
- Institutional Controls:
  - Deed recordation noting the location and nature of historical waste management and releases at the site;
  - Covenants and deed restrictions to address potential risks to human health that may remain as a result of residual soil constituents and affected groundwater within the two groundwater plumes;
- Points of Compliance: An on-site CPOC located along the downgradient property line for the benzene and solvent plumes.

The SVE system would be implemented to remove volatile soil COCs from the vadose zone within the source areas for both groundwater plumes. This technology would be capable of removing volatile constituents that are present beneath existing buildings without adversely affecting the building or facility operations. Biodegradation of the groundwater constituents would destroy VOCs present within both groundwater plumes prior to entering the Cedar River Waterway. The institutional controls included in this alternative would continue to protect human health, as has been done routinely at the site by the existing institutional controls. For this remedial alternative, a CPOC located along the downgradient property line would be used for groundwater COCs in both plumes. Based on a conceptual design, the locations for the SVE wells, the enhanced bioremediation injection wells, and the CPOC are shown on Figure 9-3.

9.4.2.1 Soil Vapor Extraction

For this remedial alternative, affected soils in the two source areas would be remediated by SVE. The approximate locations of the SVE extraction wells are shown in Figure 9-3. These wells are located to fully address the source areas. Due to the nature of this process, it is expected that volatile COCs present beneath Building 4-78 would be effectively removed. The SVE system would address essentially all vadose zone soil above the water table. The conceptual design includes 16 vapor extraction wells, as shown in Figure 9-3. These wells would be distributed throughout the two source areas to ensure full coverage of the former USTs, dispenser island and piping, and former container storage area beneath Building 4-78. A blower (approximately 320 cfm) would be used to draw soil gas from the vapor extraction

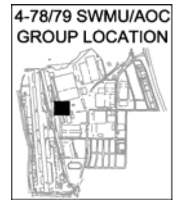
wells. It has been assumed that a vapor-phase adsorption system (consisting of potassium permanganate and activated carbon beds operated in series) would be used to control emissions from the SVE system. Air permitting may be required to address the site remediation NESHAPS regulations. Field testing would also be required prior to final design to determine site-specific design parameters for implementation of SVE at the site.

Once the soil gas monitoring system indicates that the SVE system has removed recoverable VOCs and attained soil cleanup levels, verification sampling of soils within the source areas treated by SVE would be conducted. For costing, it has been assumed that this would be accomplished in 5 years. The verification samples would be compared to the soil cleanup levels to confirm that remediation objectives had been achieved. For the conceptual design, it has been assumed that 12 push probe borings would be placed randomly within the two source areas, with soil samples collected at depths of 1 foot, 5 feet, and 10 feet bgs. Each soil sample would be analyzed for the soil COCs listed in Table 3-1. It should be noted that verification sampling may not be possible in all treated areas due to access restrictions created by buildings and site activities.

It is expected that the SVE system would effectively remove volatile COCs and attain soil cleanup levels for most of the soil throughout the two source areas, including the area beneath buildings. SVE may not be effective in reaching and removing COCs in fine-grained soils, particularly under buildings. However, this alternative would provide a permanent remedial solution for most affected soil at this site while supporting ongoing industrial activity at the Facility.

9.4.2.2 Enhanced Bioremediation

Under this alternative, enhanced bioremediation and MA would be used to address the solvent plume by adding an electron donor to enhance existing microbial activity. The enhanced bioremediation approach for Alternative 2 would be the same as that described in Section 9.4.1.2 for Alternative 1. The SVE system included in this alternative would create limited aerated zones within unsaturated soils above the water table. It is expected that this aerobic soil zone would not adversely affect the anaerobic reductive dechlorination process in the groundwater. The addition of electron donor would ensure that conditions would be maintained to support reductive dechlorination. The SVE system may create a slight increase in the demand for electron donor material. The enhanced bioremediation system for this alternative would include seven injection wells (as described for Alternative 1) spaced about



25 feet apart. For costing purposes, it was estimated that about 250 gallons of 2% emulsified vegetable oil per well (2,000 gallons total) would be injected during each event. An alternate electron donor may be specified in the final design. It has also been assumed that four injection events occurring over a 2-year period would be sufficient to achieve full degradation of groundwater COCs. The location for the enhanced bioremediation injection wells, as based on a conceptual design, is shown on Figure 9-3.

An on-site CPOC would be used for the solvent plume under this alternative, at the same location as described above for Alternative 1 and shown in Figure 9-3. The groundwater monitoring program for enhanced bioremediation under this alternative would be the same as that described for Alternative 1 in Section 9.4.1.2 and shown in Figure 9-3.

9.4.2.3 Monitored Natural Attenuation

For Alternative 2, groundwater COCs in the benzene plume would be addressed by MNA. The MNA program would be as described in Section 9.4.1.3 for Alternative 1, using the same monitoring approach. It is expected that MNA would be slightly more effective under this alternative due to the use of SVE to address source area soils. The SVE system would create an aerobic environment above the water table, which would increase oxygen availability to the shallow groundwater. The increased oxygen levels would improve aerobic degradation of the petroleum hydrocarbons present in the benzene plume.

9.4.2.4 Institutional Controls

The institutional controls for Alternative 2 would be the same as those described above in Section 9.4.1.4 for Alternative 1. Institutional controls would be required until verification sampling indicates that the cleanup standard for soil has been achieved. This would be reflected in the deed recordation and in health and safety procedures required for subsurface work in the source area. The institutional controls for the groundwater plumes would be the same as those for Alternative 1.

9.4.3 Alternative 3: Source Area Excavation and Monitored Natural Attenuation

For Alternative 3, soils in the source area for the benzene plume would be excavated and MNA would be used to address COCs in both the benzene and solvent plumes. Alternative 3 is similar to Alternative 1, except that biodegradation of organic constituents present in the solvent plume would not be enhanced by addition of electron donor. Institutional controls identical to those for Alternative 1 would be included to limit the potential for exposure to site constituents that may remain in site soil and groundwater while MNA is active. The cleanup standard for this alternative would be attained through the permanent destruction of organic constituents by ongoing natural processes.

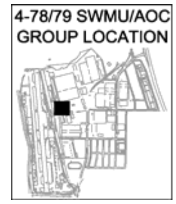
The specific elements included in this alternative are:

- Excavation of TPH/benzene source area soil in the vicinity of the former USTs where releases were identified during tank removal (URE-17, -18, -23, -24, and -54) and in the area where the underground lines supplying fuel to the dispenser island were located; the approximate excavation area is shown on Figure 9-2;
    - Soil verification sampling to confirm removal of affected soil exceeding soil cleanup levels for TPH-G and benzene;
- Groundwater monitoring using both existing and new monitoring wells located appropriately to intersect the plume at the CPOC;
- Institutional Controls:
    - Deed recordation noting the location and nature of historical waste management at the site and location where residual COCs exceed cleanup levels;
    - Covenants and deed restrictions to address potential risks to human health that may remain as a result of residual soil constituents and affected groundwater within the plume area;
- Points of Compliance: An on-site CPOC located along the downgradient property line.

For this alternative, the on-site CPOC would likely be located along the property line as shown for Alternatives 1 and 2 (see Figures 9-2 or 9-3).

9.4.3.1 Soil Excavation

For this remedial alternative, affected soils in the TPH source area would be excavated for off-site disposal, as described previously for Alternative 1 (Section 9.4.1.1). The approximate extent of the soil excavation is shown in Figure 9-2. As indicated for Alternative 1, the maximum depth of the excavation would be to the water table to limit potential sidewall stability and safety issues. Additional details concerning soil excavation are presented in Section 9.4.1.1.



9.4.3.2 Monitored Natural Attenuation

For this alternative, MNA would be applied to both groundwater plumes. Under Alternatives 1 and 2, MNA would be applied only to the benzene plume. BIOCHLOR modeling indicates that VC and *cis*-1,2-DCE would not undergo sufficient biodegradation by the time groundwater migrates to the CPOC under current conditions. MNA would be applied to the solvent plume in this alternative after the soil excavation has been completed. Removal of the source area soils would lower the source area groundwater concentrations, thereby allowing the solvent COCs to biodegrade before reaching the CPOC. Details concerning the BIOCHLOR modeling are presented in Appendix A.

The application of MNA for the benzene plume is discussed in Section 9.4.1.3 for Alternative 1. The approach for using MNA for the benzene plume under Alternative 1 would be the same for this alternative. As noted above, highly conservative modeling using BIOSCREEN indicates that groundwater COCs in the benzene plume would attain cleanup levels at the CPOC shown in Figure 9-2. The groundwater monitoring program for this alternative would be the same as described above for Alternative 1.

9.4.3.3 Institutional Controls

The following institutional controls have been included in this alternative to ensure it is protective of human health due to exposure to soil or groundwater affected by site COCs:

- Continued engineering controls, protocols, and monitoring previously established by Boeing to ensure that industrial workers inside buildings are protected and indoor air concentrations meet PELs established by the Washington Department of Labor and Industry;

- Continued engineering controls, protocols, and monitoring to ensure that temporary construction workers adhere to WAC 296-62-300, applicable Washington Labor and Industry standards, and OSHA HAZWOPER regulations (29 CFR 1919.120) for all construction work conducted in exposed areas of affected soil and groundwater; and

- Deed restrictions to limit development and use of the site.

It was assumed that deed restrictions would be established to limit future unrestricted land use without additional actions to attain compliance with appropriate soil and groundwater cleanup levels.

Geomatrix

9.5 EVALUATION OF SITE REMEDIAL ALTERNATIVES

As previously discussed, all three alternatives developed for this site meet the MTCA minimum requirements for cleanup actions. This section compares and evaluates the alternatives based on the MTCA criteria of protectiveness and risk reduction, permanence, cost, long-term effectiveness, management of short-term risks, technical and administrative implementability, public concerns, and restoration time frame. An evaluation of each alternative with respect to these evaluation criteria is summarized in Table 9-1 and is discussed below.

9.5.1 Protectiveness and Risk Reduction Evaluation

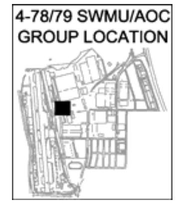
Protectiveness and risk reduction are gauged primarily on the time required for the alternative to reduce risk associated with the site and to meet cleanup levels. All three alternatives would provide good protectiveness and risk reduction. Alternative 2 is the best of the three alternatives for protectiveness and risk reduction because it would address the entire source area and provide for the greatest degree of COC removal and destruction.

9.5.2 Permanence

Permanence refers to the ability to reduce the toxicity, mobility, or volume of hazardous substances, including the permanent destruction of hazardous substances. While all three alternatives would provide a good degree of permanence in the long term, Alternative 2 would provide the highest degree of permanence and achieve it within the shortest time. Alternative 2 was ranked highest for permanence and Alternative 3 was ranked lowest due to the long time required to achieve remediation for all site COCs.

9.5.3 Cost

The cost evaluation includes all costs related to implementation of an alternative, including initial design and construction costs, operation and maintenance costs, monitoring costs, and reporting costs. The annual costs for operation, maintenance, monitoring, and reporting are recurring costs that would occur in the future. The cost evaluation considers initial implementation costs and future recurring costs using NPV analysis. For NPV calculation, recurring costs were inflated 2% annually and a discount rate of 7% was used. Details regarding the cost estimates for the three alternatives are presented in Appendix B. The present value costs for the three alternatives, in 2007 dollars, are summarized below:



Alternative	Net Present Value
1: Source Area Excavation, Enhanced Bioremediation, MA, and MNA	$1,100,000
2: Soil Vapor Extraction, Enhanced Bioremediation, MA, and MNA	$1,140,000
3: Source Area Excavation and MNA	$ 966,000

As shown by these costs, all three remedial alternatives have similar costs. Alternative 2 has the highest NPV cost, while Alternative 3 has the lowest. There is no significant cost difference between Alternatives 1 and 2. Therefore, both Alternatives 1 and 2 were ranked moderately low for cost; Alternative 3 was ranked moderately high because it has the lowest cost.

9.5.4 Long-Term Effectiveness

Long-term effectiveness includes the degree of certainty and reliability of the alternative and whether treatment residue remains from the alternative that will require management. The three alternatives considered for this site would use proven technologies and have good long-term effectiveness. Alternatives 1 and 3 produce residual wastes that would require long-term management at an off-site landfill. While Alternative 2 requires off-site management of residuals from adsorption of soil gas constituents, this management would result in destruction of the constituents. Therefore, Alternative 2 was ranked highest for long-term effectiveness.

9.5.5 Management of Short-Term Risks

Short-term risk refers to the risk to human health and the environment during implementation of the alternative. Since the implementation of Alternative 2 is the simplest and does not expose affected soils with the resulting potential worker exposure, it was rated highest for this criterion.

9.5.6 Technical and Administrative Implementability

This criterion involves whether the alternative is technically possible relative to complexity, administrative/regulatory requirements, size, access, and integration with existing operations. Alternatives 1 and 3 both require invasive construction and could cause damage to existing site structures. Given that Alternative 2 requires less invasive construction, it was rated highest for implementability.

9.5.7 Public Concerns

This criterion assesses potential community concerns with implementation of the alternative. Since all three alternatives deal with an industrial site and have an on-site CPOC, they have relatively little potential for causing public concern. Due to potential public concern with transporting excavated soil off site, Alternatives 1 and 3 were rated lower for this criterion.

9.5.8 Reasonable Restoration Time Frame

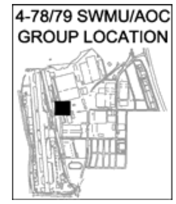
Restoration time frame looks at the practicability of a shorter restoration time frame with consideration given to a number of factors, including site risks, site use and potential use, availability of alternative water supply, effectiveness and reliability of institutional controls, and toxicity of hazardous substances at the site. As a whole, these factors are a measure of the urgency of reducing risk and achieving cleanup goals for the site. Given that the site is an industrial facility and that no imminent risks have been identified, all three alternatives would achieve a reasonable restoration time frame.

9.6 SELECTION OF THE PREFERRED SITE REMEDIAL ALTERNATIVE

Selection of a preferred alternative under MTCA requires that preference be given to alternatives that use permanent solutions (to the maximum extent practicable), provide for a reasonable restoration time frame, and consider public concerns. The analysis below defines the baseline alternative for the Building 4-78/79 SWMU/AOC group and compares the other alternatives to the baseline alternative based on the degree of permanence, reasonable restoration time frame, and the degree to which it addresses potential public concerns. Based on this comparison, the preferred remedial alternative is identified and proposed for selection as the cleanup action to be implemented for the site.

9.6.1 Baseline Remedial Alternative

The evaluation of the three remedial alternatives for this site is summarized in Table 9-1. None of the alternatives is capable of attaining the standard POC at this site. Buildings 4-78 and 4-79 are located adjacent to the source areas, and affected soil and groundwater extend beneath the buildings. These buildings are actively used to support manufacturing operations at the Facility and cannot be demolished. Therefore, it is not technically possible to remediate affected soil and groundwater beneath the buildings without creating the potential for damaging the buildings.



Based on the remedial alternative evaluation presented above and summarized on Table 9-1, the three remedial alternatives are ranked as follows for permanence:

1. Alternative 2: Soil Vapor Extraction, Enhanced Bioremediation, MA, and MNA
2. Alternative 1: Source Area Excavation, Enhanced Bioremediation, MA, and MNA
3. Alternative 3: Source Area Excavation and MNA

Alternative 2, Soil Vapor Extraction, Enhanced Bioremediation, and MNA is ranked highest for permanence and is, therefore, defined as the baseline remedial alternative. This alternative would provide the greatest degree of removal and destruction for site COCs and accomplish this removal in the shortest time. Both Alternatives 1 and 3 would provide slightly lesser levels of removal and destruction of site COCs. Alternative 2 would complete site remediation in a significantly shorter time than the other two alternatives. Alternative 2 would provide for permanent destruction of volatile organic COCs through regeneration of the spent activated carbon/permanganate adsorption system and in situ biodegradation.

9.6.2 Preferred Remedial Alternative

The remedial alternative preferred for implementation at the Building 4-78/79 SWMU/AOC group is Alternative 2, which includes SVE to address the source areas, enhanced bioremediation and MA to address the solvent plume, and MNA for the benzene plume. Based on the cost comparison presented in Section 9.5.3, the NPV cost for the three alternatives is similar. The cost for Alternative 2, the baseline alternative, is not substantially different from the NPV cost for the other two alternatives. The baseline alternative cost is essentially the same as for Alternative 1 and is slightly higher than the costs for Alternative 3. Benefits for the three alternatives are compared in Table 9-2. The baseline alternative would also provide a more rapid restoration time frame and a more extensive remediation that addresses areas beneath existing buildings. Therefore, the baseline remedial alternative, Alternative 2, has been selected as the preferred cleanup action for this site. The SVE system would remove COCs from soil within both the solvent and TPH source areas, and would result in the permanent destruction of the constituents. Enhanced bioremediation would promote rapid degradation of solvents in the solvent plume, and natural attenuation would degrade the benzene plume. The site would remain capped by the existing tarmac, pavement, and buildings, which would prevent runoff and limit infiltration of surface water. A rigorous groundwater monitoring program would ensure that the cleanup standards are attained at an on-site CPOC. The institutional controls included in Alternative 2 have been implemented by Boeing and proven

effective; Boeing would continue to maintain overall responsibility for this site and ensure that the institutional controls are properly enforced.

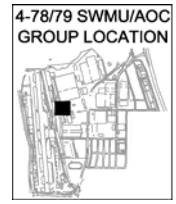
The combined technologies of SVE, enhanced bioremediation, and MNA that comprise the preferred alternative for this site would achieve the expectations for cleanup actions cited in the MTCA regulations at WAC 173-340-370 (1) – (8). The relevant expectations are addressed as follows.

- **Implement Treatment at Sites with Liquid Wastes, High Contaminant Concentrations, Highly Mobile Materials, or Discrete Areas of Contamination.** Ecology expects that treatment will be emphasized for sites meeting these general criteria. Boeing believes that while remaining COC levels are elevated, they are not high, and there is no evidence of liquid wastes at the site. The source areas are not discrete, are completely below a well maintained paved surface, and portions extend beneath existing buildings. Building 4-78 prevents ready access for removal or treatment of the solvent plume and source area. SVE would withdraw and treat volatile COCs from the source areas. Enhanced bioremediation would provide in situ treatment for organic COCs in the solvent plume. MNA would treat the benzene plume using natural processes.

- **Destroy, Detoxify, or Remove Hazardous Substances.** Ecology expects that hazardous substances will be destroyed, detoxified, or removed to below cleanup levels. Injection of substrate would ultimately destroy COCs, resulting in nontoxic degradation products. The technologies would remove, destroy, and detoxify COCs present in the source areas, solvent plume, and benzene plume. Some residuals from the SVE system could be treated off-site; the treatment would result in destruction of the contaminants. Both enhanced bioremediation and MNA would convert organic COCs to nontoxic by-products.

- **Engineering Controls for Low Contaminant Concentrations.** Ecology recognizes the need for containment for low concentrations of contaminants where treatment is impracticable. This alternative would use both in situ and ex situ treatment to destroy site COCs to the extent practicable. The existing tarmac, pavement, and buildings would provide containment to reduce the potential for constituent migration.

- **Prevent Runoff of Hazardous Substances.** Ecology expects that cleanup actions will include active measures to prevent precipitation from creating runoff that contains affected soil. This expectation would be met by the preferred alternative because the source area is entirely covered by buildings, tarmac, and pavement. The surface cover which overlies the source areas and most of the plumes is integral to Boeing's activities at the site and is well maintained. In addition to preventing runoff from contacting hazardous substances, this cover minimizes surface water



infiltration, thus resulting in decreased groundwater flow rates and increased time for groundwater to flow from the source area.

- **Consolidate On-Site Contaminants Exceeding Cleanup Levels.** Ecology expects that when contaminants are left on site exceeding cleanup levels, they will be consolidated to the extent practicable. Due to the location of the contaminants, presence of structures, and site activities at this site, it is not practicable to consolidate contaminants.

- **Prevent Runoff and Groundwater Discharge to Surface Water.** Ecology expects that the cleanup action would include active measures to prevent or minimize releases to adjacent surface water bodies via runoff or groundwater discharge, and that dilution will not be the sole method for attaining cleanup levels. Alternative 2 would meet this expectation. Available groundwater monitoring data indicate that biodegradation of organic COCs is active and significant at this site. Addition of organic substrate would accelerate these natural processes within the solvent plume. Modeling of MNA for the benzene plume indicates that MNA would degrade the benzene plume before it enters the waterway. The cleanup alternative also includes a groundwater monitoring network and program that would confirm that cleanup levels are attained in groundwater prior to reaching the CPOC.

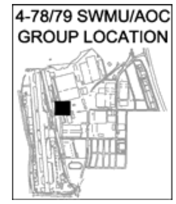
- **Ensure Appropriateness of Attenuation.** Ecology expects that natural attenuation may be appropriate if source control has been conducted to the maximum extent practicable; contaminants remaining on site do not pose unacceptable risks to human health and the environment; evidence indicates that degradation is occurring and will continue to occur at a reasonable rate; and appropriate monitoring is conducted. These expectations would all be achieved by Alternative 2. Although affected soil and groundwater have been present at the site for a long time, Boeing has implemented institutional controls that have proven effective in protecting human health and the environment at this site. Groundwater monitoring data indicate that biodegradation of organic COCs is active at the site and can be accelerated through addition of organic substrate. The high organic fraction in site soil also favors enhanced bioremediation for the chlorinated solvents. Highly conservative modeling of natural attenuation for the benzene plume indicates that cleanup levels would be met at the CPOC. Alternative 2 also includes a robust groundwater monitoring program designed to address recent guidance for MNA. The monitoring system included in the preferred alternative would confirm that cleanup levels are attained prior to groundwater discharging from Facility property.

The preferred remedial alternative would be designed and implemented to comply with applicable regulations. Potentially applicable regulations are listed in Table 9-3. These regulations govern the design, installation, and operation of remediation systems. For the preferred alternative at the Building 4-78/79 SWMU/AOC group, regulatory requirements

would be significant because COCs would be extracted and treated on site. Construction for the preferred alternative would be limited to installation of new monitoring and injection wells.

The primary regulations governing the preferred alternative would be the MTCA regulations, the Puget Sound Clean Air Agency (PSCAA) regulations, federal NESHAPS, Washington well drilling regulations for monitoring wells, solid waste disposal regulations, dangerous waste regulations, transportation regulations, and Department of Labor and Industries health and safety regulations. Well drilling rules specify well design and drilling requirements. The solid and dangerous waste regulations specify waste characterization, manifesting, and disposal requirements for drilling wastes and spent media from controlling emissions. Transportation regulations specify labeling and shipping requirements for wastes and spent media generated from implementation of the alternative. The PSCAA and NESHAPS regulations govern design and permitting for emissions from the SVE system. MTCA regulations specify remediation requirements and the cleanup standards to be attained. The preferred alternative would be designed, implemented, and monitored to comply with these regulations.

To establish baseline groundwater conditions prior to full implementation of the preferred remedial alternative, the proposed CPOC wells may be installed as an interim measure prior to completing the CAP. Results from sampling the CPOC wells would be evaluated to assess existing conditions. These results would be used to assess the remedial design presented in the CAP, which may be modified from the conceptual design presented in this FS to ensure that the optimal design is implemented.



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Geomatrix

TABLE 9-1

COMPARISON OF REMEDIAL ALTERNATIVES, BUILDING 4-78/79 SWMU/AOC GROUP[1]

Boeing Renton Facility

Renton, Washington

Standards/Criteria		Alternatives: 1 - Source Area Excavation/Enhanced Bioremediation/MA/MNA	2 - SVE/Enhanced Bioremediation/MA/MNA	3 - Source Area Excavation/MNA
Protectiveness and Risk Reduction	Pros	Removes or destroys soil TPH-G and benzene. Soil COCs addressed quickly. Destroys or immobilizes groundwater COCs.	Removes and destroys volatile soil COCs. Destroys groundwater COCs. Removes VOCs beneath buildings.	Removes and destroys soil TPH-G and benzene. Destroys organic groundwater COCs.
	Cons	Slow to achieve cleanup for Plume A groundwater. Cannot remediate soil beneath buildings. Soil COCs may remain beneath Bldg. 4-78. Off-site waste management required.	Slow to achieve cleanup for Plume A.	Long remediation time. Does not address source area soil for chlorinated VOCs.
	Rating	MH	H	MH
Permanence	Pros	Most soil COCs are removed from site. Organic groundwater COCs are destroyed.	Volatile soil COCs are destroyed with no residuals. Groundwater COCs destroyed before reaching CPOC.	Soil COCs in TPH source area removed from site. Natural carbon in site soils promotes MNA. COCs are destroyed, no toxic residuals.
	Cons	COCs may remain beneath buildings. Residuals managed at off-site facility. Off-site CPOC.	Residuals managed at off-site facility. Off-site CPOC.	Residuals managed off-site. Slow degradation rates; Off-site CPOC.
	Rating	MH	H	ML
Cost	Pros			
	Cons			
	Rating	ML	ML	MH
Long-Term Effectiveness	Pros	Removes or destroys accessible soil COCs. Groundwater organic COCs destroyed before reading CPOC.	Removes or destroys volatile soil COCs in both source areas. Organic groundwater COCs destroyed.	Removes or destroys soil COCs. Groundwater COCs destroyed at POC. Passive, natural process requires minimal operation.
	Cons	TPH COCs may remain beneath buildings. Requires long-term institutional controls. Residuals managed off-site. Periodic electron donor injection required.	Requires periodic electron donor injections. Requires institutional controls. Off-site waste management.	Requires institutional controls.
	Rating	MH	H	MH
Management of Short-Term Risks	Pros	In situ management of affected groundwater.	In situ management of affected groundwater.	In-situ management of groundwater. Simplest implementation. Minimal potential for exposure to site COCs.
	Cons	Exposure of affected soil, potential emission of dust and volatiles. Waste transportation. Requires periodic electron donor injection.	Requires periodic electron donor injection. Volatile COCs are extracted, potential for emissions.	Exposure of affected soil, potential emission of dust and volatiles. Waste transportation.
	Rating	ML	MH	ML
Technical and Administrative Implementability	Pros	Off-site landowner has indicated general acceptance for CPOC.	Only moderate impact on site activities. Off-site landowner has indicated general acceptance for CPOC.	Off-site landowner has indicated general acceptance for CPOC.
	Cons	Requires excavation and backfill permits, coordination with site manufacturing activities. Potential for damaging facilities. Periodic electron donor injection. Injection permit required. Requires City of Renton permission for CPOC.	Requires periodic electron donor injection. Injection and emission permitting.	Requires excavation and backfill permits, coordination with site manufacturing activities. Potential for damaging facilities. Periodic electron donor injection. Injection permit required. Requires City of Renton permission for CPOC.
	Rating	ML	MH	ML
Public Concerns	Pros	Industrial site.	Industrial site.	Industrial site.
	Cons	Potential odor an dust issues.	Requires City of Renton approval for CPOC. Potential air quality impacts.	Potential odor and dust issues.
	Rating	ML	MH	ML
Restoration Time Frame	Pros	Industrial site; Proven institutional controls; Alternative water available; Most rapid removal of soil COCs.	Industrial site; Proven institutional controls. Alternative water available. Fair to moderate cleanup time for soil.	Industrial site; Proven institutional controls; Alternative water available; Practicability of shorter timeframe limited by facility operations
	Cons	Does not address COCs beneath building. Practicability of shorter time frame limited by facility operations.	Practicability of shorter time frame limited by facility operations.	Longest cleanup time. Does not address soil COCs beneath buildings. Practicability of shorter time frame limited by facility operations.
	Rating	MH	MH	MH

Notes:

1. Comparison Ratings: H = Highest (if the decision were based solely on one criterion, an H score would indicate the alternative is the preferred alternative);
MH = Medium High;
ML = Medium Low;
L = Low.

TABLE 9-2

COMPARISON OF BENEFITS
BUILDING 4-78/79 SWMU/AOC GROUP[1]
Boeing Renton Facility
Renton, Washington

Benefit	Alternative 1: Source Area Excavation/Enhanced Bioremediation/MA/MNA	Alternative 2: SVE/Enhanced Bioremediation/MA/MNA	Alternative 3: Source Area Excavation/MNA
Reduced risk to on-site worker health	Moderate	High	Moderate
Reduced risk to off-site human health	High	Moderate	High
Reduced risk to the environment	High	Moderate	High
Minimal adverse impact on Facility operations	Low	Moderate	Low
Minimal restrictions on Facility traffic and access	Low	Moderate	Low
Minimal adverse impact on Facility structures and utilities	Low	High	Low

Notes:
1. Benefits for each remedial alternative are rated as follows:
   High = high benefit;
   Moderate = moderate benefit;
   Low = low benefit.

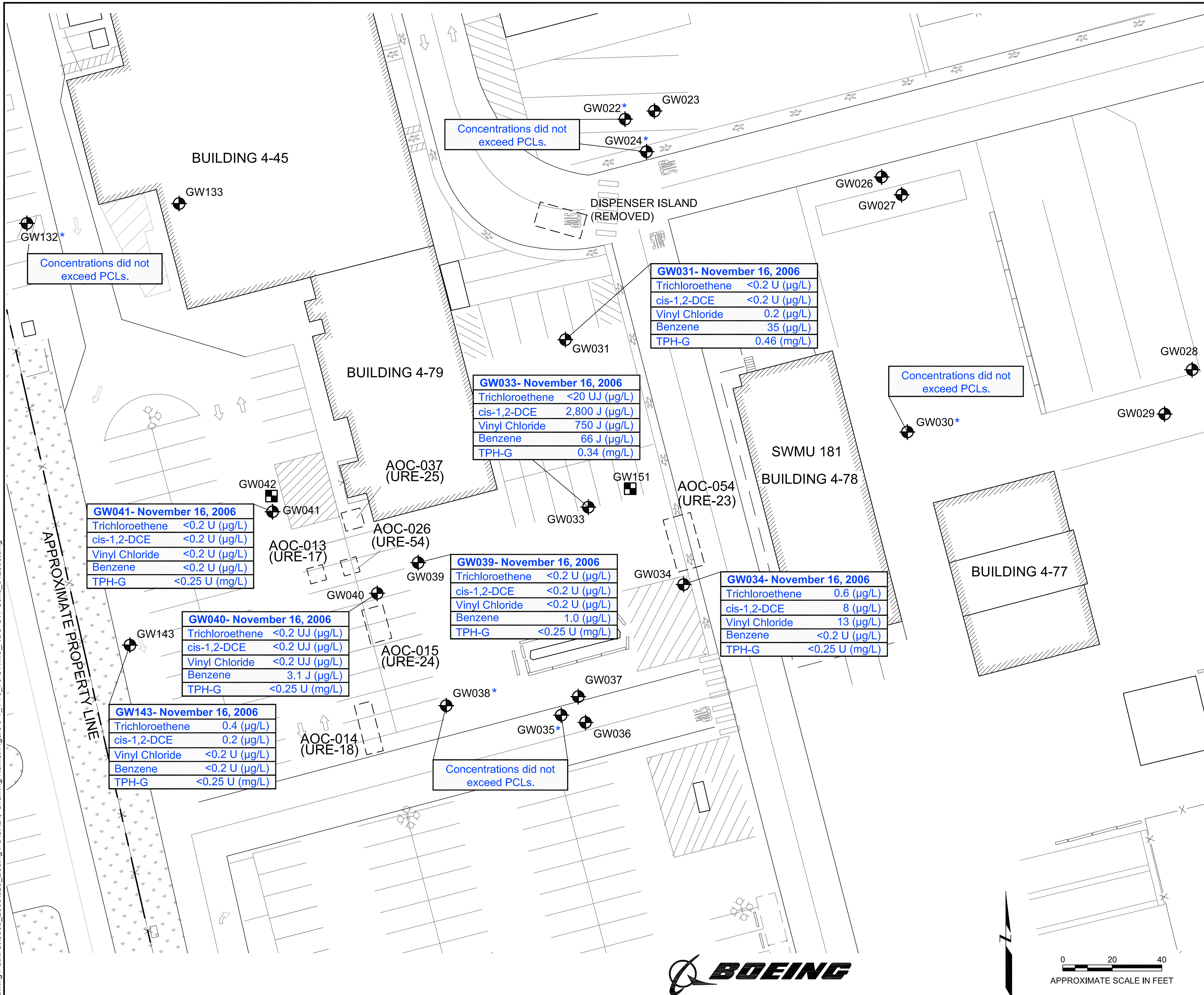
TABLE 9-3

POTENTIALLY APPLICABLE REGULATIONS
PREFERRED REMEDIAL ALTERNATIVE
BUILDING 4-78/79 SWMU/AOC GROUP

Boeing Renton Facility
Renton, Washington

Law/Regulation	Citation	Applicability
Chemical-Specific Laws and Regulations		
Washington Clean Air Act/Puget Sound Clean Air Agency Regulations	WAC 173-400	Permitting, air quality impacts
National Emission Standards for Hazardous Air Pollutants	40 CFR Part 61	Emission control requirements, permitting
Washington Dangerous Waste Regulations	WAC 173-303	Waste management, permitting requirements
Washington Model Toxics Control Act Regulations	WAC 173-340	Establishment of cleanup levels and POCs
Action-Specific Laws and Regulations		
Washington State Environmental Policy Act Regulations	WAC 197-11	Permitting, EIA/EIS[1] requirements
Washington Industrial Safety and Health Act Regulations	WAC 296-24	Occupational health and safety
Transportation regulations	49 CFR Parts 100 & 177, WAC 446-50	Transportation for wastes and materials
Washington well drilling regulations	WAC 173-160 & -162	Well design and installation standards
Washington Underground Injection Control Regulations	WAC 173-218	Underground injection permitting
Washington solid waste disposal regulations	WAC 173-304	Disposal of nondangerous waste

Notes:
1. EIA = Environmental Impact Assessment; EIS = Environmental Impact Statement.



GW031- November 16, 2006	
Trichloroethene	<0.2 U (µg/L)
cis-1,2-DCE	<0.2 U (µg/L)
Vinyl Chloride	0.2 (µg/L)
Benzene	35 (µg/L)
TPH-G	0.46 (mg/L)

GW033- November 16, 2006	
Trichloroethene	<20 UJ (µg/L)
cis-1,2-DCE	2,800 J (µg/L)
Vinyl Chloride	750 J (µg/L)
Benzene	66 J (µg/L)
TPH-G	0.34 (mg/L)

GW041- November 16, 2006	
Trichloroethene	<0.2 U (µg/L)
cis-1,2-DCE	<0.2 U (µg/L)
Vinyl Chloride	<0.2 U (µg/L)
Benzene	<0.2 U (µg/L)
TPH-G	<0.25 U (mg/L)

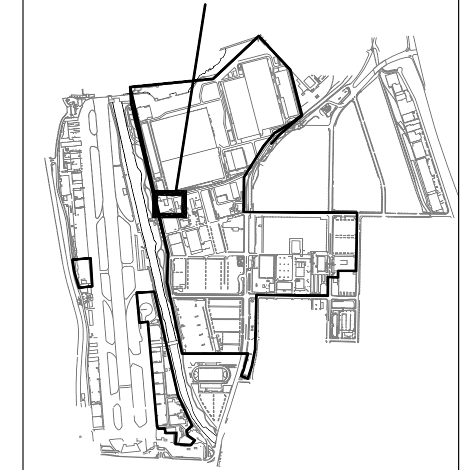
GW039- November 16, 2006	
Trichloroethene	<0.2 U (µg/L)
cis-1,2-DCE	<0.2 U (µg/L)
Vinyl Chloride	<0.2 U (µg/L)
Benzene	1.0 (µg/L)
TPH-G	<0.25 U (mg/L)

GW034- November 16, 2006	
Trichloroethene	0.6 (µg/L)
cis-1,2-DCE	8 (µg/L)
Vinyl Chloride	13 (µg/L)
Benzene	<0.2 U (µg/L)
TPH-G	<0.25 U (mg/L)

GW040- November 16, 2006	
Trichloroethene	<0.2 UJ (µg/L)
cis-1,2-DCE	<0.2 UJ (µg/L)
Vinyl Chloride	<0.2 UJ (µg/L)
Benzene	3.1 J (µg/L)
TPH-G	<0.25 U (mg/L)

GW143- November 16, 2006	
Trichloroethene	0.4 (µg/L)
cis-1,2-DCE	0.2 (µg/L)
Vinyl Chloride	<0.2 U (µg/L)
Benzene	<0.2 U (µg/L)
TPH-G	<0.25 U (mg/L)

4-78/79 SWMU/AOC GROUP LOCATION MAP



BOEING RENTON FACILITY MAP

LEGEND

- GW031 EXISTING MONITORING WELL LOCATION
- GW042 EXISTING EXTRACTION WELL LOCATION
- REMOVED UST (WESTON, 2001)
- cis-1,2-DCE cis-1,2-Dichloroethene
- TPH-G Total Petroleum Hydrocarbons-Gasoline fraction
- U Analyte was not detected above value shown
- J Analyte was positively identified; the value shown is the approximate concentration of the analyte
- UJ Analyte was not detected. Value shown is estimated detection limit.
- PCLs Preliminary Cleanup Levels

BLUE TEXT INDICATES GROUNDWATER ANALYTICAL DATA

* ANALYTICAL DATA FOR GW022, GW024, GW030, GW035, GW038, AND GW132 FROM FEBRUARY 2005

NOTES

1. HORIZONTAL DATUM: WASHINGTON STATE COORDINATE SYSTEM NORTH ZONE NAD83 (91)
   VERTICAL DATUM: NATIONAL GEODETIC VERTICAL DATUM (NGVD1929)
2. BASEMAP COMPILED BY DUANE HARTMAN & ASSOCIATES, INC., DECEMBER 1994
3. UST LOCATIONS AND PRODUCT PIPING LOCATIONS FROM FINAL REMEDIAL INVESTIGATION (WESTON, 2001a)

BUILDING 4-78/79 SWMU/AOC GROUP
GROUNDWATER CONCENTRATIONS
ABOVE PRELIMINARY CLEANUP LEVELS
Boeing Renton Facility
Renton, Washington

By: APS | Date: 05/28/08 | Project No. 8888

Geomatrix | Figure 9-1

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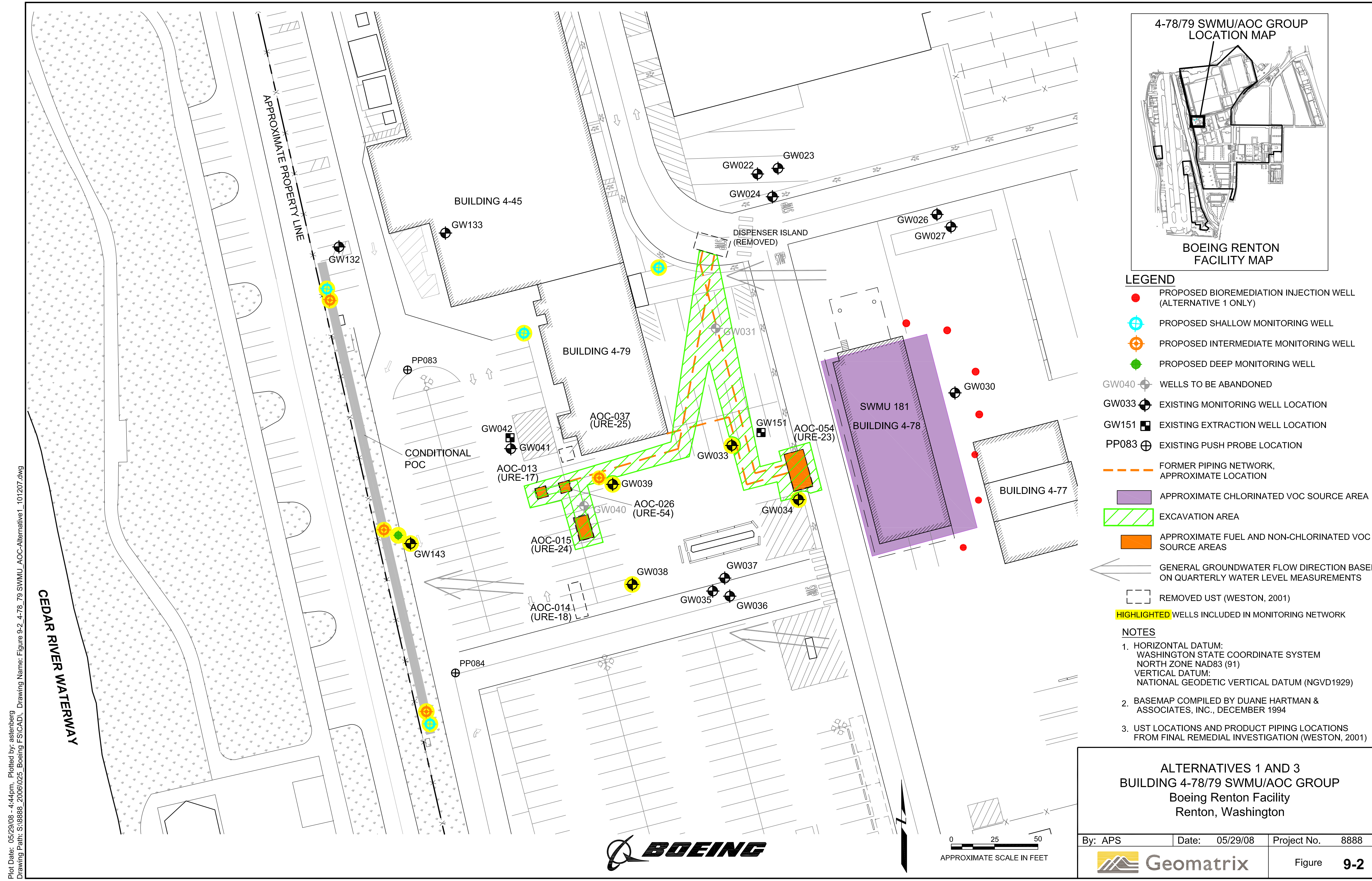
4-78/79 SWMU/AOC GROUP LOCATION MAP
BOEING RENTON FACILITY MAP
LEGEND
PROPOSED BIOREMEDIATION INJECTION WELL (ALTERNATIVE 1 ONLY)
PROPOSED SHALLOW MONITORING WELL
PROPOSED INTERMEDIATE MONITORING WELL
PROPOSED DEEP MONITORING WELL
GW040 WELLS TO BE ABANDONED
GW033 EXISTING MONITORING WELL LOCATION
GW151 EXISTING EXTRACTION WELL LOCATION
PP083 EXISTING PUSH PROBE LOCATION
FORMER PIPING NETWORK, APPROXIMATE LOCATION
APPROXIMATE CHLORINATED VOC SOURCE AREA
EXCAVATION AREA
APPROXIMATE FUEL AND NON-CHLORINATED VOC SOURCE AREAS
GENERAL GROUNDWATER FLOW DIRECTION BASED ON QUARTERLY WATER LEVEL MEASUREMENTS
REMOVED UST (WESTON, 2001)
HIGHLIGHTED WELLS INCLUDED IN MONITORING NETWORK
NOTES
1. HORIZONTAL DATUM: WASHINGTON STATE COORDINATE SYSTEM NORTH ZONE NAD83 (91) VERTICAL DATUM: NATIONAL GEODETIC VERTICAL DATUM (NGVD1929)
2. BASEMAP COMPILED BY DUANE HARTMAN & ASSOCIATES, INC., DECEMBER 1994
3. UST LOCATIONS AND PRODUCT PIPING LOCATIONS FROM FINAL REMEDIAL INVESTIGATION (WESTON, 2001)
CEDAR RIVER WATERWAY
APPROXIMATE PROPERTY LINE
BUILDING 4-45
BUILDING 4-79
BUILDING 4-78
BUILDING 4-77
SWMU 181
DISPENSER ISLAND (REMOVED)
CONDITIONAL POC
AOC-037 (URE-25)
AOC-013 (URE-17)
AOC-026 (URE-54)
AOC-015 (URE-24)
AOC-014 (URE-18)
AOC-054 (URE-23)
GW022
GW023
GW024
GW026
GW027
GW030
GW031
GW033
GW034
GW035
GW036
GW037
GW038
GW039
GW040
GW041
GW042
GW132
GW133
GW143
GW151
PP083
PP084
0 25 50
APPROXIMATE SCALE IN FEET
BOEING
ALTERNATIVES 1 AND 3
BUILDING 4-78/79 SWMU/AOC GROUP
Boeing Renton Facility
Renton, Washington
By: APS
Date: 05/29/08
Project No. 8888
Geomatrix
Figure 9-2
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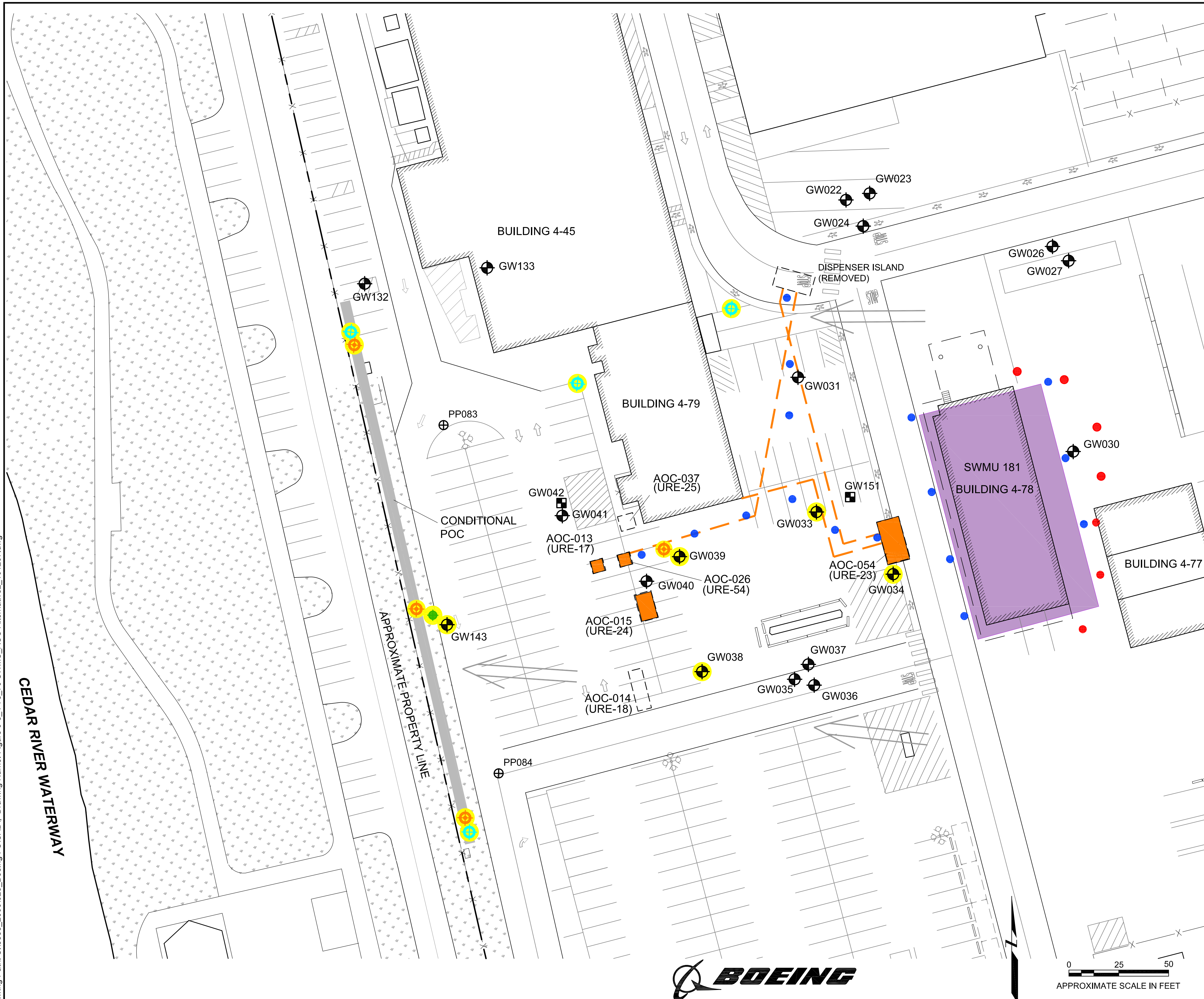
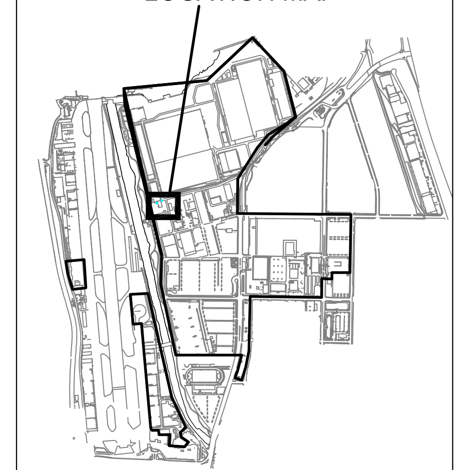


4-78/79 SWMU/AOC GROUP LOCATION MAP



BOEING RENTON FACILITY MAP

LEGEND

- PROPOSED SVE WELL
- PROPOSED BIOREMEDIATION INJECTION WELL
- PROPOSED SHALLOW MONITORING WELL
- PROPOSED INTERMEDIATE MONITORING WELL
- PROPOSED DEEP MONITORING WELL
- GW033 EXISTING MONITORING WELL LOCATION
- GW151 EXISTING EXTRACTION WELL LOCATION
- PP083 EXISTING PUSH PROBE LOCATION
- FORMER PIPING NETWORK, APPROXIMATE LOCATION
- APPROXIMATE CHLORINATED VOC SOURCE AREA
- APPROXIMATE FUEL AND NON-CHLORINATED VOC SOURCE AREAS
- GENERAL GROUNDWATER FLOW DIRECTION BASED ON QUARTERLY WATER LEVEL MEASUREMENTS
- REMOVED UST (WESTON, 2001)
- HIGHLIGHTED WELLS INCLUDED IN MONITORING NETWORK

NOTES

1. HORIZONTAL DATUM:
   WASHINGTON STATE COORDINATE SYSTEM
   NORTH ZONE NAD83 (91)
   VERTICAL DATUM:
   NATIONAL GEODETIC VERTICAL DATUM (NGVD1929)
2. BASEMAP COMPILED BY DUANE HARTMAN & ASSOCIATES, INC., DECEMBER 1994
3. UST LOCATIONS AND PRODUCT PIPING LOCATIONS FROM FINAL REMEDIAL INVESTIGATION (WESTON, 2001)

ALTERNATIVE 2
BUILDING 4-78/79 SWMU/AOC GROUP
Boeing Renton Facility
Renton, Washington

By: APS	Date: 05/29/08	Project No. 8888
Geomatrix		Figure 9-3

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10.0 DEVELOPMENT AND EVALUATION OF REMEDIAL ALTERNATIVES, FORMER FUEL FARM AOC GROUP

In this section we discuss remediation objectives, identify and evaluate remedial alternatives, and describe the preferred remedial alternative for the Former Fuel Farm AOC Group.

10.1 SITE CHARACTERIZATION SUMMARY

The Former Fuel Farm consisted of three Jet Fuel A USTs (URE-033, URE-034, URE-035) located near the south end of Renton Municipal Airport, about 200 feet southeast of Building 5-02 (see Figure 1-2). The USTs were installed in 1956 and 1957 and removed during closure activities at the Former Fuel Farm (referred to as the site in this section) in 1993. The residual petroleum hydrocarbons remaining in soil associated with the three former fuel storage tanks were identified in the Agreed Order as AOC-046, -047, and -048, respectively. URE-033, -034, and -035 were steel tanks used to store jet fuel. URE-033 and –034 had capacities of 50,000 gallons; URE-035 had a capacity of 12,000 gallons.

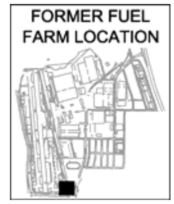
Soil sampling performed in 1994 assessed the lateral and vertical extent of TPH-impacted soil near this area. The total volume of soil above MTCA Method A cleanup level was estimated to be approximately 4,400 cubic yards (5,200 tons). Evaluation of chromatograms from Former Fuel Farm soil samples suggests the presence of Jet Fuel A petroleum products and not TPH-D or -G (Weston, 1994). Section 5.8 of the final RI Report presents the complete site characterization results for these units (Weston, 2001a). The results of the RI and subsequent interim action soil and groundwater monitoring are summarized below.

10.1.1 Historical, Present, and Future Site Use

Since closure, the Former Fuel Farm site, which is owned by the City of Renton and is leased to Boeing, has been used for employee parking. The nearby Boeing-leased buildings and areas are currently used for industrial purposes and are expected to remain in industrial use for the foreseeable future.

10.1.2 Previous Site Remedial Actions

Previous site cleanup actions in this area have been related to removal of USTs and operation of the interim action in the Former Fuel Farm site. All three of the former Jet Fuel A USTs were removed in 1993. Approximately 5,200 tons of TPH-affected soil was excavated for off-site disposal during UST removal. TPH-affected soil and groundwater were observed during removal of the tanks. The interim remedial system, which consists of a network of



bioventing and biosparging wells, continues to address the residual hydrocarbons remaining in the soil and groundwater at the site.

The ongoing interim action at the Former Fuel Farm AOC group was initiated in May 1995 following the closure and removal of URE-033 through URE-035. The interim action includes a biosparging and bioventing system designed to enhance bioremediation of the Jet Fuel A present in the subsurface. The cleanup objective for the interim action is for residual impacted soil to be reduced to the MTCA Interim TPH Policy Standards (Ecology, 1997) or prevailing MTCA provisions.

The current performance monitoring program for the Former Fuel Farm AOC group primarily consists of biannual groundwater sampling and periodic inspection of the equipment and operational systems. Biannual soil sampling in the Former Fuel Farm source area at fixed push probe locations was discontinued in June 2003. The soil sampling had been conducted repeatedly at the same locations, and the analytical results did not indicate significant changes in the source area, so additional soil sampling was discontinued with Ecology approval. Two additional downgradient groundwater monitoring wells were installed in December 2003 to augment the two existing groundwater monitoring wells at this site. The current groundwater monitoring program includes semiannual sampling of the four groundwater monitoring wells at the site.

10.1.3 Site Hydrogeology

The general stratigraphy beneath this area consists of hydraulic fill underlain by alluvium. Fill in this area consists of brown to reddish-brown, fine-grained sand with silt and gravel. Alluvium consists of medium- to coarse-grained greenish-gray sand with silt. The contact between hydraulic fill and in situ alluvium ranged from 5 to 10.5 feet bgs.

A sheet pile wall is located adjacent to the Cedar River Waterway, downgradient from the site. In 1999, the USACE constructed floodwalls and earthen levees for flood control along both the east and west sides of the Cedar River Waterway from the Logan Avenue North bridge to the mouth of the Cedar River Waterway. The concrete floodwalls (maximum height of approximately 10 feet above grade) were constructed above interlocking steel sheet piles that were driven to a minimum depth of 21 feet bgs. The sheet piling runs along the entire western bank of the waterway, from Logan Avenue to Lake Washington. According to the final RI Report, the sheet piling is not keyed into a low-permeability soil unit and functions as a

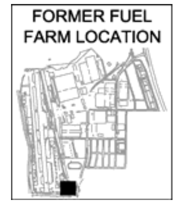
"hanging barrier wall." It is expected that the sheet pile wall affects groundwater flow, likely causing groundwater to flow beneath the piling as it approaches the waterway in the vicinity of the Former Fuel Farm.

Depth to groundwater reported in the RI ranged between 8.52 and 11.75 feet bgs. Seasonal groundwater level variations observed at these wells were approximately 1.5 feet. Groundwater in this area generally flows to the north toward the Cedar River at an average gradient of about 0.004. Groundwater elevations measured during past quarterly groundwater monitoring events have supported the expected regional pattern of northerly and northeasterly groundwater flow. At other times, the groundwater elevation data appear to show a groundwater mound centered on the approximate location of the air sparge system. Figure 10-1 shows the northerly groundwater flow direction based on groundwater levels measured on November 7, 2005, after the interim action air sparge system had been shut down for 2 weeks. The water levels measured on November 7, 2005, showed that the groundwater flow direction, in the absence of the local influence of the air sparge system, is generally to the north in accordance with the expected flow toward the Cedar River Waterway and Lake Washington. Water level measurements were made at more than 13 locations during this event, as shown in Figure 10-1.

Slug tests conducted in wells GW101 and GW102 indicated that the hydraulic conductivity of the groundwater in the area ranged from 1.7×10^{-3} to 10.9×10^{-3} cm/s. Based on a geologic cross-section presented in the final RI Report, the predominant soil type in the vadose zone is silty sand with gravel, and the soil type dominating groundwater flow is silty sand. Therefore, the dominant soil classification for both the vadose and saturated zones is SM; soil characteristics for SM soil will be used for relevant calculations in this FS.

10.1.4 Nature and Extent of Affected Soil

The results of the RI indicate that soils at the Former Fuel Farm site have been affected by residual TPH-Jet Fuel A (TPH-Jet), TPH-D, benzene, and 2-methylnaphthalene above the PCLs. Due to the degraded nature of the TPH, it is often tentatively identified during analysis, and the source of the TPH is the Jet Fuel A that was stored in these USTs. The TPH-affected soils also contain EPH and VPH fractions; however, no PCLs were calculated for these analytes. Soil sampling conducted as part of the interim action monitoring shows that that the soils in the Former Fuel Farm source area still contain TPH above the PCLs (Geomatrix, 2003a). Figure 10-2 shows the most recent soil sampling data for the Former Fuel Farm.



Historical soil sampling results and the interim action monitoring results show that soil with TPH extends from the area of the former USTs west and northwest to the push probe sampling locations PP427 and PP430. This TPH is present in a 2- to 3-foot-thick zone at approximately 10 to 13 feet in depth (Geomatrix, 2003a). The source area at the Former Fuel Farm also extends slightly to the northeast of the former USTs. The tank excavation extended to the lease boundary line, but TPH-affected soil was left in place.

10.1.5 Nature and Extent of Affected Groundwater

The groundwater in the area of the Former Fuel Farm contains TPH-Jet and TPH-D. As with soil, these results are likely due to the Jet Fuel A that was stored in the former USTs. Dissolved TPH levels in groundwater samples collected from the five push probe locations for the RI ranged from 1.4 to 7.3 mg/L, which is above the TPH PCL of 0.5 mg/L. Figure 10-2 shows the most recent groundwater analytical data for push probes and groundwater monitoring wells at the Former Fuel Farm. Monitoring wells GW183 and GW184 were installed to the north-northeast of PP427 and PP430 to define the northern extent of dissolved TPH. Groundwater samples collected in June 2003 from these new wells and from GW101 and GW102 did not contain detectable concentrations of dissolved TPH-Jet or TPH-D (Figure 10-2).

10.2 Conceptual Site Model

A preliminary conceptual model for migration of constituents present in affected soil and groundwater present at the Renton Facility was presented in Figure 2-6 of the FSWP (Geomatrix, 2004c). Based on the conceptual model, considerations presented in the FSWP, plus information specific to this site, a site-specific conceptual site model is described below. This site-specific conceptual site model identifies the media and exposure pathways that must be addressed for remedial alternatives potentially applicable to this site.

TPH-Jet, TPH-D, benzene, and 2-methylnaphthalene are present within the source area soils for the Former Fuel Farm AOC group. As shown in the general facility conceptual model presented in the FSWP, dissolved constituents associated with jet fuel can migrate from the source areas via groundwater or vapor pathways. For this site, migration via groundwater will be most significant. Constituent transport via groundwater at this site is affected by soil/groundwater interactions, biodegradation, and the presence of the sheet pile wall in the downgradient groundwater flow path. As groundwater flows through TPH-Jet-affected soil in the source area, fuel components (including benzene and 2-methylnaphthalene) may dissolve

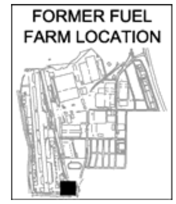
into groundwater, although no TPH-Jet components have been detected in groundwater monitoring wells surrounding the source area. Any dissolved TPH-Jet components will move with groundwater but at a different velocity due to continuing solute-soil interactions. This movement may create a plume extending downgradient from the source areas; however, no such plume was detected in the downgradient groundwater monitoring wells. TPH-Jet components present in groundwater are likely to biodegrade—the existing biosparging/bioventing network may be increasing the oxygen concentration in the subsurface, thereby encouraging aerobic biodegradation of any dissolved jet fuel components.

Groundwater near the Former Fuel Farm is likely migrating to the north-northeast from the source area toward the discharge area along the Cedar River Waterway. However, under current conditions, dissolved TPH-Jet components appear to be biodegrading completely before reaching the waterway. Volatilization of constituents from groundwater is not significant for most workers at this site, as noted in the conceptual model presented in the FSWP.

10.3 SITE REMEDIATION OBJECTIVES AND CLEANUP STANDARDS

To ensure that the remedial alternatives developed and evaluated in the FS are effective, specific remediation objectives and appropriate cleanup standards must be established. The remedial alternatives considered for potential implementation at the site must be capable of achieving remediation objectives and cleanup standards. The remediation objectives for the Renton Facility were presented in Section 2. As defined in the MTCA regulations, the cleanup standard consists of the cleanup level and the location or POC at which the cleanup levels must be met. The remedial alternatives for this site, presented in Section 10.4, may have different points of compliance while fully addressing remediation objectives and meeting cleanup levels.

The groundwater and soil COCs exceeding the PCLs established in the final RI Report for the Former Fuel Farm AOC group were identified in FSWP Tables 5-1 and 5-3, respectively. These constituents were identified by comparing detected constituent concentrations to the PCLs identified in the final RI Report; if a constituent concentration measured in any sample exceeded the PCL, the constituent was listed as a COC that must be addressed in the FS. PCLs for both soil and groundwater meeting MTCA requirements were presented in the FSWP (Tables 5-6 and 5-2, respectively) and approved by Ecology. To confirm that the COCs listed in the FSWP included all constituents detected at concentrations exceeding the approved cleanup levels, the RI soil and groundwater data were compared to the approved cleanup levels listed in the FSWP. If concentrations for constituents that were not identified as COCs



exceeded cleanup levels, it would be necessary to include them as COCs. If concentrations for previously identified COCs were below the approved cleanup levels, the constituent should be removed as a COC. No new constituents were identified as COCs for this site, and no previously identified COCs were removed as a result of this comparison.

The soil and groundwater cleanup levels for the site COCs are listed in Tables 3-1 and 3-2, respectively. The soil cleanup levels are either MTCA Method A cleanup levels or site-specific MTCA Method C cleanup levels that are protective of groundwater at the CPOC and were calculated in accordance with the procedures described in the FSWP or in accordance with recent negotiations with Ecology. The groundwater cleanup levels listed in Table 3-2 were developed as described in Section 3 and in accordance with recent negotiations with Ecology. The cleanup levels are protective of surface water, human health, and the environment.

The groundwater cleanup levels allow for the degradation that would occur between the source area and the CPOC due to natural attenuation. Modeling of natural attenuation was done using BIOSCREEN and the parameters and modeling approach described in Section 3 and in the FSWP. For constituents other than petroleum hydrocarbons, soil cleanup levels protective of groundwater were calculated using the procedures described in WAC 173-340-747(4). Details concerning modeling and partitioning calculations are included in Appendix A.

Given the natural attenuation processes observed at the site, the calculated cleanup levels would be protective of groundwater at the CPOC. These cleanup levels will be used in development and evaluation of remedial alternatives for the Former Fuel Farm site that include natural attenuation or enhanced in situ bioremediation.

10.4 SITE REMEDIAL ALTERNATIVES

Remedial alternatives have been identified and developed for the Former Fuel Farm that incorporate the remedial technologies presented in Section 4. The alternatives specifically address site conditions, the site remediation objectives, and the approved soil and groundwater cleanup levels for the Former Fuel Farm AOC group. Three remedial alternatives have been considered for this site:

- Alternative 1: Existing Biosparging/Bioventing and Monitored Attenuation
- Alternative 2: Upgraded Biosparging/Bioventing and Monitored Attenuation

- Alternative 3: Monitored Natural Attenuation

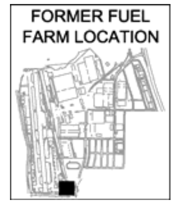
The remedial alternatives to be evaluated for this site are described below. These alternatives are evaluated against the evaluation criteria in Section 10.5.

The Former Fuel Farm is located near the south end of Renton Municipal Airport, about 200 feet southeast of Building 5-02. The area of the Former Fuel Farm is leased from the City of Renton. During the removal of the USTs, the excavation was extended to approximately the northern lease boundary line near the northeast corner of the Former Fuel Farm. TPH-affected soil extended beyond the lease boundary line to the north, under an adjacent property also owned by the City of Renton (see Figure 10-3 for the areas of affected soils) (Weston, 1994). TPH-affected soil also extended from the western portion of the Former Fuel Farm toward the northwest. This second area of affected soil remains on the Boeing leased property. Push probe sampling completed in June 2003 indicated a similar extent of TPH-affected soils (Geomatrix, 2003a). The elevated TPH-affected soil extends east from PP405 to PP420 and northwest from PP405 to PP427 and PP430 (Figure 10-3). Downgradient groundwater monitoring wells GW184 and GW183 were installed approximately 80 feet away from PP427 and PP430, and no TPH-affected soil was observed based on field observations during installation of these wells (Geomatrix, 2004a).

The affected soil is located below tarmac or pavement. The piping and wellheads of the in situ bioremediation sparge wells and venting wells extend beneath the area of the Former Fuel Farm. Various utilities, including storm drains, sanitary sewers, and other utilities, are located below the paved surface of the Former Fuel Farm site.

Regular groundwater monitoring conducted at the site has not detected TPH-Jet components dissolved in groundwater samples collected from monitoring wells located around the Former Fuel Farm. Groundwater samples collected from previous push probes within the source areas contained dissolved TPH-Jet above cleanup levels, but none of the samples collected from the groundwater monitoring wells have contained detectable concentrations of TPH-Jet.

There is no apparent plume of dissolved TPH-Jet extending from the site toward the Cedar River. The lack of a dissolved TPH-Jet plume could be attributable to extensive biodegradation of the mobile and more soluble jet fuel components, and the operation of the bioremediation interim action is probably enhancing aerobic biodegradation of these components in the subsurface and helping to curtail migration of a dissolved phase plume from the site.



MTCA requires that remedial alternatives selected for a site meet the MTCA threshold requirements for cleanup actions. The minimum threshold requirements specify that cleanup actions shall (1) protect human health and the environment, (2) comply with cleanup standards, (3) comply with applicable state and federal law, and (4) provide for compliance monitoring. In order to be considered as a potential remedial alternative for the site, the technologies considered had to pass the screening evaluation of the remedial technologies described in Section 4. In addition, the alternatives had to meet the minimum threshold requirements established by MTCA and be consistent with overall site conditions.

Based on the screening evaluation, MTCA minimum threshold requirements, and the site considerations discussed above, three remedial alternatives addressing the site COCs were developed for the Former Fuel Farm site.

10.4.1 Alternative 1: Existing Biosparging/Bioventing and Monitored Attenuation

The existing biosparging/bioventing system has operated since May 1995, and while TPH-affected soil still exists in the source area, there is no dissolved phase plume at this site. The operation of the existing interim action is likely enhancing ongoing aerobic biodegradation at this AOC group. Therefore, for this alternative, the existing biosparging/bioventing system would remain in operation. The specific elements included in this remediation alternative are:

- Enhanced aerobic bioremediation of TPH-Jet and related components (including benzene and 2-methylnaphthalene) in the source area soils by continuing to operate the existing bioremediation sparge and vent well network;
- Institutional Controls:
  - Deed recordation noting the location and nature of historical USTs and previous releases in the Former Fuel Farm area;
  - Covenants and deed restrictions to address potential risks to human health that may remain as a result of residual soil constituents and affected groundwater;
- Points of Compliance: A CPOC to allow biodegradation reactions to proceed to completion;
- Monitored Attenuation: Groundwater monitoring would be conducted to ensure that dissolved TPH-Jet concentrations remain below the cleanup level at the CPOC. Four existing groundwater monitoring wells and seven new groundwater wells (six shallow, one intermediate in depth) would be used to monitor attenuation.

For this remedial alternative, a CPOC would be established downgradient of the Former Fuel Farm to allow sufficient time for biodegradation of any TPH-Jet-affected groundwater that may be migrating away from the source areas. The CPOC would extend west from East Perimeter Road, as shown on Figure 10-3. Figure 10-3 also shows the location of the existing biosparging/bioventing well network, as well as the four existing and seven proposed groundwater monitoring wells that would be used to monitor attenuation.

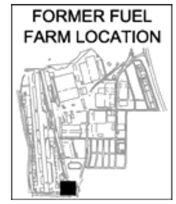
Enhanced aerobic biodegradation of TPH-Jet in the source area soils would permanently destroy soil and groundwater COCs. Institutional controls to protect human health would be implemented as the interim action remains operable, and would be continued until cleanup levels were attained throughout the source areas. Groundwater cleanup levels would be attained at the CPOC. Groundwater monitoring would be conducted to ensure that the interim action is still effective in controlling the migration of dissolved TPH-Jet at the CPOC.

10.4.1.1 Continued Operation of Existing Bioremediation System

The existing biosparge and biovent wells (Figure 10-3) seem to have assisted in remediation of the TPH-Jet-affected soils at the Former Fuel Farm since 1995. The interim action bioremediation system is simple to operate, and operational costs are relatively low. Continuing to operate the existing system would provide a stable supply of oxygen to the subsurface to encourage continued biodegradation of the TPH-Jet and its related components in the source area soils. No dissolved TPH-Jet and or other COCs have been detected in the downgradient groundwater monitoring wells. Continued operation of the interim action system would ensure that TPH-Jet and other COCs would not exceed cleanup levels at the CPOC.

10.4.1.2 Institutional Controls

Institutional controls would be incorporated into this alternative to ensure it is fully protective of human health and the environment. Institutional controls are necessary because it is expected that some COCs may remain in the soil below the Former Fuel Farm and because enhanced biodegradation of affected soils would require additional time to fully degrade the COCs. In general, the institutional controls that would be incorporated into this remedial alternative would be a continuation of the controls that have been implemented at the Renton Facility and been proven effective. These institutional controls would be established such that they are legally enforceable for current and future landowners.



Institutional controls requiring implementation of specific and appropriate health and safety procedures would be implemented for conducting any subsurface work in the immediate vicinity of the source areas and in the downgradient affected groundwater area. Formal agreement with the City of Renton would be required to implement these institutional controls outside the lease boundary line.

10.4.1.3 Monitored Attenuation

Groundwater monitoring data collected over the last several years in the vicinity of the Former Fuel Farm indicate that natural processes are at work degrading and retarding the migration of COCs, in conjunction with the ongoing interim action biosparge and biovent wells. The existing groundwater monitoring program established for the Former Fuel Farm includes four monitoring wells sampled semiannually for TPH-Jet and BTEX compounds. Analytical data for the latest sampling event are presented in the Quarterly Monitoring Report (Geomatrix, 2007a).

Based on the POC approach presented in Section 6 of the FSWP, fate and transport groundwater modeling using BIOSCREEN was conducted to evaluate the efficacy of MNA as a final remedy for this AOC group. The modeling followed the protocol established in the FSWP using approved model input parameters. The modeling results are presented in detail in Appendix A. The model results indicate that groundwater cleanup levels for all COCs would be met before groundwater reaches the CPOC for the Former Fuel Farm (Figure 10-3).

In accordance with current guidance and the approach for MNA discussed in Section 4.2.4, the conceptual monitoring program for the Former Fuel Farm is designed to:

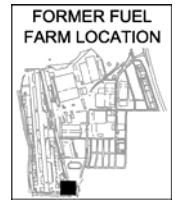
- Demonstrate that natural attenuation is occurring according to expectations;
- Identify any potentially toxic and/or mobile transformation products;
- Confirm that a plume of TPH-affected groundwater is not expanding beyond the CPOC;
- Verify that cleanup levels are attained at the CPOC;
- Verify that there is no unacceptable impact to downgradient receptors;
- Detect new releases of COCs that could impact the effectiveness of the natural attenuation remedy;

- Demonstrate the efficacy of institutional controls put in place to protect potential receptors; and
- Verify attainment of remediation objectives.

As such, this conceptual design would be appropriate for both MA and MNA alternatives. The conceptual monitoring program for Alternative 1 at the Former Fuel Farm assumes that upon selection of this remedy, a detailed MA Validation and Long-Term Sampling Work Plan would be developed to guide the process. This work plan would identify additional monitoring wells and monitoring analytes required for both characterization/validation sampling and long-term groundwater monitoring. Characterization/validation sampling would be used to demonstrate the effectiveness of MA with respect to contaminant mass reduction, attenuation rates, and temporal trends. Long-term groundwater monitoring would be used after characterization/validation monitoring to confirm that the contaminant plume was progressing toward containment or achievement of numerical goals.

For this conceptual design, it is assumed that characterization/validation sampling would consist of quarterly monitoring of new wells, and semiannual monitoring of existing wells for a minimum of 1 year. Seven new monitoring wells (six shallow and one intermediate) are assumed to be required (in addition to the four existing wells) to monitor potential plume migration. Monitoring parameters and analytes would consist of TPH-Jet, TPH-D, BTEX, SVOCs, and appropriate MA geochemical parameters [e.g. dissolved oxygen, nitrate, Fe(II), sulfate, methane, temperature, pH, specific conductance, alkalinity, oxidation/reduction potential, chloride, ethane, and TOC]. It is assumed that reporting for characterization/validation sampling would follow each quarterly event.

It is further assumed that long-term groundwater monitoring would follow for an additional 13 to 14 years (15 total years of monitoring) and would include semiannual monitoring of up to eight shallow wells for TPH-Jet, TPH-D, BTEX, SVOCs, and a limited suite of geochemical parameters (dissolved oxygen, oxidation/reduction potential, temperature, and pH). To ensure plume control, all 11 wells would be analyzed once every 5 years for the entire characterization/validation list of analytes. Wells that have had no detectable concentrations of COCs over the previous year would be considered for removal from the semiannual monitoring program. It is assumed that annual reporting would be required for long-term groundwater monitoring.



10.4.2 Alternative 2: Upgraded Biosparging/Bioventing and Monitored Attenuation

The existing biosparging/bioventing system at the Former Fuel Farm AOC group has operated since May 1995, and while TPH-affected soil still exists in the source area, there is no dissolved phase plume at this site. The operation of the existing interim action is likely enhancing ongoing aerobic biodegradation at this AOC group. However, past sampling results within the source areas indicate the presence of a distinct zone of TPH-Jet-affected soil that still contains high concentrations of TPH-Jet despite the operation of the existing system for nearly 10 years.

Review of the biosparge well boring logs and cross-sections A-A' and B-B' (as shown in Figure 2-2 of Weston, 1994) shows that the biosparge wells were installed to a depth of approximately 35 feet. The purpose of the biosparge wells is to allow for dissolution of atmospheric oxygen into the groundwater. However, as shown clearly on the cross-section, there is a distinct layer of silt located throughout the site at an approximate depth of 12 to 25 feet bgs. This layer was apparently breached during installation of the original USTs during the 1950s. As shown by the cross-sections, this layer dips to the northwest. It is possible that air injected below the silt layer rises until it encounters the base of the layer and then may buoyantly rise with the dip of the silt layer. If this occurs, the air would then bypass the silt layer and soils above it and rise within the area of the former tank excavation. This change in the air channel distribution may prevent the existing bioremediation system from reaching all of the TPH-Jet source areas.

New biosparge wells are proposed under this alternative to correct this possible deficiency. No changes in overall system operation would be expected, because these new wells would supplement rather than replace the current system.

The specific elements included in this remediation alternative are:

- Enhanced aerobic bioremediation of TPH-Jet and related components (including benzene and 2-methylnaphthalene) in the source area soils by continuing to operate the existing bioremediation sparge and vent well network;
- Installation of 13 new biosparge wells screened just above the silt layer. These wells would be installed near existing pipe runs to minimize the additional trenching required. The new wells would focus on the remaining TPH-Jet-affected soils northeast and northwest of the former USTs;
- Institutional Controls:

- Deed recordation noting the location and nature of historical USTs and previous releases in the Former Fuel Farm area;
- Covenants and deed restrictions to address potential risks to human health that may remain as a result of residual soil constituents and affected groundwater;

- Points of Compliance: A CPOC to allow biodegradation reactions to proceed to completion;
- Monitored Attenuation: Groundwater monitoring would be conducted to ensure that dissolved TPH-Jet concentrations remain below the cleanup level at the CPOC. Four existing groundwater monitoring wells, and seven new groundwater wells (one shallow, one intermediate in depth) would be used to monitor attenuation.

For this remedial alternative, a CPOC would be established downgradient of the Former Fuel Farm to allow sufficient time for biodegradation of any TPH-Jet-affected groundwater that may be migrating away from the source areas. Groundwater cleanup levels would be attained at the CPOC. The CPOC would extend west from East Perimeter Road, as shown on Figure 10-4. Figure 10-4 also shows the location of the proposed biosparge/bioventing system, as well as the four existing and seven proposed new groundwater monitoring wells that would be used to monitor attenuation.

Enhanced aerobic biodegradation of TPH-Jet in the source area soils would permanently destroy soil and groundwater COCs. Institutional controls to protect human health would be implemented as long as the interim action remains in operation, and would be continued until cleanup levels are attained throughout the potential plume and source areas. Groundwater monitoring would be conducted to ensure that the interim action is still effective in controlling the migration of dissolved TPH-Jet at the CPOC.

10.4.2.1 Upgraded Bioremediation System

The existing biosparge and biovent wells seem to have assisted in remediating the TPH-Jet-affected soils at the Former Fuel Farm since 1995. The interim action bioremediation system is simple to operate, and operational costs are relatively low. Upgrading the existing system through the addition of shallower biosparge points would not be technically difficult. Operation of the upgraded bioremediation system would provide a stable supply of oxygen to the subsurface to encourage continued biodegradation of the TPH-Jet and its related components in the source area soils. The addition of new, shallower biosparge points (Figure 10-4) would help accelerate the biodegradation of TPH-Jet-affected soils in the source area. Dissolved TPH-Jet and other COCs have not been detected in the downgradient groundwater monitoring wells; therefore, upgrading and continued operation of the interim action system would ensure that TPH-Jet and other COCs would not exceed cleanup levels at the CPOC.

10.4.2.2 Institutional Controls

The institutional controls that would be incorporated into this alternative are the same as described in Section 10.4.1.2 for Alternative 1.

10.4.2.3 Monitored Attenuation

Groundwater monitoring would be conducted under this alternative as described in Section 10.4.1.3 for Alternative 1. For conceptual design and cost estimating purposes, the same assumptions were used as described in Section 10.4.1.3 for Alternative 1.

10.4.3 Alternative 3: Monitored Natural Attenuation

While the existing bioremediation system appears to be useful in encouraging aerobic degradation of TPH-affected soils and groundwater, after nearly 10 years of operation, the original design has likely reached a point of diminishing returns because of the limitations discussed in Section 10.4.2. Current data suggest that the current bioremediation system could be shut off, and natural processes would continue to biodegrade TPH-Jet-affected soils and groundwater without the assistance provided by the interim measure. Under this alternative, the existing system would be maintained in the event that COCs were detected at the CPOC. The cleanup standard for this alternative would be attained by permanent destruction of organic constituents by the ongoing natural processes and immobilization of the nonbiodegradable COCs. The soil cleanup standard will be the cleanup levels discussed in Section 10.3 and shown in Table 3-1.

No free-phase LNAPL has been identified in groundwater monitoring wells at the Former Fuel Farm. In addition, the former Jet Fuel A USTs were removed, and TPH-affected soil was excavated to the extent practicable during UST removal. Given that other risks from the TPH-Jet in soils can be managed through institutional controls and that the soils are confined by the existing pavement or tarmac, no additional active measures are necessary to remediate soils at this site.

The specific elements included in this remedial alternative are:

- Installation of seven new groundwater monitoring wells;
- Groundwater monitoring using both existing and new monitoring wells located within the source areas and at the CPOC as shown in Figure 10-5;
- Shutdown of the existing interim measure, such that the natural groundwater conditions would reequilibrate;
- Institutional Controls:
  - Deed recordation noting the location and nature of historical USTs and previous releases in the Former Fuel Farm area;
  - Covenants and deed restrictions to address potential risks to human health that may remain as a result of residual soil constituents and affected groundwater;
- Points of Compliance: A CPOC to allow biodegradation reactions to proceed to completion;
- Monitored Natural Attenuation: Groundwater monitoring would be conducted to ensure that dissolved TPH-Jet concentrations remain below the cleanup level at the CPOC. Four existing groundwater monitoring wells, and seven new groundwater wells (four shallow, one intermediate in depth) would be used to monitor attenuation.

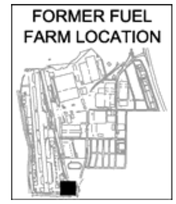
Natural attenuation of TPH-Jet in the source area soils and groundwater would permanently destroy soil and groundwater COCs. Institutional controls to protect human health would be implemented and continued until cleanup levels are attained throughout the source area. For this remedial alternative, a CPOC would be established downgradient of the Former Fuel Farm to allow sufficient time for biodegradation of any TPH-Jet-affected groundwater that may migrate away from the source areas. Groundwater cleanup levels would be attained at the CPOC. The CPOC and the proposed monitoring well network are shown on Figure 10-5.

10.4.3.1 Institutional Controls

Institutional controls incorporated into this alternative would be the same as described in Section 10.4.1.2 for Alternative 1.

10.4.3.2 Monitored Natural Attenuation

Groundwater monitoring data collected over the last several years in the vicinity of the Former Fuel Farm indicate that natural processes are at work degrading and retarding the migration of COCs, in conjunction with the ongoing interim action biosparge and biovent wells. Under this



alternative, natural attenuation would be allowed to continue, and a rigorous groundwater monitoring program would be implemented to verify that natural biodegradation processes were occurring, and that COCs were not present above cleanup levels at the CPOC. The monitoring program for MNA under Alternative 3 would be the same as described in Section 10.4.1.3 for Alternative 1. For conceptual design and cost estimating purposes, the same assumptions were used as described in Section 10.4.1.3. The groundwater monitoring network and CPOC for Alternative 3 are shown on Figure 10-5.

10.5 EVALUATION OF SITE REMEDIAL ALTERNATIVES

As previously discussed, all three alternatives developed for the site meet the MTCA minimum requirements for cleanup actions. This section compares and evaluates the alternatives based on the MTCA criteria described in Section 5.1. An analysis of each alternative with respect to the evaluation criteria is summarized in Table 10-1 and discussed below.

10.5.1 Protectiveness and Risk Reduction

Protectiveness and risk reduction are gauged primarily on the time required for the alternative to reduce risk and meet cleanup levels. Alternatives 1 and 2 are expected to keep groundwater COCs from exceeding cleanup levels at the CPOCs based on the current system's performance record. Alternative 3 should be as effective as the other alternatives, based on modeling and the readily biodegradable nature of TPH-Jet, but would take a longer time to achieve remediation. Alternatives 1 and 2 are, therefore, rated slightly higher.

10.5.2 Permanence

Permanence refers to the ability to reduce the toxicity, mobility, or volume of hazardous substances, including the permanent destruction of hazardous substances. All alternatives provide for permanent destruction of COCs. Alternative 2 is rated marginally higher for this criterion because the additional biosparge wells would target areas the current system cannot easily address, although the effect of this effort is expected to be marginal.

10.5.3 Cost

The cost evaluation includes all costs related to implementation of an alternative, including initial design and construction costs, operation and maintenance costs, monitoring costs, and reporting costs. The annual costs for operation, maintenance, monitoring, and reporting are recurring costs that occur in the future. The cost evaluation considers initial implementation costs and future recurring costs using NPV analysis. For NPV calculation, recurring costs were

inflated 2% annually, and a discount rate of 7% was used. Details regarding the cost estimates for the three alternatives are presented in Appendix B. The present value costs for the three alternatives, in 2007 dollars, are summarized below:

Alternative	Net Present Value
1: Existing Biosparging/Bioventing and Monitored Attenuation	$ 934,000
2: Upgraded Biosparging/Bioventing and Monitored Attenuation	$1,127,000
3: Monitored Natural Attenuation	$ 482,000

As shown by these costs, Alternative 3 has the lowest NPV cost while Alternative 2 has the highest. The cost for Alternative 1 is slightly lower than that for Alternative 2. Therefore, Alternative 2 ranks lowest for cost, Alternative 3 ranks highest, and Alternative 1 is intermediate.

10.5.4 Long-Term Effectiveness

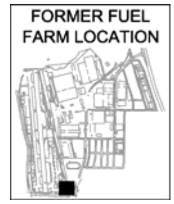
Long-term effectiveness includes the degree of certainty and reliability of the alternative and whether treatment residue remains from the alternative that will require management. All three alternatives are proven technologies, and none produces residual wastes that would require ongoing management.

10.5.5 Management of Short-Term Risks

Short-term risk refers to the risk to human health and the environment during implementation of the alternative. Since the implementation of Alternative 3 is the simplest, it is rated highest for this criterion. Alternative 2 is the most difficult alternative to implement and is therefore given the lowest ranking.

10.5.6 Technical and Administrative Implementability

This criterion involves whether the alternative is technically possible relative to complexity, administrative/regulatory requirements, size, access, and integration with existing operations. Both Alternative 1 and 3 integrate best with the facility operations because the current system is already part of existing operations, and MNA only requires that the existing treatment system be shut down so that the equipment can be easily restarted. Both Alternatives 1 and 3 are rated highest for their ease of implementability, and Alternative 2 ranks the lowest with a medium high rating.



10.5.7 Public Concern

This criterion refers to potential community concerns with the alternative. Because all three alternatives deal with a large industrial site with limited public access, they are rated the same.

10.5.8 Reasonable Restoration Time Frame

Restoration time frame looks at the practicability of a shorter restoration time frame with consideration given to a number of factors, including site risks, site use and potential use, availability of alternative water supply, effectiveness and reliability of institutional controls, and toxicity of hazardous substances at the site. As a whole, these factors are a measure of the urgency of reducing risk and achieving cleanup goals for the site. Given that the site is industrial, has proven institutional controls, and the toxicity of contaminants is moderate, all alternatives are ranked medium low. Alternative 2 may be slightly more effective at reducing the overall mass of affected soil in a shorter period of time. This slight advantage does not warrant ranking this alternative higher than the other alternatives.

10.6 Selection of Preferred Site Remedial Alternative

Selection of a preferred alternative under MTCA requires that preference be given to alternatives that use permanent solutions (to the maximum extent practicable), provide for a reasonable restoration time frame, and consider public concerns. The analysis below defines the baseline alternative for the Former Fuel Farm AOC group and compares the other alternatives to the baseline alternative based on the degree of permanence, reasonable restoration time frame, and the degree to which it addresses potential public concerns. Based on this comparison, the preferred remedial alternative is identified and proposed for selection as the cleanup action to be implemented for the site.

10.6.1 Baseline Remedial Alternative

The baseline remedial alternative for the Former Fuel Farm AOC group is Alternative 2. Although all three alternatives could be considered to be permanent cleanup actions in the sense that cleanup standards are met, this alternative is considered to have a higher degree of permanence because it relies on permanent destruction of hazardous substances and would likely provide for a slightly shorter restoration time frame than Alternative 1 or 3.

10.6.2 Comparison to Baseline Alternative

As noted above, Alternative 2 has been defined as the baseline remedial alternative for this site. Alternatives 1 and 3 will be compared to the baseline alternative in this subsection for selection

of the preferred alternative. The purpose of this comparison is to assess the benefits and costs for Alternatives 1 and 3 relative to Alternative 2. The evaluation criteria presented above and in Table 10-1 were established in accordance with the MTCA requirements cited in WAC 173-340(3)(f). Costs for the alternatives will be based on the NPV, which reflects the total cost associated with each alternative over the 15-year time period evaluated. The evaluation of benefits will be qualitative.

The benefits to be assessed in this comparison and the relative rating for the alternatives are presented in Table 10-2. The rationale for this comparison is presented below.

- **Reduced risk to on-site worker health.** All three alternatives are equal in reducing risk to site workers because they are all equally protective. Although the baseline alternative would further reduce COC concentrations within a few years, potential risks to on-site workers would not be changed substantially by the other two alternatives. The institutional controls included in each of the alternatives have been proven effective in protecting worker health and would continue to be protective.

- **Reduced risk to off-site human health.** All three alternatives were rated high for this benefit. All three would attain the cleanup level at the CPOC, which is protective of human health and the environment. The institutional controls included in all alternatives have proven to be protective of worker health on site and would also be protective of human health in off-site areas located upgradient of the CPOC. None of the alternatives would meet cleanup levels at the standard POC.

- **Reduced risk to the environment.** All three alternatives were ranked equally high for reducing potential risks to the environment. All three alternatives would be protective of the aquatic environment because they would all attain the cleanup levels at the CPOC.

- **Minimal adverse impact on Facility operations.** The baseline alternative was rated moderate for this benefit because it would impact Facility operations during installation of the new biosparging wells and piping and would require long-term operation and periodic replacement of the biosparging/biovent system components. Alternative 1 was rated moderate because the existing biosparging/biovent system would require long-term operation and periodic replacement of the biosparging/biovent system components. A high rating was given to Alternative 3, which relies on passive degradation of site COCs and would have the least impact on Facility operations.

- **Minimal restrictions on Facility traffic and access.** The baseline alternative was rated moderate for this benefit because it would impact Facility traffic and access during installation of the biosparging wells and piping. Additional impact would

FORMER FUEL FARM LOCATION

occur during periodic replacement or maintenance of biosparging/biovent system components. Alternative 1 was rated moderate because Facility traffic and access impacts would occur during periodic replacement or maintenance of biosparging/biovent system components. Alternative 3 was given a high rating because it would affect traffic only during installation of monitoring wells, most of which would occur along the CPOC, resulting in the least impact to Facility traffic and access. Alternatives 1 and 2 were ranked equal and moderate.

- **Minimal adverse impact on Facility structures and utilities.** The baseline alternative was rated low for minimizing adverse impacts on facility structures and utilities because installation of new biosparging wells and piping has the potential to affect Facility structure and utilities. Alternative 1 is already in place, and installation of the new monitoring wells would take place along the CPOC near the Facility lease line, resulting in less impact on Facility traffic and access.

The potential benefit evaluation for the three alternatives shows that Alternative 3, Monitored Natural Attenuation, would provide the greatest benefit. Alternative 1 would provide the next highest benefit, and the baseline alternative (Alternative 2) ranks lowest for benefits.

The NPV costs for the three alternatives were presented in Section 10.5.3. The baseline alternative ranks third among the three alternatives, with the highest cost. Alternative 3 has the lowest present value cost (approximately 42% of the estimated cost for the baseline alternative). Alternative 1 is ranked intermediate for cost because it would have the second highest NPV (approximately 83% of the cost for the baseline alternative). Alternative 2 would have the highest cost.

10.6.3 Preferred Remedial Alternative

As noted above, Alternative 3, Monitored Natural Attenuation, provides the greatest benefit at the lowest cost; therefore, Alternative 3 is the preferred remedial alternative for the Former Fuel Farm site. Alternative 2, as the baseline and the most permanent potential remedy, does not provide additional benefits that are commensurate with its disproportionate cost. Groundwater samples collected downgradient from the source areas and upgradient from the Cedar River Waterway show that groundwater COCs have not migrated to the waterway. Preliminary groundwater modeling of natural attenuation confirms the downgradient observations and indicates that the groundwater cleanup levels would be attained at the CPOC.

Under Alternative 3, affected soils would remain capped by maintained pavement or tarmac to prevent potential runoff and infiltration of rainfall. The former fuel farm and other off-lease areas are owned by the City of Renton. The other lease area buildings, tarmac, pavement, and

roadway further limit infiltration of surface water. The City of Renton has indicated general agreement to allow a CPOC to be located on City property. The shoreline along the waterway is occupied by an above-grade retaining wall and is not suitable for development and use. Groundwater in the area is not used for any purpose and will not likely be used in the future, and potable water is readily available from the Renton public water system. The institutional controls included in Alternative 3 have been implemented and proven by Boeing, who would continue to maintain overall responsibility for this site and ensure that the institutional controls are properly enforced.

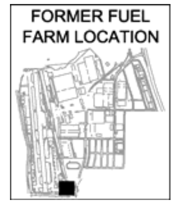
Monitored natural attenuation for this site would achieve the expectations for cleanup actions cited in the MTCA regulations at WAC 173-340-370 (1) – (8). Only those expectations relevant to large, complex sites are considered relevant to the Former Fuel Farm. The relevant expectations are addressed as follows.

- **Implement Treatment at Sites with Liquid Wastes, High Contaminant Concentrations, Highly Mobile Materials, or Discrete Areas of Contamination.** Ecology expects that treatment will be emphasized for sites meeting these general criteria. Boeing has completed removal of affected soils within the source areas to the extent practicable without adversely affecting off-lease areas. While remaining COC levels are significant, they are not high, and there is no evidence of liquid wastes at the site. The source areas are not discrete and extend beneath off-lease areas and below areas covered by asphalt or concrete pavement, preventing ready access for removal or treatment. MNA would degrade or “treat” organic COCs over the long term using natural processes that result in nontoxic degradation products.

- **Destroy, Detoxify, or Remove Hazardous Substances.** Ecology expects that hazardous substances will be destroyed, detoxified, or removed to below cleanup levels. The MNA program will result in the ultimate destruction of COCs, resulting in nontoxic degradation products.

- **Implement Engineering Controls for Low Contaminant Concentrations.** Ecology recognizes the need for containment for low concentrations of contaminants where treatment is impracticable. The on- and off-lease buildings and extensive surface pavement covering the site serve as a cap to provide containment for affected soil and groundwater over the source areas and much of the plume. The cap would remain over the site while MNA provides treatment for site COCs.

- **Prevent Runoff of Hazardous Substances.** Ecology expects that cleanup actions will include active measures to prevent precipitation from creating runoff that contains affected soil. This expectation would be met by the preferred alternative, because the source area is entirely covered by buildings, tarmac, or pavement. This surface cover is integral to Boeing’s activities at the site and is well maintained. In



addition to preventing runoff from contacting hazardous substances, the buildings and pavement minimize surface water infiltration, thus resulting in decreased groundwater flow rates and increased time for groundwater to flow from the source area to the waterway.

- **Prevent Runoff and Groundwater Discharge to Surface Water.** Ecology expects that the cleanup action would include active measures to prevent or minimize releases to adjacent surface water bodies via runoff or groundwater discharge, and that dilution will not be the sole method for attaining cleanup levels. Alternative 3 would meet this expectation. Available groundwater monitoring data indicate that biodegradation of TPH-Jet affected groundwater is active and significant at this site. Preliminary natural attenuation modeling for the site indicates that groundwater cleanup levels would be attained prior to groundwater reaching the Cedar River Waterway. The cleanup alternative also includes a groundwater monitoring network and program that would confirm that cleanup levels are attained in groundwater upstream from the waterway.

- **Ensure Appropriateness of Natural Attenuation.** Ecology expects that natural attenuation may be appropriate if source control has been conducted to the maximum extent practicable; contaminants remaining on site do not pose unacceptable risks to human health and the environment; evidence indicates that degradation is occurring and will continue to occur at a reasonable rate; and appropriate monitoring is conducted. The expectations for natural attenuation would all be achieved by Alternative 3. Boeing has conducted source removal to the extent practicable without damaging off-lease areas. Although affected soil has been present at the site for a long time, Boeing has implemented institutional controls that have proven effective in protecting human health and the environment at this site. Groundwater monitoring data indicate that biodegradation of TPH-Jet components is active at the site; the high organic fraction in site soil is expected to maintain conditions favorable to continued active biodegradation. Alternative 3 also includes a robust groundwater monitoring program designed to address recent guidance for MNA. The monitoring system included in the preferred alternative would confirm that cleanup levels are attained prior to groundwater discharging to the Cedar River Waterway.

The preferred remedial alternative would be designed to comply with applicable regulations. Potentially applicable regulations are listed in Table 10-3. These regulations govern the design, installation, and operation of remediation systems. For the preferred alternative at the Former Fuel Farm, regulatory requirements are expected to be minimal. Construction for the preferred alternative would be limited to installation of new monitoring wells, some within 200 feet of the shoreline along the Cedar River Waterway.

The primary regulations governing the preferred alternative would be the MTCA regulations, the Washington well drilling regulations for monitoring wells, the solid waste disposal regulations, the dangerous waste regulations, the transportation regulations, the Department of Labor and Industries health and safety regulations, and the Shoreline Management Act. Well drilling rules specify well design and drilling requirements. The solid and dangerous waste regulations specify waste characterization, manifesting, and disposal requirements. Transportation regulations specify labeling and shipping requirements for wastes generated from implementation of the alternative. MTCA regulations specify remediation requirements and the cleanup standards to be attained. The Shoreline Management Act specifies standards for construction activities within 200 feet of the Cedar River shoreline. The preferred alternative would be designed and implemented to comply with these regulations.

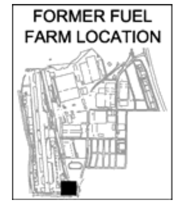


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TABLE 10-1

COMPARISON OF REMEDIAL ALTERNATIVES, FORMER FUEL FARM[1]

Boeing Renton Facility
Renton, Washington

Standards/Criteria		Alternatives: 1- Existing Biosparging/Bioventing and Monitored Attenuation	Alternatives: 2 - Upgrade Biosparging/Bioventing and Monitored Attenuation	Alternatives: 3 - Monitored Natural Attenuation
Protectiveness and Risk Reduction	Pros	Destroys COCs.	Destroys COCs.	Destroys COCs.
	Cons	Slow to achieve cleanup.	Slow to achieve cleanup.	Slow to achieve cleanup.
	Rating	MH	MH	ML
Permanence	Pros	Destroys COCs; No residuals.	Destroys COCs; No residuals.	Destroys COCs; No residuals.
	Cons	Slow degradation rates.	Slow degradation rates.	Slow degradation rates.
	Rating	MH	H	MH
Cost	Pros	System already exists.		Lowest total cost.
	Cons	High long-term costs.	High short and long-term costs.	High long-term costs.
	Rating	ML	L	MH
Long-Term Effectiveness	Pros	Destroys COCs.	Destroys COCs.	Destroys COCs; Passive, natural process.
	Cons	Active process requiring input.	Active process requiring input.	
	Rating	ML	ML	MH
Management of Short-Term Risks	Pros	System already operational.	Additional biosparge wells should improve effectiveness.	Simplest implementation; No residuals
	Cons	Existing design flaw limits effectiveness	Additional well and piping installation required.	
	Rating	MH	ML	H
Technical and Administrative Implementability	Pros	Easily implementable.	Moderately implementable.	Simple system.
	Cons			
	Rating	H	MH	H
Public Concerns	Pros	Industrial site.	Industrial site.	Industrial site.
	Cons			
	Rating	MH	MH	MH
Restoration Time Frame	Pros	Industrial site; Proven institutional controls; Alternative water available; Practicability of shorter time frame limited by facility operations.	Industrial site; Proven institutional controls; Alternative water available; Practicability of shorter time frame limited by facility operations.	Industrial site; Proven institutional controls; Alternative water available; Practicability of shorter time frame limited by facility operations.
	Cons			
	Rating	ML	ML	ML

Notes:
1. Comparison Ratings: H = Highest (if the decision were based solely on one criterion, an H score would indicate the alternative is the preferred alternative);
MH = Medium High;
ML = Medium Low;
L = Low.

TABLE 10-2

COMPARISON OF BENEFITS
FORMER FUEL FARM AOC GROUP[1]
Boeing Renton Facility
Renton, Washington

Benefit	Alternative 1: Existing Biosparge/Biovent System, Monitored Attenuation	Alternative 2: Upgraded Biosparge/Biovent System, Monitored Attenuation	Alternative 3: Monitored Natural Attenuation
Reduced risk to on-site worker health	High	High	High
Reduced risk to off-site human health	High	High	High
Reduced risk to the environment	High	High	High
Minimal adverse impact on Facility operations	Moderate	Moderate	High
Minimal restrictions on Facility traffic and access	Moderate	Moderate	High
Minimal adverse impact on Facility structures and utilities	Moderate	Low	Moderate

Notes:
1. Benefits for each remedial alternative are rated as follows:
   High = high benefit;
   Moderate = moderate benefit;
   Low = low benefit.

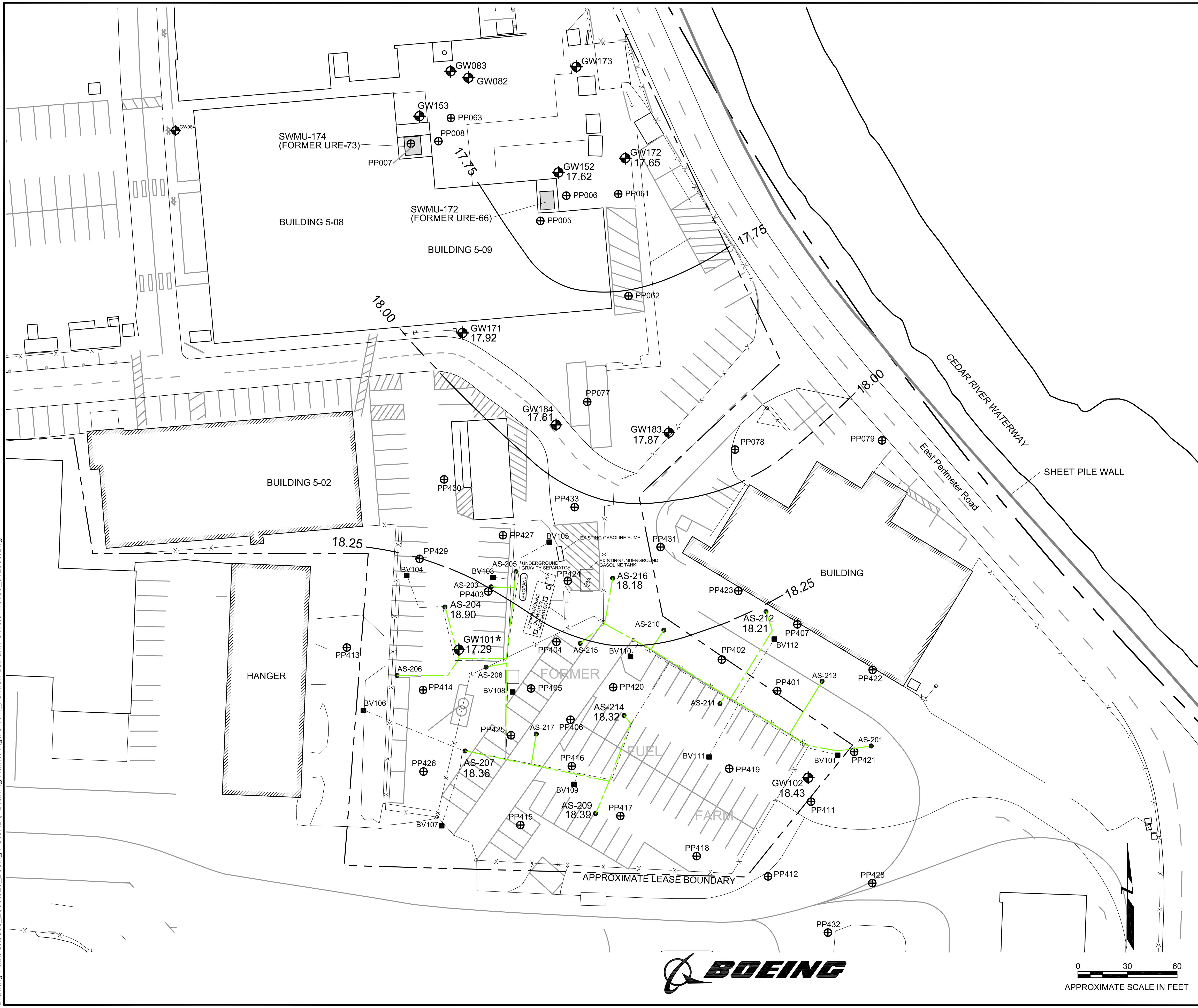
TABLE 10-3

POTENTIALLY APPLICABLE REGULATIONS
FORMER FUEL FARM AOC GROUP PREFERRED REMEDIAL ALTERNATIVE

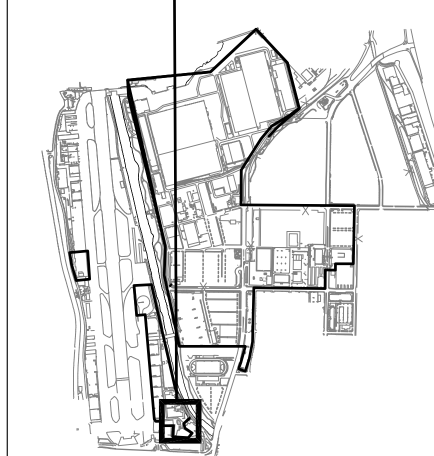
Boeing Renton Facility
Renton, Washington

Law/Regulation	Citation	Applicability
Chemical-Specific Laws and Regulations		
Washington Dangerous Waste Regulations	WAC 173-303	Waste management, permitting requirements
Washington Model Toxics Control Act Regulations	WAC 173-340	Establishment of cleanup levels and POCs
Action-Specific Laws and Regulations		
Washington State Environmental Policy Act Regulations	WAC 197-11	Permitting, EIA/EIS[1] requirements
Washington Industrial Safety and Health Act Regulations	WAC 296-24	Occupational health and safety
Transportation regulations	49 CFR Parts 100 & 177, WAC 446-50	Transportation for wastes and materials
Washington well drilling regulations	WAC 173-160 & -162	Well design and installation standards
Washington solid waste disposal regulations	WAC 173-304	Disposal of nondangerous waste
Location-Specific Regulations		
Shoreline Management Act	RCW 90.58	Standards for construction within 200 ft of shoreline

Notes:
1. EIA = Environmental Impact Assessment; EIS = Environmental Impact Statement.



FORMER FUEL FARM AOC GROUP
LOCATION MAP



BOEING RENTON
FACILITY MAP

LEGEND

- GW101 — EXISTING MONITORING WELL LOCATION
- PP042 — EXISTING PUSH PROBE LOCATION
- AS-204 — EXISTING UNDERGROUND AIR SPARGING WELL
- BV112 — EXISTING UNDERGROUND BIOVENTING WELL
- UNDERGROUND BIOVENTING LINE
- UNDERGROUND AIR SPARGING LINE
- FENCE
- GW172 17.65 — MONITORING WELL AND GROUNDWATER ELEVATION
- * GW101 HAD AN ANOMALOUS WATER LEVEL COMPARED TO ADJACENT DATA POINTS. WATER LEVEL DATA NOT USED FOR CONTOURING.
- 17.75 — CONTOUR OF EQUAL GROUNDWATER ELEVATION IN FEET ABOVE MEAN SEA LEVEL

NOTES

1. HORIZONTAL DATUM:
   WASHINGTON STATE COORDINATE SYSTEM
   NORTH ZONE NAD83 (91)
   VERTICAL DATUM:
   NATIONAL GEODETIC VERTICAL DATUM (NGVD1929)
2. BASEMAP COMPILED BY DUANE HARTMAN & ASSOCIATES, INC., DECEMBER 1994
3. PUSH PROBE LOCATIONS FROM FINAL REMEDIAL INVESTIGATION REPORT (WESTON, 2001a)
4. PIPING LOCATIONS APPROXIMATE

BOEING

FORMER FUEL FARM AOC GROUP
GROUNDWATER ELEVATIONS
NOVEMBER 7, 2005
Boeing Renton Facility
Renton, Washington

By: APS	Date: 05/28/08	Project No. 8888
Geomatrix		Figure 10-1

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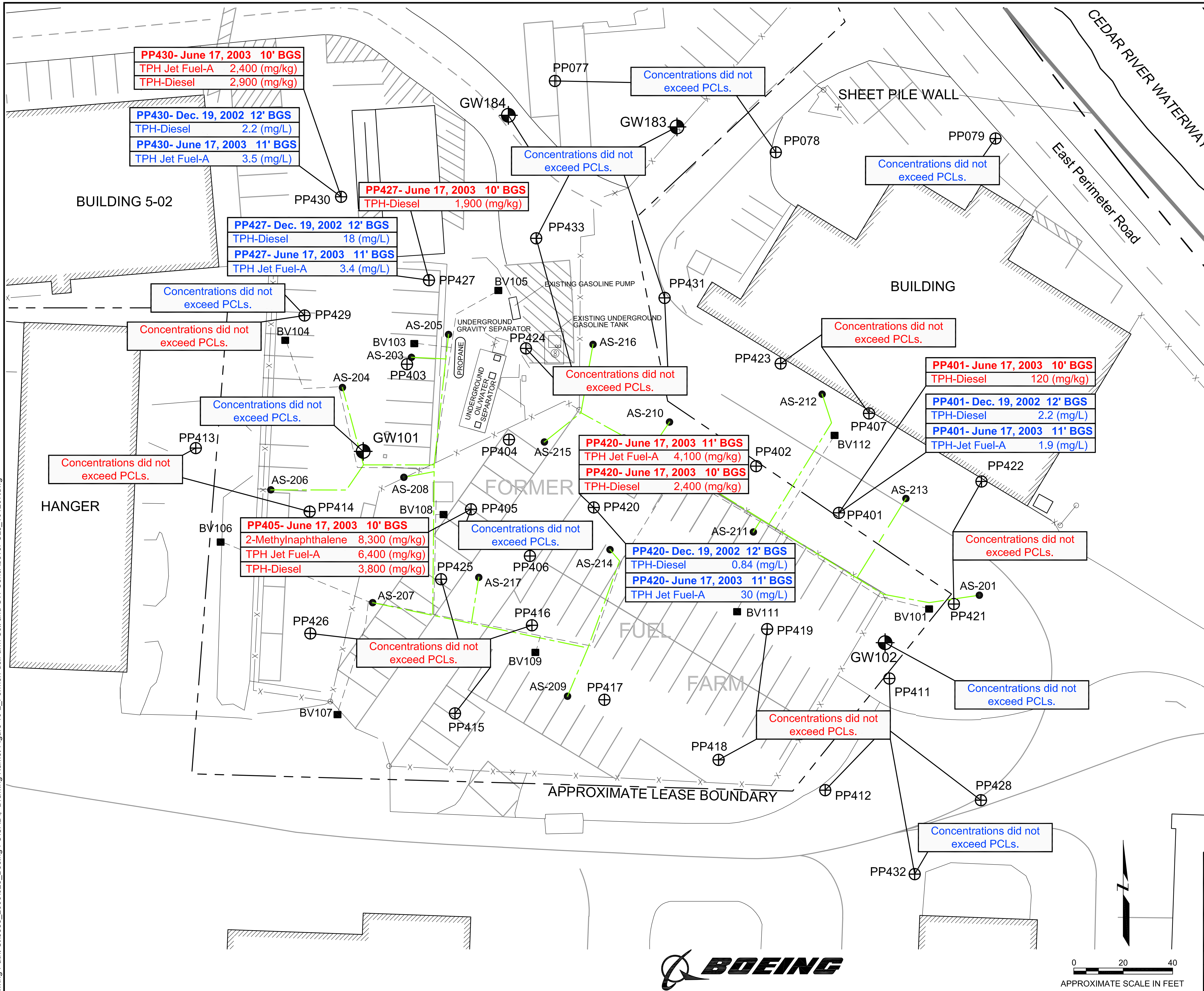

LEGEND

GW101	EXISTING MONITORING WELL LOCATION
PP042	EXISTING PUSH PROBE LOCATION
AS-204	EXISTING UNDERGROUND AIR SPARGING WELL
BV112	EXISTING UNDERGROUND BIOVENTING WELL
	UNDERGROUND BIOVENTING LINE
	UNDERGROUND AIR SPARGING LINE
	FENCE
TPH	Total Petroleum Hydrocarbons
PCLs	Preliminary Cleanup Levels

RED TEXT INDICATES SOIL ANALYTICAL DATA
BLUE TEXT INDICATES GROUNDWATER ANALYTICAL DATA

NOTES

1. HORIZONTAL DATUM: WASHINGTON STATE COORDINATE SYSTEM NORTH ZONE NAD83 (91) VERTICAL DATUM: NATIONAL GEODETIC VERTICAL DATUM (NGVD1929)
2. BASEMAP COMPILED BY DUANE HARTMAN & ASSOCIATES, INC., DECEMBER 1994
3. PUSH PROBE LOCATIONS FROM FINAL REMEDIAL INVESTIGATION REPORT (WESTON, 2001a)
4. PIPING LOCATIONS APPROXIMATE
5. ALL SOIL AND GROUNDWATER DATA FOR THE PUSH PROBES ARE THE MOST RECENT DATA AVAILABLE

FORMER FUEL FARM AOC GROUP
PUSH PROBE AND WELL LOCATION MAP
Boeing Renton Facility
Renton, Washington

By: APS	Date: 05/29/08	Project No. 8888
Geomatrix		Figure 10-2

BOEING

Plot Date: 05/29/08 - 4:57pm, Plotted by: astenberg
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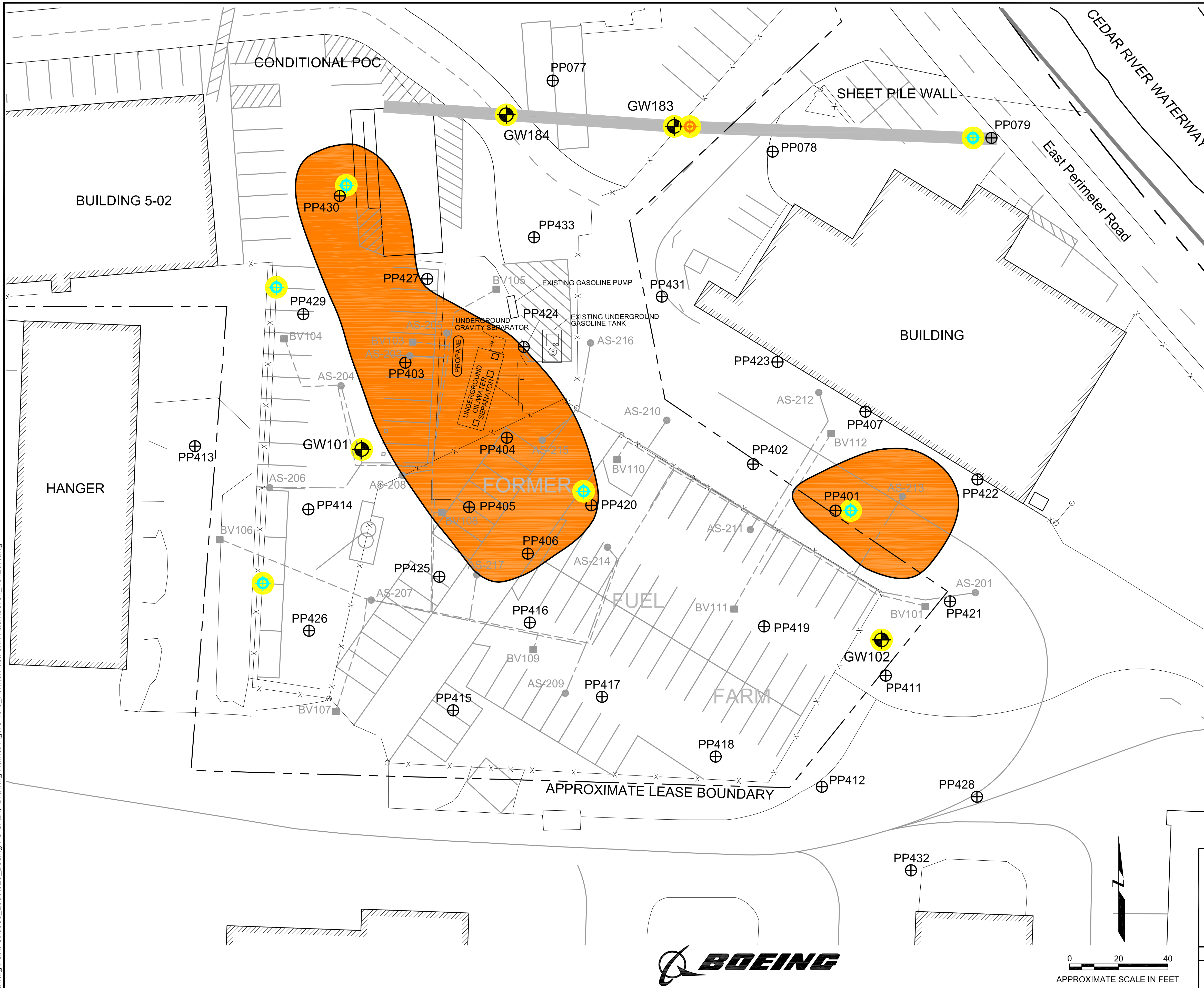

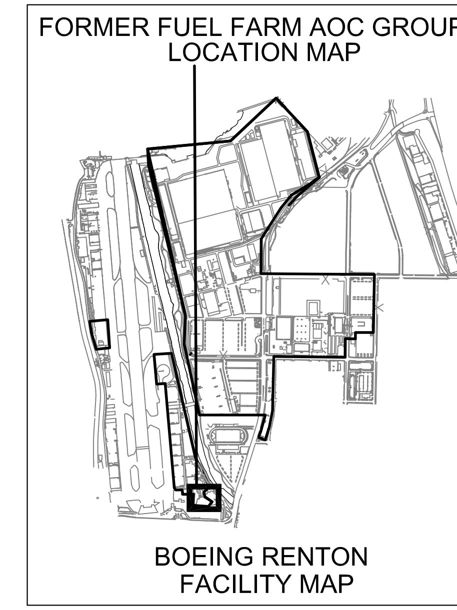

LEGEND

- PROPOSED SHALLOW MONITORING WELL
- PROPOSED INTERMEDIATE MONITORING WELL
- GW101 EXISTING MONITORING WELL LOCATION
- PP402 EXISTING PUSH PROBE LOCATION
- AS-204 EXISTING UNDERGROUND AIR SPARGING WELL
- BV112 EXISTING UNDERGROUND BIOVENTING WELL
- UNDERGROUND BIOVENTING LINE
- UNDERGROUND AIR SPARGING LINE
- FENCE
- APPROXIMATE TPH-JET SOIL AND GROUNDWATER SOURCE AREAS
- HIGHLIGHTED WELLS INCLUDED IN MONITORING NETWORK

NOTES

1. HORIZONTAL DATUM:
   WASHINGTON STATE COORDINATE SYSTEM
   NORTH ZONE NAD83 (91)
   VERTICAL DATUM:
   NATIONAL GEODETIC VERTICAL DATUM (NGVD1929)
2. BASEMAP COMPILED BY DUANE HARTMAN & ASSOCIATES, INC., DECEMBER 1994
3. PUSH PROBE LOCATIONS FROM FINAL REMEDIAL INVESTIGATION REPORT (WESTON, 2001a)
4. PIPING LOCATIONS APPROXIMATE

REMEDIAL ALTERNATIVE 1
FORMER FUEL FARM AOC GROUP
Boeing Renton Facility
Renton, Washington

By: APS	Date: 05/29/08	Project No. 8888
Geomatrix		Figure 10-3

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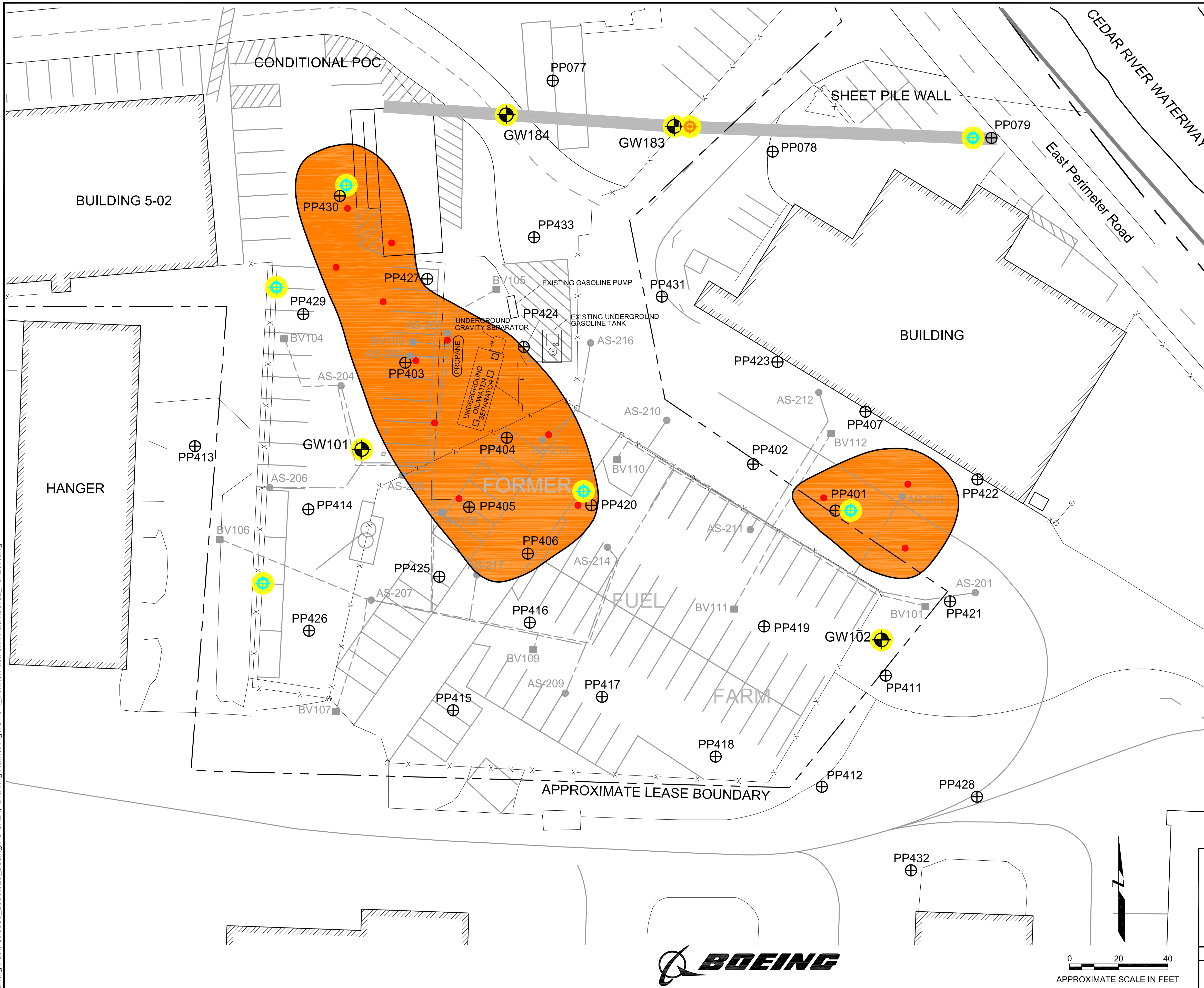

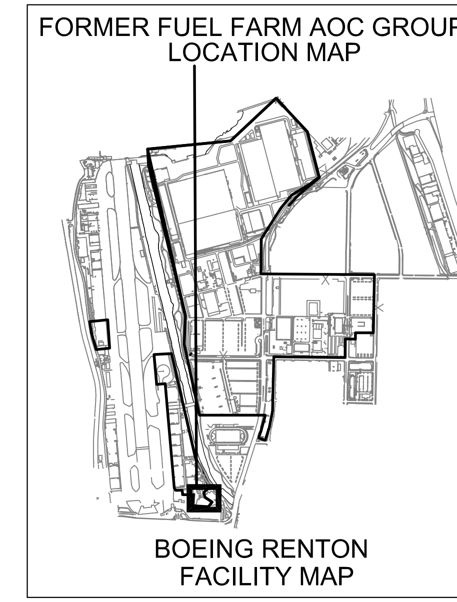

LEGEND

- PROPOSED ADDITIONAL SHALLOW AIR SPARGE WELLS
- PROPOSED SHALLOW MONITORING WELL
- PROPOSED INTERMEDIATE MONITORING WELL
- GW101 EXISTING MONITORING WELL LOCATION
- PP402 EXISTING PUSH PROBE LOCATION
- AS-204 EXISTING UNDERGROUND AIR SPARGING WELL
- BV112 EXISTING UNDERGROUND BIOVENTING WELL
- UNDERGROUND BIOVENTING LINE
- UNDERGROUND AIR SPARGING LINE
- FENCE
- APPROXIMATE TPH-JET SOIL AND GROUNDWATER SOURCE AREAS
- HIGHLIGHTED WELLS INCLUDED IN MONITORING NETWORK

NOTES

1. HORIZONTAL DATUM:
   WASHINGTON STATE COORDINATE SYSTEM
   NORTH ZONE NAD83 (91)
   VERTICAL DATUM:
   NATIONAL GEODETIC VERTICAL DATUM (NGVD1929)
2. BASEMAP COMPILED BY DUANE HARTMAN & ASSOCIATES, INC., DECEMBER 1994
3. PUSH PROBE LOCATIONS FROM FINAL REMEDIAL INVESTIGATION REPORT (WESTON, 2001a)
4. PIPING LOCATIONS APPROXIMATE

REMEDIAL ALTERNATIVE 2
FORMER FUEL FARM AOC GROUP
Boeing Renton Facility
Renton, Washington

By: APS | Date: 05/29/08 | Project No. 8888

Geomatrix | Figure **10-4**

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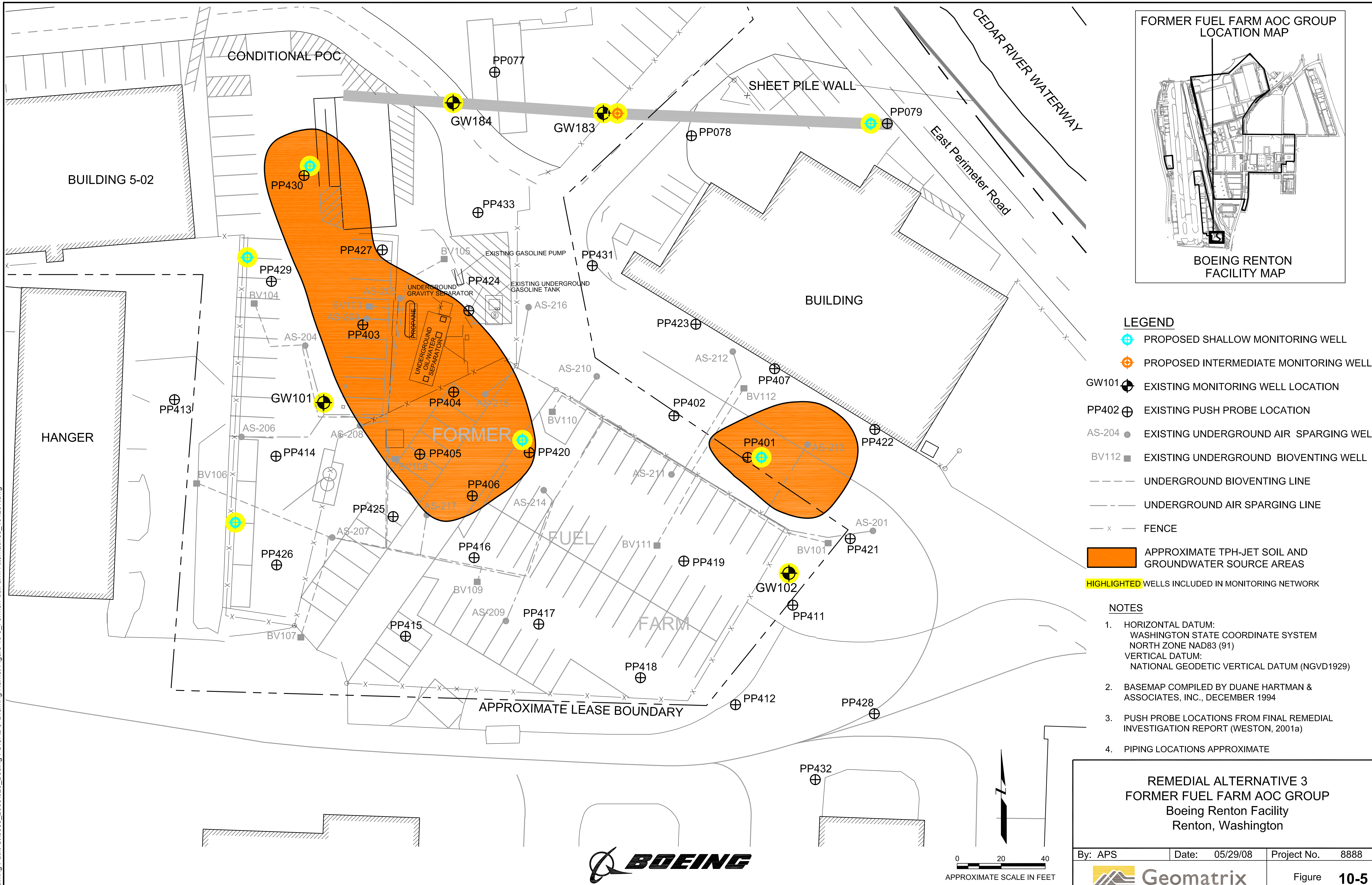

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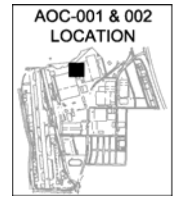
11.0 DEVELOPMENT AND EVALUATION OF REMEDIAL ALTERNATIVES, AOC-001 AND AOC-002

In this section we discuss remediation objectives, identify and evaluate remedial alternatives, and describe the preferred remedial alternative for AOC-001 and AOC-002. In documents prepared prior to the FS, AOC-001 and AOC-002 were addressed collectively with AOC-003, since they are located in the northern portion of the Renton Facility and because they have similar COCs. However, AOC-001 and AOC-002 are co-located and AOC-003 is almost 500 feet to the south. The final RI Report shows that affected groundwater associated with AOC-003 does not extend to AOCs-001 and -002. Additional investigation conducted after the final RI Report was prepared (Geomatrix 2004g) has identified a plume extending to the west from AOCs-001 and -002 that is larger than was identified in the final RI Report; this larger affected area has been designated as AOCs-001 and -002 in this FS. Because separate plumes are associated with AOCs-001 and -002 and with AOC-003, these AOCs have been separated for evaluation in this FS. AOCs-001 and -002 are addressed in this section of this FS report. Remedial alternatives for AOC-003 are presented and discussed in Section 12.0.

11.1 SITE CHARACTERIZATION SUMMARY

AOC-001 and AOC-002, two areas of concern, were originally associated with former USTs URE-01 and URE-02, respectively. The former steel USTs were located near the northwest corner of Building 4-81 in the northern portion of the Facility as shown in Figure 1-2. The Lake Washington shoreline is approximately 350 feet northwest of the former location of these USTs. Both USTs were installed in 1980 for storage of MEK and toluene. Each steel tank had a capacity of 500 gallons, and both tanks were placed within a cylindrical concrete vault for secondary containment.

After these USTs were removed in July 1986, toluene was detected in the water within the secondary containment structure. Subsequent subsurface investigation identified toluene and VC in groundwater samples collected in the area adjacent to URE-01 and URE-02 and in a large area just to the southwest. Section 5.4 of the final RI Report presents the complete RI characterization results for these units (Weston, 2001a). This area was subsequently investigated in several phases of post-RI investigation to further delineate the nature and extent of affected soil and groundwater. The results of the first two phases of the post-RI investigation were reported in the FSWP (Geomatrix, 2004c). Additional sampling was conducted after completing the FSWP. The results of the most recent, third phase of post-RI



investigation was reported to Ecology in a memorandum (Geomatrix, 2004g). The combined results of the RI investigation and all the post-RI investigations are summarized below.

11.1.1 Historical, Present, and Future Site Use

This northern portion of the Facility where AOCs-001 and -002 are located has been used for airplane manufacturing since before World War II. The area between Buildings 4-21 and 4-81 and Lake Washington is currently used for the outside storage of airplane jigs and miscellaneous parts. The area around AOCs-001 and -002 also serves as a tow path for partially completed aircraft. Due to the very high load-bearing capacity needed in this area, the concrete tarmac is commonly at least a foot thick and reinforced by rebar. These buildings and areas are currently used for industrial purposes and are expected to remain in industrial use for the foreseeable future.

11.1.2 Previous Site Remedial Actions

Two interim actions have been conducted for AOCs-001 and -002. The first was implemented in 1986 when the USTs in the source areas were removed. The second was conducted in 2005. Each interim action is described briefly below.

11.1.2.1 AOC-001 and -002 Interim Action, 1986

Both of the USTs at AOCs-001 and -002 were removed in July 1986. A total of 130 cubic yards of soil was removed from the URE-01 and URE-02 excavation following removal of the tanks and secondary containment vault. Groundwater near the tanks had contained dissolved toluene ranging from 0.2 to 100 mg/L. Approximately 4,600 gallons of water was pumped from the URE-01 and URE-02 excavation in an effort to remove the contaminated groundwater.

11.1.2.2 AOC-001 and -002 Interim Action, 2005

An interim measure was implemented for AOCs-001 and -002 in 2005 to address affected soil in the source area and to enhance bioremediation of groundwater constituents. This interim measure was implemented in accordance with a work plan approved by Ecology (Geomatrix, 2005); the work was performed in October and November 2005. The interim measure included the following:

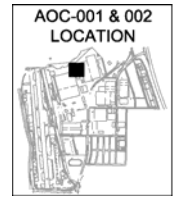
- Installation and sampling of nine direct push boreholes for collection of soil and groundwater samples to more thoroughly delineate the extent of affected soil near the source area;

- Excavation and off-site disposal of approximately 340 cubic yards of affected soil from the primary source area;
- Recovery and treatment of approximately 35,000 gallons of groundwater from the source area excavation;
- Installation of two injection lines for potential future injection of electron donor to enhance bioremediation;
- Placement of 4,800 lbs of food-grade sodium lactate and 6,300 lbs of emulsified food-grade vegetable oil to promote reductive dechlorination of site COCs in groundwater;
- Collection and analysis of soil samples to confirm attainment of cleanup levels;
- Backfill and restoration of the tarmac above the excavation; and
- Installation of eight new groundwater monitoring wells.

The results of the nine additional direct push boreholes were reported to Ecology in the Bimonthly Status Report (Geomatrix, 2005a). The interim measure work and confirmation sampling results were reported to Ecology in a memorandum dated January 27, 2006 (Geomatrix, 2006a). The new groundwater monitoring wells were installed as described in a memo dated April 26, 2006 (Geomatrix 2006b). Soil confirmation samples indicate that affected soil exceeding soil cleanup levels for AOCs-001 and -002 has been removed from the site. Confirmation data also indicate that soil affected with petroleum hydrocarbons has been removed from the source area. Groundwater monitoring data collected subsequent to the interim action indicate that biodegradation is active and that concentrations of chlorinated VOCs are decreasing.

11.1.3 Site Hydrogeology

The site hydrogeology was described in the final RI Report and is summarized here. The general stratigraphy beneath this area consists of fill and alluvium. Fill materials consist of greenish-brown fine- to medium-grained sand with silt and gravel. Beneath the fill, the alluvium consists of greenish-gray clayey silt to silty clay with a high content of organic matter represented by wood fragments and roots. Boring logs from the nine push probes conducted for the RI indicate that the depth of the contact between hydraulic fill materials and alluvium ranges from approximately 6 to 10 feet bgs. Boring logs from monitoring wells and the recent



deeper push probes show a lower permeability peaty silt layer directly underlying the alluvium from approximately 10 to 24 feet bgs (Weston, 2001a; Geomatrix, 2004c).

Groundwater levels measured during the RI (in monitoring wells GW049, GW050, GW051, and GW052) ranged from 1.4 to 3.2 feet bgs. Seasonal variations in groundwater levels during the RI ranged from 0.35 to 0.64 foot. Groundwater contours included in the final RI Report indicate that groundwater beneath this site flows to the northwest toward Lake Washington at an average gradient of approximately 0.001. Slug tests conducted in wells GW049, GW050, and GW051 indicated that the hydraulic conductivity of the shallow aquifer ranged from 1.4×10^{-3} to 5.0×10^{-3} cm/s.

Based on a geologic cross-section presented in the final RI Report and results of the recent investigation, it was determined that the predominant soil type in the limited vadose zone is silty to poorly graded sands, and the soil type dominating groundwater flow is also silty and poorly graded sands. Therefore, the dominant soil classification for both the limited vadose and saturated zones is SM; soil characteristics for SM soil are used for relevant calculations in this FS report.

11.1.4 Nature and Extent of Affected Soil

The results of the RI and post-RI investigations indicate that the site soils contained VOCs that exceeded the soil cleanup levels defined in the final FSWP (Geomatrix, 2004c). The analytical results from the recent soil investigations conducted at this site are summarized on Figure 11-1.

During the RI investigation, TCE (330 µg/kg) exceeded the PCL in a soil sample from PP011, near AOC-001, at a depth of 2 feet bgs. During the most recent push probe investigation, soil samples collected from PP136, PP137, and PP138 contained concentrations of COCs that exceed the soil cleanup level for silty sands. Soil samples from PP136 had *cis*-1,2-DCE and VC; soil samples from PP137 had VC; and soil samples from PP138 had TCE, *cis*-1,2-DCE, VC, TPH-G, and TPH-D (diesel and oil) at concentrations exceeding CULs. Soil samples from PP138 contained the highest concentrations of these constituents. Borings PP138 and PP151 had TPH-G detections that exceeded the TPH-G soil cleanup level. These soil samples were collected from an area located to the southwest of the former location of AOCs-001 and -002, which has been defined as the primary source area for AOC-001/002. The concentrations of these compounds in the later soil samples were several orders of magnitude higher than those seen in the earlier soil samples.

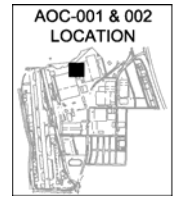
In sum, as shown on Figure 11-1, two source areas have been identified in AOC-001/002; the larger or primary source area is located in the vicinity of PP138, and the smaller or secondary source area is located in the vicinity of PP011, northwest of the primary source area and adjacent to the location of the former URE-01 and URE-02. As noted above, further delineation was conducted around the primary source area in support of the 2005 interim action. Affected soil exceeding soil cleanup levels has been removed from the primary source area, as shown in Figure 11-1 and described in Section 11.1.2.2.

11.1.5 Nature and Extent of Affected Groundwater

The nature and extent of affected groundwater associated with AOCs-001 and -002 have been delineated through the RI, Supplemental RI, and subsequent site investigations. Affected groundwater extends downgradient from the area identified as the primary soil source area in Section 11.1.4. Groundwater samples collected from direct push boreholes during the Supplemental RI and reported in the FSWP (Geomatrix, 2004c) and in a more recent investigation (Geomatrix, 2004g) contained dissolved chlorinated VOCs at concentrations exceeding cleanup levels defined in the FSWP. The extent of VC defines the extent of affected groundwater for this site. The nature and extent of VOC-affected groundwater is defined for the uppermost water bearing unit. The extent of affected groundwater is shown in Figures 11-2 and 11-3; the data plotted on Figure 11-3 are based on data from monitoring wells, which are more representative of present groundwater quality than are direct push samples plotted on Figure 11-2. The data of Figure 11-3 also reflect groundwater quality after the 2005 interim action. The groundwater quality data indicate that the extent of affected groundwater is limited to the area near the excavated source area (i.e., within about 250 feet of the primary source area).

The activities that caused the release of VOCs other than toluene and MEK in the area are not known. Given that PCE has not been detected, the primary solvent released appears to be TCE. The widespread presence of *cis*-1,2-DCE and VC indicates that biodegradation via reductive dechlorination is active at this site. Site investigation data also indicate that petroleum hydrocarbons, MEK, and acetone coexist with the chlorinated solvents over much of the area, but are below cleanup levels.

Groundwater samples collected below the lower permeability peaty silt layer underlying this site and downgradient from the primary source area did not exceed groundwater cleanup levels for any of the VOCs. Groundwater samples were not collected below the peaty silt layer in the



primary source area to minimize the chance for cross-contamination. The results of the downgradient groundwater sampling indicate that groundwater beneath the silty peat layer has not been affected by VOCs.

11.2 CONCEPTUAL SITE MODEL

A preliminary conceptual model for migration of constituents present in affected soil and groundwater at the Facility was presented in Figure 2-6 of the FSWP (Geomatrix, 2004c). Based on the conceptual model and considerations presented in the FSWP plus information specific to this site, a site-specific conceptual site model is described below. This site-specific conceptual site model identifies the media and exposure pathways that must be addressed for remedial alternatives potentially applicable to this site.

TCE, the degradation by-products of TCE, and TPH-G were present in soil within the AOCs-001 and -002 primary source area at concentrations exceeding cleanup levels. As shown in the Facility conceptual model presented in the FSWP, VOCs and TPH-G can migrate from the source area via groundwater or vapor pathways. For this site, migration via groundwater will be most significant. The groundwater level is very shallow at this site, with minimal vadose zone available for vapor phase transport. Constituent transport via groundwater at this site is affected by soil/groundwater interactions and biodegradation. As groundwater flows through soils affected by VOCs and TPH-G in the source area, adsorbed VOCs and petroleum hydrocarbons will dissolve into groundwater, as shown by the presence of VC, *cis*-1,2-DCE, and benzene in samples collected downgradient of the source area. Dissolved constituents will move with groundwater but at differing velocities because of continuing solute-soil interactions. Constituent migration has created a plume extending downgradient from the source area. TCE, *cis*-1,2-DCE, VC, and benzene are present in groundwater at concentrations exceeding the approved cleanup levels. These constituents are more likely to biodegrade in situ than to volatilize from the groundwater at this site.

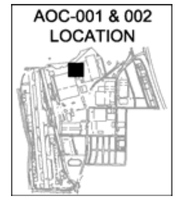
The extent of groundwater affected by dissolved VOCs appears to be limited to the uppermost groundwater zone and extends downgradient from the primary source area. The VOC-affected groundwater is migrating to the northwest and north from the source area toward the discharge area along the Lake Washington shoreline. Volatilization of constituents from groundwater is not significant for most workers at this site, as noted in the conceptual model presented in the FSWP.

11.3 SITE REMEDIATION OBJECTIVES AND CLEANUP STANDARDS

The remediation objectives for the Renton Facility were presented in Section 2.0 of this report. The remedial alternatives developed and evaluated for this site will be capable of attaining the remediation objectives and the cleanup standards presented in this section. As defined in the MTCA regulations, the cleanup standard consists of the cleanup level and the location or POC at which the cleanup levels must be met. The remedial alternatives for this site, presented below in Section 11.4, may have different points of compliance while fully addressing remediation objectives and meeting cleanup levels.

The groundwater and soil COCs exceeding the PCLs established in the final RI Report for AOCs-001 and -002 were identified in FSWP Tables 5-1 and 5-3, respectively. These constituents were identified by comparing detected constituent concentrations to the PCLs identified in the final RI Report; if a constituent concentration measured in any sample exceeded the PCL, the constituent was listed as a COC that must be addressed in the FS. Cleanup levels for both soil and groundwater that meet MTCA requirements were presented in the FSWP (Tables 5-6 and 5-2, respectively) and approved by Ecology. The cleanup levels for PCE, TCE, and VC presented in the approved FSWP were subsequently changed by Ecology; cleanup levels for these constituents were calculated as described in Section 3, based on negotiations and correspondence with Ecology. To confirm that the COCs listed in the FSWP included all constituents detected at concentrations exceeding the approved cleanup levels, the site soil and groundwater characterization data collected in the RI and post-RI investigations were compared to the approved cleanup levels listed in the FSWP. If concentrations for constituents that were not identified as COCs exceeded cleanup levels, it would be necessary to include them as COCs. If concentrations for previously identified COCs were below the approved cleanup levels, the constituent should be removed as a COC. Based on this comparison toluene was removed as a groundwater COC, but benzene was added because post-RI data indicated that benzene was detected at a concentration slightly above the cleanup level. Soil samples collected during post-RI investigations at AOCs-001 and -002 contained TCE, VC, *cis*-1,2-DCE, and TPH-G above the approved soil cleanup levels listed in the FSWP. Therefore, additional soil COCs for the site include *cis*-1,2-DCE and TPH-G.

It should be noted that PCE was originally listed as a groundwater COC for AOC-001/002 and AOC-003 in the final RI Report and the FSWP. However the only groundwater sample that contained PCE at concentrations exceeding the PCL during recent monitoring was located at



AOC-003. Therefore, PCE is not listed as a COC for AOCs-001 and -002 and it has been included as a COC for AOC-003 (see Section 12).

The soil and groundwater cleanup levels for the site COCs are listed in Tables 3-1 and 3-2, respectively. The soil cleanup levels are either MTCA Method A cleanup levels or site-specific MTCA Method C cleanup levels that are protective of groundwater at the CPOC and were calculated in accordance with the procedures described in the FSWP or in accordance with recent negotiations with Ecology. The groundwater cleanup levels listed in Table 3-2 were developed as described in Section 3 and in accordance with recent negotiations with Ecology. The cleanup levels are protective of surface water, human health, and the environment.

These cleanup levels are used in development and evaluation of remedial alternatives for AOCs-001 and -002 that include natural attenuation or enhanced in situ bioremediation.

11.4 SITE REMEDIAL ALTERNATIVES

Remedial alternatives that incorporate the remedial technologies presented in Section 4.0 have been identified and developed for AOCs-001 and -002. The alternatives specifically address site conditions, the site remedial objectives, and the approved soil and groundwater cleanup levels for AOCs-001 and -002. Development of these alternatives is based on present site conditions, considering the previously implemented interim actions. Two remedial alternatives have been considered for this site:

- Alternative 1: Enhanced Bioremediation and Monitored Attenuation
- Alternative 2: Monitored Natural Attenuation

The remedial alternatives to be evaluated for this site are described below. These alternatives are evaluated against the evaluation criteria in Section 11.5.

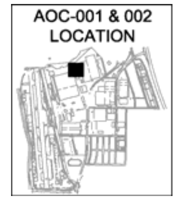
The AOCs-001 and -002 site is located in the north-central portion of the Renton Facility, near the northwest corner of Building 4-81. The Facility property line lies to the north of the site, with either Lake Washington or Washington Department of Natural Resources (DNR) land north of the property line. All on-site property adjacent to AOCs-001 and -002 is owned by Boeing and used solely for industrial purposes.

Site characterization data presented in the final RI Report and in post-RI sampling indicate that there are two source areas present in the site. The primary source area is located in the vicinity

of PP136, PP137, and PP138 (see Figure 11-1). The secondary source area is in the vicinity of the two former USTs (URE-01 and URE-02). In general, the primary source area had higher COC concentrations than the secondary source area. Both source areas are affected by chlorinated VOCs; the primary source area is also affected by TPH-G at concentrations exceeding cleanup levels. The primary source area is generally accessible and is not near any aboveground structures. The secondary source area is adjacent to substantial underground utilities, including a stormwater diversion structure and a stormwater wet vault (Figure 11-1). Affected soil in the primary source area was removed by excavation in October/November 2005, as described in Section 11.1.2.2.

A plume of affected groundwater exceeding cleanup levels for site COCs is present in the areas downgradient from the source areas. The area of affected groundwater is shown by the groundwater monitoring data on Figures 11-2 and 11-3; Figure 11-2 presents historic data collected from push probe borings, and Figure 11-3 presents more recent data collected from groundwater monitoring wells. The chlorinated VOC plume extends from just south of PP138 toward Lake Washington to just north of PP098. Laterally, the plume extends from about a location east of PP135 eastward to just west of PP013, which is located east of where the former USTs were located. The extent of the plume is generally defined based on the presence of VC (the most mobile degradation product) exceeding the cleanup level, as this is the most widespread groundwater COC and has the lowest cleanup level. AOCs-001 and -002 are located within the tow path used for moving partially completed aircraft from Building 4-81 to other portions of the Facility. This tow path is a significant site activity that will affect access to AOCs-001 and -002 for remedial construction. Use of the area as a tow path will also affect the design of any remediation system.

Site investigation data indicate that affected groundwater is present downgradient of the source areas. A groundwater sample collected from PP130, near the Lake Washington shoreline, was found to contain benzene at a concentration of 1.3 µg/L, just slightly above the cleanup level shown in Table 3-2. A groundwater sample collected from PP119, just northeast of PP130, had 380 µg/L of naphthalene, which exceeded the cleanup level in Table 3-2. The cleanup level for naphthalene is based on the MTCA Method B cleanup level for protection of human health; no ambient water quality criteria or drinking water criteria have been established for naphthalene. While Lake Washington has been designated as a potential source for public water supply, no potable water system is currently supplied from Lake Washington. Due to the isolated occurrence of naphthalene and benzene, the potential for natural biodegradation of these two



constituents in the subsurface environment, and the very low concentration of benzene detected, these two COCs will not be addressed by the remedial alternatives. However, these COCs will be included as monitoring parameters for all alternatives considered for this site.

MTCA requires that remedial alternatives selected for a site meet the MTCA threshold requirements for cleanup actions. The minimum threshold requirements specify that cleanup actions shall (1) protect human health and the environment, (2) comply with cleanup standards, (3) comply with applicable state and federal law, and (4) provide for compliance monitoring. To be considered as a potential remedial alternative for the site, the technologies considered had to pass the screening evaluation of the remedial technologies described in Section 4.0. In addition, the alternatives must meet the minimum threshold requirements established by MTCA and must be consistent with overall site conditions and land use. The remedial alternatives were also developed to consider the interim measures that have been implemented for AOCs-001 and -002.

Based on the screening evaluation, MTCA minimum threshold requirements, and the site considerations discussed above, two remedial alternatives addressing the significant site COCs were developed for AOCs-001 and -002, as described below.

11.4.1 Alternative 1: Enhanced Bioremediation and Monitored Attenuation

Remediation Alternative 1 for AOCs-001 and -002 includes enhanced bioremediation to actively degrade the chlorinated VOCs present in AOC-001/002 groundwater and source area soils. As noted previously, affected soil within the primary source area was removed as an interim measure; enhanced bioremediation within the primary source area was also implemented as an interim measure.

The specific elements included in this remediation alternative are as follows:

- Enhanced anaerobic bioremediation of chlorinated VOCs in the groundwater plume and the secondary source area by addition of electron donor and nutrients, as appropriate;
- Monitored attenuation for groundwater using both existing and new monitoring wells located appropriately along the POC;
- Institutional Controls:

- Deed recordation noting the location and nature of historical USTs and previous releases in the AOCs-001 and -002 area;

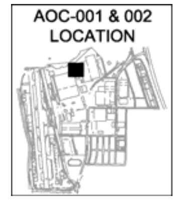
- Covenants and deed restrictions to address potential risks to human health that may remain as a result of residual soil constituents and affected groundwater;

- Points of Compliance: A CPOC established in accordance with procedures developed by Ecology to be protective of water quality in Lake Washington.

The source removal and enhanced bioremediation already implemented in the primary source area has been effective in substantially reducing constituent concentrations. The most recent groundwater monitoring data (see Figure 11-3) demonstrate rapid attenuation of chlorinated VOCs as groundwater flows toward Lake Washington. Analysis of confirmation samples collected during the interim measure indicate that soils exceeding the soil cleanup levels (which were present only within the primary source area) have been removed. Enhanced biodegradation of chlorinated VOCs within the plume would permanently destroy groundwater COCs through biodegradation. Available data from post-interim measure groundwater monitoring indicate that the chlorinated VOCs are being degraded to nontoxic end products. Institutional controls to protect human health would be implemented during implementation of the enhanced biodegradation program and would be continued until cleanup levels are attained throughout the plume and source areas. For this remedial alternative, MA would be conducted using a CPOC that would be established between the Lake Washington shoreline and the source areas. Site-specific groundwater cleanup levels established in accordance with procedures developed by Ecology would be attained at the CPOC. The preliminary design of the enhanced bioremediation and groundwater monitoring program and the projected location of the CPOC are shown on Figure 11-4.

11.4.1.1 Containment by Capping

The area around AOC-001/002 is essentially capped by the existing tarmac. Due to the heavy industrial use of this area, the concrete tarmac is 12 to 18 inches thick. The tarmac is also sloped to promote runoff, which is collected in existing storm sewers. This tarmac functions as a cap and would limit the potential for soil COCs to leach into groundwater and limit the potential for direct exposure of human or ecological receptors to soil or groundwater COCs. By significantly limiting recharge into the AOC-001/002 area, the tarmac would reduce groundwater flow velocities and increase the travel time for groundwater flowing toward Lake Washington. The increased travel time would improve conditions for biodegradation of



groundwater constituents. The existing concrete tarmac cover over AOC-001/002 would improve the performance of this remedial alternative.

11.4.1.2 Enhanced Bioremediation and Monitored Attenuation

Alternative 1 includes enhanced bioremediation and MA to address affected groundwater and any remaining affected soil within the saturated zone at AOC-001/002. The reductive dechlorination processes that are active at this site would be enhanced by further addition of electron donor and nutrients, as appropriate. By increasing the concentration of electron donor and any nutrients that may be deficient, biological activity would be enhanced and the rate of biodegradation would increase, thereby destroying the chlorinated solvents and their degradation products. An electron donor (such as molasses, lactate, or emulsified vegetable oil) would be injected into affected groundwater along the upgradient edge of the plume and source areas, as shown on Figure 11-4. The conceptual enhanced bioremediation design developed for this alternative includes the injection lines placed in the primary source area during the 2005 interim measure and three new injection wells located at the secondary source area. This preliminary design addresses both source areas and the two “legs” of the plume, as described above. Each injection well at the secondary source area would be installed to the top of the silt/peat layer underlying the site, at an approximate depth of 10 to 12 feet bgs. The wells would be screened through the entire saturated zone, with the top of the screen at about 2 feet bgs. A mobile system consisting of tank, mixers, and pumps would be used to inject electron donor and nutrients as needed into each injection well and into the two injection pipe risers located in the primary source area. Electron donor injected into these wells and risers would cover the constituent source areas and move downgradient as the groundwater moves, eventually covering the affected groundwater area and saturated soils within the two source areas. The quarry spalls used to backfill the primary source area would provide a long-term reservoir of electron donor in the most highly contaminated portion of AOC-001/002.

Based on this conceptual design, a total of three new injection wells would be installed. It has been assumed that six injection events over a 3-year period would be sufficient to achieve full degradation of groundwater COCs within the secondary source area. For the conceptual design, it has been estimated that 600 pounds of sodium lactate would be injected for each event, to be divided equally among the three injection wells.

As noted previously, electron donor was placed into the primary source area as part of the interim measure. A second injection event for the primary source area was completed in 2007

as an interim measure (Geomatrix, 2007). Based on these two injection events for the primary source area, it has been assumed that one additional injection event using the same volume of electron donor and injection methods described in the work plan (Geomatrix, 2007) will be necessary to fully attain the cleanup standard for this site. It has been assumed that a combined total of 11,000 gallons of emulsified vegetable oil will be injected into IPR1 and IPR2.

Preliminary modeling using BIOCHLOR indicates that biodegradation would be effective in attaining cleanup levels at the CPOC shown on Figure 11-4. Details concerning the BIOCHLOR modeling are presented in Appendix A.

Monitored attenuation would be accomplished using a network of groundwater monitoring wells to assess the effectiveness of enhanced bioremediation and confirm that the cleanup standard is met while the plume is being treated. Since the plume extends downgradient from the two source areas, an on-site CPOC would be used to ensure the cleanup standard is being attained during the bioremediation program. The assumed location for the CPOC is near the shoreline of Lake Washington, as shown on Figure 11-4. It is expected that enhanced bioremediation will attain the standard POC in the future, after biodegradation processes have proceeded to completion. Due to the similarities between enhanced bioremediation and natural attenuation, the conceptual MA program for this alternative has been designed to address guidance for MNA as discussed in Section 4.2.4.

The MA monitoring program for AOCs-001 and -002 would be designed to:

- Demonstrate that biodegradation is occurring and is the primary mechanism for attenuation of site COCs;
- Identify any potentially toxic and/or mobile transformation products;
- Verify that the plume is not expanding beyond the CPOC;
- Verify that cleanup levels are attained at the CPOC;
- Verify that there is no unacceptable impact to potential downgradient receptors;
- Detect new releases of COCs that could impact the effectiveness of the remedy;
- Demonstrate the efficacy of the institutional controls to protect potential receptors; and
- Verify attainment of remediation objectives.

For this alternative, a detailed MA monitoring plan would be developed to document the monitoring program. This plan would identify existing and additional monitoring wells and analytes that would be required for both characterization/validation sampling and long-term groundwater monitoring. Characterization/validation sampling would be done during the initial implementation to demonstrate the effectiveness of enhanced bioremediation with respect to COC mass reduction, attenuation rates, and temporal trends. Long-term monitoring would be used after the characterization/validation sampling program was completed to confirm that the COC plume is progressing toward and eventually attaining numerical cleanup goals.

For this conceptual program, it was assumed that characterization/validation sampling would consist of quarterly monitoring of nine monitoring wells for a minimum of 1 year after implementation of Alternative 1. The conceptual design for the monitoring system includes nine existing wells shown in Figure 11-4. The types of wells installed would be nested monitoring wells that include shallow wells (approximately 10 to 15 feet bgs) and deep wells completed just below the silt/peat layer (approximately 35 feet bgs). Monitoring parameters and analytes for each of these wells would include all groundwater COCs for AOC-001/002 listed in Table 3-2. Analyses during the first 1 to 2 years of quarterly monitoring would include the full suite of MNA geochemical parameters for chlorinated solvent plumes [dissolved oxygen, nitrate, Fe(II), sulfate, methane, temperature, pH, specific conductance, alkalinity, oxidation/reduction potential, and TOC]. For the conceptual design, it was assumed that quarterly sampling would be conducted for 2 years, data reporting for characterization/validation sampling would follow each quarterly sampling event, and an annual report would be prepared evaluating and discussing the monitoring data.

Long-term groundwater monitoring would follow the initial characterization/validation sampling program. For the conceptual design used in this FS, it was assumed that quarterly sampling would be conducted for 2 years followed by long-term semiannual monitoring for an additional 13 years (15 years of monitoring total). The sampling frequency and the duration of the groundwater monitoring program would be based on the results of performance monitoring, and may be adjusted as appropriate. The long-term semiannual sampling was assumed for the five CPOC wells for the AOC-001/002 groundwater COCs listed in Table 3-2 and a limited suite of geochemical parameters (dissolved oxygen, oxidation/reduction potential, temperature, and pH). The full suite of MNA geochemical parameters would be analyzed in samples collected once every 5 years from all nine wells. It was also assumed that long-term groundwater monitoring results would be reported to Ecology annually.

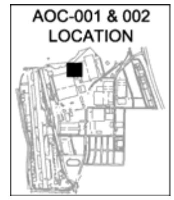
11.4.1.3 *Institutional Controls*

Institutional controls would be incorporated into this alternative to ensure it is fully protective of human health and the environment. Institutional controls are necessary because it is expected that some COCs may remain within site soil and groundwater during implementation of the enhanced bioremediation program while biodegradation is active. In general, the institutional controls that would be incorporated into this remedial alternative would be a continuation of the controls that have been implemented at the Renton Facility and that have been proven effective. These institutional controls would be established such that they are legally enforceable for current and future landowners.

The nature and location (including depth) of the former USTs and known releases at AOCs-001 and -002 would be recorded on the deed to the property. This recordation would identify the nature of the releases from these units and inform any future landowners of potential human health or ecological issues related to the release. This alternative would also include deed restrictions that would limit future use of the site to industrial purposes. The deed restriction would require additional remedial actions to attain unrestricted cleanup levels prior to supporting nonindustrial site use. The remedial actions would need to demonstrate compliance with soil and groundwater cleanup levels appropriate for unrestricted site use.

An institutional control restricting the recovery and use of groundwater beneath and downgradient of the site would be implemented. This control would apply to the two source areas defined within AOCs-001 and -002 and the downgradient area extending to the Lake Washington shoreline. Recovery of groundwater in this area for any purpose other than construction dewatering would be prohibited.

Institutional controls requiring specific and appropriate health and safety procedures would be implemented for conducting any subsurface work in the immediate vicinity of the source areas and in the downgradient plume. These controls would be a continuation of institutional controls already in place at the Facility. These controls would cover all subsurface work, including excavation and installation or maintenance of underground utilities. In the downgradient plume areas where only affected groundwater is present, the institutional controls would require appropriate health and safety procedures for subsurface work, such as excavation below the water table, where direct contact with affected groundwater or inhalation of vapors released from groundwater may occur.



11.4.2 Alternative 2: Monitored Natural Attenuation

Remediation Alternative 2 incorporates MNA rather than enhanced bioremediation to destroy site COCs within affected groundwater. All other elements of this alternative are the same as described above for Alternative 1 (i.e., containment by concrete tarmac that would effectively cap the affected area, groundwater monitoring, and institutional controls). The specific elements included in this remediation alternative are as follows:

- MNA using a network of monitoring wells located along a CPOC to address dissolved COCs within the groundwater plume;
- Institutional Controls:
    - Deed recordation noting the location and nature of historical USTs and previous releases in the AOC-001/002 area;
    - Covenants and deed restrictions to address potential risks to human health that may remain as a result of residual soil constituents and affected groundwater;
- A CPOC established in accordance with procedures developed by Ecology to be protective of water quality in Lake Washington.

Affected soil exceeding soil cleanup levels has been excavated and removed from the primary source area as part of an interim measure, as described in Section 11.1.2.2. Chlorinated VOCs within the plume would be permanently destroyed by natural attenuation reactions, which have been demonstrated to include active biodegradation of chlorinated VOCs to nontoxic end products. The monitoring well network along the CPOC would ensure that the natural attenuation processes attain the cleanup standard. The conceptual monitoring well network for this alternative is the same as for Alternative 1, and is shown on Figure 11-4.

11.4.2.1 Containment by Capping

The AOCs-001 and -002 area is essentially capped by the existing tarmac, as discussed in detail for Alternative 1 in Section 11.4.1.1.

11.4.2.2 Monitored Natural Attenuation

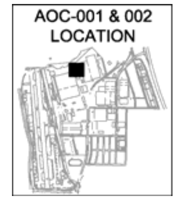
MNA would be used to attain the groundwater cleanup levels at a CPOC established upgradient from the Lake Washington shoreline, as shown on Figure 11-4. Based on the POC approach presented in Section 6 of the FSWP, and as modified in negotiations and correspondence with Ecology, fate and transport groundwater modeling using BIOCHLOR was conducted to evaluate the potential efficacy of MNA as a final remedy for the AOC-001/002 site. The

modeling followed the protocol established in the FSWP and in subsequent negotiations and correspondence with Ecology using the approved model input parameters presented in the FSWP. The BIOCHLOR model was calibrated using groundwater data for AOC-001/002 collected during and subsequent to the RI. Modeling indicates that natural attenuation may attain the cleanup levels for the groundwater COCs (TCE, *cis*-1,2-DCE, and VC) at the CPOC shown in Figure 11-4 given sufficient time to achieve them. Details regarding the modeling are presented in Appendix A.

In accordance with MNA guidance and the approach discussed in Section 4.2.4, the conceptual monitoring program for AOCs-001 and -002 is designed to:

- Demonstrate that natural attenuation is occurring and that biodegradation is the primary process contributing to the decrease in concentration for site COCs;
- Identify any potentially toxic and/or mobile transformation products;
- Verify that the plume is not expanding beyond the CPOC;
- Verify that applicable cleanup levels are attained at the CPOC;
- Verify that there is no unacceptable impact to potential downgradient receptors;
- Detect new releases of COCs that could impact the effectiveness of the natural attenuation remedy;
- Demonstrate the efficacy of the institutional controls to protect potential receptors; and
- Verify attainment of remediation objectives.

For this alternative, a detailed MNA monitoring plan would be developed to document the monitoring program. This plan would identify existing and additional monitoring wells and analytes that would be required for both characterization/validation sampling and long-term groundwater monitoring. Characterization/validation sampling would be used to demonstrate the effectiveness of MNA with respect to COC mass reduction, attenuation rates, and temporal trends. Long-term groundwater monitoring would be used after the characterization/validation sampling program was completed to confirm that the COC plume is progressing toward achievement of numerical cleanup goals. The preliminary groundwater monitoring network for this alternative is shown in Figure 11-4.



For this conceptual program, it was assumed that characterization/validation sampling would consist of quarterly monitoring of nine monitoring wells for a minimum of 1 year after implementation of Alternative 2. It was assumed that the monitoring well network would include nine existing wells to effectively monitor potential plume migration and attainment of the cleanup standard. Monitoring parameters and analytes for each of these wells would include all groundwater COCs listed for AOC-001/002 in Table 3-2 plus the full suite of MNA geochemical parameters for chlorinated solvent plumes [dissolved oxygen, nitrate, Fe(II), sulfate, methane, temperature, pH, specific conductance, alkalinity, oxidation/reduction potential, and TOC]. For the conceptual design used in this FS, it was assumed that data reporting for characterization/validation sampling would follow each quarterly sampling event and an annual report would be prepared evaluating and discussing the monitoring data.

Long-term groundwater monitoring would follow the initial characterization/validation sampling program, which was assumed to last 2 years for cost estimation purposes. The long-term monitoring would be conducted for an additional 13 to 14 years (15 years of monitoring total), with semiannual sampling of the five CPOC wells for the groundwater COCs for AOC-001/002 presented in Table 3-2 and a limited suite of geochemical parameters (dissolved oxygen, oxidation/reduction potential, temperature, and pH). To monitor overall plume control, all nine wells would be analyzed once every 5 years for the full list of characterization/validation analytes. For the conceptual design of this alternative, it was assumed that long-term groundwater monitoring results would be reported to Ecology annually.

11.4.2.3 Institutional Controls

The institutional controls for Alternative 2 would be the same as those described above in Section 11.4.1.3 for Alternative 1. Institutional controls would be required during the implementation of the MNA program and continue until general cleanup levels are attained throughout the site. The institutional controls for this alternative would include the deed recordation and health and safety procedures discussed previously for Alternative 1. The proven institutional controls currently being implemented at the Renton Facility would continue.

11.5 EVALUATION OF SITE REMEDIAL ALTERNATIVES

As previously discussed, the two remedial alternatives developed for this site meet the MTCA minimum requirements for cleanup actions. This section compares and evaluates the alternatives based on the MTCA criteria of protectiveness and risk reduction, permanence, cost,

long-term effectiveness, management of short-term risks, technical and administrative implementability, public concerns, and restoration time frame. An evaluation of each alternative with respect to these evaluation criteria is summarized in Table 11-1 and is discussed below.

11.5.1 Protectiveness and Risk Reduction Evaluation

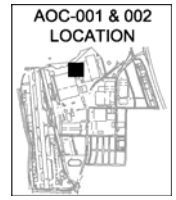
Protectiveness and risk reduction are gauged primarily on the time required for the alternative to reduce risk associated with the site and to meet cleanup levels. Both site alternatives provide good protectiveness and risk reduction. Both alternatives are expected to attain cleanup levels. Alternative 1 is rated slightly higher for this criterion because it would be expected to achieve cleanup levels in a shorter time than Alternative 2.

11.5.2 Permanence

Permanence refers to the ability to reduce the toxicity, mobility, or volume of hazardous substances, including the permanent destruction of hazardous substances. For this site, the two alternatives would provide an equivalent degree of permanence. Both alternatives would result in the removal or destruction of site COCs in groundwater. The two alternatives were rated equal for this criterion.

11.5.3 Cost

The cost evaluation includes all costs related to implementation of an alternative, including initial design and construction costs, operation and maintenance costs, monitoring costs, and reporting costs. The annual costs for operation, maintenance, monitoring, and reporting are recurring costs that occur in the future. The cost evaluation considers initial implementation costs and future recurring costs using NPV analysis. For NPV calculation, recurring costs were inflated 2% annually, and a discount rate of 7% was used. Details regarding the cost estimates for the three alternatives are presented in Appendix B. The present value costs for the two alternatives, in 2007 dollars, are summarized below:



Alternative	Net Present Value
1: Enhanced Bioremediation, and Monitored Attenuation	$524,000
2: Monitored Natural Attenuation	$466,000

As shown by these costs, Alternative 1 has the higher NPV cost. Therefore, Alternative 2 ranks higher for cost.

11.5.4 Long-Term Effectiveness

Long-term effectiveness includes the degree of certainty and reliability of the alternative and whether treatment residue remains from the alternative that will require management. The two alternatives considered for this site utilize proven technologies and both have good long-term effectiveness. Neither alternative would produce residual waste that would require management at an off-site facility. Both alternatives rely on in situ biological processes to destroy soil and groundwater COCs. Alternative 1, which includes enhanced bioremediation, would require active operation to achieve a faster remediation, while Alternative 2, which relies on natural attenuation, is a passive process with no active operating requirements. Alternative 1 was ranked higher for long-term effectiveness because it would attain cleanup objectives faster than Alternative 2.

11.5.5 Management of Short-Term Risks

Short-term risk refers to the risk to human health and the environment during implementation of the alternative. Since both alternatives require minimal invasive construction, both were ranked medium high for this criterion.

11.5.6 Technical and Administrative Implementability

This criterion gauges whether the alternative is technically possible relative to complexity, administrative/regulatory requirements, size, access, and integration with existing operations. Alternative 1 would require minor permitting and minor waste manifesting (disposal of well cuttings). Due to the minor difference between the two alternatives, both were ranked equal for this criterion.

11.5.7 Public Concerns

This criterion assesses potential community concerns with implementation of the alternative. Since both alternatives deal only with an industrial facility and the CPOC would be located on site, they are expected to have minimal potential for public concern. Both alternatives were given a high ranking for having low public concerns.

11.5.8 Reasonable Restoration Time Frame

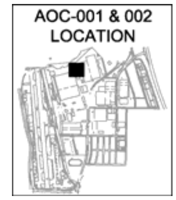
Restoration time frame looks at the practicability of a shorter restoration time frame with consideration given to a number of factors, including site risks, site use and potential use, availability of alternative water supply, effectiveness and reliability of institutional controls, and toxicity of hazardous substances at the site. As a whole, these factors are a measure of the urgency of reducing risk and achieving cleanup goals for the site. Given that the site is an industrial facility and that no imminent risks have been identified, both alternatives would achieve a reasonable restoration time frame and were ranked equal for this criterion.

11.6 SELECTION OF THE PREFERRED SITE REMEDIAL ALTERNATIVE

Selection of a preferred alternative under MTCA requires that a preference be given to alternatives that use permanent solutions (to the maximum extent practicable), provide for a reasonable restoration time frame, and consider public concerns. The analysis below defines the baseline alternative for AOCs-001 and -002 and compares the other alternative to the baseline alternative based on the degree of permanence, reasonable restoration time frame, and the degree to which it addresses potential public concerns. Based on this comparison, the preferred remedial alternative is identified and proposed for selection as the cleanup action to be implemented for the AOC-001/002 site.

11.6.1 Baseline Remedial Alternative

The evaluation of the two remedial alternatives for this site is summarized in Table 11-1. Neither of the alternatives is capable of attaining the standard POC at this site. Facility manufacturing activities limit active remediation that can be conducted within the plume and source areas. Affected groundwater extends beneath the tow-path for partially completed aircraft, and daily access to the tow path is critical to ongoing industrial activities. Access to the tow-path is controlled very strictly. Therefore, it is not practicable to fully remediate affected soil and groundwater without disrupting critical manufacturing processes.



Based on the remedial alternative evaluation presented above and summarized on Table 11-1, the two remedial alternatives were both ranked medium high for permanence. While the two alternatives were ranked equal for permanence, Alternative 1, Enhanced Bioremediation and MA, would achieve cleanup levels more rapidly than Alternative 2, which relies on natural attenuation to degrade constituents in the groundwater plume. Therefore, Alternative 1 is defined as the baseline remedial alternative. This alternative provides for enhanced biological activity to destroy groundwater COCs and provides the shortest remediation time. Neither alternative would generate significant residual waste (other than monitoring wastes) that would be ultimately managed in an off-site facility.

11.6.2 Comparison to Baseline Alternative

As noted above, Alternative 1 has been defined as the baseline remedial alternative for this site. Alternative 2 will be compared to the baseline alternative in the following subsections for selection of the preferred alternative. The purpose of this comparison is to assess the benefits and costs for Alternative 2 relative to Alternative 1. The evaluation criteria presented above and in Table 11-1 were established in accordance with the MTCA requirements cited in WAC 173-340(3)(f). Costs for the alternatives will be based on the NPV, which reflects the total cost associated with each alternative over the 15-year time period evaluated. The evaluation of benefits will be qualitative.

The benefits to be assessed in this comparison and the relative rating for the alternatives are presented in Table 11-2. The rationale for this comparison is presented below.

- **Reduced risk to on-site worker health.** Both alternatives would be equal in reducing risk to site workers because they would be equally protective. Although the baseline alternative would remove volatile COCs within a few years, potential risks to on-site workers are minimal, as the AOC is located beneath the tarmac, with minimal potential for worker exposure. Due to the low potential for worker exposure, potential risks to site workers would not be changed substantially by either alternative. The institutional controls included in each of the alternatives have been proven effective in protecting worker health and would continue to be protective.

- **Reduced risk to off-site human health.** Both alternatives were rated high for this benefit. Both would attain the cleanup level at the CPOC, which is protective of human health and the environment. The institutional controls included in the alternatives that have proven to be protective of worker health on site would also be protective of human health in off-site areas located upgradient of the CPOC. The

existing, well maintained surface cover would limit the potential for exposure to soils, to soil vapors, and would limit erosion.

- **Reduced risk to the environment.** Both alternatives were rated high for this benefit. Both alternatives would be protective of the aquatic environment because they would attain the cleanup levels at the CPOC. As noted above for human health exposure, both alternatives would equally limit potential exposure pathways.

- **Minimal adverse impact on Facility operations.** The baseline alternative was rated moderate for this benefit because it would impact Facility operations during installation of the enhanced bioremediation system and would require long-term operation and periodic injection of substrate. A high rating was given to Alternative 2, which would rely on passive degradation of site COCs and would have the least impact on Facility operations.

- **Minimal restrictions on Facility traffic and access.** The baseline alternative was rated moderate for this benefit because it would impact Facility traffic and access during installation of the enhanced bioremediation system and during operation. Additional impact would occur during periodic addition of substrate. Alternative 2 was given a high rating because it would affect traffic only during installation of monitoring wells, resulting in the least impact on Facility traffic and access.

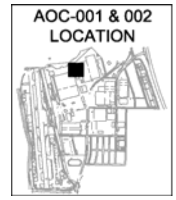
- **Minimal adverse impact on Facility structures and utilities.** The baseline alternative and Alternative 2 were both rated high for minimizing adverse impacts on facility structures and utilities. Neither of these two alternatives would potentially affect the integrity of site improvements.

The potential benefit evaluation for the alternatives shows that Alternative 2, Monitored Natural Attenuation, would provide the greatest benefit due to reduced impacts on Facility traffic, access, structures, and utilities. While both alternatives would provide comparable protection of human health and the environment, Alternative 1 would provide more rapid restoration time and is the more permanent alternative.

The NPV costs for both alternatives were presented in Section 11.5.3. The baseline alternative ranks second among the alternatives and would have the higher cost (approximately 12% higher than the cost for Alternative 2).

11.6.3 Preferred Remedial Alternative

The baseline remedial alternative, Alternative 1, has been selected as the preferred cleanup action for this site. Benefits for the two remedial alternatives are compared in Table 11-2. Alternatives 1 and 2 would generally provide comparable benefits. The baseline alternative



(Alternative 1) would provide a more rapid restoration time frame and would also have a greater impact on facility operations. As noted in Section 11.5.3, the NPV cost for implementation of the two alternatives is not substantially different. While the cost for the baseline alternative is greater than the cost for Alternative 2, this cost difference (approximately 12%) is not considered disproportionate. The previously implemented interim measure has removed much of the affected soil exceeding the soil cleanup levels, thereby reducing the source strength. The existing concrete tarmac cover would eliminate runoff and limit infiltration of surface water. Enhanced bioremediation would rapidly and permanently destroy constituents present in groundwater. The MA program would ensure that the cleanup standard is attained. The proven institutional controls would continue to be implemented to ensure that worker health and safety continue to be maintained.

Alternative 1 would achieve the expectations for cleanup actions cited in the MTCA regulations at WAC 173-340-370 (1) – (8). Only those expectations relevant to large, complex sites are considered relevant to AOC-001 and -002. The relevant expectations are addressed as follows:

- **Implement Treatment at Sites with Liquid Wastes, High Contaminant Concentrations, Highly Mobile Materials, or Discrete Areas of Contamination.** Ecology expects that treatment will be emphasized for sites meeting these general criteria. Under the previously implemented interim measure, soil with high COC concentrations has been removed from the site and groundwater has been treated to destroy the COCs to acceptable levels. While remaining COC concentrations are significant, they are being actively remediated by enhanced bioremediation and have decreased substantially in the past year. Site characterization data provide no evidence of liquid wastes at the site. Enhanced bioremediation followed by MA will degrade or "treat" organic COCs using in situ natural processes that result in nontoxic degradation products.

- **Destroy, Detoxify, or Remove Hazardous Substances.** Ecology expects that hazardous substances will be destroyed, detoxified, or removed to below cleanup levels. The 2005 interim measure included excavation and off-site treatment/disposal of affected soil and in situ bioremediation of source area groundwater. The ongoing and proposed enhanced bioremediation for in situ treatment of remaining soil and groundwater will leave only nontoxic degradation products. The preferred alternative would fulfill these expectations.

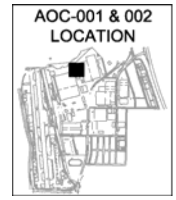
- **Implement Engineering Controls for Low Contaminant Concentrations.** Ecology recognizes the need for containment for low concentrations of contaminants where treatment is impracticable. Under the 2005 interim measure, only low concentrations remain within the primary source area. The ongoing and

proposed enhanced bioremediation will leave only very low COC concentrations at the site. The concrete tarmac will provide effective containment for residual COCs at the site.

- **Prevent Runoff of Hazardous Substances.** Ecology expects that cleanup actions will include active measures to prevent precipitation from creating runoff that contains affected soil. This expectation would be met by the preferred alternative because the source area is entirely covered by concrete tarmac. This surface cover is integral to Boeing's activities at the site and is well maintained. In addition to preventing runoff from contacting hazardous substances, the pavement minimizes surface water infiltration, thus resulting in decreased groundwater flow rates and increased time for groundwater to flow from the source areas to the lake.

- **Prevent Runoff and Groundwater Discharge to Surface Water.** Ecology expects that the cleanup action would include active measures to prevent or minimize releases to adjacent surface water bodies via runoff or groundwater discharge, and that dilution will not be the sole method for attaining cleanup levels. Alternative 1 would meet this expectation. Available groundwater monitoring data indicate that enhanced biodegradation of organic COCs is active and significant at this site, and that groundwater COCs have likely not discharged to the lake at concentrations exceeding cleanup levels. The natural degradation process would be enhanced by the remedial alternative, resulting in more rapid degradation. The presence of nontoxic degradation by-products in monitoring samples collected at AOCs-001 and -002 (Geomatrix, 2006c) shows that degradation is active and that dilution is not the predominant mechanism for reducing COC concentrations. The cleanup alternative also includes a groundwater monitoring network and program that would confirm that cleanup levels would be attained in groundwater at a CPOC established using methods established by Ecology.

- **Ensure Appropriateness of Natural Attenuation.** Ecology expects that natural attenuation may be appropriate if source control has been conducted to the maximum extent practicable; contaminants remaining on site do not pose unacceptable risks to human health and the environment; evidence indicates that degradation is occurring and will continue to occur at a reasonable rate; and appropriate monitoring is being conducted. The expectations for natural attenuation would all be achieved by Alternative 1. Source removal has been completed for the site. Treatment is also ongoing under the interim action, and further treatment would be provided through additional enhanced bioremediation. These actions have significantly reduced COC concentrations within the source area and would continue to reduce concentrations in the downgradient groundwater plume. Preliminary modeling has indicated that natural attenuation of constituents leaching from remaining source area soils would attain site-specific cleanup levels prior to reaching the CPOC defined for this alternative. Site characterization data indicate that COC concentrations would not cause risks to on-site workers. The institutional controls included in the preferred alternative have been implemented by Boeing for



several years and have been proven effective in protecting human health and the environment at this site. Groundwater monitoring data indicate that biodegradation of organic COCs is active at the site; the high organic fraction in site soil is expected to maintain conditions favorable to continued active biodegradation. Alternative 1 also includes a robust groundwater monitoring program designed to address EPA guidance for MNA of chlorinated VOCs. The monitoring system included in the preferred alternative would confirm that cleanup levels are attained prior to groundwater discharging to the Lake Washington.

The preferred remedial alternative would be designed to comply with applicable regulations. Potentially applicable regulations are listed in Table 11-3. These regulations govern the design, installation, and operation of remediation systems. For the preferred alternative at AOCs-001 and -002, several regulatory requirements must be met. Construction for the preferred alternative would be limited to installation of three injection wells.

The primary regulations governing the preferred alternative would be the MTCA regulations, the Washington well drilling regulations for monitoring wells, the solid waste disposal regulations, the dangerous waste regulations, the transportation regulations for disposal of well installation and sampling wastes the Underground Injection Control regulations, the Department of Labor and Industries health and safety regulations for all site related work, and the Shoreline Management Act. Well drilling rules specify well design and drilling requirements. Underground injection control regulations must be addressed for injection of electron donor for enhanced bioremediation. The solid waste regulations and the dangerous waste regulations specify waste characterization, manifesting, and disposal requirements. Transportation regulations specify labeling and shipping requirements for wastes generated from implementation of the alternative. MTCA regulations specify remediation requirements and the cleanup standards to be attained. The Shoreline Management Act specifies standards for construction activities within 200 feet of a shoreline. The preferred alternative would be designed and implemented to comply with these regulations.

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TABLE 11-1

COMPARISON OF REMEDIAL ALTERNATIVES, AOC-001 and AOC-002[1]

Boeing Renton Facility
Renton, Washington

Standards/Criteria		Alternatives	
		1 - Enhanced Bioremediation/Monitored Attenuation	2 - Monitored Natural Attenuation
Protectiveness and Risk Reduction	Pros	Rapidly destroys groundwater COCs.	Removes or destroys COCs in source area quickly. Destroys organic groundwater COCs. Immobilizes metals.
	Cons	A few years are required to achieve cleanup standards for groundwater. Active injection of electron donor required.	Very long remediation time.
	Rating	MH	ML
Permanence	Pros	Groundwater COCs are permanently destroyed; no toxic residuals.	Natural carbon in site soils promotes MNA. COCs are destroyed, no toxic residuals.
	Cons	Toxic degradation products are generated and are present in groundwater for the short term.	Toxic degradation products are generated and are present in groundwater for the short term.
	Rating	MH	MH
Cost	Pros		Lowest total cost.
	Cons	Moderate initial costs, high long-term monitoring costs.	Low initial costs, high long-term monitoring costs.
	Rating	ML	MH
Long-Term Effectiveness	Pros	Groundwater COCs destroyed. Remediation complete in 2-4 years.	Slow destruction of COCs; passive, natural process.
	Cons		Remediation time likely to be greater than 10 years.
	Rating	H	MH
Management of Short-Term Risks	Pros	In situ management of affected groundwater.	Simplest implementation, in situ management of groundwater.
	Cons	Well drilling and active injection of electron donor required.	
	Rating	MH	MH
Technical and Administrative Implementability	Pros	Site is readily accessible. No technical or physical constraints.	Site is readily accessible. No technical or physical constraints.
	Cons	Well drilling, periodic electron donor injection. Injection permitting required.	.
	Rating	MH	MH
Public Concerns	Pros	Industrial site, minimal potential impact on public.	Industrial site, minimal potential impact on public.
	Cons		
	Rating	H	H
Restoration Time Frame	Pros	Industrial site; Proven institutional controls; Alternative water available; More rapid removal of groundwater COCs.	Industrial site; Proven institutional controls; Alternative water available.
	Cons	Expected time to complete remediation is 2-4 years.	Longer cleanup time, expected to require 10 or more years.
	Rating	MH	MH

Notes:
1. Comparison Ratings: H = Highest (if the decision were based solely on one criterion, an H score would indicate the alternative is the preferred alternative);
MH = Medium High;
ML = Medium Low;
L = Low.

TABLE 11-2

COMPARISON OF BENEFITS[1]
AOC-001 AND AOC-002
Boeing Renton Facility
Renton, Washington

Benefit	Alternative 1: Enhanced Bioremediation/MA	Alternative 2: MNA
Reduced risk to on-site worker health	Moderate	Moderate
Reduced risk to off-site human health	High	High
Reduced risk to the environment	High	High
Minimal adverse impact on Facility operations	Moderate	High
Minimal restrictions on Facility traffic and access	Moderate	High
Minimal adverse impact on Facility structures and utilities	High	High

Notes:
1. Benefits for each remedial alternative are rated as follows:
   High = high benefit;
   Moderate = moderate benefit;
   Low = low benefit.

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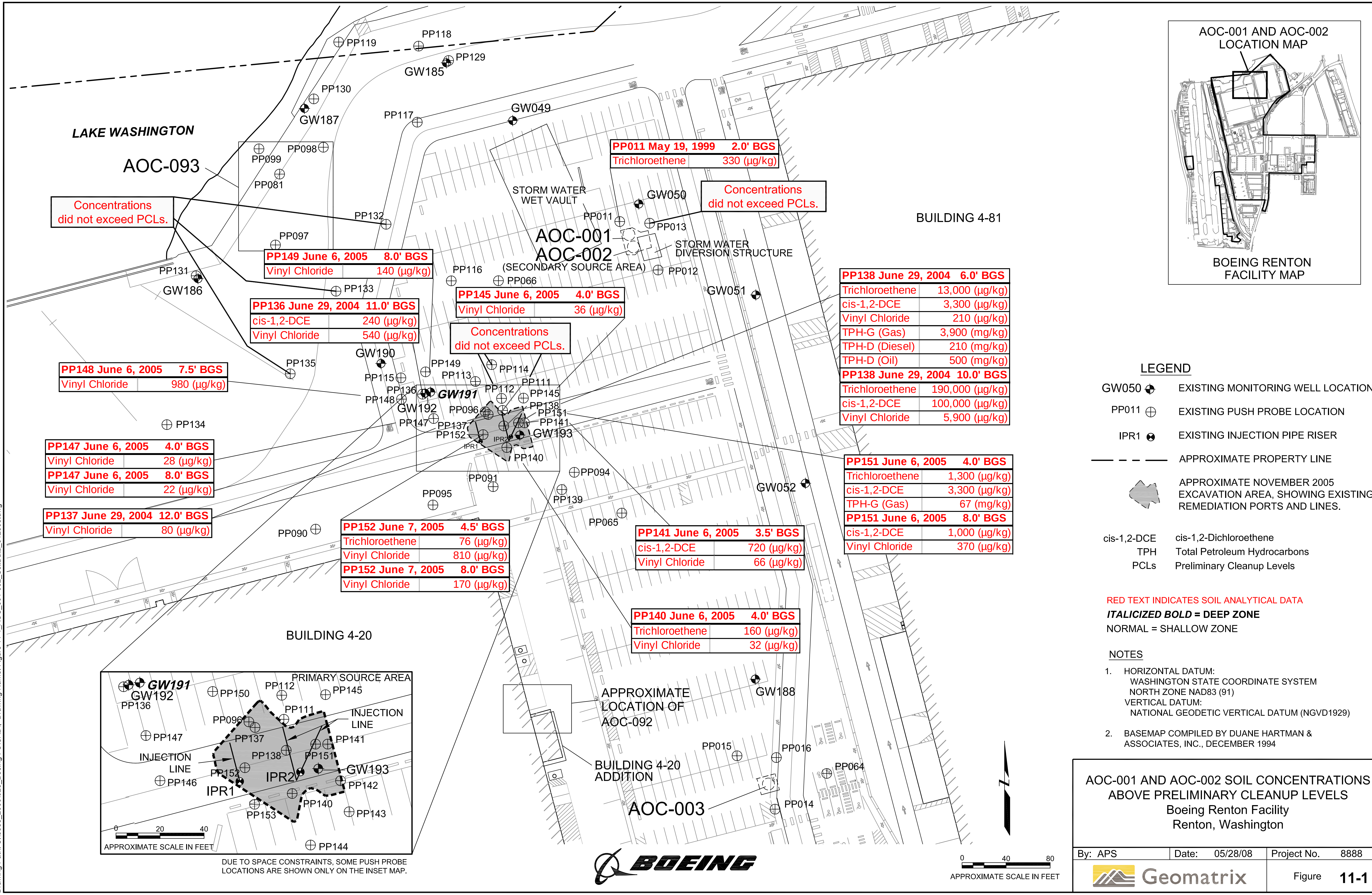
TABLE 11-3

POTENTIALLY APPLICABLE REGULATIONS
AOC-001 AND AOC-002 PREFERRED REMEDIAL ALTERNATIVE

Boeing Renton Facility
Renton, Washington

Law/Regulation	Citation	Applicability
Chemical-Specific Laws and Regulations		
Washington Dangerous Waste Regulations	WAC 173-303	Waste management
Washington Model Toxics Control Act Regulations	WAC 173-340	Establishment of cleanup levels and POCs
Action-Specific Laws and Regulations		
Washington State Environmental Policy Act Regulations	WAC 197-11	Permitting, EIA/EIS[1] requirements
Washington Industrial Safety and Health Act Regulations	WAC 296-24	Occupational health and safety
Transportation regulations	49 CFR Parts 100 & 177, WAC 446-50	Transportation for wastes and materials
Washington well drilling regulations	WAC 173-160 & -162	Well design and installation standards
Washington Underground Injection Control Regulations	WAC 173-218	Underground injection permitting
Washington solid waste disposal regulations	WAC 173-304	Disposal of nondangerous waste
Location-Specific Regulation		
Shoreline Management Act	RCW 90.58	Standards in constructions within 200 feet of shoreline

Notes:
1. EIA = Environmental Impact Assessment; EIS = Environmental Impact Statement.



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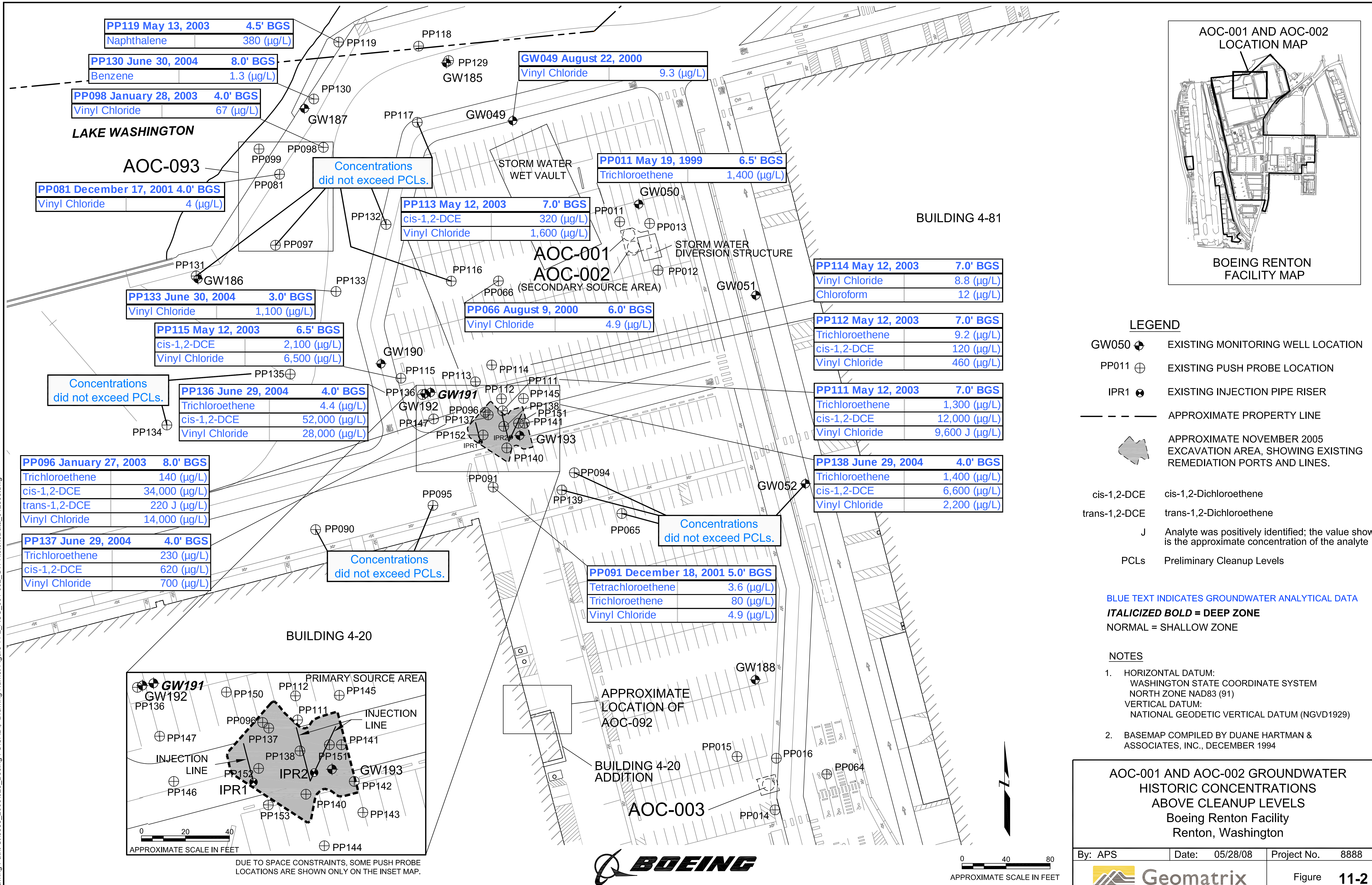

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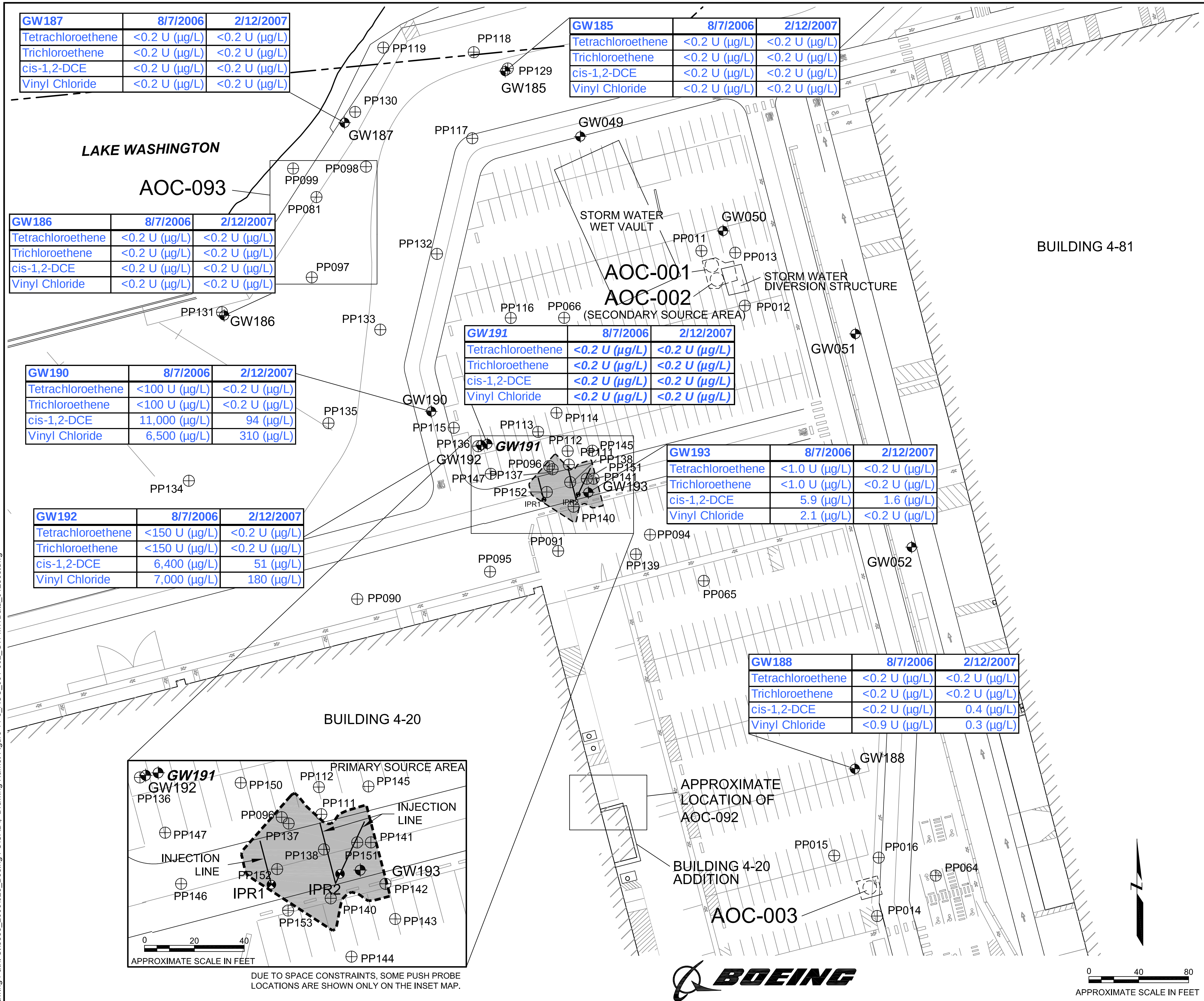

GW187	8/7/2006	2/12/2007
Tetrachloroethene	<0.2 U (µg/L)	<0.2 U (µg/L)
Trichloroethene	<0.2 U (µg/L)	<0.2 U (µg/L)
cis-1,2-DCE	<0.2 U (µg/L)	<0.2 U (µg/L)
Vinyl Chloride	<0.2 U (µg/L)	<0.2 U (µg/L)

GW185	8/7/2006	2/12/2007
Tetrachloroethene	<0.2 U (µg/L)	<0.2 U (µg/L)
Trichloroethene	<0.2 U (µg/L)	<0.2 U (µg/L)
cis-1,2-DCE	<0.2 U (µg/L)	<0.2 U (µg/L)
Vinyl Chloride	<0.2 U (µg/L)	<0.2 U (µg/L)

GW186	8/7/2006	2/12/2007
Tetrachloroethene	<0.2 U (µg/L)	<0.2 U (µg/L)
Trichloroethene	<0.2 U (µg/L)	<0.2 U (µg/L)
cis-1,2-DCE	<0.2 U (µg/L)	<0.2 U (µg/L)
Vinyl Chloride	<0.2 U (µg/L)	<0.2 U (µg/L)

GW191	8/7/2006	2/12/2007
Tetrachloroethene	***<0.2 U (µg/L)***	***<0.2 U (µg/L)***
Trichloroethene	***<0.2 U (µg/L)***	***<0.2 U (µg/L)***
cis-1,2-DCE	***<0.2 U (µg/L)***	***<0.2 U (µg/L)***
Vinyl Chloride	***<0.2 U (µg/L)***	***<0.2 U (µg/L)***

GW190	8/7/2006	2/12/2007
Tetrachloroethene	<100 U (µg/L)	<0.2 U (µg/L)
Trichloroethene	<100 U (µg/L)	<0.2 U (µg/L)
cis-1,2-DCE	11,000 (µg/L)	94 (µg/L)
Vinyl Chloride	6,500 (µg/L)	310 (µg/L)

GW193	8/7/2006	2/12/2007
Tetrachloroethene	<1.0 U (µg/L)	<0.2 U (µg/L)
Trichloroethene	<1.0 U (µg/L)	<0.2 U (µg/L)
cis-1,2-DCE	5.9 (µg/L)	1.6 (µg/L)
Vinyl Chloride	2.1 (µg/L)	<0.2 U (µg/L)

GW192	8/7/2006	2/12/2007
Tetrachloroethene	<150 U (µg/L)	<0.2 U (µg/L)
Trichloroethene	<150 U (µg/L)	<0.2 U (µg/L)
cis-1,2-DCE	6,400 (µg/L)	51 (µg/L)
Vinyl Chloride	7,000 (µg/L)	180 (µg/L)

GW188	8/7/2006	2/12/2007
Tetrachloroethene	<0.2 U (µg/L)	<0.2 U (µg/L)
Trichloroethene	<0.2 U (µg/L)	<0.2 U (µg/L)
cis-1,2-DCE	<0.2 U (µg/L)	0.4 (µg/L)
Vinyl Chloride	<0.9 U (µg/L)	0.3 (µg/L)

LEGEND

GW050 — EXISTING MONITORING WELL LOCATION

PP011 — EXISTING PUSH PROBE LOCATION

IPR1 — EXISTING INJECTION PIPE RISER

— — — APPROXIMATE PROPERTY LINE

APPROXIMATE NOVEMBER 2005 EXCAVATION AREA, SHOWING EXISTING REMEDIATION PORTS AND LINES.

cis-1,2-DCE — cis-1,2-Dichloroethene

U — Analyte was not detected above value shown

***ITALICIZED BOLD* = DEEP ZONE**

NORMAL = SHALLOW ZONE

BLUE TEXT INDICATES GROUNDWATER ANALYTICAL DATA

NOTES

1. HORIZONTAL DATUM:
   WASHINGTON STATE COORDINATE SYSTEM
   NORTH ZONE NAD83 (91)
   VERTICAL DATUM:
   NATIONAL GEODETIC VERTICAL DATUM (NGVD1929)
2. BASEMAP COMPILED BY DUANE HARTMAN & ASSOCIATES INC., DECEMBER, 1994

AOC-001 AND AOC-002 RECENT GROUNDWATER MONITORING WELL CONCENTRATIONS ABOVE PRELIMINARY CLEANUP LEVELS
Boeing Renton Facility
Renton, Washington

By: APS	Date: 05/28/08	Project No. 8888
Geomatrix		Figure 11-3

Plot Date: 05/28/08 - 9:59am, Plotted by: astenberg
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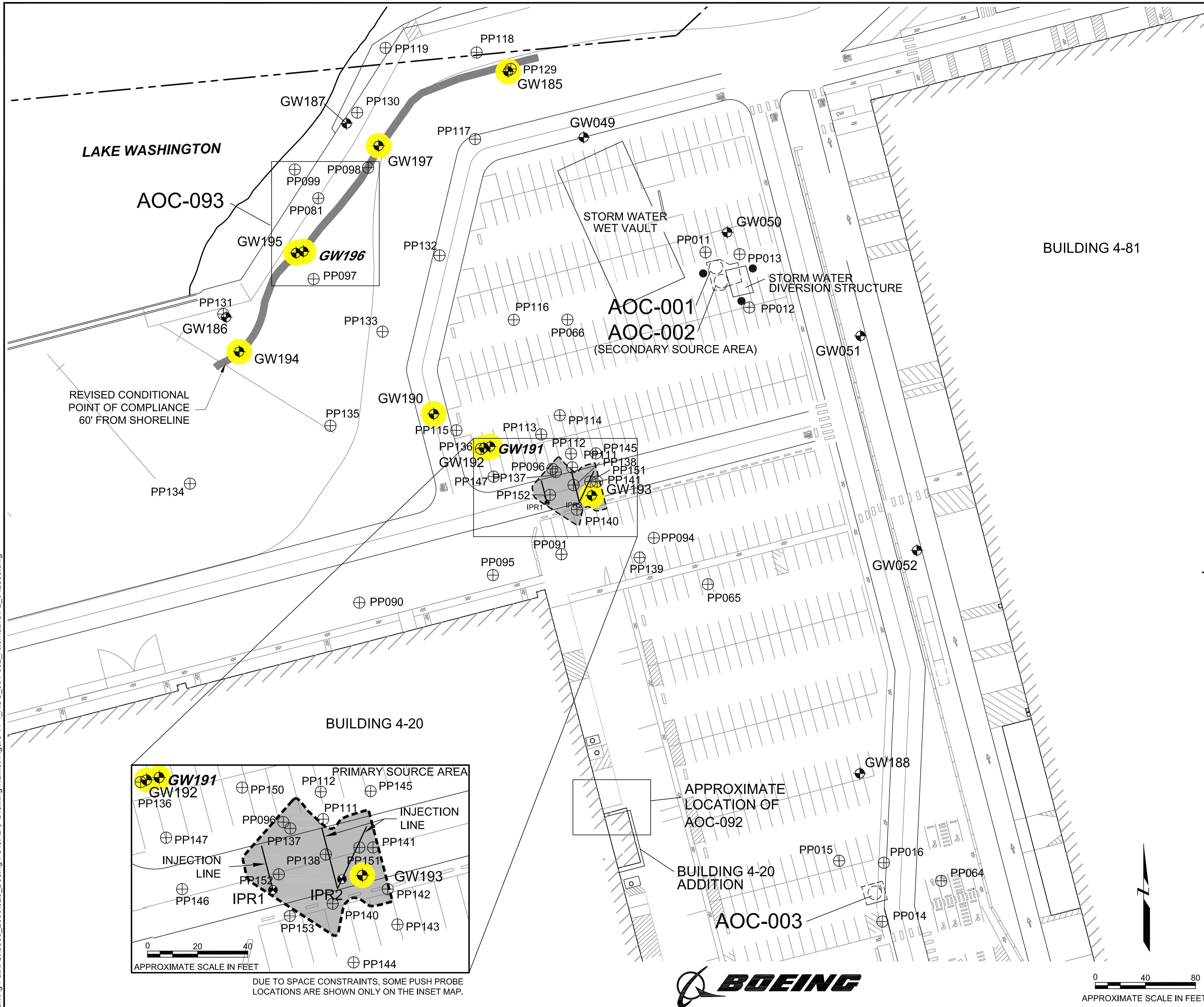
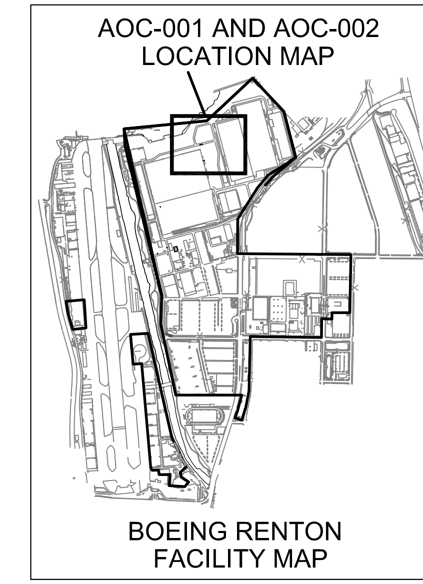




LEGEND

- ● PROPOSED ELECTRON DONOR INJECTION WELL
- GW050 EXISTING MONITORING WELL LOCATION
- PP011 EXISTING PUSH PROBE LOCATION
- IPR1 EXISTING INJECTION PIPE RISER
- — — — APPROXIMATE PROPERTY LINE
- APPROXIMATE NOVEMBER 2005 EXCAVATION AREA, SHOWING EXISTING REMEDIATION PORTS AND LINES.

HIGHLIGHTED WELLS INCLUDED IN MONITORING NETWORK

***ITALICIZED BOLD* = DEEP ZONE**

NORMAL = SHALLOW ZONE

NOTES

1. HORIZONTAL DATUM:
   WASHINGTON STATE COORDINATE SYSTEM
   NORTH ZONE NAD83 (91)
   VERTICAL DATUM:
   NATIONAL GEODETIC VERTICAL DATUM (NGVD1929)
2. BASEMAP COMPILED BY DUANE HARTMAN & ASSOCIATES, INC., DECEMBER 1994

AOC-001 AND AOC-002
ALTERNATIVES 1 AND 2
Boeing Renton Facility
Renton, Washington

By: APS	Date: 05/28/08	Project No. 8888
Geomatrix		Figure 11-4

Plot Date: 05/28/08 - 10:00am, Plotted by: astenberg
Drawing Path: S:\8888_2006\025_Boeing FS\CAD\, Drawing Name: Figure 11-4_AOC_001-002_Alternative1-2_012808.dwg

12.0 DEVELOPMENT AND EVALUATION OF REMEDIAL ALTERNATIVES, AOC-003

In this section we discuss remediation objectives, identify and evaluate remedial alternatives, and describe the preferred remedial alternative for AOC-003.

12.1 SITE CHARACTERIZATION SUMMARY

AOC-003 (referred to in this section as the site) represents the former UST URE-03 that was located just west of Building 4-81 (see Figure 1-2). The former UST was installed in 1980 and was used to store MEK and toluene. The UST was constructed of steel within a cylindrical concrete vault for secondary containment and had a capacity of 500 gallons.

Following the removal of this UST in July 1986, toluene was detected in the water found between the tank and concrete vault. Groundwater samples from the area adjacent to former URE-03 did not contain detectable concentrations of solvents. Section 5.9 of the final RI Report presents the complete site characterization results for this AOC (Weston, 2001a). The results of the RI investigation are summarized below.

12.1.1 Historical, Present, and Future Site Use

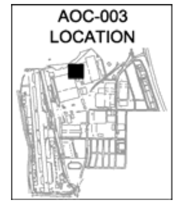
The former UST at AOC-003 was used to store MEK and toluene. The area near AOC-003 is used as a parking lot and a tow path for airplanes. The adjacent buildings and areas are presently used for industrial purposes and are expected to remain in industrial use for the foreseeable future.

12.1.2 Previous Site Remedial Actions

After URE-03 was removed in 1986, a total of 74 cubic yards of soil was excavated from around the former tank location. Because groundwater samples collected near the tank contained dissolved toluene at a concentration of 10 mg/L, approximately 3,600 gallons were pumped from the URE-03 excavation to recover the dissolved toluene.

12.1.3 Site Hydrogeology

The general stratigraphy beneath this area consists of fill and alluvium. Fill materials consist of greenish-brown, fine- to medium-grained sand with silt and gravel. Beneath the fill, alluvium consists of greenish-gray clayey silt to silty clay with a high content of organic matter represented by wood fragments and roots. Boring logs from the three nearby push probes indicate that the depth of the contact between hydraulic fill materials and alluvium is



approximately 10 feet bgs. Boring logs from PP016 indicate the presence of a lower permeability peaty silt layer directly underlying the fill at that location.

Groundwater levels measured in nearby monitoring wells GW049, GW050, GW051, and GW052 ranged from 1.4 to 3.2 feet bgs. Seasonal variations in groundwater levels ranged from 0.35 to 0.64 feet. Groundwater in the area of AOC-003 flows to the northwest toward Lake Washington at an average gradient of approximately 0.001. Slug tests were conducted in wells GW049, GW050, GW051, and indicated that the hydraulic conductivity of the shallow aquifer near AOC-003 ranged from 1.4×10^{-3} to 5.0×10^{-3} cm/s.

Based on a geologic cross-section presented in the final RI Report, the predominant soil type in the vadose zone is silty sand with gravel, and the soil type dominating groundwater flow is silty sand. Therefore, the dominant soil classification for both the vadose and saturated zones is SM; soil characteristics for SM soil will be used for relevant calculations in this FS.

12.1.4 Nature and Extent of Affected Soil

The results of the RI indicate that AOC-003 soil contains TCE above its PCL, as defined in the final RI Report (Weston, 2001a). The analytical results from soil investigations conducted at this site are summarized on Figure 12-1. TCE at PP015 (89 µg/kg) and PP016 (66 µg/kg) exceeded the PCL of 54 µg/kg but was lower than the soil cleanup level in Table 3-1. None of the remaining soil samples collected during the RI at AOC-003 contained TCE at concentrations exceeding the PCL or cleanup level for TCE. Therefore, the affected soil appears limited to the immediate vicinity of the push probes. TCE has been defined as a soil COC for AOC-003.

12.1.5 Nature and Extent of Affected Groundwater

PCE and VC were detected at concentrations exceeding their respective groundwater PCLs in groundwater samples collected at PP016. Figure 12-1 shows groundwater sample analytical results that exceeded the PCLs. Groundwater samples collected from nearby push probes PP014 and PP015 were not analyzed for chlorinated VOCs during the RI because these chemicals were not COCs for this former UST during the first phase of the RI field work (Weston, 2001a). PP064 was installed approximately 40 feet to the southeast of PP016 and did not contain dissolved VOCs above the PCLs. No COCs were detected above PCLs in PP065 and GW052 located north of AOC-003. Therefore, the extent of affected groundwater at AOC-003 has been defined.

12.2 CONCEPTUAL SITE MODEL

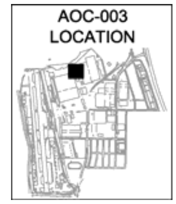
A preliminary conceptual model for migration of constituents present in affected soil and groundwater present at the Renton facility was presented in Figure 2-6 of the FSWP (Geomatrix, 2004c). Based on the conceptual model and considerations presented in the FSWP plus information specific to this site, a site-specific conceptual site model is described below. This site-specific conceptual site model identifies the media and exposure pathways that must be addressed for remedial alternatives potentially applicable to this site.

TCE is present in soil within the source area for AOC-003. As shown in the Facility conceptual model presented in the FSWP, TCE can migrate from the source areas via groundwater or vapor pathways. For this site, migration via groundwater will be most significant. Constituent transport via groundwater at this site is affected by soil/groundwater interactions and biodegradation. As groundwater flows through TCE-affected soil in the source area, adsorbed TCE may dissolve into groundwater, although no TCE was detected in groundwater samples collected at the same push probe locations where TCE-affected soil was identified. Any dissolved TCE will move with groundwater but at a different velocity due to continuing solute-soil interactions. This movement may create a plume extending downgradient from the source area; however, no such plume was detected in the adjacent push probes.

The extent of groundwater affected by dissolved VOCs has been defined in the area downgradient of PP016. The source of the VOCs is likely the shallow soils at the site, which contain concentrations of VOCs above the PCL. The VOC-affected groundwater will migrate to the north-northwest from the source area toward Lake Washington. However, the low concentrations of VC and PCE in the groundwater at PP016 will likely degrade into ethene and chloride salts before reaching the downgradient push probe location PP065 or monitoring well GW052. Volatilization of constituents from groundwater is not significant for most workers at this site, as noted in the conceptual model presented in the FSWP. Boeing installed a downgradient groundwater monitoring well (GW188) at AOC-003 to monitor VOC concentrations downgradient of PP016 (Geomatrix, 2004g).

12.3 SITE REMEDIATION OBJECTIVES AND CLEANUP STANDARDS

The remediation objectives for the Renton Facility were presented in Section 2 of this report. Cleanup levels applicable to the Facility were proposed in the FSWP and were subsequently approved by Ecology. The cleanup levels for PCE, TCE, and VC presented in the approved



FSWP were subsequently changed by Ecology; cleanup levels for these constituents were calculated as described in Section 3, based on negotiations and correspondence with Ecology. The remedial alternatives developed and evaluated for this site will be capable of attaining the remediation objectives and cleanup levels presented in this section.

As defined in the MTCA regulations, the cleanup standard consists of the cleanup level and the location or POC at which the cleanup level must be met. The remedial alternatives for this site, presented below in Section 12.4, may have different points of compliance while fully addressing remediation objectives and meeting cleanup levels.

The groundwater and soil COCs exceeding the PCLs established in the final RI Report for AOC-003 were identified in FSWP Tables 5-1 and 5-3, respectively. These constituents were identified by comparing detected constituent concentrations to the PCLs identified in the final RI Report; if a constituent concentration measured in any sample exceeded the PCL, the constituent was listed as a COC that must be addressed in the FS. Cleanup levels for both soil and groundwater meeting MTCA requirements were presented in the FSWP (Tables 5-6 and 5-2, respectively) and approved by Ecology. To confirm that the COCs listed in the FSWP included all constituents detected at concentrations exceeding the approved cleanup levels, the RI soil and groundwater data were compared to the approved cleanup levels listed in the FSWP. If concentrations for constituents that were not identified as COCs exceeded cleanup levels, it would be necessary to include them as COCs. If concentrations for previously identified COCs were below the approved cleanup levels, the constituent should be removed as a COC. No new constituents were identified as COCs for this site, and no previously identified COCs were removed as a result of this comparison. Table 5-3 of the FSWP erroneously listed VC as a soil COC for AOC-003; however, no VC was detected in the RI soil samples from this AOC above the PCL, so VC is not listed as a soil COC on Table 3-1.

The soil and groundwater cleanup levels for the site COCs are listed in Tables 3-1 and 3-2, respectively. The soil cleanup levels are either MTCA Method A cleanup levels or site-specific MTCA Method C cleanup levels that are protective of groundwater at the CPOC and were calculated in accordance with the procedures described in the FSWP or in accordance with recent negotiations with Ecology. The groundwater cleanup levels listed in Table 3-2 were developed as described in Section 3 and in accordance with recent negotiations with Ecology. The cleanup levels are protective of surface water, human health, and the environment.

The cleanup levels allow for the degradation that would occur between the source area and the CPOC due to natural attenuation. Details concerning modeling and cleanup level calculations are included in Section 3 and Appendix A. These cleanup levels will be used in development and evaluation of remedial alternatives for AOC-003, which include natural attenuation or enhanced in situ bioremediation.

12.4 DESCRIPTION OF SITE REMEDIAL ALTERNATIVES

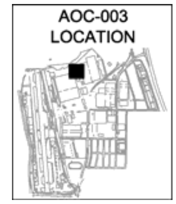
AOC-003 is located at the north side of the Facility between Buildings 4-20 and 4-81. The RI and the FSWP grouped AOC-003 with AOC-001/002 because of their proximal locations and similar COCs. However, AOC-003 is several hundred feet upgradient of AOC-001/002, and the current data suggest that there is no commingling of contaminants from these areas. For these reasons, this FS deals with AOC-003 as a separate entity. AOC-001/002 will continue to be treated as a single entity.

AOC-003 is located in an area that serves dual purposes. Most of the time, this site is used as an employee parking area for the Facility. However, parking within this area is closed in the late afternoon and evening so that the area can be used as a tow path for commercial airplanes. Airplanes manufactured at the site are moved along this tow path to reach other areas of the facility or, upon their completion, are moved to the Renton Airport where they depart the site. Maintaining an open tow path is critical to the operation of the Renton facility, and this requirement could limit or constrain remedial alternatives.

MTCA requires that remedial alternatives selected for a site meet the MTCA threshold requirements for cleanup actions. The minimum threshold requirements specify that cleanup actions shall (1) protect human health and the environment, (2) comply with cleanup standards, (3) comply with applicable state and federal law, and (4) provide for compliance monitoring. To be considered as a potential remedial alternative for the site, the technologies considered had to pass the screening evaluation of the remedial technologies, which is described in Section 4. In addition, the alternatives had to meet the minimum threshold requirements established by MTCA and be consistent with overall site conditions.

Based on the screening evaluation, MTCA minimum threshold requirements, and the site considerations discussed above, the following two remedial alternatives addressing groundwater COCs were developed for AOC-003, as described below.

- Alternative 1: Monitored Natural Attenuation



- Alternative 2: Enhanced Bioremediation and Monitored Attenuation

An alternative incorporating SVE was also initially considered for this AOC but was eliminated because of the limited available vadose zone, making SVE inappropriate for the site. The depth to groundwater for this AOC is typically between 1.5 and 3 feet bgs.

12.4.1 Alternative 1: Monitored Natural Attenuation

Alternative 1 is composed of the following two primary elements: institutional controls and MNA. The groundwater cleanup standard for this alternative will be the groundwater cleanup levels for AOC-003 COCs previously discussed and a CPOC downgradient of the site as shown on Figure 12-1. The soil cleanup standard will be the soil cleanup levels discussed in Section 12.3 and shown in Table 3-1. Since the detected levels of VOCs in source area soils (TCE at PP015 [89 µg/kg] and PP016 [66 µg/kg]) do not exceed the soil cleanup level of 90 µg/kg for TCE, the existing VOC concentrations in soil are protective of groundwater at the CPOC. Given that other risks from the VOCs in soils can be managed through institutional controls (discussed below) and that the soils are confined by the existing pavement or tarmac, no other active measures are necessary to remediate soils. Since detected TCE in soil is within the saturated zone, the source area TCE would gradually biodegrade. As described in Appendix A, concentrations detected within the source area are predicted to degrade to concentrations below the MTCA Method B cleanup levels prior to reaching Lake Washington.

12.4.1.1 Institutional Controls

The following institutional controls are included to reduce the risk of human exposure to impacted soil or groundwater:

- Continued engineering controls, protocols, and monitoring previously established by Boeing to ensure that industrial workers inside buildings are protected and indoor air concentrations meet PELs established by the Washington Department of Labor and Industry;

- Continued engineering controls, protocols, and monitoring to ensure that temporary construction workers adhere to WAC 296-62-300, applicable Washington Labor and Industry standards, and OSHA HAZWOPER regulations (29CFR1919.120) for all construction work conducted in exposed areas of affected soil and groundwater; and

- Deed restrictions to limit development and use of the site.

It is anticipated that deed restrictions would be established to limit future nonindustrial land use without additional specific actions to demonstrate compliance with soil and groundwater cleanup levels for unrestricted site use.

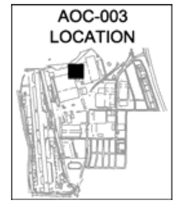
12.4.1.2 Monitored Natural Attenuation

As previously discussed in Section 4.2.4, groundwater monitoring data collected over the last several years at the Facility indicate that natural processes are at work degrading and retarding the migration of COCs. Based on the POC approach presented in Section 6 of the FSWP, fate and transport groundwater modeling using BIOCHLOR was conducted to evaluate the efficacy of MNA as a final remedy for this AOC. The modeling followed the protocol established in the FSWP, as modified by Ecology in meetings and correspondence subsequent to finalizing the FSWP, using approved model input parameters. The modeling results, presented in detail in Appendix A, are in general agreement with the preliminary modeling conducted for the FSWP. The model results indicate that while groundwater cleanup levels for all COCs are not met in groundwater directly below the AOC, active biodegradation is occurring.

In accordance with current guidance and the approach discussed in Section 4.2.4, the conceptual monitoring program for Alternative 1 is designed to:

- Demonstrate that natural attenuation is occurring according to expectations;
- Identify any potentially toxic and/or mobile transformation products;
- Verify that the plume is not expanding beyond the CPOC;
- Verify that cleanup levels are attained at the CPOC;
- Verify that there is no unacceptable impact to downgradient receptors;
- Detect new releases of COCs that could impact the effectiveness of the natural attenuation remedy;
- Demonstrate the efficacy of institutional controls put in place to protect potential receptors; and
- Verify attainment of remediation objectives.

The conceptual monitoring program for Alternative 1 at AOC-003 assumes that upon selection of this remedy, a detailed MNA Validation and Long-Term Sampling Work Plan would be developed to guide the process. This work plan would identify additional monitoring wells and



monitoring analytes that would be required for both characterization/validation sampling and long-term groundwater monitoring. Characterization/validation sampling would be used to demonstrate the effectiveness of MNA with respect to contaminant mass reduction, attenuation rates, and temporal trends. Long-term groundwater monitoring would be conducted after characterization/validation monitoring to confirm that the contaminant plume is progressing toward containment or achievement of numerical goals.

For this conceptual design, it is assumed that characterization/validation sampling would consist of quarterly monitoring of three monitoring wells for a minimum of 1 year. Three new monitoring wells (one shallow source area well, one shallow CPOC well, and one intermediate depth CPOC well) are assumed to be required (in addition to existing Well GW188, which was installed in August 2004) to monitor the source area and plume migration. Monitoring parameters and analytes would consist of VOCs (contaminants and daughter products), as well as the full suite of MNA geochemical parameters [dissolved oxygen, nitrate, Fe(II), sulfate, methane, temperature, pH, specific conductance, alkalinity, oxidation/reduction potential, chloride, ethane, and TOC]. It is assumed that reporting for characterization/validation sampling would follow each quarterly event.

It is further assumed that long-term groundwater monitoring would follow for an additional 13 to 14 years (15 total years of monitoring) and include semiannual monitoring of four wells for VOCs (contaminants and daughter products) and a limited suite of geochemical parameters (dissolved oxygen, oxidation/reduction potential, temperature, and pH). To ensure plume control all four wells would be analyzed once every 5 years for the entire characterization/validation list of analytes. The frequency of sampling and the duration of the groundwater monitoring program would be based on the results of performance monitoring, and may be adjusted as appropriate. It is assumed that annual reporting would be required for long-term groundwater monitoring.

12.4.2 Alternative 2: Enhanced Bioremediation and Monitored Attenuation

Alternative 2 consists of the following three primary elements: institutional controls, enhanced bioremediation, and MA. The groundwater cleanup standard for this alternative will be the groundwater cleanup levels for AOC-003 COCs previously discussed in Section 12.3 and the CPOC shown on Figure 12-1. The soil cleanup standard will be the soil cleanup levels discussed in Section 12.3 and shown in Table 3-1. Because the detected levels of VOCs in source area soils (TCE at PP015 [89 µg/kg] and at PP016 [66 µg/kg]) do not exceed the soil

cleanup levels of 90 µg/kg for TCE, the existing VOC concentrations in soil are protective of groundwater at the CPOC. Given that other risks from the VOCs in soils can be managed through institutional controls (Section 12.4.1.1) and that the soils are confined by the existing pavement or tarmac, no active measures are required to remediate soils. Since detected TCE in soil is within the saturated zone, the source area TCE would gradually biodegrade. This alternative would also include introduction of electron donor to further promote the natural biodegradation that is occurring at the site.

12.4.2.1 Institutional Controls

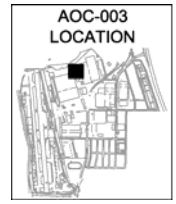
Institutional controls for Alternative 2 would be similar to those discussed above for Alternative 1.

12.4.2.2 Enhanced Bioremediation

The final design for this alternative, if selected for implementation, would be determined in a cleanup action plan (CAP); injection of electron donor could be done using dedicated injection wells or using direct-push methods. The conceptual design of enhanced bioremediation for Alternative 2 assumes a series of four injection wells in an injection zone surrounding the source area. The injection wells, constructed of 2-inch-diameter polyvinyl chloride (PVC), are assumed to be screened in the impacted aquifer between 5 and 15 feet bgs. It is further assumed that the electron donor substrate injected would be emulsified vegetable oil, sodium lactate, or some other similar substrate. For the conceptual design, it is assumed that a total of 1,000 gallons of 2% emulsified vegetable oil would be injected into the four injection wells in approximately equal portions. It is also assumed that three applications (at 1-year intervals) would be required to effectively treat the aquifer, resulting in a total injection of 3,000 gallons of 2% emulsified vegetable oil. For costing of this remedial alternative, it is assumed that pilot testing is not needed, as enhanced bioremediation using emulsified vegetable has been performed at the Facility as an interim measure.

12.4.2.3 Monitored Attenuation

Monitored attenuation for this alternative is intended to be a final "polishing" mechanism, following the active enhanced bioremediation, to ensure that the cleanup levels defined in Section 3 for all COCs are met at the CPOC. With this alternative, it is assumed that MA would commence after the first enhanced bioremediation injection event, and would consist of long-term groundwater monitoring for three shallow wells and one deeper well, as described above in Section 12.4.1.2 for Alternative 1. Groundwater monitoring would be conducted



quarterly and semiannually as described for Alternative 1 for VOCs (contaminants and daughter products) and a limited suite of geochemical parameters (dissolved oxygen, oxidation/reduction potential, temperature, and pH). To ensure plume control, all monitoring wells would be analyzed once every 5 years for the entire list of analytes. It is assumed that monitoring would continue for a total of 15 years, and that annual reporting would be required for the duration.

12.5 EVALUATION OF SITE REMEDIAL ALTERNATIVES

As previously discussed, both alternatives developed for the site meet the MTCA minimum requirements for cleanup actions. This section compares and evaluates the alternatives based on the MTCA criteria. An analysis of both alternatives with respect to the evaluation criteria is summarized in Table 12-1 and is discussed below.

12.5.1 Protectiveness and Risk Reduction Evaluation

Protectiveness and risk reduction are gauged primarily on the time required for the alternative to reduce risk and meet cleanup levels. Because it would employ an active technology, Alternative 2 would be expected to most quickly reduce COCs in groundwater to cleanup levels and is rated higher for risk reduction.

12.5.2 Permanence

Permanence refers to the ability to reduce the toxicity, mobility, or volume of hazardous substances, including the permanent destruction of hazardous substances. Both Alternatives 1 and 2 would provide permanent destruction of COCs. Alternative 2 is rated higher for this criterion because the permanent constituent destruction is more controlled and expected to occur at a faster rate.

12.5.3 Cost

The cost evaluation includes all costs related to implementation of an alternative, including initial design and construction costs, operation and maintenance costs, monitoring costs, and reporting costs. The annual costs for operation, maintenance, monitoring, and reporting are recurring costs that would occur in the future. The cost evaluation considers initial implementation costs and future recurring costs using NPV analysis. For NPV calculation, recurring costs were inflated 2% annually and a discount rate of 7% was used. Details regarding the cost estimates for the three alternatives are presented in Appendix B. The net present value costs for the two alternatives, in 2007 dollars, are summarized below:

Alternative	Net Present Value
1: Monitored Natural Attenuation	$353,000
2: Enhanced Bioremediation and Monitored Attenuation	$405,000

As shown by these costs, Alternative 2 has the higher NPV cost while Alternative 1 has the lowest. Therefore, Alternative 1 ranks higher for cost and Alternative 2 ranks lower.

12.5.4 Long-Term Effectiveness

Long-term effectiveness includes the degree of certainty and reliability of the alternative and whether treatment residue remains from the alternative that would require management. Both Alternatives 1 and 2 are based on proven technologies and neither produces residual wastes that would require ongoing management.

12.5.5 Management of Short-Term Risks

Short-term risk refers to the risk to human health and the environment during implementation of the alternative. Because Alternative 1 would be simpler to implement than Alternative 2 and does not require construction of a treatment or injection system, it is rated higher for this criterion.

12.5.6 Technical and Administrative Implementability

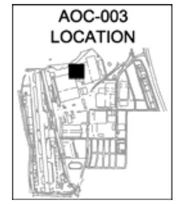
This criterion involves whether the alternative is technically feasible relative to complexity, administrative/regulatory requirements, size, access, and integration with existing operations. Given that Alternative 1 is a small, simple system that integrates well with the Facility operations, it is rated higher than Alternative 2.

12.5.7 Public Concerns

This criterion looks at potential community concerns with the alternative. Since both alternatives deal with an industrial site with limited public access, they are rated equally.

12.5.8 Reasonable Restoration Time Frame

Restoration time frame assesses the practicability of a shorter restoration time frame with consideration given to a number of factors, including site risks, site use and potential use,



availability of alternative water supply, effectiveness and reliability of institutional controls, and toxicity of hazardous substances at the site. As a whole, these factors are a measure of the urgency of reducing risk and achieving cleanup goals for the site. Given that the site is industrial, has limited public access, and poses low risk to the public, both alternatives are ranked medium low for this criterion.

12.6 SELECTION OF THE PREFERRED SITE REMEDIAL ALTERNATIVE

Selection of a preferred alternative under MTCA requires that a preference be given to alternatives that use permanent solutions (to the maximum extent practicable), provide for a reasonable restoration time frame, and consider public concerns. The analysis below compares the baseline alternative (the alternative that provides the greatest degree of permanence) to the other alternatives based on degree of permanence, reasonable restoration time frame, and public concerns. According to MTCA (WAC 173-340-200), a permanent solution or permanent cleanup action means a cleanup action in which cleanup standards can be met without further action being required at the site involved, other than the approved disposal of any residue from the treatment of hazardous substances.

12.6.1 Baseline Remedial Alternative

The baseline remedial alternative for AOC-003 is Alternative 2. Although both alternatives could be considered to be permanent cleanup actions in the sense that cleanup standards are met, this alternative is considered to have a higher degree of permanence because it provides permanent destruction of hazardous substances and would likely provide for a shorter restoration time frame than Alternative 1.

The evaluation of both remedial alternatives for this site is summarized in Table 12-1. Neither of the alternatives is capable of attaining the standard POC at this site. However, both alternatives are capable of meeting cleanup levels at the on-site CPOC located less than 200 feet from the source area. Because AOC-003 is located within the active aircraft tow path (a critical Facility operation), other alternatives that might interfere with this operation are not desirable.

12.6.2 Comparison to Baseline Alternative

As noted above, Alternative 2 has been defined as the baseline remedial alternative for this site. Alternative 1 will be compared to the baseline alternative in the following subsections for selection of the preferred alternative. The purpose of this comparison is to assess the benefits

and costs for Alternative 1 relative to Alternative 2. The evaluation criteria presented above and in Table 12-1 were established in accordance with the MTCA requirements cited in WAC 173-340(3)(f). Costs for the alternatives will be based on the NPV, which reflects the total cost associated with each alternative over the 15-year time period evaluated. The evaluation of benefits will be qualitative.

The benefits to be assessed in this comparison and the relative rating for the alternatives are presented in Table 12-2. The rationale for this comparison is presented below.

- **Reduced risk to on-site worker health.** Both alternatives would be equal in reducing risk to site workers because they would be equally protective. Although the baseline alternative would remove volatile COCs within a few years, potential risks to on-site workers would not be changed substantially by the other alternative. The institutional controls included in each of the alternatives have been proven effective in protecting worker health and would continue to be protective.

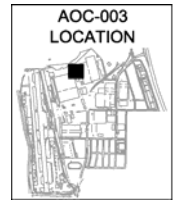
- **Reduced risk to the off-site human health.** Both alternatives were rated high for this benefit. Both would attain the cleanup level at the CPOC, which is protective of human health and the environment. The institutional controls included in the alternatives that have proven to be protective of worker health on site would also be protective of human health in off-site areas located upgradient of the CPOC.

- **Reduced risk to the environment.** Both alternatives were rated high for this benefit. Both alternatives would be protective of the aquatic environment because they would attain the cleanup levels at the CPOC.

- **Minimal adverse impact on Facility operations.** The baseline alternative was rated moderate for this benefit because it would impact Facility operations during installation of the enhanced bioremediation system and requires longer term operation and periodic injection of substrate. A high rating was given to Alternative 1, which would rely on passive degradation of site COCs and would have the least impact on Facility operations.

- **Minimal restrictions on Facility traffic and access.** The baseline alternative was rated moderate for this benefit because it would impact Facility traffic and access during installation of the enhanced bioremediation system and during operation. Additional impact would occur during periodic addition of substrate. Alternative 1 was given a high rating because it would only affect traffic during installation of monitoring wells, resulting in the least impact on Facility traffic and access.

- **Minimal adverse impact on Facility structures and utilities.** The baseline alternative and Alternative 1 were both rated high for minimizing adverse impacts



on facility structures and utilities. Neither of these two alternatives would potentially affect the integrity of site improvements.

The potential benefit evaluation for the alternatives shows that Alternative 1, Monitored Natural Attenuation, would provide the greatest benefit. The baseline alternative (Alternative 2) would provide the next higher benefit, and is ranked as the most permanent alternative.

The NPV costs for both alternatives were presented in Section 12.5.3. The baseline alternative ranks second among the alternatives and would have the higher cost (approximately 15% higher than the cost for Alternative 1).

12.6.3 Preferred Remedial Alternative

Alternative 2 is the preferred remedial alternative for the AOC-003 site. Alternative 2, as the baseline and the most permanent potential remedy, does not provide additional benefits over Alternative 1. However, it may achieve these benefits quicker and does not have a disproportionate cost. Under Alternative 2, affected soils would remain capped by maintained pavement or tarmac, which would prevent potential runoff and infiltration of rainfall. Groundwater in the area is not used for any purpose, and potable water is readily available from the Renton public water system. The institutional controls included in Alternative 2 have been implemented and proven by Boeing, who would continue to maintain overall responsibility for this site and ensure that the institutional controls are properly enforced.

Enhanced bioremediation and MA for this site would achieve the expectations for cleanup actions cited in the MTCA regulations at WAC 173-340-370 (1) – (8). Only those expectations relevant to large, complex sites are considered relevant to AOC-003. The relevant expectations are addressed as follows:

- **Implement Treatment at Sites with Liquid Wastes, High Contaminant Concentrations, Highly Mobile Materials, or Discrete Areas of Contamination.** Ecology expects that treatment will be emphasized for sites meeting these general criteria. Boeing believes that while remaining COC levels are elevated, they are not high, and there is no evidence of liquid wastes at the site. The source areas are not discrete and extend beneath the aircraft tow path, preventing ready access for removal or treatment. Enhanced bioremediation will degrade or "treat" organic COCs over the long term using enhanced natural processes that result in nontoxic degradation products.

- **Destroy, Detoxify, or Remove Hazardous Substances.** Ecology expects that hazardous substances will be destroyed, detoxified, or removed to below cleanup levels. Injection of substrate will ultimately destroy COCs resulting in nontoxic degradation products.

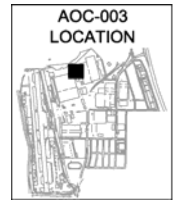
- **Implement Engineering Controls for Low Contaminant Concentrations.** Ecology recognizes the need for containment for low concentrations of contaminants where treatment is impracticable. This alternative uses treatment to enhance destruction of contaminants wherever practicable.

- **Prevent Runoff of Hazardous Substances.** Ecology expects that cleanup actions will include active measures to prevent precipitation from creating runoff that contains affected soil. This expectation would be met by the preferred alternative because the source area is entirely covered by pavement or tarmac. The surface cover near this site is integral to Boeing's activities at the site and is well maintained. In addition to preventing runoff from contacting hazardous substances, the pavement or tarmac minimizes surface water infiltration, thus resulting in decreased groundwater flow rates and increased time for groundwater to flow from the source area to the waterway.

- **Consolidate On-site Contaminants Exceeding Cleanup Levels.** Ecology expects that when contaminants are left on site exceeding cleanup levels that they will be consolidated to the extent practicable. At this site, due to the location of the contaminants, it is not practicable to consolidate contaminants. However, implementation of the preferred alternative will ultimately reduce contaminants to levels below cleanup levels.

- **Prevent Runoff and Groundwater Discharge to Surface Water.** Ecology expects that the cleanup action would include active measures to prevent or minimize releases to adjacent surface water bodies via runoff or groundwater discharge, and that dilution will not be the sole method for attaining cleanup levels. Alternative 2 would meet this expectation. Available groundwater monitoring data indicate that biodegradation of organic COCs is active and significant at this site. Addition of organic substrate will accelerate these natural processes. The cleanup alternative also includes a groundwater monitoring network and program that would confirm that groundwater cleanup levels are attained at an on-site CPOC less than 200 feet downgradient of the AOC and before groundwater can reach Lake Washington.

- **Ensure Appropriateness of Attenuation.** Ecology expects that natural attenuation may be appropriate if source control has been conducted to the maximum extent practicable; contaminants remaining on site do not pose unacceptable risks to human health and the environment; evidence indicates that degradation is occurring and will continue to occur at a reasonable rate; and appropriate monitoring is conducted. These expectations would all be achieved by Alternative 2. Although



affected soil and groundwater have been present at the site for a long time, Boeing has implemented effective institutional controls that have proven effective in protecting human health and the environment at this site. Groundwater monitoring data indicate that biodegradation of organic COCs is active at the site and can be accelerated through addition of organic substrate; coupled with the high organic fraction in site soil, additional substrate is expected to accelerate conditions favorable to continued active biodegradation. Alternative 2 also includes a robust groundwater monitoring program designed to address recent guidance for MNA. The monitoring system included in the preferred alternative would confirm that cleanup levels are attained prior to groundwater discharging to Lake Washington.

The preferred remedial alternative would be designed to comply with applicable regulations. Potentially applicable regulations are listed in Table 12-3. These regulations govern the design, installation, and operation of remediation systems. For the preferred alternative at AOC-003, regulatory requirements are expected to be minimal. Construction for the preferred alternative would be limited to installation of new monitoring and injection wells.

The primary regulations governing the preferred alternative would be the MTCA regulations, the Washington well drilling regulations for monitoring wells, the solid waste disposal regulations, the dangerous waste regulations, the transportation regulations, and the Department of Labor and Industries health and safety regulations. Well drilling rules specify well and direct-push design and drilling requirements. The solid and dangerous waste regulations specify waste characterization, manifesting, and disposal requirements for soil from drilling operations. Transportation regulations specify labeling and shipping requirements for wastes generated from implementation of the alternative. The Washington Underground Injection Control regulations would also apply to the injection of substrate to groundwater. MTCA regulations specify remediation requirements and the cleanup standards to be attained. The alternative would require environmental analysis and public notice in accordance with the MTCA and SEPA requirements. The preferred alternative would be designed and implemented to comply with these regulations.

TABLE 12-1

COMPARISON OF REMEDIAL ALTERNATIVES, AOC-003[1]

Boeing Renton Facility
Renton, Washington

Standards/Criteria		Alternatives	
		1 - Monitored Natural Attenuation	2 - Enhanced Bioremediation/MA
Protectiveness and Risk Reduction	Pros	Destroys COCs.	Destroys COCs.
	Cons	Slow to achieve cleanup.	
	Rating	ML	MH
Permanence	Pros	Natural carbon promotes MNA; Destroys COCs; No residuals.	Destroys COCs; No residuals; Reasonably rapid cleanup.
	Cons	Slow degradation rates.	
	Rating	MH	H
Cost	Pros	Lower cost.	
	Cons		Higher cost.
	Rating	H	MH
Long-Term Effectiveness	Pros	Destroys COCs; Passive, natural process.	Destroys COCs.
	Cons		Requires periodic injections.
	Rating	MH	MH
Management of Short-Term Risks	Pros	Simplest implementation; No residuals.	
	Cons		Requires periodic injections.
	Rating	H	MH
Technical and Administrative Implementability	Pros	Simple system.	Simple system.
	Cons		Requires periodic injections; Injection permit required.
	Rating	H	MH
Public Concerns	Pros	Industrial site.	Industrial site.
	Cons		
	Rating	MH	MH
Restoration Time Frame	Pros	Industrial site; Proven institutional controls; Alternative water available; Practicability of shorter time frame limited by facility operations.	Industrial site; Proven institutional controls; Alternative water available; Practicability of shorter time frame limited by facility operations.
	Cons		
	Rating	ML	ML

Notes:

1. Comparison Ratings: H = Highest (if the decision were based solely on one criterion, an H score would indicate the alternative is the preferred alternative);
   MH = Medium High;
   ML = Medium Low;
   L = Low.

TABLE 12-2

COMPARISON OF BENEFITS[1]
AOC-003
Boeing Renton Facility
Renton, Washington

Benefit	Alternative 1: Monitored Natural Attenuation	Alternative 2: Enhanced Bioremediation
Reduced risk to on-site worker health	High	High
Reduced risk to off-site human health	High	High
Reduced risk to the environment	High	High
Minimal adverse impact on Facility operations	High	Moderate
Minimal restrictions on Facility traffic and access	High	Moderate
Minimal adverse impact on Facility structures and utilities	High	High

Notes:
1. Benefits for each remedial alternative are rated as follows:
   High = high benefit;
   Moderate = moderate benefit;
   Low = low benefit.

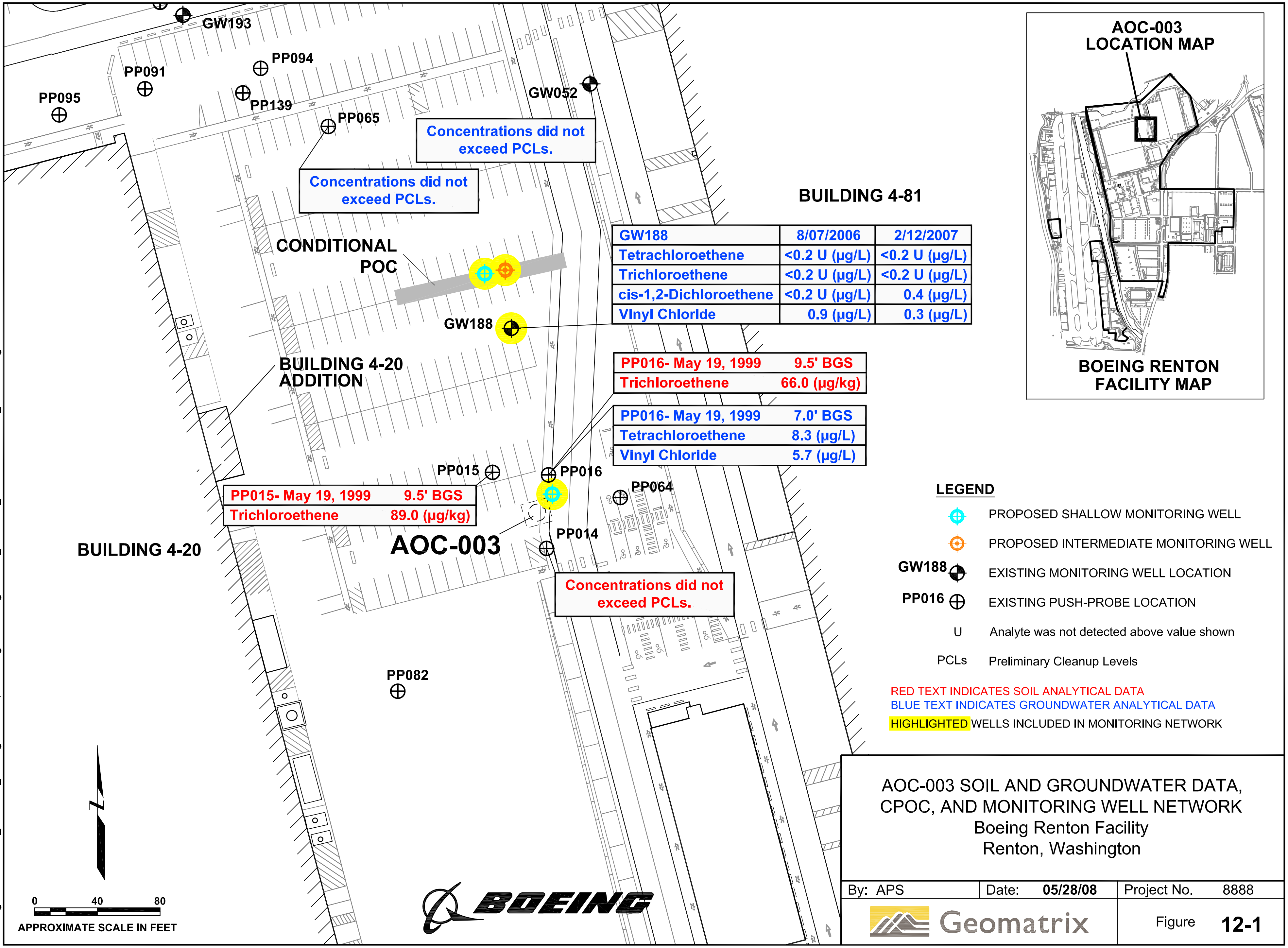
Geomatrix

TABLE 12-3

POTENTIALLY APPLICABLE REGULATIONS
AOC-003 PREFERRED REMEDIAL ALTERNATIVE
Boeing Renton Facility
Renton, Washington

Law/Regulation	Citation	Applicability
Chemical-Specific Laws and Regulations		
Washington Dangerous Waste Regulations	WAC 173-303	Waste management, permitting requirements
Washington Model Toxics Control Act Regulations	WAC 173-340	Establishment of cleanup levels and POCs
Action-Specific Laws and Regulations		
Washington State Environmental Policy Act Regulations	WAC 197-11	Permitting, EIA/EIS[1] requirements
Washington Industrial Safety and Health Act Regulations	WAC 296-24	Occupational health and safety
Transportation regulations	49 CFR Parts 100 & 177, WAC 446-50	Transportation for wastes and materials
Washington well drilling regulations	WAC 173-160 & -162	Well design and installation standards
Washington Underground Injection Control Regulations	WAC 173-218	Underground injection permitting
Washington solid waste disposal regulations	WAC 173-304	Disposal of nondangerous waste

Notes:
1. EIA = Environmental Impact Assessment; EIS = Environmental Impact Statement.



GW188	8/07/2006	2/12/2007
Tetrachloroethene	<0.2 U (µg/L)	<0.2 U (µg/L)
Trichloroethene	<0.2 U (µg/L)	<0.2 U (µg/L)
cis-1,2-Dichloroethene	<0.2 U (µg/L)	0.4 (µg/L)
Vinyl Chloride	0.9 (µg/L)	0.3 (µg/L)

PP016- May 19, 1999	9.5' BGS
Trichloroethene	66.0 (µg/kg)

PP016- May 19, 1999	7.0' BGS
Tetrachloroethene	8.3 (µg/L)
Vinyl Chloride	5.7 (µg/L)

PP015- May 19, 1999	9.5' BGS
Trichloroethene	89.0 (µg/kg)

LEGEND

- PROPOSED SHALLOW MONITORING WELL
- PROPOSED INTERMEDIATE MONITORING WELL
- GW188 — EXISTING MONITORING WELL LOCATION
- PP016 — EXISTING PUSH-PROBE LOCATION
- U — Analyte was not detected above value shown
- PCLs — Preliminary Cleanup Levels

RED TEXT INDICATES SOIL ANALYTICAL DATA
BLUE TEXT INDICATES GROUNDWATER ANALYTICAL DATA
HIGHLIGHTED WELLS INCLUDED IN MONITORING NETWORK

AOC-003 SOIL AND GROUNDWATER DATA, CPOC, AND MONITORING WELL NETWORK
Boeing Renton Facility
Renton, Washington

By: APS | Date: 05/28/08 | Project No. 8888

Geomatrix

Figure 12-1

Plot Date: 05/28/08 - 1:49pm, Plotted by: astenberg
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13.0 DEVELOPMENT AND EVALUATION OF REMEDIAL ALTERNATIVES, AOC-004

In this section we discuss remediation objectives, identify and evaluate remedial alternatives, and describe the preferred remedial alternative for AOC-004.

13.1 SITE CHARACTERIZATION SUMMARY

AOC-004 is the designation for former UST URE-04, which was a 250-gallon steel UST located approximately 10 feet east of Building 4-21 (see Figure 1-2). This UST was used for the storage of gasoline and likely contained leaded gasoline prior to the mid-1970s. The installation date for the tank is unknown. Section 5.10 of the final RI Report presents the complete site characterization results for these units (Weston, 2001a). The results of the RI investigation are summarized below.

13.1.1 Historical, Present, and Future Site Use

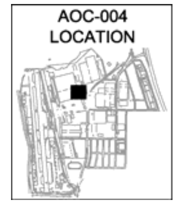
The area around the former UST URE-04 is primarily used for parking. Building 4-21 is currently used for industrial purposes and is expected to remain in industrial use for the foreseeable future.

13.1.2 Previous Site Remedial Actions

The former URE-04 was removed in December 1986. During removal of the tank, a thin layer of floating product (gasoline) was observed on the water in the excavation. There is no documentation to indicate if gasoline-impacted soil was removed from the excavation.

13.1.3 Site Hydrogeology

The general stratigraphy beneath this area consists of fill and alluvium. Fill at this AOC consists of brown, fine- to medium-grained sand with silt and gravel. Hydraulic fill extends to approximately 5 feet bgs. A silty clay lens was observed below the contact with the fill materials and overlying the silty sand in PP068. Alluvium beneath the fill consists of greenish-gray, fine-grained sand with silt. The well installed during the RI (GW174) is the only groundwater monitoring well near AOC-004. The groundwater elevation at GW174 was measured at 4.28 feet bgs. Groundwater in this area flows toward the northwest. The average gradient ranges from approximately 0 to 0.002. A slug test conducted in well GW174 indicated a hydraulic conductivity of 1.2×10^{-3} cm/s.



Based on a geologic cross-section presented in the final RI Report, the predominant soil type in the vadose zone is silty sand with gravel, and the soil type dominating groundwater flow is silty sand. Therefore, the dominant soil classification for both the vadose and saturated zones is SM; soil characteristics for SM soil are used for relevant calculations in this FS.

13.1.4 Nature and Extent of Affected Soil

Acetone, benzene, ethylbenzene, toluene, and TPH-G were detected in a soil sample from PP017, which was advanced through the subsurface at the former UST location. The aromatic hydrocarbons are components of TPH-G, which was detected at a concentration of 1,200 mg/kg in a soil sample collected from 2 to 4 feet bgs. A deeper sample at this same location contained no detectable VOCs and only 8 mg/kg of TPH-G. TPH-G was also identified above the PCL in a soil sample from PP018, at 42 mg/kg. Analytical results from the soil investigation are summarized in Figure 13-1.

13.1.5 Nature and Extent of Affected Groundwater

Benzene was detected at 29 µg/L and 13 µg/L in groundwater samples from PP017 and PP018, respectively, which are above the groundwater PCL for benzene of 1 µg/L. TPH-G was also detected at 0.93 mg/L in a groundwater sample from PP017. Analytical results from the groundwater investigation at the site are summarized on Figure 13-1. The extent of benzene- and TPH-G-affected groundwater was limited to PP017 and PP018. TPH-G and benzene were not detected above the PCLs in the downgradient push probe PP019 or groundwater monitoring well GW174. No other VOCs were detected above the PCLs in groundwater samples collected during the RI.

13.2 CONCEPTUAL SITE MODEL

A preliminary conceptual model for migration of constituents present in affected soil and groundwater at the Renton Facility was presented in Figure 2-6 of the FSWP (Geomatrix, 2004b). Based on the conceptual model and considerations presented in the FSWP plus information specific to this site, a site-specific conceptual site model is described below. This site-specific conceptual site model identifies the media and exposure pathways that must be addressed for remedial alternatives potentially applicable to this site.

Benzene and other aromatic VOCs, acetone, and TPH-G are likely present in soil within the source area for AOC-004. As shown in the Facility conceptual model presented in the FSWP, benzene or TPH-G can migrate from the source areas via groundwater or vapor pathways. For

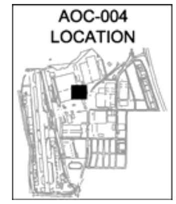
this site, migration via groundwater will be most significant. Constituent transport via groundwater at this site is affected by soil/groundwater interactions and biodegradation. As groundwater flows through benzene- and TPH-G-affected soil in the source area, adsorbed aromatic VOCs or TPH-G components may dissolve into groundwater, as observed in PP017 and PP018. Any dissolved VOCs or TPH-G components will move with groundwater but at a different velocity because of continuing solute-soil interactions. This movement may create a plume extending downgradient from the source areas; however, no dissolved TPH-G or aromatic VOCs were detected in groundwater samples from PP019 and GW174. If these constituents are present in groundwater, they are more likely to biodegrade than to volatilize.

The extent of groundwater affected by dissolved aromatic VOCs and TPH-G appears limited to the area near PP017. The source of the aromatic VOCs and TPH-G in the shallow soil can be attributed to a past release from the former UST. The acetone detected in the soil sample from PP017 was considered a nontarget analyte for this AOC (Weston, 2001a); however, no acetone was detected in the groundwater samples. The aromatic VOC- and TPH-G-affected groundwater should migrate to the north-northwest from the source area. However, the lack of detectable aromatic compounds or TPH-G at downgradient groundwater sampling points suggests that these constituents are biodegrading as they migrate. Volatilization of constituents from groundwater is not significant for most workers at this site, as noted in the conceptual site model presented in the FSWP.

13.3 SITE REMEDIATION OBJECTIVES AND CLEANUP STANDARDS

The remediation objectives for the Renton Facility were presented in Section 2. Cleanup levels applicable to the Facility were proposed in the FSWP and subsequently approved by Ecology. Cleanup levels were subsequently recalculated as described in Section 3 based on comments by Ecology. The remedial alternatives developed and evaluated for this site will be capable of attaining the remediation objectives and cleanup standards presented in this section. As defined in the MTCA regulations, the cleanup standard consists of the cleanup level and the location or POC at which the cleanup level must be met. The remedial alternatives for this site, presented below in Section 13.4, may have different points of compliance while fully addressing remediation objectives and meeting cleanup levels.

The groundwater and soil COCs exceeding the PCLs established in the final RI Report for AOC-004 were identified in FSWP Tables 5-1 and 5-3, respectively. These constituents were identified by comparing detected constituent concentrations to the PCLs identified in the final



RI Report; if a constituent concentration measured in any sample exceeded the PCL, the constituent was listed as a COC that must be addressed in the FS. Cleanup levels for both soil and groundwater meeting MTCA requirements were presented in the FSWP (Tables 5-6 and 5-2, respectively) and approved by Ecology.

The soil and groundwater cleanup levels for the site COCs are listed in Tables 3-1 and 3-2, respectively. The soil cleanup levels are either MTCA Method A cleanup levels or site-specific MTCA Method C cleanup levels that are protective of groundwater at the CPOC and were calculated in accordance with the procedures described in the FSWP or in accordance with recent negotiations with Ecology. The groundwater cleanup levels listed in Table 3-2 were developed as described in Section 3 and in accordance with recent negotiations with Ecology. The cleanup levels are protective of surface water, human health, and the environment.

The cleanup levels allow for the degradation that would occur between the source area and the CPOC due to natural attenuation. Details concerning modeling and cleanup level calculations are included in Section 3 and Appendix A. These cleanup levels will be used in development and evaluation of remedial alternatives for AOC-004 that involve natural attenuation or enhanced in situ bioremediation.

13.4 DESCRIPTION OF SITE REMEDIAL ALTERNATIVES

Information available when the former UST URE-04 was excavated and removed in 1986 did not indicate if gasoline-impacted soil was removed from the excavation. The UST was located within approximately 10 feet of Building 4-21. Analytical data from the RI indicate that TPH-G and associated compounds were present in site soils and groundwater at levels exceeding PCLs in the RI and cleanup levels in the FSWP. Soil sample results from the RI indicate that TPH-G concentrations detected above the PCL appear to occur very close to the former UST location and the building. Furthermore, the RI results indicate that the vertical extent of these constituents is less than 10 feet bgs (Weston, 2001a). Due to the proximity of remaining affected soil to the foundation and footings of Building 4-21 (approximately 7 feet bgs), Boeing believes that additional soil excavation may need to be limited as it may threaten the building.

MTCA requires that remedial alternatives selected for a site meet the MTCA threshold requirements for cleanup actions. The minimum threshold requirements specify that cleanup actions shall (1) protect human health and the environment, (2) comply with cleanup standards,

(3) comply with applicable state and federal law, and (4) provide for compliance monitoring. In order to be considered as a potential remedial alternative for the site, the technologies considered had to pass the screening evaluation of the remedial technologies, which is described in Section 4. In addition, the alternatives had to meet the minimum threshold requirements established by MTCA and had to be consistent with overall site conditions.

Based on the screening evaluation, MTCA minimum threshold requirements, and the site considerations discussed above, two remedial alternatives addressing groundwater COCs were assembled for AOC-004:

- Alternative 1: Monitored Natural Attenuation
- Alternative 2: Enhanced Bioremediation and Monitored Attenuation

13.4.1 Alternative 1: Monitored Natural Attenuation

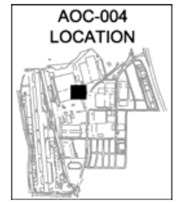
Alternative 1 consists of the following primary elements: institutional controls, MNA, and excavation and disposal of limited quantities of affected soil. The groundwater cleanup standard for this alternative will be the groundwater cleanup levels for AOC-004 COCs discussed in Section 13.3 and a CPOC shown on Figure 13-1. The soil cleanup standard will be the cleanup levels discussed in Section 13.3 and shown in Table 3-1.

No LNAPL has been identified in monitoring well GW174 installed near AOC-004. The soil sample from PP017 contained TPH-G at a concentration of 1,200 mg/kg, which slightly exceeds the residual saturation screening level for weathered gasoline of 1,000 mg/kg and is also above the MTCA Method A cleanup level for TPH-G. Therefore, additional action, such as sampling and analysis for VPH/EPH analysis or excavation of soils affected by TPH-G, will be taken. For the purposes of evaluating this alternative, limited excavation of soil affected by TPH-G will be included as a conservative measure under this alternative.

13.4.1.1 Institutional Controls

The following institutional controls are included to reduce the risk of human exposure to impacted soil or groundwater:

- Continued engineering controls, protocols, and monitoring previously established by Boeing to ensure that industrial workers inside buildings are protected and indoor air concentrations meet PELs established by the Washington Department of Labor and Industry;



- Continued engineering controls, protocols, and monitoring to ensure that temporary construction workers adhere to WAC 296-62-300, applicable Washington Labor and Industry standards, and OSHA HAZWOPER regulations (29 CFR 1919.120) for all construction work conducted in exposed areas of affected soil and groundwater; and

- Deed restrictions to limit development and use of the site.

It was assumed that deed restrictions would be established to limit future nonindustrial land use without additional specific actions to demonstrate compliance with soil and groundwater cleanup levels appropriate for unrestricted site use.

13.4.1.2 Monitored Natural Attenuation

Since shallow soil at PP017 exceeded MTCA Method A cleanup levels for TPH-G, limited excavation of affected soil will be performed in the AOC-004 source area. While a soil sample collected at PP018 also exceeded Method A cleanup levels for TPH-G, excavation below the water table will not be performed. In addition, the groundwater sample collected at PP018 contained 550 µg/L of TPH-G, which may be partially responsible for the observed TPH-G exceedance in soil at PP017.

Based on the POC approach presented in Section 6 of the FSWP, fate and transport groundwater modeling using BIOSCREEN was conducted to evaluate the efficacy of MNA as a final remedy for this AOC. The modeling followed the protocol established in the FSWP using approved model input parameters. The modeling results, presented in detail in Appendix A, are in agreement with the preliminary modeling conducted for the FSWP. The model results indicate that groundwater cleanup levels for all COCs fall rapidly with increased distance from the source and are met at a CPOC about 40 feet downgradient of the source area (Figure 13-1).

The development of a valid remedial approach for MNA at AOC-004 also requires a monitoring plan designed to verify the existence of and quantify the extent of enhanced and natural attenuation processes. In accordance with recent guidance and the approach discussed in Section 4.2.4, the conceptual monitoring program for AOC-004 is designed to:

- Demonstrate that natural attenuation is occurring according to expectations;

- Identify any potentially toxic and/or mobile transformation products;

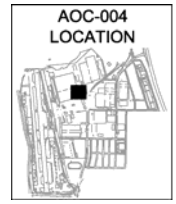
- Verify that the plume is not expanding beyond the CPOC;

- Verify that cleanup levels are obtained at the CPOC;
- Verify that there is no unacceptable impact to downgradient receptors;
- Detect new releases of COCs that could impact the effectiveness of the natural attenuation remedy;
- Demonstrate the efficacy of institutional controls put in place to protect potential receptors; and
- Verify attainment of remediation objectives.

The conceptual monitoring program for Alternative 1 at AOC-004 assumes that upon selection of this remedy, a detailed MNA Validation and Long-Term Sampling Work Plan would be developed to guide the process. This work plan would identify additional monitoring wells and monitoring analytes that would be required for both characterization/validation sampling and long-term groundwater monitoring. Characterization/validation sampling would be used to demonstrate the effectiveness of MNA with respect to contaminant mass reduction, attenuation rates, and temporal trends. Long-term groundwater monitoring would be used after characterization/validation monitoring to confirm that the contaminant plume is progressing toward containment or achievement of numerical goals.

For this conceptual design, it is assumed that characterization/validation sampling would consist of quarterly monitoring of three monitoring wells for a minimum of 1 year. Three new monitoring wells (two shallow and one intermediate) are assumed to be required to monitor plume migration. The three new monitoring wells would be installed along the CPOC, as shown in Figure 13-1. Monitoring parameters and analytes would consist of acetone, benzene, ethylbenzene, toluene, TPH-G, as well as the full suite of MNA geochemical parameters for hydrocarbon sites [dissolved oxygen, nitrate, Fe(II), sulfate, methane, temperature, pH, specific conductance, alkalinity, and oxidation/reduction potential]. It is assumed that reporting for characterization/validation sampling would follow each quarterly event.

It is further assumed that long-term groundwater monitoring would follow for an additional 13 to 14 years (15 total years of monitoring) and would include semiannual monitoring of two shallow wells for acetone, benzene, ethylbenzene, toluene, TPH-G, and a limited suite of geochemical parameters (dissolved oxygen, oxidation/reduction potential, temperature, and pH). To verify plume control, all three wells would be analyzed once every 5 years for the entire characterization/validation list of analytes. The frequency of sampling and the duration



of the groundwater monitoring program would be based on the results of performance monitoring, and may be adjusted as appropriate. It is assumed that annual reporting would be required for long-term groundwater monitoring.

13.4.2 Alternative 2: Enhanced Bioremediation and Monitored Attenuation

Alternative 2 consists of three primary elements: institutional controls, enhanced bioremediation, and MA. The groundwater cleanup standard for this alternative will be the groundwater cleanup levels for AOC-004 COCs previously discussed and a CPOC as shown on Figure 13-1. The soil cleanup standard will be the cleanup levels discussed in Section 13.3 and shown in Table 3-1.

13.4.2.1 Institutional Controls

Institutional controls for Alternative 2 would be the same as discussed in Section 13.4.1.1 for Alternative 1.

13.4.2.2 Enhanced Bioremediation

As with Alternative 1, limited excavation of soil will be performed in the AOC-004 source area near PP017. This limited excavation will be the same extent for both alternatives.

Enhanced bioremediation for AOC-004 would consist of injecting a terminal electron acceptor (TEA), such as ORC, ammonium nitrate, or calcium nitrate, into the source area groundwater to promote degradation of petroleum compounds. For conservative estimation of remediation costs, it was assumed that approximately 300 pounds of ORC would be injected directly into the subsurface at nine points located in the immediate vicinity of the source area at depths of approximately 4 feet to 14 feet bgs. If a nitrate were selected as the TEA, an equivalent dosage would be determined and injected in the same general manner as assumed for the ORC.

13.4.2.3 Monitored Attenuation

Monitored attenuation for this alternative is intended to be a final “polishing” mechanism, following the active enhanced bioremediation, to ensure that cleanup levels for all COCs are met at the CPOC. With this alternative, it is assumed that MA would follow enhanced bioremediation and consist of the long-term groundwater monitoring for three new wells, as described in Section 13.4.1.2 for Alternative 1. Groundwater monitoring would be conducted semiannually for acetone, benzene, ethylbenzene, toluene, TPH-G, and a limited suite of geochemical parameters (dissolved oxygen, oxidation/reduction potential, temperature, and

pH). To verify plume control, all three monitoring wells would be analyzed once every 5 years for the entire list of analytes. It is assumed that monitoring would continue following active remediation for a total of 15 years of monitoring, and that annual reporting would be required for the duration.

13.5 EVALUATION OF SITE REMEDIAL ALTERNATIVES

As previously discussed, both alternatives developed for the site meet the MTCA minimum requirements for cleanup actions. This section compares and evaluates the alternatives based on the MTCA criteria described in Section 5.1. An analysis of each alternative with respect to the evaluation criteria is summarized in Table 13-1 and discussed below.

13.5.1 Protectiveness and Risk Reduction

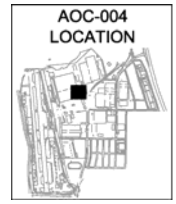
Protectiveness and risk reduction are gauged primarily on the time required for the alternative to reduce risk and meet cleanup levels. Although Alternative 2 would not destroy all of the COCs, of the two alternatives it is expected to most quickly reduce COCs in groundwater to cleanup levels and is rated higher for this criterion.

13.5.2 Permanence

Permanence refers to the ability to reduce the toxicity, mobility, or volume of hazardous substances, including the permanent destruction of hazardous substances. Both Alternatives 1 and 2 provide permanent destruction of COCs. Alternative 2 is rated higher for this criterion because the reduction of the hazardous waste volume from the site is expected to occur at a much faster rate.

13.5.3 Cost

The cost evaluation includes all costs related to implementation of an alternative, including initial design and construction costs, operation and maintenance costs, monitoring costs, and reporting costs. The annual costs for operation, maintenance, monitoring, and reporting are recurring costs that occur in the future. The cost evaluation considers initial implementation costs and future recurring costs using NPV analysis. For NPV calculation, recurring costs were inflated 2% annually and a discount rate of 7% was used. Details regarding the cost estimates for the three alternatives are presented in Appendix B. The present value costs for the three alternatives, in 2007 dollars, are summarized below:



Alternative	Net Present Value
1: Monitored Natural Attenuation	$333,000
2: Enhanced Bioremediation and Monitored Attenuation	$382,000

As shown by these costs, Alternative 1 has a lower NPV cost while Alternative 2 has higher cost. Therefore, Alternative 1 ranks higher for cost and Alternative 2 ranks lower.

13.5.4 Long-Term Effectiveness

Long-term effectiveness includes the degree of certainty and reliability of the alternative and whether treatment residue remains from the alternative that will require management. Both Alternatives 1 and 2 are proven technologies and neither produces residual wastes that would require ongoing management.

13.5.5 Management of Short-Term Risks

Short-term risk refers to the risk to human health and the environment during implementation of the alternative. Because the implementation of Alternative 1 is simpler than Alternative 2 and it does not require handling of ORC, it is rated higher for this criterion.

13.5.6 Technical and Administrative Implementability

This criterion is gauged by whether the alternative is technically possible relative to complexity, administrative/regulatory requirements, size, access, and integration with existing operations. Given that Alternative 1 is a small, simple system that integrates best with the Facility operations, it is rated higher.

13.5.7 Public Concerns

This criterion involves potential community concerns with the alternative. Since both alternatives deal with a large industrial site with limited public access, they are rated the same.

13.5.8 Reasonable Restoration Time Frame

Restoration time frame looks at the practicability of a shorter restoration time frame with consideration given to a number of factors, including site risks, site use and potential use, availability of alternative water supply, effectiveness and reliability of institutional controls, and toxicity of hazardous substances at the site. As a whole, these factors are a measure of the urgency of reducing risk and achieving cleanup goals for the site. Given that the site is

industrial, has proven institutional controls, and the toxicity of contaminants is moderate, both alternatives are ranked medium low.

13.6 SELECTION OF THE PREFERRED SITE REMEDIAL ALTERNATIVE

Selection of a preferred alternative under MTCA requires that preference be given to alternatives that use permanent solutions (to the maximum extent practicable), provide for a reasonable restoration time frame, and consider public concerns. The analysis below defines the baseline alternative for AOC-004 and compares the other alternatives to the baseline alternative based on the degree of permanence, reasonable restoration time frame, and the degree to which it addresses potential public concerns. Based on this comparison, the preferred remedial alternative is identified and proposed for selection as the cleanup action to be implemented for the site.

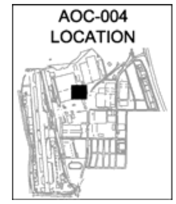
13.6.1 Baseline Remedial Alternative

The baseline remedial alternative for AOC-004 is Alternative 2. Although both alternatives could be considered to be permanent cleanup actions in the sense that cleanup standards are met, this alternative would likely provide for a shorter restoration time frame than Alternative 1.

The evaluation of both remedial alternatives for this site is summarized in Table 13-1. Neither of the alternatives is capable of attaining the standard POC at this site. However, both alternatives are capable of meeting the CPOC located on site about 40 feet from the source area.

13.6.2 Comparison to Baseline Alternative

As noted above, Alternative 2 has been defined as the baseline remedial alternative for this site. Alternative 1 will be compared to the baseline alternative in the following subsections for selection of the preferred alternative. The purpose of this comparison is to assess the benefits and costs for Alternative 1 relative to Alternative 2. The evaluation criteria presented above and in Table 13-1 were established in accordance with the MTCA requirements cited in WAC 173-340(3)(f). Costs for the alternatives will be based on the NPV, which reflects the total cost associated with each alternative over the 15-year time period evaluated. The evaluation of benefits will be qualitative.



The benefits to be assessed in this comparison and the relative rating for the alternatives are presented in Table 13-2. The rationale for this comparison is presented below.

- **Reduced risk to on-site worker health.** Both alternatives are equal in reducing risk to site workers because they are both equally protective. Although the baseline alternative would remove volatile COCs within a few years, potential risks to on-site workers would not be changed substantially by the other alternative. The institutional controls included in each of the alternatives have been proven effective in protecting worker health and would continue to be protective.

- **Reduced risk to off-site human health.** Both alternatives were rated high for this benefit. Both would attain the cleanup level at the CPOC, which is protective of human health and the environment. The institutional controls included in the alternatives that have proven to be protective of worker health on site would also be protective of human health in off-site areas located upgradient of the CPOC.

- **Reduced risk to the environment.** Both alternatives were rated high for this benefit. Both alternatives would be protective of the aquatic environment because they would attain the cleanup levels at the CPOC.

- **Minimal adverse impact on Facility operations.** Both alternatives were rated moderate for this benefit because they both would impact Facility operations due to excavation in the source area.

- **Minimal restrictions on Facility traffic and access.** Both alternatives were rated moderate for this benefit because they both would impact Facility traffic and access during excavation in the source area.

- **Minimal adverse impact on Facility structures and utilities.** Both alternatives were rated moderate, because excavation adjacent to Building 4-21 has the potential to affect the structural integrity of the building.

The potential benefit evaluation for the alternatives shows that both alternatives would provide the same level of benefits.

The NPV costs for both alternatives were presented in Section 13.5.3. The baseline alternative ranks second among the alternatives and would have the higher cost (approximately 15% higher than the cost for Alternative 1).

13.6.3 Preferred Remedial Alternative

Alternative 2 is the preferred remedial alternative for the AOC-004 site. Alternative 2, as the baseline and the most permanent potential remedy, does not provide additional benefits over

Alternative 1. However, it may achieve these benefits quicker and does not have a disproportionate cost. The institutional controls included in Alternative 2 have been implemented and proven by Boeing, who would continue to maintain overall responsibility for this site and ensure that the institutional controls are properly enforced.

Enhanced bioremediation and MA for this site would achieve the expectations for cleanup actions cited in the MTCA regulations at WAC 173-340-370 (1) – (8). Only those expectations relevant to large, complex sites are considered relevant to AOC-004. The relevant expectations are addressed as follows.

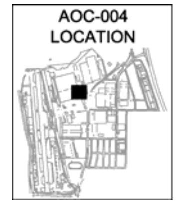
- **Implement Treatment at Sites with Liquid Wastes, High Contaminant Concentrations, Highly Mobile Materials, or Discrete Areas of Contamination.** Ecology expects that treatment will be emphasized for sites meeting these general criteria. Boeing believes that while remaining COC levels are elevated, they are not high, and there is no evidence of liquid wastes at the site. The source area is discrete but may extend beneath the building, limiting ready access for removal or treatment. Enhanced bioremediation will degrade or "treat" organic COCs over the long term using enhanced natural processes that result in nontoxic degradation products.

- **Destroy, Detoxify, or Remove Hazardous Substances.** Ecology expects that hazardous substances will be destroyed, detoxified, or removed to below cleanup levels. Excavation of affected soil will remove some COCs, and addition of ORC will ultimately destroy COCs, resulting in nontoxic degradation products.

- **Implement Engineering Controls for Low Contaminant Concentrations.** Ecology recognizes the need for containment for low concentrations of contaminants where treatment is impracticable. This alternative would use treatment to enhance destruction of contaminants wherever practicable.

- **Prevent Runoff of Hazardous Substances.** Ecology expects that cleanup actions will include active measures to prevent precipitation from creating runoff that contains affected soil. This expectation would be met by the preferred alternative because the source is covered by the building, tarmac, or pavement. In addition to preventing runoff from contacting hazardous substances, this cover minimizes surface water infiltration, thus resulting in decreased groundwater flow rates and increased time for groundwater to flow from the source area to the waterway.

- **Consolidate On-site Contaminants Exceeding Cleanup Levels.** Ecology expects that when contaminants are left on site exceeding cleanup levels that they will be consolidated to the extent practicable. Due to the location of the contaminants, it is not practicable to consolidate contaminants at this site.



- **Prevent Runoff and Groundwater Discharge to Surface Water.** Ecology expects that the cleanup action would include active measures to prevent or minimize releases to adjacent surface water bodies via runoff or groundwater discharge, and that dilution will not be the sole method for attaining cleanup levels. Alternative 2 would meet this expectation. Available groundwater monitoring data indicate that biodegradation of organic COCs is active and significant at this site. Addition of ORC will accelerate these natural processes. The cleanup alternative also includes a groundwater monitoring network and program that would confirm that cleanup levels are attained in groundwater at a CPOC about 40 feet downgradient of the AOC and before groundwater can reach Lake Washington.

- **Ensure Appropriateness of Attenuation.** Ecology expects that natural attenuation may be appropriate if source control has been conducted to the maximum extent practicable; contaminants remaining on site do not pose unacceptable risks to human health and the environment; evidence indicates that degradation is occurring and will continue to occur at a reasonable rate; and appropriate monitoring is conducted. These expectations would all be achieved by Alternative 2. Although affected soil and groundwater have been present at the site for a long time, Boeing has implemented effective institutional controls that have proven effective in protecting human health and the environment at this site. Groundwater monitoring data indicate that biodegradation of organic COCs is active at the site and can be accelerated through addition of ORC. Alternative 2 also includes a robust groundwater monitoring program designed to address recent guidance for MNA. The monitoring system included in the preferred alternative would confirm that cleanup levels are attained prior to groundwater discharging to Lake Washington.

The preferred remedial alternative would be designed to comply with applicable regulations. Potentially applicable regulations are listed in Table 13-3. These regulations govern the design, installation, and operation of remediation systems. For the preferred alternative at AOC-004, regulatory requirements are expected to be minimal. Construction for the preferred alternative would be limited to excavation in the source area and installation of new monitoring wells. The primary regulations governing the preferred alternative would be the MTCA regulations, the Washington well drilling regulations for monitoring wells, The Underground Injection Control regulations, the solid waste disposal regulations, the dangerous waste regulations, the transportation regulations, and the Department of Labor and Industries health and safety regulations. Well drilling rules specify well design and drilling requirements. The solid and dangerous waste regulations specify waste characterization, manifesting, and disposal requirements. The Underground Injection Control regulations apply to the injection of substrate or TEA to groundwater. Transportation regulations specify labeling and shipping requirements for wastes generated from implementation of the alternative. MTCA regulations

specify remediation requirements and the cleanup standards to be attained. The preferred alternative would be designed and implemented to comply with these regulations.

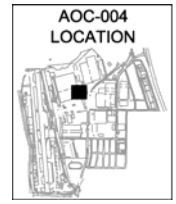


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TABLE 13-1

COMPARISON OF REMEDIAL ALTERNATIVES, AOC-004[1]

Boeing Renton Facility

Renton, Washington

Standards/Criteria		Alternatives	
		1 - Monitored Natural Attenuation	**2 - Enhanced Bioremediation/MA**
Protectiveness and Risk Reduction	Pros	Destroys COCs.	Destroys COCs.
	Cons	Slow to achieve cleanup.	
	Rating	ML	MH
Permanence	Pros	Destroys COCs; No residuals.	Destroys COCs; Reasonably rapid cleanup.
	Cons	Slow degradation rates.	
	Rating	MH	H
Cost	Pros	Lower cost.	
	Cons		Higher cost
	Rating	H	MH
Long-Term Effectiveness	Pros	Destroys COCs; Passive, natural process.	Destroys COCs, Mostly passive process.
	Cons		
	Rating	MH	MH
Management of Short-Term Risks	Pros	Simple implementation; No residuals.	Simple implementation, No residuals.
	Cons	Minor short-term risk associated with limited excavation of affected soils.	Short-term risk associated with limited excavation of affected soils and electron donor injection.
	Rating	H	MH
Technical and Administrative Implementability	Pros	Simple system.	Simple system.
	Cons	Limited excavation of affected soils	Limited excavation of affected soils; Injection permit needed.
	Rating	H	MH
Public Concerns	Pros	Industrial site.	Industrial site.
	Cons		
	Rating	MH	MH
Restoration Time Frame	Pros	Industrial site; Proven institutional controls; Alternative water available; Practicability of shorter time frame limited by facility operations.	Industrial site; Proven institutional controls; Alternative water available; Practicability of shorter time frame limited by facility operations.
	Cons		
	Rating	ML	ML

Notes:

1. Comparison Ratings: H = Highest (if the decision were based solely on one criterion, an H score would indicate the alternative is the preferred alternative); MH = Medium High; ML = Medium Low; L = Low.

TABLE 13-2

COMPARISON OF BENEFITS[1]
AOC-004
Boeing Renton Facility
Renton, Washington

Benefit	Alternative 1: Monitored Natural Attenuation	Alternative 2: Enhanced Bioremediation and Monitored Attenuation
Reduced risk to on-site worker health	High	High
Reduced risk to off-site human health	High	High
Reduced risk to the environment	High	High
Minimal adverse impact on Facility operations	Moderate	Moderate
Minimal restrictions on Facility traffic and access	Moderate	Moderate
Minimal adverse impact on Facility structures and utilities	Moderate	Moderate

Notes:
1. Benefits for each remedial alternative are rated as follows:
   High = high benefit;
   Moderate = moderate benefit;
   Low = low benefit.

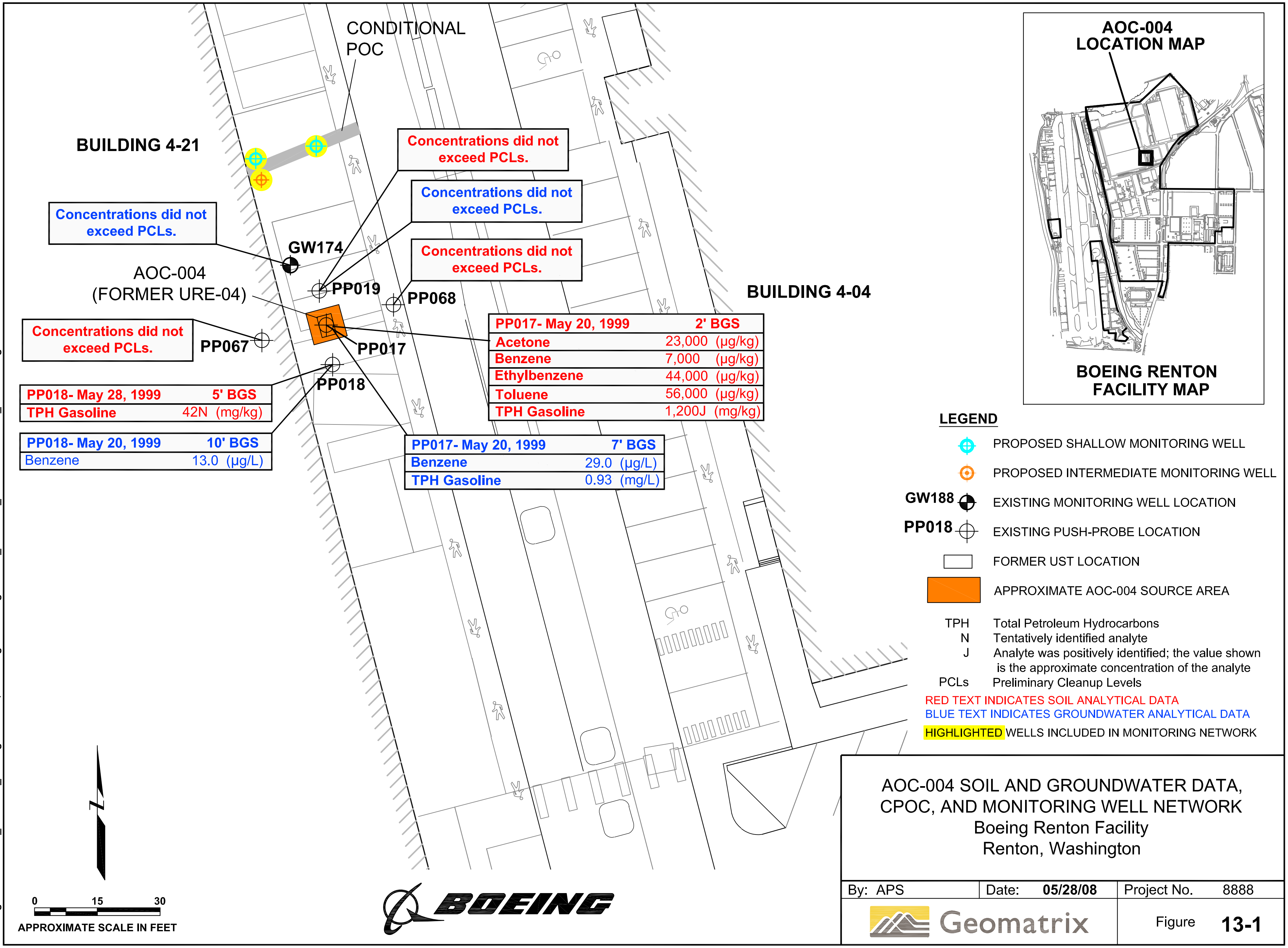
TABLE 13-3

POTENTIALLY APPLICABLE REGULATIONS
AOC-004 PREFERRED REMEDIAL ALTERNATIVE

Boeing Renton Facility
Renton, Washington

Law/Regulation	Citation	Applicability
Chemical-Specific Laws and Regulations		
Washington Dangerous Waste Regulations	WAC 173-303	Waste management, permitting requirements
Washington Model Toxics Control Act Regulations	WAC 173-340	Establishment of cleanup levels and POCs
Action-Specific Laws and Regulations		
Washington State Environmental Policy Act Regulations	WAC 197-11	Permitting, EIA/EIS requirements[1]
Washington Industrial Safety and Health Act Regulations	WAC 296-24	Occupational health and safety
Transportation regulations	49 CFR Parts 100 & 177, WAC 446-50	Transportation for wastes and materials
Washington well drilling regulations	WAC 173-160-162	Well design and installation standards
Washington underground injection control regulations	WAC 173-218	Underground injection permitting
Washington solid waste disposal regulations	WAC 173-304	Disposal of nondangerous waste

Notes:
1. EIA = Environmental Impact Assessment; EIS = Environmental Impact Statement.



AOC-004 SOIL AND GROUNDWATER DATA, CPOC, AND MONITORING WELL NETWORK
Boeing Renton Facility
Renton, Washington

By: APS | Date: 05/28/08 | Project No. 8888

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Figure 13-1

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14.0 DEVELOPMENT AND EVALUATION OF REMEDIAL ALTERNATIVES, AOC-034/035

In this section we discuss remediation objectives, identify and evaluate remedial alternatives, and describe the preferred remedial alternative for AOC-034 and AOC-035.

14.1 SITE CHARACTERIZATION SUMMARY

AOC-034/035 (the site) is the location of former underground storage tanks URE-07 and URE-08. The former steel UST were located adjacent to the south side of Building 4-41, as shown in Figure 1-2. The general site layout is shown on Figure 14-1.

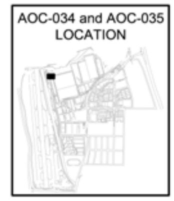
14.1.1 Historical, Present, and Future Site Use

Both USTs URE-07 and URE-08 were installed in 1980 for storage of MEK and toluene, but were reportedly never used. Each steel tank had a capacity of 500 gallons (Weston, 2001a). Both USTs were removed in 1987.

14.1.2 Previous Site Remedial Actions

During removal of the USTs in September 1987, volatile organic vapors were noted in the northwest corner of the excavation. Subsequent subsurface investigation in 1999 identified VC in soil (5.2 µg/kg) and groundwater (1.8 µg/L) samples collected in the area adjacent to URE-07 and URE-08; however, these levels were not high enough to warrant further investigation at that time. Complete RI characterization results for these units are presented in Section 5.13 of the final RI Report (Weston, 2001a).

In 2006, Boeing met and exchanged correspondence with Ecology regarding the use of 0.2 µg/L as the appropriate groundwater cleanup level for vinyl chloride at various CPOCs at the Facility. The intent of these discussions was to define a cleanup level at these CPOCs that will result in groundwater that does not exceed the ambient water quality criterion of 0.025 µg/L of vinyl chloride at the shoreline of Lake Washington or the bank of the Cedar River Waterway. As described in the AOC-034 and -035 Work Plan, Geomatrix calculated and reported a cleanup standard of 1.8 µg/kg vinyl chloride for soil at the Facility that is protective of the adjusted groundwater cleanup level (Geomatrix, 2006d). Because vinyl chloride was detected during the RI in samples from boring PP032 adjacent to AOC-034 and AOC-035 at concentrations higher than 1.8 µg/kg, the area was proposed for further investigation to determine whether remedial action would be necessary to reduce concentrations of VOC-affected soil and groundwater. Additional soil and groundwater testing was completed in



December 2006 and the results were presented to Ecology in a memorandum dated January 22, 2007 (Geomatrix, 2007b).

14.1.3 Site Hydrogeology

The site hydrogeology is described in detail in the final RI Report and is summarized below. The general stratigraphy below the site is alluvium overlain by fill materials. The fill materials are present from the surface to approximately 9 feet bgs and include reddish- to greenish-brown fine- to medium grained sand with silt and gravel. The alluvial materials beneath the fill are made up of greenish-gray medium- to coarse-grained sand with silt and gravel and greenish-gray very fine-grained sand with silt.

Depth to groundwater beneath the site ranges from approximately 2.5 to 5.5 feet bgs and groundwater in the area generally flows west-northwest towards the Cedar River Waterway and Lake Washington, as shown by the groundwater elevations and groundwater contour map in Figure 14-1.

14.1.4 Nature and Extent of Affected Soil

Twelve soil samples were collected from push probes in the area during the RI. While MEK and VOCs were detected in some of the samples, no samples contained constituents at concentrations above the PCLs established for the RI. Five soil samples were collected as part of the December 2006 investigation and analyzed for VC, TCE, and *cis*-1,2-DCE. Results of the 2006 laboratory analysis of soil and groundwater samples are summarized on Figures 14-2 and 14-3, respectively. VC was not detected in soil at PP161, which was placed at the same location (PP032) where 5.2 µg/kg VC was detected in soil samples collected in 1999. TCE was the only compound detected in the most recently collected soil samples. It was detected in one sample, collected from the downgradient boring location PP164, at a concentration of 1.9 µg/kg.

14.1.5 Nature and Extent of Affected Groundwater

Of the four groundwater samples collected during the RI, vinyl chloride was the only compound detected, and it was detected in only one sample (PP032) at a concentration of 1.8 µg/L. Five groundwater samples were also collected as part of the December 2006 investigation and analyzed for VC, TCE, and *cis*-1,2-DCE. VC and *cis*-1,2-DCE were detected in groundwater samples collected from two of the five boring locations, PP160 and PP161. Detected concentrations of *cis*-1,2-DCE were 0.2 and 0.5 µg/L, which are below the

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groundwater cleanup level of 0.65 µg/L at the proposed CPOC. The concentration of VC from samples collected at PP160 and PP161 was 0.6 and 2.7 µg/L, respectively, which exceeds the CPOC cleanup level of 0.29 µg/L for AOC-034/035.

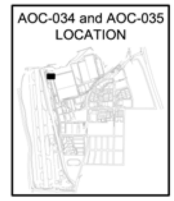
14.2 CONCEPTUAL SITE MODEL

The former USTs at the site were installed with the intent of using them to store a mixture of MEK and toluene, but were reportedly never used. When the tanks were removed in 1987, VOC vapors were detected in the northwest corner of the excavation immediately adjacent to Building 4-41. During the RI, MEK and toluene were the target analytes, but these compounds were not detected above their respective PCLs. However, VC, a nontarget analyte, was detected in both soil and groundwater in PP032 located immediately south of the building where the VOC vapors were noted in 1987. Sampling and analytical testing conducted in December 2006 indicate that VC is still present in groundwater in this area. The conceptual site model suggests that additional impacted soil may remain beneath Building 4-41 and may be impacting groundwater. The amount and location of the impacted soil are unknown. VC can migrate from impacted soils via vapor and groundwater pathways.

Groundwater impacted by VC is present in the source area, and additional VC may be present in site soils beneath the building. The VC-affected groundwater will migrate to the northwest from the source area toward the confluence of the Cedar River Waterway and Lake Washington. However, modeling suggests that the VC present at low concentrations in groundwater will degrade into ethane and chloride salts and concentrations of VC will fall below the ambient water quality criterion of 0.025 µg/L, before the VC reaches these surface water bodies.

14.3 SITE REMEDIATION OBJECTIVES AND CLEANUP STANDARDS

The remediation objectives for the Renton Facility were presented in Section 2. Cleanup levels applicable to the Facility were proposed in the FSWP and were subsequently negotiated with Ecology. The remedial alternatives developed and evaluated for this site will be capable of attaining the remediation objectives and cleanup standards presented in this section. As defined in the MTCA regulations, the cleanup standard consists of the cleanup level and the location or CPOC at which the cleanup level must be met. The remedial alternatives for this site, presented below in Section 14.4, may have different points of compliance while fully addressing remediation objectives and meeting cleanup levels.



No groundwater or soil COCs exceeded the original PCLs established in the final RI Report for AOC-034/035. The original approach was that any constituent concentrations measured in any sample exceeding the PCL resulted in the constituent listed as a COC that must be addressed in the FS. AOC-034/035 was added to the FS, with VC as a soil and groundwater COC, because VC soil concentrations were above the negotiated adjusted cleanup level (Table 3-1) and because groundwater concentrations exceeded the negotiated CPOC cleanup level (Table 3-2).

The soil and groundwater cleanup levels for the site COCs are listed in Tables 3-1 and 3-2, respectively. The soil cleanup levels are either MTCA Method A cleanup levels or site-specific MTCA Method C cleanup levels that are protective of groundwater at the CPOC and were calculated in accordance with the procedures described in the FSWP or in accordance with recent negotiations with Ecology. The groundwater cleanup levels listed in Table 3-2 were developed as described in Section 3 and in accordance with recent negotiations with Ecology. The cleanup levels are protective of surface water, human health, and the environment.

The cleanup levels allow for the degradation that would occur between the source area and the CPOC due to natural attenuation. Details concerning modeling and cleanup level calculations are included in Section 3 and Appendix A. These cleanup levels will be used in development and evaluation of remedial alternatives for AOC-034/035 that involve natural attenuation or enhanced in situ bioremediation.

14.4 DESCRIPTION OF SITE REMEDIAL ALTERNATIVES

MTCA requires that remedial alternatives selected for a site meet the MTCA threshold requirements for cleanup actions. The minimum threshold requirements specify that cleanup actions shall (1) protect human health and the environment, (2) comply with cleanup standards, (3) comply with applicable state and federal law, and (4) provide for compliance monitoring. In order to be considered as a potential remedial alternative for the site, the technologies considered had to pass the screening evaluation of the remedial technologies described in Section 4. In addition, the alternatives had to meet the minimum threshold requirements established by MTCA and had to be consistent with overall site conditions.

Based on the screening evaluation, MTCA minimum threshold requirements, and the site considerations discussed above, two remedial alternatives addressing groundwater COCs were assembled for AOC-034/035:

- Alternative 1: Monitored Natural Attenuation

- Alternative 2: Enhanced Bioremediation and Monitored Attenuation

14.4.1 Alternative 1: Monitored Natural Attenuation

Alternative 1 consists of two primary elements: institutional controls and MNA. The groundwater cleanup standard for this alternative will be the groundwater cleanup levels for AOC-034/035 COCs previously discussed and the CPOC shown on Figure 14-1. The soil cleanup standard will be the cleanup levels discussed in Section 14.3 and shown in Table 3-1. Because the detected levels of VOCs in source area soils do not currently (2006 results) exceed the cleanup levels, the existing VOC concentrations in soil are protective of groundwater at the CPOC.

14.4.1.1 Institutional Controls

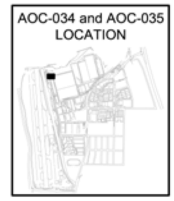
The following institutional controls are included to reduce the risk of human exposure to impacted soil or groundwater:

- Continued engineering controls, protocols, and monitoring previously established by Boeing to ensure that industrial workers inside buildings are protected and indoor air concentrations meet PELs established by the Washington Industrial Safety and Health Act (WISHA);
- Additional indoor air monitoring for vinyl chloride in the south and southwest corner of the building and comparison to WISHA PELs and MTCA cleanup levels;
- Continued engineering controls, protocols, and monitoring to ensure that temporary construction workers adhere to WAC 296-62-300, applicable Washington Labor and Industry standards, and OSHA HAZWOPER regulations (29 CFR 1919.120) for all construction work conducted in exposed areas of affected soil and groundwater; and
- Deed restrictions to limit development and use of the site.

Deed restrictions would be established to limit future nonindustrial land use without additional specific actions to demonstrate compliance with soil and groundwater cleanup levels appropriate for unrestricted site use.

14.4.1.2 Monitored Natural Attenuation

Based on the CPOC approach presented in Section 6 of the FSWP, fate and transport groundwater modeling using BIOCHLOR was conducted to evaluate the efficacy of MNA as a final remedy for this AOC. The modeling followed the protocol established in the FSWP using approved model input parameters. The model results indicate that concentrations of all COCs



fall rapidly with increased distance from the source; that cleanup levels will be met at the CPOC (approximately 60 feet from the source area); and that this CPOC and groundwater cleanup level of 0.29 µg/L for VC will result in VC groundwater concentrations of less than 0.025 µg/L before groundwater discharges to the Cedar River Waterway or Lake Washington.

The development of a valid remedial approach for MNA at AOC-034/035 also requires a monitoring plan designed to verify the existence of and quantify the extent of enhanced and natural attenuation processes. In accordance with recent guidance and the approach discussed in Section 4.2.4, the conceptual monitoring program for AOC-034/035 is designed to:

- Demonstrate that natural attenuation is occurring according to expectations;
- Identify any potentially toxic and/or mobile transformation products;
- Verify that the plume is not expanding beyond the CPOC;
- Verify that cleanup levels are attained at the CPOC;
- Verify that there is no unacceptable impact to downgradient receptors;
- Detect new releases of COCs that could impact the effectiveness of the natural attenuation remedy;
- Demonstrate the efficacy of institutional controls put in place to protect potential receptors; and
- Verify attainment of remediation objectives.

The conceptual monitoring program for Alternative 1 at AOC-034/035 assumes that upon selection of this remedy, a detailed MNA Validation and Long-Term Sampling Work Plan would be developed to guide the process. This work plan would identify additional monitoring wells and monitoring analytes that would be required for both characterization/validation sampling and long-term groundwater monitoring. Characterization/validation sampling would be used to demonstrate the effectiveness of MNA with respect to contaminant mass reduction, attenuation rates, and temporal trends. Long-term groundwater monitoring would be used after characterization/validation monitoring to confirm that the contaminant plume is progressing toward containment or achievement of numerical goals.

For this conceptual design, it is assumed that characterization/validation sampling would consist of quarterly monitoring of four monitoring wells for a minimum of 1 year. Four new shallow monitoring wells are assumed to be required to monitor plume migration. Monitoring parameters and analytes would consist of VOCs (contaminants and daughter products), as well as the full suite of MNA geochemical parameters [dissolved oxygen, nitrate, Fe(II), sulfate, methane, temperature, pH, specific conductance, alkalinity, oxidation/reduction potential, chloride, ethane, and TOC]. It is assumed that reporting for characterization/validation sampling would follow each quarterly event.

It is further assumed that long-term groundwater monitoring would follow for an additional 13 to 14 years (15 total years of monitoring) and include semiannual monitoring of four shallow wells for VOCs (contaminants and daughter products) and a limited suite of geochemical parameters (dissolved oxygen, oxidation/reduction potential, temperature, and pH). To ensure plume control, all four wells would be analyzed once every 5 years for the entire characterization/validation list of analytes. It is assumed that annual reporting would be required for long-term groundwater monitoring.

14.4.2 Alternative 2: Enhanced Bioremediation and Monitored Attenuation

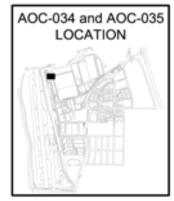
Alternative 2 consists of three primary elements: institutional controls, enhanced bioremediation, and MA. The groundwater cleanup standard for this alternative will be the groundwater cleanup levels for AOC-034/035 COCs previously discussed and a CPOC as shown on Figure 14-1. The soil cleanup standard will be the soil cleanup levels discussed in Section 14.3 and shown in Table 3-1. Because the current levels of VOCs in source area soils do not exceed the soil cleanup levels, the existing VOC concentrations in soil are protective of groundwater at the CPOC.

14.4.2.1 Institutional Controls

Institutional controls for Alternative 2 would be the same as described in Section 14.4.1.1 for Alternative 1.

14.4.2.2 Enhanced Bioremediation

Enhanced bioremediation for AOC-034/035 would consist of increasing the reductive capacity of the subsurface aqueous system by providing additional growth substrates for microbial activity. The final design for this alternative, if selected for implementation, would be determined in a cleanup action plan; injection of electron donor could be done using dedicated injection wells or using direct-push methods. The conceptual design of enhanced bioremediation for Alternative 2 assumes a series of four injection wells would be installed in



an injection zone surrounding the source area. It is assumed that the injection wells, constructed of 2-inch-diameter PVC, would be screened in the impacted aquifer between approximately 6 feet and 14 feet bgs. It is further assumed that the electron donor substrate injected would be emulsified vegetable oil, sodium lactate, or other similar substrate. For the conceptual design, it is assumed that a total of 1,000 gallons of 2% emulsified vegetable oil would be injected into the four injection wells in approximately equal portions. It is also assumed that three applications (at approximately 1-year intervals) would be required to effectively treat the aquifer, resulting in a total injection of 3,000 gallons of 2% emulsified vegetable oil. For costing of this remedial alternative, it is assumed that pilot testing is not needed, as enhanced bioremediation using either emulsified vegetable oil or carbohydrate has been performed successfully at the Facility as an interim measure.

14.4.2.3 Monitored Attenuation

Monitored attenuation for this alternative is intended to be a final "polishing" mechanism, following the active enhanced bioremediation, to ensure that cleanup levels for all COCs are met at the CPOC. With this alternative, it is assumed that MA would commence after the first enhanced bioremediation injection event and consist of the long-term groundwater monitoring program for four shallow wells described in Section 14.4.1.2 for Alternative 1. Groundwater monitoring would be conducted semiannually for VOCs (contaminants and daughter products) and a limited suite of geochemical parameters (dissolved oxygen, oxidation/reduction potential, temperature, and pH). To ensure plume control, all four monitoring wells would be analyzed once every 5 years for the entire list of analytes. It is assumed that monitoring would continue following active remediation for a total of 15 years of monitoring and that annual reporting would be required for the duration.

14.5 EVALUATION OF SITE REMEDIAL ALTERNATIVES

Both alternatives developed for the site meet the MTCA minimum requirements for cleanup actions. This section compares and evaluates the alternatives based on the MTCA criteria described in Section 5.1. An analysis of each alternative with respect to the evaluation criteria is summarized in Table 14-1 and discussed below.

14.5.1 Protectiveness and Risk Reduction

Protectiveness and risk reduction are gauged primarily on the time required for the alternative to reduce risk and meet cleanup levels. Although Alternative 2 would not destroy all of the

COCs, of the two alternatives, it is expected to most quickly reduce COCs in groundwater to cleanup levels and is rated higher for this criterion.

14.5.2 Permanence

Permanence refers to the ability to reduce the toxicity, mobility, or volume of hazardous substances, including the permanent destruction of hazardous substances. Both Alternatives 1 and 2 provide permanent destruction of COCs. Alternative 2 is rated higher for this criterion because the permanent reduction of the hazardous constituents from the site is expected to occur at a much faster rate.

14.5.3 Cost

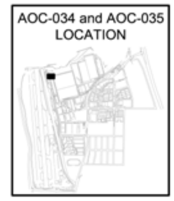
The cost evaluation includes all costs related to implementation of an alternative, including initial design and construction costs, operation and maintenance costs, monitoring costs, and reporting costs. The annual costs for operation, maintenance, monitoring, and reporting are recurring costs that occur in the future. The cost evaluation considers initial implementation costs and future recurring costs using NPV analysis. For NPV calculation, recurring costs were inflated 2% annually, and a discount rate of 7% was used. Details regarding the cost estimates for the three alternatives are presented in Appendix B. The present value costs for the two alternatives, in 2007 dollars, are summarized below:

Alternative	Net Present Value
1: Monitored Natural Attenuation	$331,000
2: Enhanced Bioremediation and Monitored Attenuation	$371,000

As shown by these costs, Alternative 1 has lower NPV cost, while Alternative 2 has higher cost. Therefore, Alternative 1 ranks higher for cost, and Alternative 2 ranks lower.

14.5.4 Long-Term Effectiveness

Long-term effectiveness includes the degree of certainty and reliability of the alternative and whether treatment residue remains from the alternative that will require management. Both Alternatives 1 and 2 are proven technologies; however Alternative 2 is rated higher for this criterion because the permanent destruction is more controlled and expected to occur at a faster rate.



14.5.5 Management of Short-Term Risks

Short-term risk refers to the risk to human health and the environment during implementation of the alternative. Because the implementation of Alternative 1 is simpler than Alternative 2 and it does not require construction of a treatment or injection system, it is rated higher for this criterion.

14.5.6 Technical and Administrative Implementability

This criterion involves whether the alternative is technically possible relative to complexity, administrative/regulatory requirements, size, access, and integration with existing operations. Given that Alternative 1 is a small, simple system that integrates best with the Facility operations, it is rated higher.

14.5.7 Public Concerns

This criterion involves potential community concerns with the alternative. Since both alternatives deal with a large industrial site with limited public access, they are rated the same.

14.5.8 Reasonable Restoration Time Frame

Restoration time frame looks at the practicability of a shorter restoration time frame with consideration given to a number of factors, including site risks, site use and potential use, availability of alternative water supply, effectiveness and reliability of institutional controls, and toxicity of hazardous substances at the site. As a whole, these factors are a measure of the urgency of reducing risk and achieving cleanup goals for the site. Given that the site is industrial, has proven institutional controls, and the toxicity of contaminants is moderate, both alternatives are ranked medium low.

14.6 Selection of the Preferred Site Remedial Alternative

Selection of a preferred alternative under MTCA requires that preference be given to alternatives that use permanent solutions (to the maximum extent practicable), provide for a reasonable restoration time frame, and consider public concerns. The analysis below defines the baseline alternative for AOC-034/035 and compares the other alternatives to the baseline alternative based on the degree of permanence, reasonable restoration time frame, and the degree to which it addresses potential public concerns. Based on this comparison, the preferred remedial alternative is identified and proposed for selection as the cleanup action to be implemented for the site.

14.6.1 Baseline Remedial Alternative

The baseline remedial alternative for AOC-034/035 is Alternative 2. Although both alternatives could be considered to be permanent cleanup actions in the sense that cleanup standards are met, this alternative would likely provide for a shorter restoration time frame than Alternative 1.

The evaluation of both remedial alternatives for this site is summarized in Table 14-1. Neither of the alternatives is capable of attaining the standard POC at this site. However, both alternatives are capable of meeting the CPOC located on site and about 60 feet from the source area.

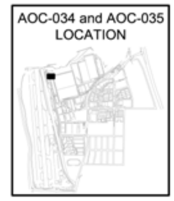
14.6.2 Comparison to Baseline Alternative

As noted above, Alternative 2 has been defined as the baseline remedial alternative for this site. Alternative 1 will be compared to the baseline alternative in the following subsections for selection of the preferred alternative. The purpose of this comparison is to assess the benefits and costs for Alternative 1 relative to Alternative 2. The evaluation criteria presented above and in Table 14-1 were established in accordance with the MTCA requirements cited in WAC 173-340(3)(f). Costs for the alternatives will be based on the NPV, which reflects the total cost associated with each alternative over the 15-year time period evaluated. The evaluation of benefits will be qualitative.

The benefits to be assessed in this comparison and the relative rating for the alternatives are presented in Table 14-2. The rationale for this comparison is presented below:

- **Reduced risk to on-site worker health.** Both alternatives are equal in reducing risk to site workers because they are all equally protective. Although the baseline alternative would remove volatile COCs within a few years, potential risks to on-site workers would not be changed substantially by the other alternative. The institutional controls included in each of the alternatives have been proven effective in protecting worker health and would continue to be protective.

- **Reduced risk to off-site human health.** Both alternatives were rated high for this benefit. Both would attain the cleanup level at the CPOC, which is protective of human health and the environment. The institutional controls included in the alternatives that have proven to be protective of worker health on site would also be protective of human health in off-site areas located upgradient of the CPOC.



- **Reduced risk to the environment.** Both alternatives were rated high for this benefit. Both alternatives would be protective of the aquatic environment because they would attain the cleanup levels at the CPOC.

- **Minimal adverse impact on Facility operations.** The baseline alternative was rated moderate for this benefit because it would impact Facility operations during direct injection at the source area. A high rating was given to Alternative 1, which relies on passive degradation of site COCs and would have the least impact on Facility operations.

- **Minimal restrictions on Facility traffic and access.** The baseline alternative was rated moderate for this benefit because it would impact Facility traffic and access during direct injection at the source area. Alternative 1 was given a high rating because it would affect traffic only during installation of monitoring wells, resulting in the least impact on Facility traffic and access.

- **Minimal adverse impact on Facility structures and utilities.** Both alternatives were rated high for minimizing adverse impacts on facility structures and utilities. Neither alternative includes excavation, due to the location of the source area in relation to the Building 4-21 footings and foundation.

The potential benefit evaluation for the alternatives shows that Alternative 1, Monitored Natural Attenuation, would provide greater benefit. The baseline alternative (Alternative 2) would provide the next higher benefit.

The NPV costs for both alternatives were presented in Section 14.5.3. The baseline alternative ranks second among the alternatives and would have the higher cost (approximately 12% higher than the cost for Alternative 1).

14.6.3 Preferred Remedial Alternative

Alternative 2 is the preferred remedial alternative for the AOC-034/035 site. Alternative 2, as the baseline and the most permanent potential remedy, does not provide additional benefits over Alternative 1. However, it may achieve these benefits quicker and does not have a disproportionate cost. The institutional controls included in Alternative 2 have been implemented and proven by Boeing, who would continue to maintain overall responsibility for this site and ensure that the institutional controls are properly enforced.

Enhanced bioremediation and MA for this site would achieve the expectations for cleanup actions cited in the MTCA regulations at WAC 173-340-370 (1) – (8). Only those expectations

relevant to large, complex sites are considered relevant to AOC-034/035. The relevant expectations are addressed as follows.

- **Implement Treatment at Sites with Liquid Wastes, High Contaminant Concentrations, Highly Mobile Materials, or Discrete Areas of Contamination.** Ecology expects that treatment will be emphasized for sites meeting these general criteria. Boeing believes that while remaining COC levels are elevated, they are not high, and there is no evidence of liquid wastes at the site. The source area is discrete but may extend beneath the building, preventing ready access for removal or treatment. Enhanced bioremediation would degrade or "treat" organic COCs over the long term using enhanced natural processes that result in nontoxic degradation products.

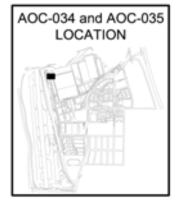
- **Destroy, Detoxify, or Remove Hazardous Substances.** Ecology expects that hazardous substances will be destroyed, detoxified, or removed to below cleanup levels. Addition of growth substrates such as sodium lactate would ultimately destroy COCs resulting in nontoxic degradation products.

- **Implement Engineering Controls for Low Contaminant Concentrations.** Ecology recognizes the need for containment for low concentrations of contaminants where treatment is impracticable. This alternative would use treatment to enhance destruction of contaminants wherever practicable.

- **Prevent Runoff of Hazardous Substances.** Ecology expects that cleanup actions will include active measures to prevent precipitation from creating runoff that contains affected soil. This expectation would be met by the preferred alternative because the source is covered by the building, tarmac, or pavement. In addition to preventing runoff from contacting hazardous substances, this cover minimizes surface water infiltration, thus resulting in decreased groundwater flow rates and increased time for groundwater to flow from the source area to the waterway.

- **Consolidate On-site Contaminants Exceeding Cleanup Levels.** Ecology expects that when contaminants are left on site exceeding cleanup levels that they will be consolidated to the extent practicable. Due to the location of the contaminants, it is not practicable to consolidate contaminants at this site.

- **Prevent Runoff and Groundwater Discharge to Surface Water.** Ecology expects that the cleanup action would include active measures to prevent or minimize releases to adjacent surface water bodies via runoff or groundwater discharge, and that dilution will not be the sole method for attaining cleanup levels. Alternative 2 would meet this expectation. Available groundwater monitoring data indicate that biodegradation of organic COCs is active and significant at this site. Addition of growth substrates such as sodium lactate would accelerate these natural processes. The cleanup alternative would also include a groundwater monitoring network and program that would confirm that cleanup levels are attained in



groundwater about 60 feet downgradient of the AOC and before groundwater can reach the Cedar River or Lake Washington.

- **Ensure Appropriateness of Attenuation.** Ecology expects that natural attenuation may be appropriate if source control has been conducted to the maximum extent practicable; contaminants remaining on site do not pose unacceptable risks to human health and the environment; evidence indicates that degradation is occurring and will continue to occur at a reasonable rate; and appropriate monitoring is conducted. These expectations would all be achieved by Alternative 2. Although affected soil and groundwater have been present at the site for a long time, Boeing has implemented effective institutional controls that have proven effective in protecting human health and the environment at this site. Groundwater monitoring data indicate that biodegradation of organic COCs is active at the site and can be accelerated through addition of growth substrates. Alternative 2 also includes a robust groundwater monitoring program designed to address recent guidance for MNA. The monitoring system included in the preferred alternative would confirm that cleanup levels are attained prior to groundwater discharging to the Cedar River Waterway or Lake Washington.

The preferred remedial alternative would be designed to comply with applicable regulations. Potentially applicable regulations are listed in Table 14-3. These regulations govern the design, installation, and operation of remediation systems. For the preferred alternative at AOC-034/035, regulatory requirements are expected to be minimal. Construction for the preferred alternative would be limited to installation of new monitoring wells and injection wells or injection probes. The primary regulations governing the preferred alternative would be the MTCA regulations, the Washington well drilling regulations for monitoring wells, the underground injection control regulations, the solid waste disposal regulations, the dangerous waste regulations, the transportation regulations, and the Department of Labor and Industries health and safety regulations. Well drilling rules specify well design and drilling requirements. The solid and dangerous waste regulations specify waste characterization, manifesting, and disposal requirements. Transportation regulations specify labeling and shipping requirements for wastes generated from implementation of the alternative. Underground injection control regulations govern injection well design, drilling, and registration requirements. MTCA regulations specify remediation requirements and the cleanup standards to be attained. The preferred alternative would be designed and implemented to comply with these regulations.

To establish baseline groundwater conditions at the proposed CPOC, the groundwater monitoring wells may be installed as part of an interim action prior to completion of the CAP. Results from the installation and water quality testing at the CPOC wells may be used during

the CAP process to reevaluate the remedial design and ensure that this selected alternative is optimal for this AOC and would meet site remediation objectives.

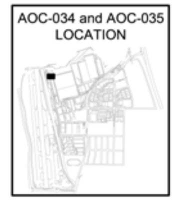


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TABLE 14-1

COMPARISON OF REMEDIAL ALTERNATIVES, AOC-034/035[1]

Boeing Renton Facility
Renton, Washington

Standards/Criteria		Alternatives: 1 - Monitored Natural Attenuation	Alternatives: 2 - Enhanced Bioremediation/MA
Protectiveness and Risk Reduction	Pros	Destroys COCs.	Destroys COCs.
	Cons	Slow to achieve cleanup.	
	Rating	ML	MH
Permanence	Pros	Natural carbon promotes MNA; Destroys COCs; No residuals.	Destroys COCs; No residuals; Reasonably rapid cleanup.
	Cons	Slow degradation rates.	
	Rating	MH	H
Cost	Pros	Lower cost.	
	Cons		Higher cost.
	Rating	H	MH
Long-Term Effectiveness	Pros	Destroys COCs; Passive, natural process.	Destroys COCs.
	Cons		Requires periodic injections.
	Rating	M	MH
Management of Short-Term Risks	Pros	Simplest implementation; No residuals.	
	Cons		Requires periodic injections.
	Rating	H	MH
Technical and Administrative Implementability	Pros	Simple system.	Simple system.
	Cons		Requires periodic injections; Injection permit required.
	Rating	H	MH
Public Concerns	Pros	Industrial site.	Industrial site.
	Cons		
	Rating	MH	MH
Restoration Time Frame	Pros	Industrial site; Proven institutional controls; Alternative water available; Practicability of shorter time frame limited by facility operations.	Industrial site; Proven institutional controls; Alternative water available; Practicability of shorter time frame limited by facility operations.
	Cons		
	Rating	ML	ML

Notes:

1. Comparison Ratings: H = Highest (if the decision were based solely on one criterion, an H score would indicate the alternative is the preferred alternative);
MH = Medium High;
M = Medium
ML = Medium Low;
L = Low.

TABLE 14-2

COMPARISON OF BENEFITS[1]
AOC-034/035
Boeing Renton Facility
Renton, Washington

Benefit	Alternative 1: Monitored Natural Attenuation	Alternative 2: Enhanced Bioremediation
Reduced risk to on-site worker health	High	High
Reduced risk to off-site human health	High	High
Reduced risk to the environment	High	High
Minimal adverse impact on Facility operations	High	Moderate
Minimal restrictions on Facility traffic and access	High	Moderate
Minimal adverse impact on Facility structures and utilities	High	High

Notes:
1. Benefits for each remedial alternative are rated as follows:
   High = high benefit;
   Moderate = moderate benefit;
   Low = low benefit.

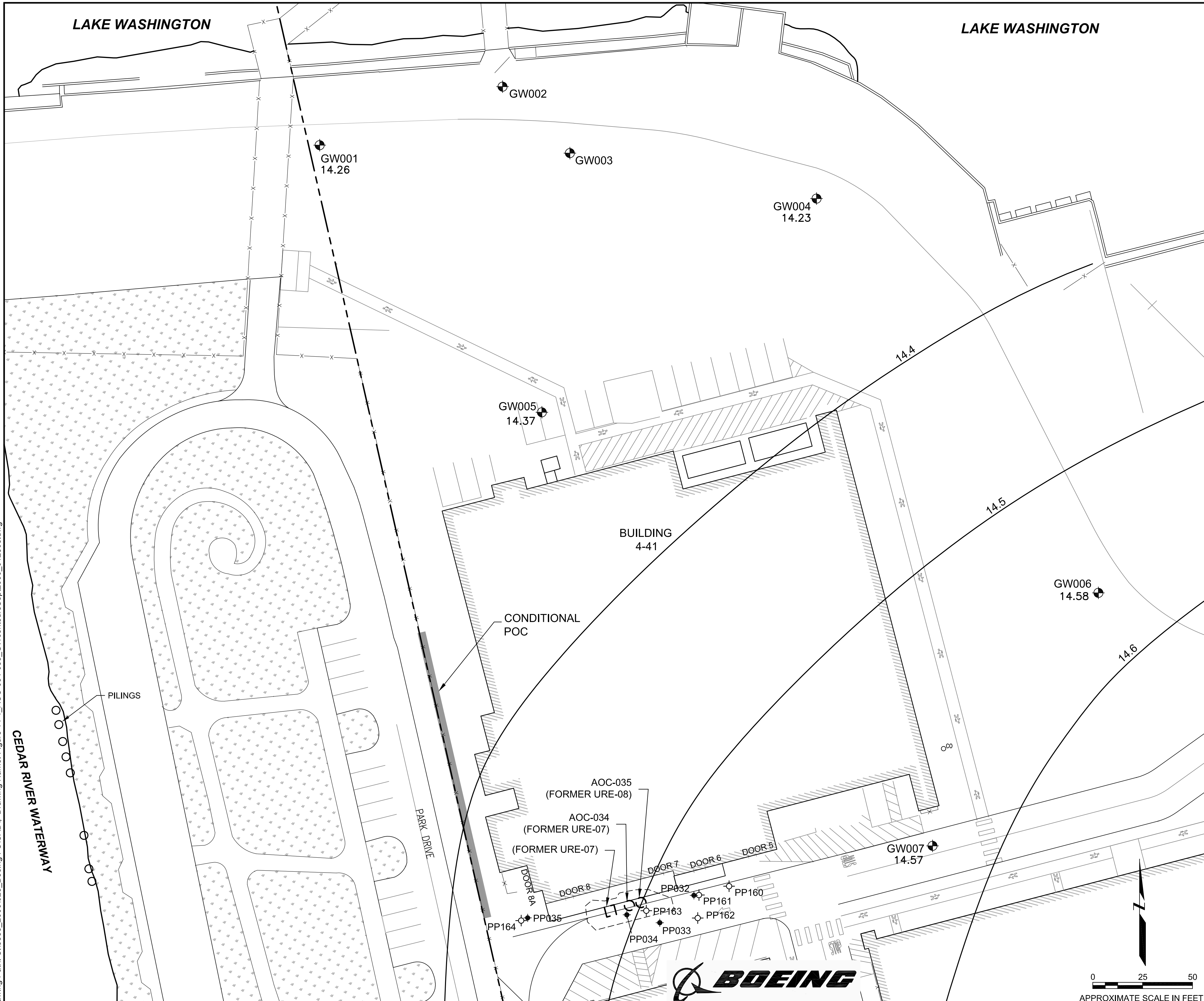
TABLE 14-3

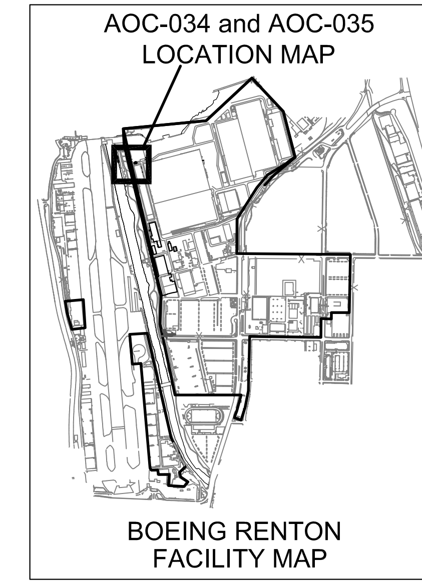
POTENTIALLY APPLICABLE REGULATIONS
AOC-034/035 PREFERRED REMEDIAL ALTERNATIVE

Boeing Renton Facility
Renton, Washington

Law/Regulation	Citation	Applicability
Chemical-Specific Laws and Regulations		
Washington Dangerous Waste Regulations	WAC 173-303	Waste management, permitting requirements
Washington Model Toxics Control Act Regulations	WAC 173-340	Establishment of cleanup levels and POCs
Action-Specific Laws and Regulations		
Washington State Environmental Policy Act Regulations	WAC 197-11	Permitting, EIA/EIS[1] requirements
Washington Industrial Safety and Health Act Regulations	WAC 296-24	Occupational health and safety
Transportation regulations	49 CFR Parts 100 & 177, WAC 446-50	Transportation for wastes and materials
Washington well drilling regulations	WAC 173-160 & -162	Well design and installation standards
Washington Underground Injection Control Regulations	WAC 173-218	Underground injection permitting
Washington solid waste disposal regulations	WAC 173-304	Disposal of nondangerous waste

Notes:
1. EIA = Environmental Impact Assessment; EIS = Environmental Impact Statement.





LEGEND

GW006 14.58	MONITORING WELL LOCATION GROUNDWATER ELEVATION (FEET)
PP162	12/14/2006 PUSH-PROBE SOIL AND GROUNDWATER SAMPLE LOCATION
PP032	HISTORICAL PUSH-PROBE LOCATION
	LIMITS OF PREVIOUS EXCAVATION (HART CROWSER 1987)
	FORMER UST LOCATION
	FENCE
14.5	GROUNDWATER ELEVATION CONTOUR IN 0.1 FOOT INTERVAL (SEPTEMBER 2000)
cis-1,2-DCE	cis-1,2-Dichloroethene
U	Analyte was not detected above value shown
ND	Not Detected

NOTES

1. HORIZONTAL DATUM:
   WASHINGTON STATE COORDINATE SYSTEM
   NORTH ZONE NAD83 (91)
   VERTICAL DATUM:
   NATIONAL GEODETIC VERTICAL DATUM (NGVD1929)
2. BASEMAP COMPILED BY DUANE HARTMAN & ASSOCIATES, INC., DECEMBER 1994
3. GROUNDWATER ELEVATION CONTOURS AND HISTORIC PUSH PROBE LOCATIONS FROM FINAL REMEDIAL INVESTIGATION REPORT (WESTON, 2001a)

AOC-034 and AOC-035
GROUNDWATER ELEVATIONS
SEPTEMBER 2000
Boeing Renton Facility
Renton, Washington

By: APS	Date: 05/28/08	Project No. 8888
Geomatrix		Figure **14-1**

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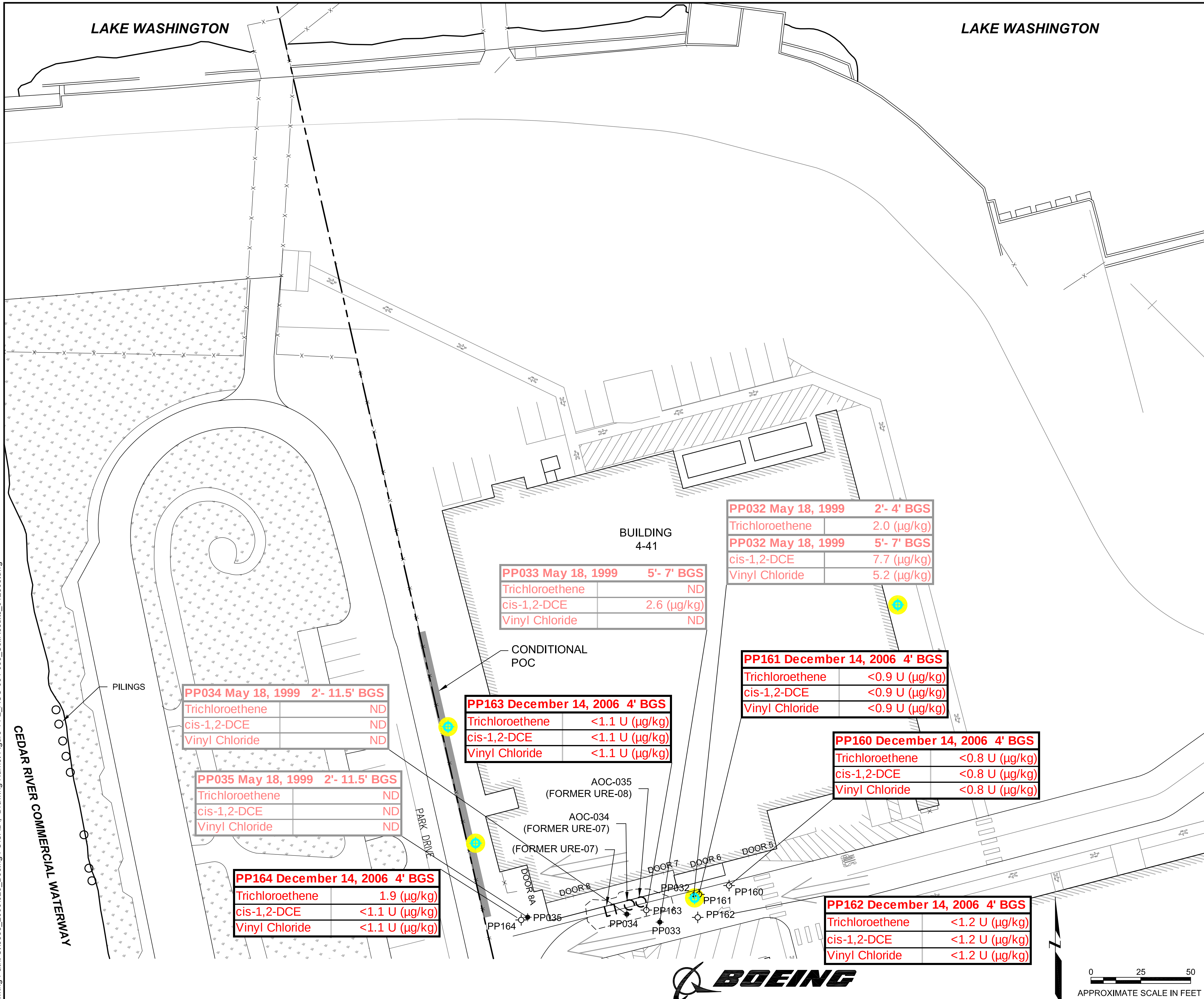

LEGEND

- PROPOSED SHALLOW MONITORING WELL
- PP162 — 12/14/2006 PUSH-PROBE SOIL AND GROUNDWATER SAMPLE LOCATION
- PP032 — HISTORICAL PUSH-PROBE LOCATION
- GENERAL DIRECTION OF GROUNDWATER GRADIENT OBSERVED DURING THE RI
- LIMITS OF PREVIOUS EXCAVATION
- FORMER UST LOCATION
- FENCE
- cis-1,2-DCE — cis-1,2-Dichloroethene
- U — Analyte was not detected above value shown
- ND — Not detected

HIGHLIGHTED WELLS INCLUDED IN MONITORING NETWORK

RED TEXT INDICATES SOIL ANALYTICAL DATA

AOC-034 and AOC-035 SOIL DATA, CPOC, AND MONITORING WELL NETWORK
Boeing Renton Facility
Renton, Washington

By: APS	Date: 05/28/08	Project No. 8888
Geomatrix		Figure 14-2

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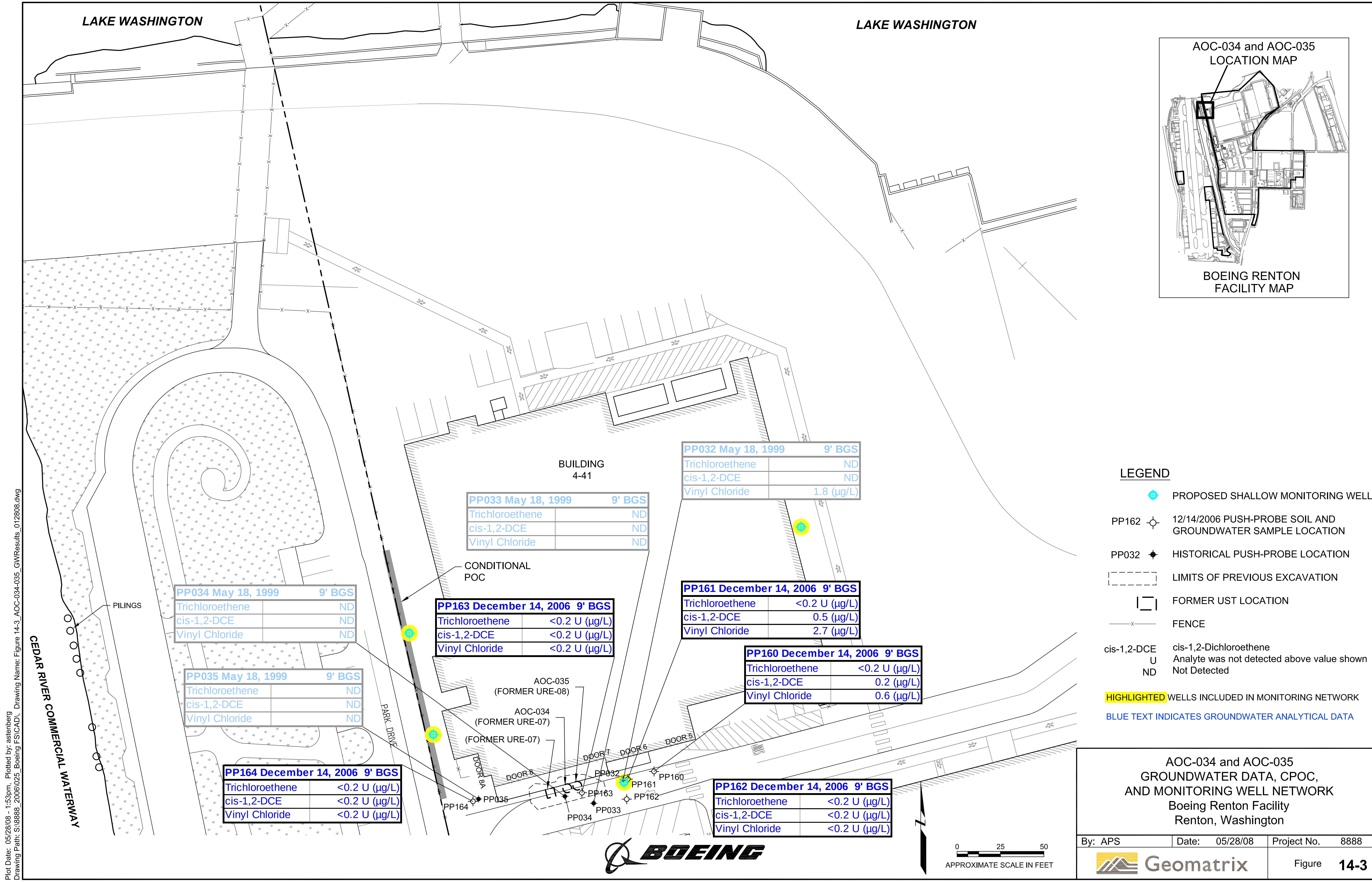

LAKE WASHINGTON
LAKE WASHINGTON
AOC-034 and AOC-035 LOCATION MAP
BOEING RENTON FACILITY MAP
BUILDING 4-41
PP032 May 18, 1999 9' BGS
Trichloroethene ND
cis-1,2-DCE ND
Vinyl Chloride 1.8 (µg/L)
PP033 May 18, 1999 9' BGS
Trichloroethene ND
cis-1,2-DCE ND
Vinyl Chloride ND
CONDITIONAL POC
PP034 May 18, 1999 9' BGS
Trichloroethene ND
cis-1,2-DCE ND
Vinyl Chloride ND
PILINGS
PP163 December 14, 2006 9' BGS
Trichloroethene <0.2 U (µg/L)
cis-1,2-DCE <0.2 U (µg/L)
Vinyl Chloride <0.2 U (µg/L)
PP161 December 14, 2006 9' BGS
Trichloroethene <0.2 U (µg/L)
cis-1,2-DCE 0.5 (µg/L)
Vinyl Chloride 2.7 (µg/L)
PP160 December 14, 2006 9' BGS
Trichloroethene <0.2 U (µg/L)
cis-1,2-DCE 0.2 (µg/L)
Vinyl Chloride 0.6 (µg/L)
PP035 May 18, 1999 9' BGS
Trichloroethene ND
cis-1,2-DCE ND
Vinyl Chloride ND
CEDAR RIVER COMMERCIAL WATERWAY
PARK DRIVE
AOC-035 (FORMER URE-08)
AOC-034 (FORMER URE-07)
(FORMER URE-07)
DOOR 8A
DOOR 8
DOOR 7
DOOR 6
DOOR 5
PP164
PP035
PP032
PP163
PP161
PP160
PP162
PP033
PP034
PP164 December 14, 2006 9' BGS
Trichloroethene <0.2 U (µg/L)
cis-1,2-DCE <0.2 U (µg/L)
Vinyl Chloride <0.2 U (µg/L)
PP162 December 14, 2006 9' BGS
Trichloroethene <0.2 U (µg/L)
cis-1,2-DCE <0.2 U (µg/L)
Vinyl Chloride <0.2 U (µg/L)
N
0 25 50
APPROXIMATE SCALE IN FEET
BOEING
LEGEND
PROPOSED SHALLOW MONITORING WELL
PP162 12/14/2006 PUSH-PROBE SOIL AND GROUNDWATER SAMPLE LOCATION
PP032 HISTORICAL PUSH-PROBE LOCATION
LIMITS OF PREVIOUS EXCAVATION
FORMER UST LOCATION
FENCE
cis-1,2-DCE cis-1,2-Dichloroethene
U Analyte was not detected above value shown
ND Not Detected
HIGHLIGHTED WELLS INCLUDED IN MONITORING NETWORK
BLUE TEXT INDICATES GROUNDWATER ANALYTICAL DATA
AOC-034 and AOC-035 GROUNDWATER DATA, CPOC, AND MONITORING WELL NETWORK
Boeing Renton Facility
Renton, Washington
By: APS
Date: 05/28/08
Project No. 8888
Geomatrix
Figure 14-3
Plot Date: 05/28/08 - 1:53pm, Plotted by: astenberg
Drawing Path: S:\8888_2006\025_Boeing FS\CAD\, Drawing Name: Figure 14-3_AOC-034-035_GWResults_012808.dwg

15.0 DEVELOPMENT AND EVALUATION OF REMEDIAL ALTERNATIVES, AOC-060

In this section we discuss remediation objectives, identify and evaluate remedial alternatives, and describe the preferred remedial alternative for AOC-060.

15.1 SITE CHARACTERIZATION SUMMARY

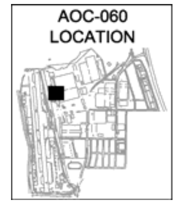
AOC-060 consists of a former vapor degreaser secondary containment sump located in Building 4-42 (see Figure 1-2). The former vapor degreaser was used primarily for cleaning metal parts with TCE. The secondary containment sumps of the former degreaser were removed in December 1993. Results from assessment activities conducted since December 1993 have indicated the presence of VOCs in soil and groundwater in the vicinity of the degreaser. Interim action was initiated after closure of the degreaser and consists of quarterly groundwater monitoring.

The source of VOCs at this AOC was probably releases of TCE from the former vapor degreaser and/or its associated sumps. Subsequent to the release, degradation of the TCE has occurred to form *cis*-1,2-DCE and VC. The presence of these breakdown products indicates that biodegradation is active in this area. As groundwater flows through the affected saturated zone soil near the former degreaser, any adsorbed VOCs may dissolve into the groundwater. The affected groundwater has migrated southwest, beneath the Cedar River Trail Park.

Section 5.17 of the final RI Report contains the complete results of the RI for this site (Weston, 2001a). Additional site characterization data are presented in Section 3.2.2 of the FSWP (Geomatrix, 2004c). The results of the RI and additional data collection are summarized below.

15.1.1 Historical, Present, and Future Site Use

Secondary containment for the former vapor degreaser included sumps SRE-2345, -2346, -2347, and -2348, which were constructed in 1942. SRE-2345, the main sump, was constructed of concrete and had a capacity of approximately 6,000 gallons. Three smaller sumps, SRE-2346, -2347, and -2348, extended below the base of SRE-2345. SRE-2346 was a steel sump with a 20-gallon capacity. Sumps SRE-2347 and SRE-2348 were constructed of concrete and had capacities of 13 and 18 gallons, respectively. The sumps were removed in 1993, and there is no documentation of any soils being excavated at that time. The lack of soil removal may be due to the depth of the sumps, which may have been at or below the seasonal high



groundwater level (4 to 6 feet bgs). Building 4-42 is currently used as offices and associated work space supporting airplane manufacturing facilities. As a part of the manufacturing complex, Building 4-42 is currently considered industrial and is expected to remain so for the foreseeable future.

15.1.2 Previous Site Remedial Actions

The degreaser was closed and the sumps were removed in 1993. Interim action at AOC-060 was initiated following the closure. During the RI, more than a dozen monitoring wells were installed in the vicinity of AOC-060, and quarterly sampling and analysis of monitoring wells for COCs occurred for almost 10 years. Interim action at AOC-060 currently consists of semiannual groundwater monitoring.

15.1.3 Site Hydrogeology

The general stratigraphy consists of hydraulic fill underlain by alluvium. The depth of the hydraulic fill beneath the area increases westward toward the Cedar River Waterway. The fill consists of light brown to brown sand with variable amounts of silt and gravel. Alluvium underlying the fill generally consists of interbeds of gray silty sand, gray clayey silt, and gray sandy silt. Boring logs from nearby monitoring wells indicate that the contact between fill materials and alluvium ranges from approximately 3 to 7 feet bgs.

As measured at monitoring wells, the depth to groundwater ranged from 3.5 to 6.4 feet bgs. Typical seasonal variations in groundwater level are approximately 0.9 feet. Groundwater in the vicinity of AOC-060 generally flows to the northwest toward the Cedar River Waterway.

Groundwater elevations in wells GW159 and GW160 located adjacent to the Cedar River Waterway are slightly higher than water levels in GW149 and GW150. The hydraulic gradient is approximately 0.001 and remains constant throughout the year. A steeper gradient is observed east-southeast of the site. Groundwater levels may have been affected by the operation of the nearby Building 4-78/79 groundwater extraction system, which had a 600-foot radius of influence.

Results for hydraulic conductivity of aquifer materials from slug tests conducted in monitoring wells in the vicinity of AOC-060 ranged from 1 x 10^{-3} to 2.8 x 10^{-2} cm/s.

15.1.4 Nature and Extent of Affected Soil

During closure of the sumps at AOC-060, analyses of soil samples collected in the immediate vicinity of the former degreaser showed detectable levels of VOCs, including TCE, VC, and *cis*-1,2-DCE. After the degreaser was removed, the subsequent investigation focused on defining the impacts to groundwater in the nearby area, because Building 4-42 is an active facility.

15.1.5 Nature and Extent of Affected Groundwater

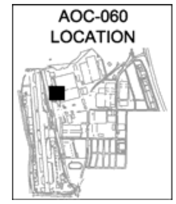
Recent groundwater results are presented on Figure 15-1. These data are considered typical of present groundwater quality at AOC-060, as described in the third quarter 2006 monitoring report (Geomatrix, 2006c). During groundwater monitoring events, *cis*-1,2-DCE and VC have been consistently detected in samples from shallow monitoring wells at concentrations greater than the PCLs, along with occasional detection of TCE at concentrations just above the PCL. No VOCs have been detected in samples from any of the three wells screened in the intermediate zone (i.e., Wells GW011, GW013, and GW015).

As the data of Figure 15-1 show, only samples from Well GW147 had detectable concentrations of TCE during the most recent monitoring events. Vinyl chloride was detected in only one off-site well (GW150) at a concentration of 0.2 µg/L.

15.2 CONCEPTUAL SITE MODEL

A preliminary conceptual model for migration of constituents present in affected soil and groundwater present at the Facility was presented in Figure 2-6 of the FSWP (Geomatrix, 2004c). Based on the conceptual model, considerations presented in the FSWP, plus information specific to this site, a site-specific conceptual site model is described below. This site-specific conceptual site model identifies the media and exposure pathways that must be addressed for remedial alternatives potentially applicable to this site.

Based on site characteristics and topography, only migration of chlorinated solvents is expected to be significant. The predominant release mechanism for chlorinated solvents and their degradation by-products is most likely soil leaching to groundwater and migration in groundwater to the Cedar River Waterway. Constituent transport via groundwater at this site is affected by soil/groundwater interactions and biodegradation as groundwater flows to the Cedar River Waterway. The dissolved chlorinated solvent constituents will move with groundwater but at a different velocity because of continuing solute-soil interactions. These constituents



will also undergo degradation, such that the constituents originally released (e.g., TCE) will be transformed to generate degradation products (*cis*-1,2-DCE, VC). These degradation products will also biodegrade, ultimately producing ethene and chloride salts.

The extent of groundwater affected by dissolved VOCs extends west of the source area, where the former vapor degreaser and sumps were located. The affected groundwater is migrating to the west toward the discharge area along the Cedar River Waterway. Volatilization of constituents from groundwater is not significant for most workers at this site, as noted in the conceptual model presented in the FSWP. Furthermore, a quantitative risk evaluation has been conducted to estimate risks to recreational users of the Cedar River Park Trail. The results of this evaluation were presented in Section 7.2 of the FSWP (Geomatrix, 2004c) and concluded that groundwater constituents downgradient from AOC-060 do not pose a significant risk to human health.

15.3 SITE REMEDIATION OBJECTIVES AND CLEANUP STANDARDS

The remediation objectives for the Renton Facility were presented in Section 2 of this report. Cleanup levels applicable to the Facility were proposed in the FSWP and subsequently approved by Ecology. The remedial alternatives developed and evaluated for this site will be capable of attaining the remediation objectives and cleanup levels presented in this section. As defined in the MTCA regulations, the cleanup standard consists of the cleanup level and the location or POC at which the cleanup level must be met. The remedial alternatives for this site, presented below in Section 15.4, may have different points of compliance while fully addressing remediation objectives and meeting cleanup levels.

The groundwater and soil COCs for AOC-060 were identified in FSWP Tables 5-1 and 5-3, respectively. The COCs listed in Tables 5-1 and 5-3 of the FSWP were identified by comparing detected constituent concentrations to the PCLs identified in the final RI Report; if a constituent concentration measured in any sample exceeded the PCL, the constituent was listed as a COC. The COCs for AOC-060 include VC, TCE, and *cis*-1,2-DCE in groundwater. Recent monitoring results for this site are shown on Figure 15-1. No COCs have been identified for soil at AOC-060.

The soil and groundwater cleanup levels for the site COCs are listed in Tables 3-1 and 3-2, respectively. The soil cleanup levels are either MTCA Method A cleanup levels or site-specific MTCA Method C cleanup levels that are protective of groundwater at the CPOC and were

calculated in accordance with the procedures described in the FSWP or in accordance with recent negotiations with Ecology. The groundwater cleanup levels listed in Table 3-2 were developed as described in Section 3 and in accordance with recent negotiations with Ecology. The cleanup levels are protective of surface water, human health, and the environment.

The cleanup levels allow for the degradation that would occur between the source area and the CPOC due to natural attenuation. Details concerning modeling and cleanup level calculations are included in Section 3 and Appendix A. These cleanup levels will be used in development and evaluation of remedial alternatives for AOC-060 that involve natural attenuation or enhanced in situ bioremediation.

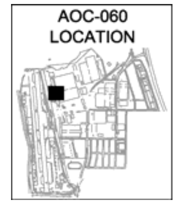
15.4 DESCRIPTION OF SITE REMEDIAL ALTERNATIVES

AOC-060 is located within Building 4-42 at the western edge of the Facility. The building is currently used for offices supporting airplane manufacturing at the Facility, and access for remedial activities would be severely limited. Since the building is located within 60 feet of the property line with the City of Renton Cedar River Trail Park, access outside of the building is also somewhat limited. A utility corridor for buried utilities runs along the property boundary. Within the property boundary, the area most available for remediation or monitoring activities is a 50-foot-wide strip between the west edge of Building 4-42 and the utility corridor. Because of its location inside the building and the depth of the sumps, no soil COCs were identified for AOC-060.

MTCA requires that remedial alternatives selected for a site meet the MTCA threshold requirements for cleanup actions. The minimum threshold requirements specify that cleanup actions shall (1) protect human health and the environment, (2) comply with cleanup standards, (3) comply with applicable state and federal law, and (4) provide for compliance monitoring. In order to be considered as a potential remedial alternative for the site, the technologies considered had to pass the screening evaluation of the remedial technologies described in Section 4. In addition, the alternatives had to meet the minimum threshold requirements established by MTCA and had to be consistent with overall site conditions.

Based on the screening evaluation, MTCA minimum threshold requirements, and the site considerations discussed above, the following three remedial alternatives addressing groundwater COCs were developed for AOC-060:

- Alternative 1: Monitored Natural Attenuation



- Alternative 2: Enhanced Bioremediation and Monitored Attenuation
- Alternative 3: Air Sparging, Soil Vapor Extraction, and Monitored Attenuation

15.4.1 Alternative 1: Monitored Natural Attenuation

Components of Alternative 1 include institutional controls and a monitoring program designed to confirm the effectiveness of MNA. The cleanup standard for this alternative will be the groundwater cleanup levels for AOC-060 listed in Table 3-2; the site-specific cleanup levels would apply at the CPOC located in the Cedar River Trail Park, as shown on Figure 15-2.

15.4.1.1 Institutional Controls

The following institutional controls are included to reduce the risk of human exposure to impacted soil or groundwater:

- Continued engineering controls, protocols, and monitoring previously established by Boeing to ensure that industrial workers inside buildings are protected and indoor air concentrations meet PELs established by the Washington Department of Labor and Industry;
- Continued engineering controls, protocols, and monitoring to ensure that temporary construction workers adhere to WAC 296-62-300, applicable Washington Labor and Industry standards, and OSHA HAZWOPER regulations (29CFR1919.120) for all construction work conducted in exposed areas of affected soil and groundwater;
- Deed restrictions to limit development and use of the site; and
- Covenants and restrictions to limit development and use of the adjacent Cedar River Trail Park.

It is anticipated that deed restrictions would be established to limit future unrestricted land use without additional actions to attain compliance with appropriate soil and groundwater cleanup levels. It is further assumed that an off-site CPOC would be established for this alternative with permission granted by the off-site landowner (the City of Renton). In conjunction with permission for an off-site CPOC, it is anticipated that the City of Renton would formalize internal restrictions and institutional controls for temporary construction or maintenance workers in the Cedar River Trail Park following Boeing's example.

15.4.1.2 Monitored Natural Attenuation

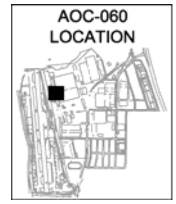
Groundwater monitoring data collected over the last 12 years in the vicinity of AOC-060 indicate that natural processes are at work degrading and retarding the migration of COCs (as

discussed in Section 4.2.4). The current groundwater monitoring program includes 13 monitoring wells that are monitored semiannually for VOCs. Historical trend analysis of the groundwater (Geomatrix, 2006c) shows that concentrations of COCs in samples from many wells have dropped substantially since monitoring began in 1995. Based on these data, no off-site wells had detectable concentrations of *cis*-1,2-DCE or TCE, and only one off-site well (GW150) had a detectable concentration of VC. The highest detections of TCE and VC remain in on-site wells. Samples from the monitoring wells closest to the river (Wells GW159 and GW160) were below detection limits for all COCs. The trend in decreasing concentration over time also suggests that the remaining source materials have a minimal extent, much reduced concentrations, or both.

Fate and transport groundwater modeling using BIOCHLOR was conducted to evaluate the efficacy of MNA as a potential final remedy for this AOC and to establish an appropriate CPOC and site-specific cleanup levels. The modeling followed the protocol established in the FSWP, as subsequently modified in meetings and correspondence with Ecology, using approved model input parameters. The modeling results, presented in detail in Appendix A, are in general agreement with the preliminary modeling conducted for the FSWP. The model results indicate that the site-specific groundwater cleanup levels for all COCs applicable at the CPOC shown on Figure 15-2 would be met.

In accordance with current guidance and the approach discussed in Section 4.2.4, the conceptual monitoring program for AOC-060 is designed to:

- Demonstrate that natural attenuation is occurring and that biodegradation permanently destroys site COCs;
- Identify any potentially toxic and/or mobile transformation products;
- Verify that the plume is not expanding beyond the CPOC;
- Verify that cleanup levels are attained at the CPOC;
- Verify that there is no unacceptable impact to downgradient receptors;
- Detect new releases of COCs that could impact the effectiveness of the natural attenuation remedy;
- Demonstrate the efficacy of institutional controls put in place to protect potential receptors; and



- Verify attainment of remediation objectives.

The conceptual monitoring program for Alternative 1 at AOC-060 assumes that if this alternative is selected, a detailed MNA Validation and Long-Term Sampling Work Plan would be developed to guide the process. This work plan would identify additional monitoring wells and monitoring analytes required for both characterization/validation sampling and long-term groundwater monitoring. Characterization/validation sampling would be used to demonstrate the effectiveness of MNA with respect to contaminant mass reduction, attenuation rates, and temporal trends. Long-term groundwater monitoring would be used after characterization/validation monitoring to confirm that the contaminant plume is progressing toward containment or achievement of numerical goals.

For this conceptual design, it is assumed that characterization/validation sampling would consist of continued semiannual sampling of existing wells, and quarterly monitoring of new monitoring wells for a minimum of 1 year. Three new monitoring wells are assumed to be required (in addition to 10 existing wells) to monitor plume migration; one new intermediate monitoring well would be completed at the CPOC to monitor groundwater quality in the intermediate saturated zone. Monitoring parameters and analytes would consist of TCE, *cis*-1,2-DCE, and VC (contaminants and daughter products) as well as the appropriate MNA geochemical parameters for chlorinated solvent plumes [e.g., dissolved oxygen, nitrate, Fe(II), sulfate, methane, temperature, pH, specific conductance, alkalinity, oxidation/reduction potential, chloride, ethane, and TOC]. It is assumed that reporting for characterization/validation sampling would follow each quarterly event.

It is further assumed that long-term groundwater monitoring would follow for an additional 13 to 14 years (15 total years of monitoring) and include semiannual monitoring of 13 shallow and intermediate depth wells for VOCs (contaminants and daughter products) and a limited suite of geochemical parameters (dissolved oxygen, oxidation/reduction potential, temperature, and pH). To ensure plume control, all 13 wells would be analyzed once every 5 years for the entire characterization/validation list of analytes. Long-term groundwater sampling frequency and the duration of the groundwater monitoring program would be based on the results of performance monitoring and may be adjusted as appropriate. It is assumed that annual reporting would be required for long-term groundwater monitoring.

15.4.2 Alternative 2: Enhanced Bioremediation and Monitored Attenuation

Alternative 2 consists of three elements: institutional controls, enhanced bioremediation, and MA. The cleanup standard for this alternative would be the groundwater cleanup levels for AOC-060 COCs previously discussed and a CPOC in the Cedar River Trail Park, as shown on Figure 15-2.

15.4.2.1 Institutional Controls

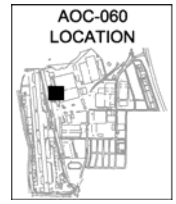
Institutional controls for Alternative 2 would be the same as those discussed in Section 15.4.1.1 for Alternative 1.

15.4.2.2 Enhanced Bioremediation

The conceptual design of enhanced bioremediation for AOC-060 Alternative 2 employs a series of eight injection wells in an injection zone located between Building 4-42 and the utility corridor to the west of the building (see Figure 15-2). The injection wells, constructed of 4-inch-diameter PVC, are assumed to be screened in the impacted aquifer between 5 and 15 feet bgs. It is further assumed that the growth substrate injected would be emulsified vegetable oil, sodium lactate, or another similar carbohydrate substrate. Similar substrates have been used successfully at interim actions conducted at the Facility. For estimating the cost of this alternative, it has been assumed that a total of 2,000 gallons of 2% emulsified vegetable oil would be injected into the injection wells in approximately equal portions. It is also assumed that three applications (at approximately 1 year intervals) would be required to effectively treat the aquifer. The actual design may be different from the conceptual design used for this FS. For estimating costs of this alternative, it has been assumed that no pilot test would be necessary, as this approach has proven effective in interim measures conducted at the Facility.

15.4.2.3 Monitored Attenuation

Monitored attenuation for this alternative is intended to be a final “polishing” mechanism following the active enhanced bioremediation to ensure that cleanup levels for all COCs are met at the CPOC. With this alternative, it is assumed that MA would follow enhanced bioremediation and consist of long-term groundwater monitoring for 13 wells (10 existing wells and 3 new wells), as described in Section 15.4.1.2 for Alternative 1. Groundwater monitoring would be conducted quarterly and semiannually as described for Alternative 1 for VOCs (contaminants and daughter products) and a limited suite of geochemical parameters (dissolved oxygen, oxidation/reduction potential, temperature, and pH). To ensure plume control, all 13 monitoring wells would be analyzed once every 5 years for the entire list of



analytes. It is assumed that monitoring would continue following active remediation for a total of 15 years of monitoring and that annual reporting would be required for the duration.

15.4.3 Alternative 3: Air Sparging, Soil Vapor Extraction, and Monitored Attenuation

Alternative 3 is composed of four elements: institutional controls, air sparging, SVE, and MA. The cleanup standard for this alternative would be the groundwater cleanup levels for AOC-060 COCs discussed in Section 15.3 and the CPOC in the Cedar River Trail Park shown on Figure 15-2.

15.4.3.1 Institutional Controls

Institutional controls for Alternative 3 would be the same as those discussed in Section 15.4.1.1 for Alternative 1.

15.4.3.2 Air Sparging

The air sparging conceptual design for AOC-060/Alternative 3 consists of four air sparging wells installed just east of the western property boundary outside of the utility corridor (see Figure 15-2). The wells would be constructed of 2-inch-diameter PVC pipe, spaced 35 to 40 feet apart, and would be screened below the seasonal low water table from approximately 10 to 15 feet bgs. The sparging wells, designed to strip VOCs from groundwater, would be connected to a compressor and air distribution system designed to continually feed about 5 standard cubic feet per minute (scfm) of air to each sparging well. The compressor system would be constructed either in available space in Building 4-42 or in a compressor building established next to the building. VOC-laden air from the sparging wells would be collected by the SVE system discussed below.

15.4.3.3 Soil Vapor Extraction

The conceptual design for the SVE system for AOC-060 Alternative 3 includes five SVE wells (three wells staggered between the four air sparging wells, one well about 20 feet north of, and one well about 20 feet south of the outside sparging wells), as shown in Figure 15-2. These wells would be constructed of 4-inch-diameter PVC pipe and screened above the water table to collect VOC-laden air from the sparging system and the limited vadose zone (depth to groundwater averages 4 to 5 feet bgs) at the site. The vapor extraction wells would be connected to a vacuum blower system capable of removing at least 20 scfm from each vapor extraction well. The air stream would be routed for treatment through a combination GAC and permanganate unit in order to remove VOCs, including VC, prior to discharge to the

atmosphere. For cost estimation purposes, it was assumed the SVE system would be operated for 5 years.

15.4.3.4 Monitored Attenuation

Monitored attenuation for this alternative is intended to be a final "polishing" mechanism following the active air sparging/soil vapor extraction to ensure that cleanup levels for all COCs are met at the CPOC. With this alternative, it is assumed that MA would be implemented during and after installation of the air sparging/SVE system and would consist of the long-term monitoring program in 13 monitoring wells described in Section 15.4.1.2 for Alternative 1. Groundwater monitoring would be conducted semiannually for VOCs (contaminants and daughter products) and a limited suite of geochemical parameters (dissolved oxygen, oxidation/reduction potential, temperature, and pH). To ensure plume control, all 13 monitoring wells would be analyzed once every 5 years for the entire list of analytes. It is assumed that monitoring would continue following active operation of the sparge/SVE system for a total of 15 years of monitoring and that annual reporting would be required for the duration. For cost estimation purposes it was assumed that quarterly monitoring would be conducted for the first 2 years of the monitoring program.

15.5 EVALUATION OF SITE REMEDIAL ALTERNATIVES

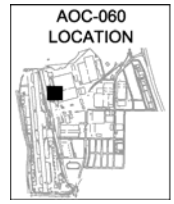
As previously discussed, all three alternatives developed for the site meet the MTCA minimum requirements for cleanup actions. This section compares and evaluates the alternatives based on the MTCA criteria described in Section 5.1. An analysis of each alternative with respect to the evaluation criteria is summarized in Table 15-1 and is discussed below.

15.5.1 Protectiveness and Risk Reduction Evaluation

Protectiveness and risk reduction are gauged primarily on the time required for the alternative to reduce risk and meet cleanup levels. Although in Alternative 3 some of the COCs may be transferred off site with the spent sorbent rather than destroyed in situ, of the three alternatives, it is expected to most quickly reduce COCs in groundwater to cleanup levels and is rated highest for this criterion. Alternative 2 is rated next highest followed by Alternative 1.

15.5.2 Permanence

Permanence refers to the ability to reduce the toxicity, mobility, or volume of hazardous substances, including the permanent destruction of hazardous substances. Both Alternatives 1



and 2 provide permanent destruction of all COCs. Alternative 3 is rated highest for this criterion because the destruction is more controlled and is expected to occur at a faster rate.

15.5.3 Cost

The cost evaluation includes all costs related to implementation of an alternative, including initial design and construction costs, operation and maintenance costs, monitoring costs, and reporting costs. The annual costs for operation, maintenance, monitoring, and reporting are recurring costs that occur in the future. The cost evaluation considers initial implementation costs and future recurring costs using NPV analysis. For NPV calculation, recurring costs were inflated 2% annually and a discount rate of 7% was used. Details regarding the cost estimates for the three alternatives are presented in Appendix B. The present value costs for the three alternatives, in 2007 dollars, are summarized below:

Alternative	Net Present Value
1: Monitored Natural Attenuation	$521,000
2: Enhanced Bioremediation and Monitored Attenuation	$626,000
3: Air Sparging, Soil Vapor Extraction, and Monitored Attenuation	$993,000

As shown by these costs, Alternative 3 has the highest NPV cost, while Alternative 1 has the lowest. Therefore, Alternative 3 ranks lowest for cost, Alternative 1 ranks highest, and Alternative 2 is intermediate.

15.5.4 Long-Term Effectiveness

Long-term effectiveness includes the degree of certainty and reliability of the alternative and whether treatment residue that will require management remains from the alternative. Both Alternatives 1 and 2 are proven technologies and neither produces residual wastes that would require ongoing management. Alternative 3 would produce spent sorbent requiring management during SVE operation. Alternatives 1 and 2 were rated medium high and Alternative 3 was rated medium low.

15.5.5 Management of Short-Term Risks

Short-term risk refers to the risk to human health and the environment during implementation of the alternative. Because Alternative 1 is the simplest to implement of the three alternatives, does not require construction of a treatment system, and does not require handling of residuals, it is rated highest for this criterion.

15.5.6 Technical and Administrative Implementability

This criterion involves whether the alternative is technically possible relative to complexity, administrative/regulatory requirements, size, access, and integration with existing operations. Given that Alternative 1 is a small, simple system that integrates well with the facility operations, it is rated highest.

15.5.7 Public Concerns

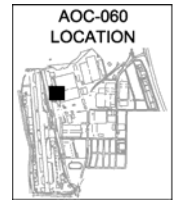
This criterion involves potential community concerns with the alternative. Since all three alternatives deal with an industrial site but have an impact on the adjacent Cedar River Trail Park, they are rated the same.

15.5.8 Reasonable Restoration Time Frame

Restoration time frame involves the practicability of a shorter restoration time frame, with consideration given to a number of factors including site risks, site use and potential use, availability of alternative water supply, effectiveness and reliability of institutional controls, and toxicity of hazardous substances at the site. As a whole, these factors are a measure of the urgency of reducing risk and achieving cleanup goals for the site. Given that the site is industrial, has proven institutional controls, and the toxicity of contaminants is moderate, all three alternatives are ranked medium low.

15.6 SELECTION OF THE PREFERRED SITE REMEDIAL ALTERNATIVE

Selection of a preferred alternative under MTCA requires that a preference be given to alternatives that use permanent solutions (to the maximum extent practicable), alternatives that provide for a reasonable restoration time frame, and alternatives that consider public concerns. The analysis below compares the baseline alternative (the alternative that provides the greatest degree of permanence) to the other alternatives based on degree of permanence, reasonable restoration time frame, and public concerns. According to MTCA (WAC 173-340-200), a permanent solution or permanent cleanup action means a cleanup action in which cleanup



standards can be met without further action being required at the site involved, other than the approved disposal of any residue from the treatment of hazardous substances.

15.6.1 Baseline Remedial Alternative

The evaluation of the three remedial alternatives for this site is summarized in Table 15-1. None of the alternatives is capable of attaining the standard POC at this site. Building 4-42 is located above the source areas, and affected soil and groundwater extend beneath the building. This building is actively used to support manufacturing operations at the Facility and cannot be demolished without a severe impact on the Facility operation. Therefore, it is not possible to remediate all affected soil and groundwater beneath the building at this time.

Based on the remedial alternative evaluation presented above and summarized on Table 15-1, the three remedial alternatives are ranked as follows for permanence:

1. Alternative 3: Air Sparging, Soil Vapor Extraction, and Monitored Attenuation
2. Alternative 2: Enhanced Bioremediation and Monitored Attenuation
3. Alternative 1: Monitored Natural Attenuation

Based on this ranking, Alternative 3, Air Sparging, Soil Vapor Extraction, and Monitored Attenuation, is defined as the baseline remedial alternative. This alternative provides the greatest degree of removal for site COCs and accomplishes this removal in the shortest time. Both Alternatives 1 and 2 provide equivalent levels of removal and destruction of site COCs; however, Alternative 3 would complete site remediation in a significantly shorter time, and would provide for permanent destruction of volatile organic COCs through the AS/SVE system and biodegradation. During AS/SVE operations, VOCs present in extracted soil vapor would be adsorbed or oxidized on site using permanganate and activated carbon adsorbers. The permanganate adsorber would destroy VC present in extracted soil gas. The activated carbon adsorber would remove VOCs from the soil gas; the adsorbed VOCs would be permanently destroyed during off-site carbon regeneration.

15.6.2 Comparison to Baseline Alternative

As noted above, Alternative 3 has been defined as the baseline remedial alternative for this site. Alternatives 1 and 2 will be compared to the baseline alternative in this section for selection of the preferred alternative. The purpose of this comparison is to assess the benefits and costs for Alternatives 1 and 2 relative to Alternative 3. The evaluation criteria presented above and in

Table 15-2 were established in accordance with the MTCA requirements cited in WAC 173-340(3)(f). Costs for the alternatives will be based on the NPV, which reflects the total cost associated with each alternative over the 15-year time period evaluated. The evaluation of benefits will be qualitative.

The benefits to be assessed in this comparison and the relative rating for the alternatives are presented in Table 15-2. The rationale for this comparison is presented below.

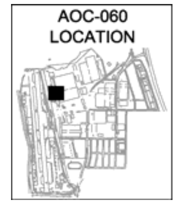
- **Reduced risk to on-site worker health.** All three alternatives are equal in reducing risk to site workers because they are all equally protective. Although the baseline alternative would remove volatile COCs within a few years, potential risks to on-site workers would not be changed substantially by the other two alternatives. The institutional controls included in each of the alternatives have been proven effective in protecting worker health and would continue to be protective.

- **Reduced risk to off-site human health.** Alternatives 1 and 2 were rated high for this benefit, while the baseline alternative was rated moderate for reducing risks to off-site human health. All three would attain the cleanup level at the CPOC, which is protective of human health and the environment. The institutional controls included in all alternatives that have proven to be protective of worker health on site would also be protective of human health in off-site areas located upgradient of the CPOC. However, the baseline alternative actively withdraws volatile COCs from the subsurface, which creates the potential for emissions that may impact off-site receptors.

- **Reduced risk to the environment.** Alternatives 1 and 2 were ranked higher than the baseline alternative for reducing potential risks to the environment. The active removal of volatile COCs using SVE that would result from the baseline alternative creates the potential for emissions to the atmosphere, which could migrate to off-site ecological receptors. All three alternatives would be protective of the aquatic environment because they would all attain the cleanup levels at the CPOC.

- **Minimal adverse impact on Facility operations.** The baseline alternative was rated low for this benefit because it would impact Facility operations during installation of the AS/SVE system and require long-term operation and periodic replacement of AS/SVE system components. Alternative 2 was rated moderate because of the repeated applications of substrate. A high rating was given to Alternative 1, which relies on passive degradation of site COCs and would have the least impact on Facility operations.

- **Minimal restrictions on Facility traffic and access.** The baseline alternative was rated moderate for this benefit because it would impact Facility traffic and access during installation and operation of the AS/SVE system. Additional impact would occur during periodic replacement or maintenance of AS/SVE system components.



Alternative 2 was also given a moderate rating benefit because it would impact Facility traffic and access during installation of the injection system and during reapplication of substrate. Alternative 1 was given a high rating because it would only affect traffic during installation of monitoring wells resulting in the least impact on Facility traffic and access.

- **Minimal adverse impact on Facility structures and utilities.** The baseline alternative and Alternative 2 were both rated moderate for minimizing adverse impacts on facility structures and utilities. Both of these two alternatives would require installation of wells adjacent to Building 4-42 and associated utility lines. Alternative 1 was given a high rating because it would only potentially affect facility improvements during installation of monitoring wells, resulting in the least potential impact on Facility structures and utilities.

The potential benefit evaluation for the three alternatives shows that Alternative 1, Monitored Natural Attenuation, would provide the greatest benefit. Alternative 2 would provide the next highest benefit, and Alternative 3 ranks lowest for benefits.

The NPV costs for the three alternatives were presented in Section 15.5.3. The baseline alternative ranks third among the three alternatives, with the highest cost. Alternative 1 would have the lowest present value cost (approximately 52% of the estimated cost for the baseline alternative). Alternative 2 would have an intermediate cost (approximately 63% of the cost for the baseline alternative). Alternative 1 is ranked highest for cost because it would have the lowest NPV.

15.6.3 Preferred Remedial Alternative

Alternative 1, Monitored Natural Attenuation, provides the greatest benefit at the lowest cost; therefore, Alternative 1 is the preferred remedial alternative for the AOC-060 site. Alternative 3, as the baseline and the most permanent potential remedy, does not provide additional benefits that are commensurate with its disproportionate cost. Ample evidence was collected during the RI to demonstrate that natural biodegradation of organic soil and groundwater COCs is active at this site. Groundwater samples collected downgradient from the source areas and upgradient from the Cedar River Waterway show that groundwater COC concentrations are declining with time and COCs have not migrated to the waterway. Preliminary groundwater modeling of natural attenuation agrees with the downgradient observations and indicates that the groundwater cleanup levels would be attained at the off-site CPOC.

Under Alternative 1, affected soils would remain capped by either buildings or maintained pavement or tarmac to prevent potential runoff and infiltration of rainfall. While the affected groundwater plume extends beyond the Facility property line, the off-site area is owned by the City of Renton and consists of a public road and a narrow strip of property along the eastern shoreline of the Cedar River Waterway (the Cedar River Trail Park). The roadway further limits infiltration of surface water. The City of Renton has indicated general agreement to allow a CPOC to be located on their property. Groundwater in the area is not used for any purpose, and potable water is readily available from the Renton public water system. The institutional controls included in Alternative 1 have been implemented and proven by Boeing, who would continue to maintain overall responsibility for this site and ensure that the institutional controls are properly enforced.

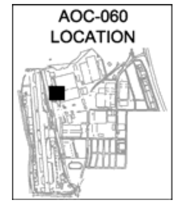
Monitored natural attenuation for this site would achieve the expectations for cleanup actions cited in the MTCA regulations at WAC 173-340-370 (1) – (8). Only those expectations relevant to large, complex sites are considered relevant to AOC-060. The relevant expectations are addressed as follows.

- **Implement Treatment at Sites with Liquid Wastes, High Contaminant Concentrations, Highly Mobile Materials, or Discrete Areas of Contamination.** Ecology expects that treatment will be emphasized for sites meeting these general criteria. Boeing believes that while remaining COC levels are elevated, they are not high, and there is no evidence of liquid wastes at the site. The source areas are not discrete and extend beneath Building 4-42, preventing ready access for removal or treatment. MNA will degrade or "treat" organic COCs over the long term using natural processes that result in nontoxic degradation products.

- **Destroy, Detoxify, or Remove Hazardous Substances.** Ecology expects that hazardous substances will be destroyed, detoxified, or removed to below cleanup levels. MNA will ultimately destroy COCs resulting in nontoxic degradation products and meeting cleanup levels at the CPOC.

- **Implement Engineering Controls for Low Contaminant Concentrations.** Ecology recognizes the need for containment for low concentrations of contaminants where treatment is impracticable. This alternative uses containment by the building to limit migration from soil to groundwater.

- **Prevent Runoff of Hazardous Substances.** Ecology expects that cleanup actions will include active measures to prevent precipitation from creating runoff that contains affected soil. This expectation would be met by the preferred alternative because the source area is entirely covered by Building 4-42. In addition to preventing runoff from contacting hazardous substances, the building minimizes



surface water infiltration, thus resulting in decreased groundwater flow rates and increased time for groundwater to flow from the source area to the waterway.

- **Consolidate On-site Contaminants Exceeding Cleanup Levels.** Ecology expects that when contaminants are left on site exceeding cleanup levels that they will be consolidated to the extent practicable. At this site, due to the location of the contaminants under the building, it is not practicable to consolidate contaminants.

- **Prevent Runoff and Groundwater Discharge to Surface Water.** Ecology expects that the cleanup action would include active measures to prevent or minimize releases to adjacent surface water bodies via runoff or groundwater discharge, and that dilution would not be the sole method for attaining cleanup levels. Alternative 1 would meet this expectation. Available groundwater monitoring data indicate that biodegradation of organic COCs is active and significant at this site. The cleanup alternative also includes a groundwater monitoring network and program that would confirm that cleanup levels are attained in groundwater before groundwater can reach the Cedar River Waterway.

- **Ensure Appropriateness of Attenuation.** Ecology expects that natural attenuation may be appropriate if source control has been conducted to the maximum extent practicable; contaminants remaining on site do not pose unacceptable risks to human health and the environment; evidence indicates that degradation is occurring and will continue to occur at a reasonable rate; and appropriate monitoring is conducted. These expectations would all be achieved by Alternative 1. Soil removal is not practicable at this time because of the location under an actively used building. Although affected soil and groundwater have been present at the site for a long time, Boeing has implemented effective institutional controls that have proven effective in protecting human health and the environment at this site. Groundwater monitoring data indicate that biodegradation of organic COCs is active at the site; coupled with the high organic fraction in site soil, site conditions are favorable to continued active biodegradation. Alternative 1 also includes a robust groundwater monitoring program designed to address recent guidance for MNA. The monitoring system included in the preferred alternative would confirm that cleanup levels are attained prior to groundwater discharging to the Cedar River Waterway.

The preferred remedial alternative would be designed to comply with applicable regulations. Potentially applicable regulations are listed in Table 15-3. These regulations govern the design, installation, and operation of remediation systems. For the preferred alternative at AOC-060, regulatory requirements are expected to be minimal. Construction for the preferred alternative would be limited to installation of new monitoring wells, some within 200 feet of the shoreline along the Cedar River Waterway.

The primary regulations governing the preferred alternative would be the MTCA regulations, the Washington well drilling regulations for monitoring wells, the solid waste disposal regulations, the dangerous waste regulations, the transportation regulations, and the Department of Labor and Industries health and safety regulations. Well drilling rules specify well design and drilling requirements. The solid and dangerous waste regulations specify waste characterization, manifesting, and disposal requirements. Transportation regulations specify labeling and shipping requirements for wastes generated from implementation of the alternative. MTCA regulations specify remediation requirements and the cleanup standards to be attained. The preferred alternative would be designed and implemented to comply with these regulations.

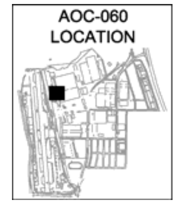


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TABLE 15-1

COMPARISON OF REMEDIAL ALTERNATIVES, AOC-060[1]

Boeing Renton Facility
Renton, Washington

Standards/Criteria		Alternatives		
		1 - Monitored Natural Attenuation	2 - Enhanced Bioremediation/MA	3 - Air Sparging/Soil Vapor Extraction/MA
Protectiveness and Risk Reduction	Pros	Destroys COCs.	Destroys COCs.	Removes COCs; Fastest to achieve cleanup levels in majority of plume.
	Cons	Slow to achieve cleanup.		Requires off-site waste management
	Rating	ML	MH	H
Permanence	Pros	Natural carbon promotes MNA; Destroys COCs; No residuals.	Destroys COCs; No residuals; Reasonably rapid cleanup.	Removes COCs rapidly; Fastest to achieve cleanup levels in majority of plume
	Cons	Slow degradation rates; Off-site CPOC.	Off-site CPOC.	Off-site CPOC.
	Rating	MH	MH	H
Cost	Pros	Lowest Cost.		
	Cons			Highest Cost.
	Rating	H	MH	L
Long-Term Effectiveness	Pros	Destroys COCs; Passive, natural process.	Destroys COCs.	Removes COCs.
	Cons		Requires periodic injections.	Requires engineering controls; Requires off-site waste management.
	Rating	MH	MH	ML
Management of Short-Term Risks	Pros	Simplest implementation; No residuals		
	Cons		Requires periodic injections.	Some risks related to handling of residuals
	Rating	H	MH	MH
Technical and Administrative Implementability	Pros	Simple system.	Simple system.	Removes COCs.
	Cons	Off-site landowner permission needed.	Requires periodic injections; Off-site landowner permission needed; Injection permit required	Complex system; Requires engineering controls; Requires air permitting; Active operation and maintenance; off-site landowner permission
	Rating	H	MH	ML
Public Concerns	Pros	Industrial site.	Industrial site.	Industrial site.
	Cons	Requires City of Renton approval for CPOC.	Requires City of Renton approval for CPOC.	Requires City of Renton approval for CPOC.
	Rating	MH	MH	MH
Restoration Time Frame	Pros	Industrial site; Proven institutional controls; Alternative water available; Practicability of shorter time frame limited by facility operations	Industrial site; Proven institutional controls; Alternative water available; Practicability of shorter time frame limited by facility operations	Industrial site; Proven institutional controls; Alternative water available; Practicability of shorter time frame limited by facility operations
	Cons			
	Rating	ML	ML	ML

Notes:
1. Comparison Ratings: H = Highest (if the decision were based solely on one criterion, an H score would indicate the alternative is the preferred alternative);
MH = Medium High;
ML = Medium Low;
L = Low.

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TABLE 15-2

COMPARISON OF BENEFITS[1]
AOC-060
Boeing Renton Facility
Renton, Washington

Benefit	Alternative 1: Monitored Natural Attenuation	Alternative 2: Enhanced Bioremediation and Monitored Attenuation	Alternative 3: AS/SVE and Monitored Attenuation
Reduced risk to on-site worker health	High	High	High
Reduced risk to off-site human health	High	High	Moderate
Reduced risk to the environment	High	High	Moderate
Minimal adverse impact on Facility operations	High	Moderate	Low
Minimal restrictions on Facility traffic and access	High	Moderate	Moderate
Minimal adverse impact on Facility structures and utilities	High	Moderate	Moderate

Notes:
1. Benefits for each remedial alternative are rated as follows:
   High = high benefit;
   Moderate = moderate benefit;
   Low = low benefit.

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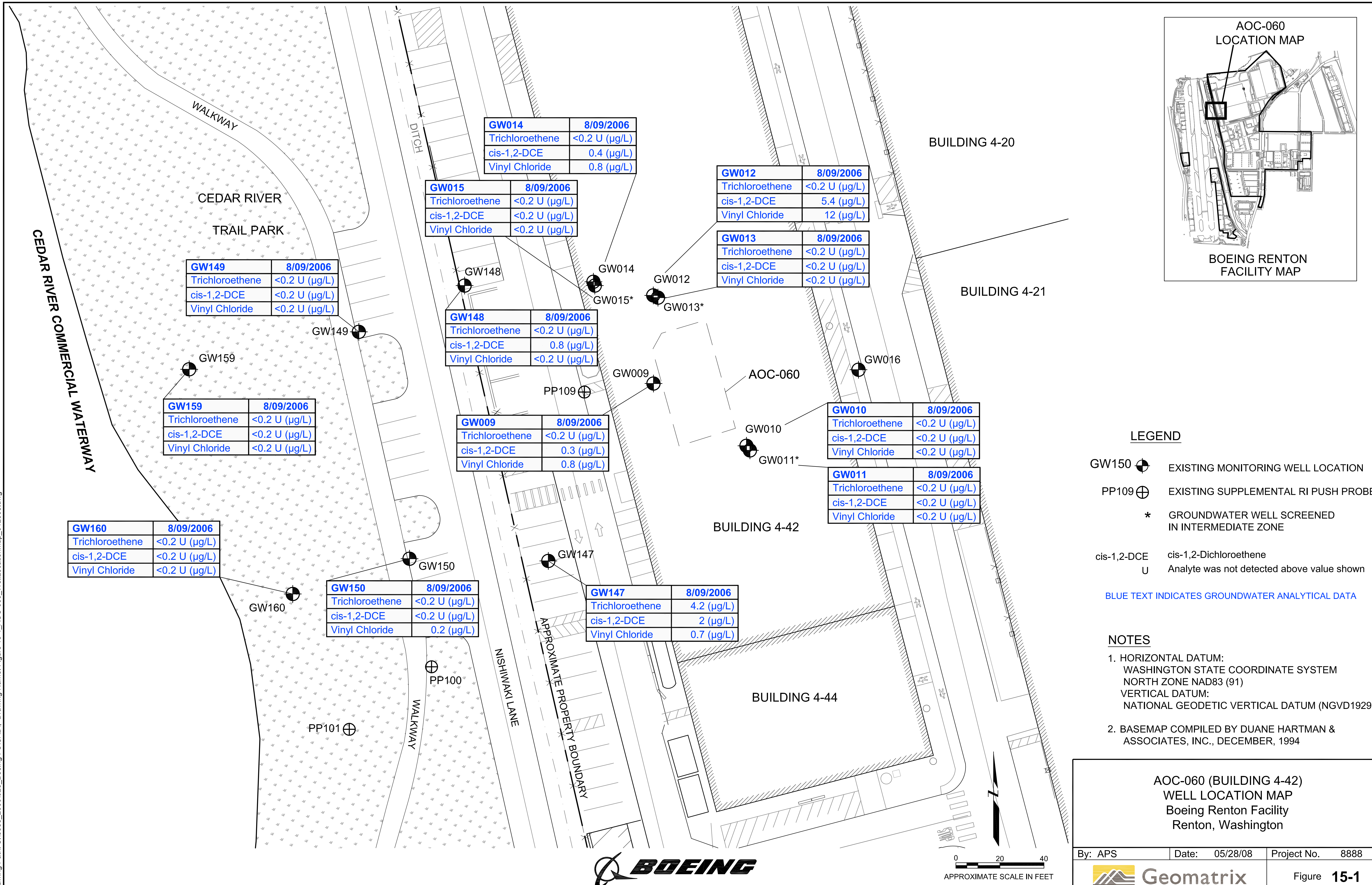
TABLE 15-3

POTENTIALLY APPLICABLE REGULATIONS
AOC-060 PREFERRED REMEDIAL ALTERNATIVE

Boeing Renton Facility
Renton, Washington

Law/Regulation	Citation	Applicability
Chemical-Specific Laws and Regulations		
Washington Dangerous Waste Regulations	WAC 173-303	Waste management, permitting requirements
Washington Model Toxics Control Act Regulations	WAC 173-340	Establishment of cleanup levels and POCs
Action-Specific Laws and Regulations		
Washington State Environmental Policy Act Regulations	WAC 197-11	Permitting, EIA/EIS[1] requirements
Washington Industrial Safety and Health Act Regulations	WAC 296-24	Occupational health and safety
Transportation regulations	49 CFR Parts 100 & 177, WAC 446-50	Transportation for wastes and materials
Washington well drilling regulations	WAC 173-160 & -162	Well design and installation standards
Washington solid waste disposal regulations	WAC 173-304	Disposal of nondangerous waste
Location-Specific Regulations		
Shoreline Management Act	RCW 90.58	Standards for construction within 200 ft of shoreline

Notes:
1. EIA = Environmental Impact Assessment; EIS = Environmental Impact Statement.



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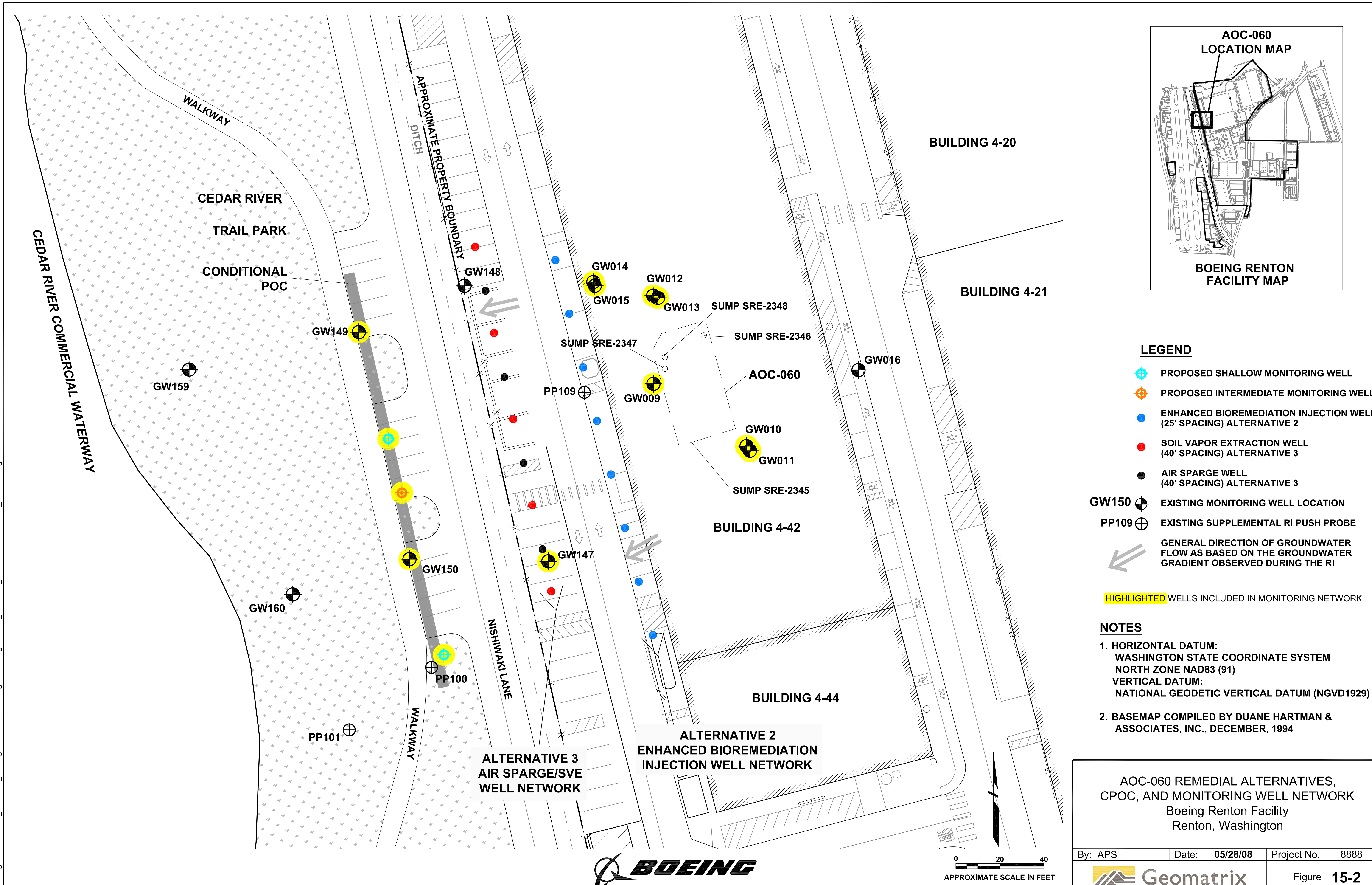

NOTES

1. HORIZONTAL DATUM:
   WASHINGTON STATE COORDINATE SYSTEM
   NORTH ZONE NAD83 (91)
   VERTICAL DATUM:
   NATIONAL GEODETIC VERTICAL DATUM (NGVD1929)
2. BASEMAP COMPILED BY DUANE HARTMAN & ASSOCIATES, INC., DECEMBER, 1994

AOC-060 REMEDIAL ALTERNATIVES,
CPOC, AND MONITORING WELL NETWORK
Boeing Renton Facility
Renton, Washington

By: APS	Date: 05/28/08	Project No. 8888
Geomatrix		Figure 15-2

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16.0 DEVELOPMENT AND EVALUATION OF REMEDIAL ALTERNATIVES, AOC-090

In this section we discuss remediation objectives, identify and evaluate remedial alternatives, and describe the preferred remedial alternative for AOC-090.

16.1 SITE CHARACTERIZATION SUMMARY

AOC-090 is located near the southwest corner of former Building 4-64 (see Figure 1-2). During the installation of an underground fire protection water line and fire hydrant in July 1999, approximately 40 cubic yards of soil was excavated to a depth of approximately 6 feet bgs. Laboratory analysis of soil samples collected from the stockpiled soil indicated elevated concentrations of selected VOCs (TCE and carbon tetrachloride) as well as TPH-G, TPH-D, and TPH-MO. The source of the elevated concentrations is unknown. AOC-090 was subsequently investigated as part of the RI.

16.1.1 Historical, Present, and Future Site Use

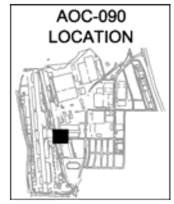
AOC-090 is located near the southwest corner of former Building 4-64. This building was used by Boeing for aircraft preflight checks until it and Building 4-65 (the Gate D-30 Guard House) were demolished in early 2004 to prepare the site for construction of a new parking area. The area was paved in early fall 2004 and the parking area was put to use. As a part of the manufacturing complex, the parking area is considered industrial and is expected to remain industrial for the foreseeable future.

16.1.2 Previous Site Remedial Actions

The initial investigation performed in the Building 4-65 yard in December 1999 consisted of:

- Collection of 48 soil samples from 12 push probe locations and collection of eight groundwater samples from four push probe locations;
- Analysis of the soil and groundwater samples for VOCs, TPH-G, and diesel- and motor-oil-range TPH (TPH-D extended).

A tiered sampling approach was described in the final RI Report. Tier 3 sampling followed Tier 1 and Tier 2 sampling. The purpose of the Tier 3 sampling at AOC-090 was to characterize the nature and extent of VOC and TPH constituents in the soil and groundwater in the area. The scope of work included:



- Installation of five pairs of groundwater monitoring wells (GW161 and GW162, GW163 and GW164, GW165 and GW166, GW167 and GW168, and GW169 and GW170) (GW167 through GW170 were removed and decommissioned as part of an interim remedial action in 2004 as described below);

- Collection of 49 soil samples from nine push probe locations (PP051 through PP059) and three groundwater monitoring well borings (GW161, GW167, and GW169);

- Collection of 11 groundwater samples from one push probe (PP058) and 10 monitoring well locations;

- Analysis of 44 soil samples and 11 groundwater samples for VOCs, and TPH-G, -D, and -MO. Additional soil samples were also analyzed for bulk dry density, TOC, particle size distribution (i.e., grain size analysis), and total porosity; and

- Measurement of groundwater depths from the 10 monitoring wells to evaluate groundwater flow direction and gradient.

The results of this work indicated that VC was present in groundwater near the western Facility boundary with the Cedar River Trail Park at concentrations exceeding the PCLs. A detailed discussion of the investigation at this unit is presented in the final RI Report (Weston, 200la).

During the development of the FSWP, additional investigative work was completed and a groundwater monitoring program was developed for the area. The investigative work included additional push probes and installation of three additional groundwater monitoring clusters in the Cedar River Trail Park and one additional groundwater monitoring well cluster on Boeing property. The monitoring wells were completed in December 2003. The groundwater monitoring program for AOC-090 was initiated in February 2004 and consists of:

- Semiannual collection of groundwater samples from on-site wells GW163, GW164, GW166, GW175, and GW176;

- Semiannual collection of groundwater samples from off-site wells GW177, GW178, GW179, GW180, GW181, and GW182; and

- Quarterly measurement of water levels from all existing AOC-090 groundwater monitoring wells, the six off-site wells, and GW144 (which is located south of AOC-090 on Apron D).

The primary objective of the groundwater monitoring program is to assess the nature and extent of VC-affected groundwater at AOC-090 and off site in the Cedar River Trail Park.

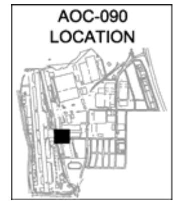
Remedial actions completed in the area include the excavation of 40 cubic yards of soil initially removed in 1999 as part of the fire protection water line installation. Additionally, Building 4-64 and the Gate D-30 Guard House were demolished in 2004 to prepare the site for construction of a new parking area. Coincident with the building demolition, an interim action was conducted at AOC-090 to remove TPH- and VOC-affected soil exceeding cleanup levels in the source area to the extent practicable. The area of excavation was initially planned to cover an area approximately 80 feet by 60 feet just south of the former Building 4-64 footprint. However, due to field screening results, additional soils were removed and excavation was extended beneath former Building 4-64. Throughout the excavation, soil was excavated to the water table at a depth of approximately 7 feet bgs. Soils requiring different off-site disposal means (i.e., solvent- versus TPH-affected soils) were segregated during excavation. Approximately 250 cubic yards of solvent-affected soil and 1,240 cubic yards of TPH-affected soil were removed during the excavation.

Following soil removal, 16.68 tons of molasses was added to the excavation area to act as an organic carbon source for groundwater at the site and promote ongoing VOC degradation processes. Perforated drainpipe was installed during backfill along the southern extent of the excavation area, parallel to the gas line on North 6th Street. The purpose of the pipe is for potential future remedial action, such as reapplication of organic carbon substrate or soil venting. The pipe was placed directly against the native soil on the one to one (1:1) sloping side of the southern wall of the excavation, approximately 3 feet bgs. The pipe consists of 4-inch wrapped drain tile. Subsequent monitoring of groundwater beneath and downgradient of the excavation, where the molasses was placed, indicates substantial degradation of TCE in groundwater and a substantial rise in concentration of the final, nontoxic biodegradation products (methane, ethane, and ethene) (Geomatrix, 2006c).

16.1.3 Site Hydrogeology

The general stratigraphy beneath this area consists of fill underlain by alluvium. The fill consists of brown to reddish-brown, fine- to medium-grained sand with silt and gravel. Alluvium beneath the fill consists of interbedded reddish-brown to greenish-gray fine-grained sand with silt and variable amounts of clay and reddish-brown to greenish-gray clayey silt, and peat layers. The fill extends from approximately 2.5 to 7 feet bgs.

The area near and downgradient of AOC-090 was investigated extensively using push probes and monitoring wells. The alluvium at AOC-090 extends off-site towards the Cedar River



Waterway. The relatively fine-grained silt layer present at approximately 10 to 21 feet bgs along Nishiwaki Lane appears to be continuous, overlying a layer of silty to poorly graded sand 4 to 6 feet thick. This deeper sand layer is consistent with that seen on site at the AOC-090 source area (Geomatrix 2004c). The depths cited above are approximate because of elevation changes within the park. The lower permeability silt layer separates a shallower sand interval from a deeper sand interval, splitting the uppermost aquifer into two units designated the shallow unit and the intermediate unit.

The depth to groundwater in the shallower sand interval ranges from approximately 5.4 to 7.1 feet bgs. Seasonal variation in the water table was estimated at approximately 3.6 feet for the area. Groundwater in this area generally flows to the west toward the Cedar River Waterway. Based on data from ongoing corrective action monitoring at AOC-090, the groundwater in the shallow aquifer is blocked by the steel sheet pile barrier along the river, and groundwater flow is split. Groundwater in the shallow sand interval flows both to the north and south, around the sheet pile barrier to enter the Cedar River Waterway. Figure 16-1 shows groundwater elevation contours for the groundwater in the shallower sand interval. The groundwater elevation contours suggest that groundwater flows to the north and south along the sheet pile wall. This representative groundwater elevation map is based on water level measurements taken on February 14 and 15, 2007.

The range in average hydraulic gradient in the shallow interval ranges from 0.001 to 0.003; and the gradient is typically flatter during the drier summer season. Slug tests were conducted in monitoring wells GW065, GW169, and GW170 near AOC-090. These tests indicated that the hydraulic conductivity of shallow groundwater in the area ranged from 7.2×10^{-5} to 7.2×10^{-4} cm/s, which is consistent with a clayey silt or clayey sand lithology.

During the RI, the groundwater elevation in each of the five deeper groundwater monitoring wells was 0.28 to 0.5 feet higher than the adjacent shallow well. These measurements indicate that there is a potential for vertically upward groundwater flow in this area. Groundwater in the deeper sandy interval (i.e., the intermediate unit) flows to the west-southwest, and does not appear to be affected by the sheet-pile wall. The hydraulic gradient in the intermediate zone was measured during the RI at 0.002 (based on Figure 5-17F from the final RI Report) (Weston, 2001a). Figure 16-2, adapted from Figure 5-17F from the final RI Report, shows the groundwater flow direction in the intermediate unit; these groundwater elevation data are more representative of actual aquifer characteristics than data from the current well network because

of the longer baseline period available from the historic water levels provided by former monitoring well GW-169.

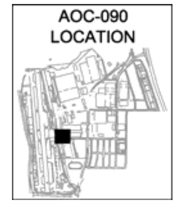
16.1.4 Nature and Extent of Affected Soil

During the interim action in 2004, nearly all of the affected soil above the water table was removed. Soil removal at the south end of the excavation was limited by the presence of a high-pressure natural gas line. Excavation could not extend closer than 5 feet from the gas line, with soil graded at a 1:1 slope from the base of the excavation, without affecting the stability of the pipeline. Excavation south of the gas line was also impracticable due to the presence of North 6th Street and associated buried utilities beneath it.

An on-site electrical duct bank also limited soil excavation. The duct bank runs east to west through the excavation area at a depth of approximately 2.5 feet bgs. Soil was removed above the duct bank and graded at a 1:1 slope from the duct bank to the bottom of the excavation.

All soil confirmation sample results from sample locations on the perimeter of the final excavation area were below the VOC and TPH cleanup/comparison levels described in the Final AOC-090 Interim Action Work Plan (Geomatrix, 2004b), except for those on the south side near the gas line. The results for the three perimeter confirmation soil samples analyzed for additional SVOCs and metals constituents were all below the cleanup/comparison levels, except for copper in two samples. The cleanup/comparison level for copper is 36 mg/kg, based on the Puget Sound Natural Background value. Concentrations in these samples were 41.7 mg/kg and 52.6 mg/kg. These values are not substantially above the Puget Sound 90th percentile natural background concentration as reported by Ecology (Ecology, 1994). No other COCs were present at levels exceeding cleanup/comparison levels in these two samples (Geomatrix, 2004b).

Three samples (EX01, EX02, and EX03) were collected from the sidewall of the excavation adjacent to the gas pipeline. These samples contained VOCs and TPH-G, -D, and –MO above the VOC and TPH cleanup/comparison levels described in the Final AOC-090 Interim Action Work Plan. The interim action technical memorandum includes a summary of analytical results from the interim action in Table 1 and sample locations in Figure 1 of the memorandum (Geomatrix, 2004f).



16.1.5 Nature and Extent of Affected Groundwater

The results from the RI (Weston, 2001a) indicated that the extent of affected groundwater was not defined off site in areas to the south and west of the original excavation for the fire protection water line. Therefore, additional off-site push probes were installed along North 6th Street to define the extent of the affected groundwater. These investigations showed that VC-affected groundwater extends off site into the adjacent Cedar River Trail Park. The groundwater monitoring program for AOC-090 was initiated in February 2004 with the goal of defining the nature and extent of VC-affected groundwater at AOC-090 and off site in the Cedar River Trail Park. Additional monitoring wells completed in the intermediate unit were installed in 2006. The monitoring results from August 2006 and February 2007 are presented on Figure 16-3. These data indicate that shallow groundwater is affected beneath the Cedar River Trail Park both north and south of AOC-090, with the most highly affected water beneath the source area. Data for the intermediate unit generally show localized areas affected by VC at sub-part per billion levels. The source area well (Well GW189) shows that significant concentrations of site COCs remain in the shallow saturated zone. The most recent groundwater data for AOC-090 are provided in the MTCA Corrective Action Quarterly Monitoring Reports.

16.2 CONCEPTUAL SITE MODEL

A preliminary conceptual model for migration of constituents present in affected soil and groundwater at the Renton Facility was presented in Figure 2-6 of the FSWP (Geomatrix, 2004c). Based on the conceptual model and considerations presented in the FSWP, plus information specific to this site, a site-specific conceptual site model is described below. This site-specific conceptual site model identifies the media and exposure pathways that must be addressed for remedial alternatives potentially applicable to this site.

Based on site characteristics and topography, constituent migration is expected to be significant only for chlorinated solvents. The predominant release mechanism for chlorinated solvents and their degradation by-products is most likely by leaching from soil to groundwater and then migration in groundwater to the Cedar River Waterway. Constituent transport via groundwater at this site is affected by soil/groundwater interactions and biodegradation as groundwater flows to the Cedar River. The dissolved chlorinated solvent constituents will move with groundwater but at a different velocity because of continuing solute-soil interactions. These constituents will also undergo degradation that transforms the constituents originally released (e.g., TCE) to generate degradation products (*cis*-1,2-DCE and VC). These degradation

products will also biodegrade, ultimately producing nontoxic products, including ethene and chloride salts.

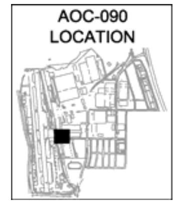
The extent of groundwater affected by dissolved VOCs extends northwest of the source area. Groundwater in the shallow and intermediate units follows different flow paths to the Cedar River Waterway. Shallow groundwater is affected by the presence of the sheet pile wall located between AOC-090 and the Cedar River Waterway; due to this low-permeability barrier, shallow groundwater originating in the source area flows both north and south around the sheet pile wall, as shown by the groundwater contours in Figure 16-1. Given the depth of the barrier wall, groundwater within the intermediate zone flows directly to the west, beneath the sheet pile barrier, as shown in Figure 16-2. The different flow paths for groundwater at these different depths must be considered in evaluating remedial alternatives for this site.

Volatilization of constituents from groundwater is not significant for most workers at this site, as noted in the conceptual model presented in the FSWP. Furthermore, a quantitative risk evaluation has been conducted to estimate risks to recreational users of the Cedar River Trail Park. The results of this evaluation were presented in Section 7.2 of the FSWP (Geomatrix, 2004c) and concluded that average VC groundwater concentrations approaching 13,200 µg/L would be necessary to create an excess cancer risk for park users. Off-site groundwater concentrations near AOC-090 are several orders of magnitude less than this threshold level; therefore, the off-site plume does not represent a potential risk to human health.

16.3 SITE REMEDIATION OBJECTIVES AND CLEANUP STANDARDS

The remediation objectives for the Renton Facility were presented in Section 2 of this report. Cleanup levels applicable to the Facility were proposed in the FSWP and subsequently approved by Ecology. The remedial alternatives developed and evaluated for this site will be capable of attaining the remediation objectives and cleanup standards presented in this section. As defined in the MTCA regulations, the cleanup standard consists of the cleanup level and the location or POC at which the cleanup level must be met. The remedial alternatives for this site, presented below in Section 16.4, may have different points of compliance while fully addressing remediation objectives and meeting cleanup levels.

The groundwater and soil COCs for AOC-090 were identified in the FSWP Tables 5-1 and 5-3, respectively. The COCs listed in Tables 5-1 and 5-3 of the FSWP were identified by comparing detected constituent concentrations to the PCLs identified in the final RI Report; if a



constituent concentration measured in any sample exceeded the PCL, the constituent was listed as a COC. Cleanup levels for both soil and groundwater were presented in the FSWP (Tables 5-6 and 5-2) and approved by Ecology for use in the FS. The cleanup levels for PCE, TCE, and VC presented in the approved FSWP were subsequently changed by Ecology; cleanup levels for these constituents were recalculated as described in Section 3, based on negotiations and correspondence with Ecology.

The soil and groundwater cleanup levels for the site COCs are listed in Tables 3-1 and 3-2, respectively. The soil cleanup levels are either MTCA Method A cleanup levels or site-specific MTCA Method C cleanup levels that are protective of groundwater at the CPOC and were calculated in accordance with the procedures described in the FSWP or in accordance with recent negotiations with Ecology. The groundwater cleanup levels listed in Table 3-2 were developed as described in Section 3 and in accordance with recent negotiations with Ecology. The cleanup levels are protective of surface water, human health, and the environment.

The cleanup levels allow for the degradation that would occur between the source area and the CPOC due to natural attenuation. Details concerning modeling and cleanup level calculations are included in Section 3 and Appendix A. These cleanup levels will be used in development and evaluation of remedial alternatives for AOC-090 that involve natural attenuation or enhanced in situ bioremediation.

16.4 DESCRIPTION OF SITE REMEDIAL ALTERNATIVES

AOC-090 is located at the western edge of the Renton Facility directly north of North 6th Street. An interim action consisting of soil removal in the source area was completed in May 2004. Most of the affected soils within the source area that could be accessed were excavated and removed. Because the AOC is located within 50 feet of the property line of the Cedar River Trail Park and directly north of North 6th Street, access is limited. Several utility corridors for buried utilities run through the AOC, along North 6th Street, and along the property boundary. The pipeline and road are owned by others and are active. Removal of additional affected soil is not a practical option, as it would require removal and replacement of portions of the road, the gas pipeline, and the other public utilities that are within the North 6th Street right-of-way.

MTCA requires that remedial alternatives selected for a site meet the MTCA threshold requirements for cleanup actions. The minimum threshold requirements specify that cleanup

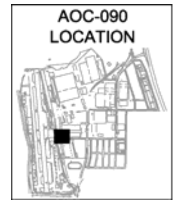
actions shall (1) protect human health and the environment, (2) comply with cleanup standards, (3) comply with applicable state and federal law, and (4) provide for compliance monitoring. In order to be considered as a potential remedial alternative for the site, the technologies considered had to pass the screening evaluation of the remedial technologies described in Section 4. In addition, the alternatives had to meet the minimum threshold requirements established by MTCA and be consistent with overall site conditions.

Based on the screening evaluation, MTCA minimum threshold requirements, and the site considerations discussed above, the following three remedial alternatives addressing groundwater COCs were developed for AOC-090.

- Alternative 1: Monitored Attenuation
- Alternative 2: Enhanced Bioremediation and Monitored Attenuation
- Alternative 3: Soil Vapor Extraction and Monitored Attenuation

16.4.1 Alternative 1: Monitored Attenuation

Alternative 1 is composed of the following two primary elements: institutional controls and MA. This alternative is predicated by the interim source removal action conducted at the site in 2004 and by the enhanced bioremediation process established by the addition of molasses to the excavation backfill. The groundwater cleanup standard for this alternative will be the AOC-090 groundwater cleanup levels listed in Table 3-2; these cleanup levels are applicable at the two sets of CPOCs identified in Figure 16-4. Due to the different flow paths for the shallow and intermediate depth groundwater, different CPOCs have been established for the two depth zones. Additionally, two CPOCs have been established for the shallow zone due to the flow divide created by the sheet pile wall in the Cedar River Trail Park. The soil cleanup standard will be the soil cleanup levels discussed in Section 16.3 and shown in Table 3-1. Detected levels of TPH-G, TPH-D, and TPH-MO in source area soils do not exceed the soil cleanup levels. Confirmation samples from the south wall of the excavation during the 2004 interim remedial measure contained levels of *cis*-1,2-DCE, TCE, and PCE above soil cleanup levels. However, the interim action removed the main bulk of contaminant mass, and the presence of degradation products in water samples from downgradient wells confirm that natural biodegradation is occurring at the site. Natural biodegradation processes have been further enhanced by the addition of organic carbon source during the 2004 interim remedial action. It is expected that ongoing natural biodegradation would continue to reduce the contaminant mass, resulting in cleanup levels being achieved at the CPOC within 15 years.



LNAPL was previously identified in monitoring well GW168 installed near AOC-090 prior to the interim action soil removal. As part of the 2004 interim action, this well was decommissioned and the soil around it, including soil in the capillary zone impacted by LNAPL, was removed. In addition, other site soils that may have been contributing to the LNAPL at GW168 have been removed. The maximum TPH concentrations detected in samples collected following the 2004 interim action from remaining soils near the gas line area are 1,200 mg/kg for TPH-G, 5,700 mg/kg for TPH-D, and 10,000 mg/kg for TPH-MO. These concentrations are below the residual saturation levels of 5,833 mg/kg for TPH-G (gasoline), 13,333 mg/kg for TPH-D (middle distillates), and 53,067 mg/kg TPH-MO (lube and heavy fuel oil) in a fine to medium sand (Brost and De Vaull, 2000). Given that removal of additional soil is impracticable due to utility constraints and that most of the site is underlain by silty or clayey sands and clayey silts, accumulation of additional LNAPL is unlikely and the residual saturation requirement of MTCA has been met.

Given that (1) impacted soils have been removed to the extent practicable, (2) the risks from the VOCs and TPH in soils can be managed through institutional controls (discussed below), and (3) the remaining soils are either confined by the recently placed parking lot asphalt cover or are inaccessible due to the gas pipeline, no additional active measures are necessary to remediate soils.

16.4.1.1 Institutional Controls

The following institutional controls are included to reduce the risk of human exposure to impacted soil or groundwater:

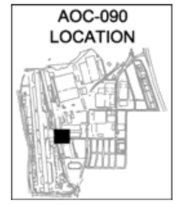
- Continued engineering controls, protocols, and monitoring previously established by Boeing to ensure that industrial workers inside buildings are protected and indoor air concentrations meet PELs established by the Washington Department of Labor and Industry;
- Continued engineering controls, protocols, and monitoring to ensure that temporary construction workers adhere to WAC 296-62-300, applicable Washington Labor and Industry standards, and OSHA HAZWOPER regulations (29 CFR 1919.120) for all construction work conducted in exposed areas of affected soil and groundwater;
- Deed restrictions to limit development and use of the site; and,
- Covenants and restrictions to limit development and use of the adjacent Cedar River Trail Park.

It is anticipated that deed restrictions would be established to limit future unrestricted land use without additional actions to attain compliance with appropriate soil and groundwater cleanup levels. It is further assumed that off-site CPOCs would be established for this alternative with permission granted by the off-site landowner, the City of Renton. In conjunction with permission for off-site CPOCs, it is anticipated that the City of Renton would formalize internal restrictions and institutional controls for temporary construction or maintenance workers in the park and roadway following Boeing's example.

16.4.1.2 Monitored Attenuation

Groundwater monitoring data collected over the last several years in the vicinity of AOC-090 indicate that natural processes are at work degrading and retarding the migration of COCs (as discussed in Section 4.2.4). These natural processes were enhanced by the application of molasses to the AOC-090 excavation prior to backfilling. The groundwater monitoring program established for AOC-090 included 13 monitoring wells monitored semiannually for VOCs. Analytical data collected through 2006 are presented in the Fourth Quarter 2006 Monitoring Report (Geomatrix, 2007a). These data show a substantial decrease in TCE concentrations within the source area and a substantial increase in the concentration of nontoxic degradation end products (i.e., ethane and ethene). Based on these data, the molasses has successfully enhanced biodegradation in the source area. Samples collected in August 2006 and February 2007 from monitoring wells located outside the source area (with the exception of Well GW181) had COCs either below detectable levels or at detectable concentrations below 1 µg/L, as shown on Figure 16-3.

In general accordance with the POC approach presented in Section 6 of the FSWP, fate and transport modeling using BIOCHLOR and BIOSCREEN was conducted to evaluate the efficacy of MA as a final remedy for this AOC. The modeling followed the protocol established in the FSWP, as subsequently modified in meetings and correspondence with Ecology, using approved model input parameters. The initial model input was not adjusted to reflect the results of the interim action source removal and is therefore considered to be a conservative estimate. The modeling results, presented in detail in Appendix A, are in general agreement with the preliminary modeling conducted for the FSWP. The model results were used to establish the site-specific groundwater cleanup levels applicable at the CPOCs for both the shallow and intermediate zones. As the data presented in Figure 16-3 and the quarterly monitoring reports show, COCs are present in samples collected at the CPOC at concentrations slightly exceeding the site-specific cleanup levels. Since most source area soils were removed



in 2004 and biodegradation has been enhanced, it is expected that COC concentrations will continue to degrade and that the site-specific cleanup levels will be attained at the CPOCs in the future.

Implementation of MA at AOC-090 requires that a monitoring plan be designed and implemented to verify the effectiveness of enhanced and natural attenuation processes. In accordance with current guidance and the approach for MNA discussed in Section 4.2.4, the conceptual monitoring program for AOC-090 is designed to:

- Demonstrate that MA is occurring and that biodegradation is the primary factor for decreasing COC concentrations;
- Identify any potentially toxic and/or mobile transformation products;
- Verify that the plume is not expanding beyond the CPOC;
- Verify that cleanup levels are attained at the CPOC;
- Verify that there is no unacceptable impact to potential downgradient receptors;
- Detect new releases of COCs that could impact the effectiveness of the monitored attenuation remedy;
- Demonstrate the efficacy of institutional controls put in place to protect potential receptors; and
- Verify attainment of remediation objectives.

The conceptual monitoring program for Alternative 1 at AOC-090 assumes that upon selection of this remedy, a detailed MA Validation and Long-Term Sampling Work Plan would be developed to guide the process. This work plan would identify monitoring wells and monitoring analytes that would be required for both characterization/validation sampling and long-term groundwater monitoring. Characterization/validation sampling would be used to demonstrate the effectiveness of MA with respect to contaminant mass reduction, attenuation rates, and temporal trends. Long-term groundwater monitoring would be used after characterization/validation monitoring to confirm that the contaminant plume is progressing toward containment or achievement of numerical goals. Due to the very low site-specific cleanup levels that apply to intermediate zone groundwater at the CPOC, it will be necessary to use an analytical method based on SIM to detect site COCs at appropriate concentrations.

These specialized analytical methods would be used for monitoring only the intermediate zone groundwater.

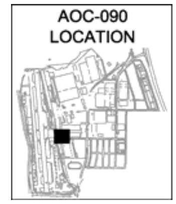
For this conceptual design, it is assumed that characterization/validation sampling would consist of semiannual and/or quarterly monitoring of selected monitoring wells, as illustrated in Figure 16-4. Only the deeper wells would be monitored for the well pairs located along the intermediate zone CPOC. Monitoring parameters and analytes will consist of VOCs (contaminants and daughter products), TPH-D, TPH-G, TPH-MO, as well as appropriate MA geochemical parameters [e.g., dissolved oxygen, nitrate, Fe(II), sulfate, methane, temperature, pH, specific conductance, alkalinity, oxidation/reduction potential, chloride, ethane, and TOC]. It is assumed that reporting for characterization/validation sampling would follow each quarterly event.

It is further assumed that long-term groundwater monitoring would follow for an additional 13 to 14 years (15 total years of monitoring) and would include semiannual monitoring of the 8 shallow wells and 5 intermediate wells for VOCs (contaminants and daughter products) and a limited suite of geochemical parameters (dissolved oxygen, oxidation/reduction potential, temperature, and pH). To ensure plume control, all 13 wells would be analyzed once every 5 years for the entire characterization/validation list of analytes. It is assumed that annual reporting would be required for long-term groundwater monitoring. For cost estimation, it was assumed that quarterly monitoring would be performed for 2 years followed by 13 years of semiannual monitoring. Long-term groundwater sampling frequency and the duration of the groundwater monitoring program would be based on results of performance monitoring, and may be adjusted as appropriate.

16.4.2 Alternative 2: Enhanced Bioremediation and Monitored Attenuation

Alternative 2 consists of three primary elements: institutional controls, additional enhanced bioremediation, and MA. The cleanup standard for this alternative will be the groundwater cleanup levels for AOC-090 COCs discussed in Section 16.3 and the two sets of CPOCs shown on Figure 16-5. The soil cleanup standard will be the soil cleanup levels discussed in Section 16.3 and shown in Table 3-1.

As previously discussed in Section 16.4.1, LNAPL was previously identified in monitoring well GW168 installed near AOC-090 prior to the interim action soil removal. As part of the interim action, this well was decommissioned and the soil around it, including soil in the



capillary zone impacted by LNAPL, was removed. In addition, other site soils that may have been contributing to the LNAPL at GW168 have been removed. Given that other risks from the VOCs and TPH in soils can be managed through institutional controls (discussed below) and that the remaining soils are either confined by the recently placed parking lot asphalt cover or are inaccessible due to the gas pipeline, no additional active measures are necessary to remediate soils.

16.4.2.1 Institutional Controls

Institutional controls for Alternative 2 would be the same as those discussed in Section 16.4.1.1 for Alternative 1.

16.4.2.2 Enhanced Bioremediation

Enhanced bioremediation for AOC-090 would consist of increasing the reductive capacity of the subsurface aqueous system by providing additional electron donor substrate to enhance the existing microbial activity. Increased bacterial growth due to the introduction of substrate results in the rapid consumption of naturally occurring dissolved inorganic constituents called electron acceptors (such as nitrate and sulfate), thereby creating conditions favorable for reductive dehalogenation of target compounds.

For this alternative, additional electron donor would be injected into the shallow and intermediate depth zones beneath the source area. The conceptual design employs the perforated drainpipe that was installed during the interim action along the southern extent of the excavation area, parallel to the gas line on North 6th Street. This drainpipe would be supplemented by installation of nine new injection wells, as shown on Figure 16-5. The pipe and new injection wells would be used for injection of organic carbon substrate, such as sodium lactate, emulsified vegetable oil, or molasses. The drainpipe was placed directly against the native soil on the one to one sloping side of the southern wall of the excavation, approximately 3 feet bgs. The pipe has three legs; one approximately 30 feet long on the eastern end of the southern wall, one approximately 18 feet long in the middle of the southern wall, and one approximately 18 feet long to the west of the middle section on the southern wall. Access ports (designated IPR3 and IPR4 on Figure 16-5) are located at two places; one between the two shorter sections of pipe (accesses both these sections) and one at the eastern end of the 30-foot section of pipe. The pipe consists of 4-inch wrapped drain tile.

It is further assumed that the electron donor substrate injected into the drainpipe system would be sodium lactate or other similar substrate. For cost estimation purposes, it was assumed that the initial injection would consist of 1,000 gallons of electron donor injected into the intermediate depth zone using injection wells, 4,000 gallons into the shallow depth zone using injection wells, and 1,000 gallons injected into the vadose/shallow zones using the drainpipe. It was assumed that the electron donor would be 2% emulsified vegetable oil (potable water would be used for diluting the concentrated product). It was also assumed that three applications (at 1-year intervals) would be required to effectively treat affected groundwater at this site; a total injection volume of 2,000 gallons was assumed for the annual injection. Monitored attenuation would be implemented simultaneously with substrate injection and would continue after the final injection, as described below.

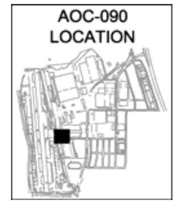
16.4.2.3 Monitored Attenuation

Monitored attenuation for this alternative is intended to be a final "polishing" mechanism, following the active enhanced bioremediation, to ensure that cleanup levels for all COCs are met at the CPOCs. The MA program for this alternative is assumed to be the same as described in Section 16.4.1.2 above for Alternative 1. Cost estimates for this alternative are based on the same assumptions used for the Alternative 1 cost estimate.

16.4.3 Alternative 3: Soil Vapor Extraction and Monitored Attenuation

Alternative 3 is composed of three primary elements: institutional controls, SVE, and MA. The cleanup standard for this alternative will be the groundwater cleanup levels for AOC-090 COCs discussed in Section 16.3 and the two sets of CPOCs shown on Figure 16-4 and as discussed above for Alternatives 1 and 2. The key components for Alternative 3 are shown on Figure 16-4.

As discussed in Section 16.4.1, LNAPL was previously identified in monitoring well GW168 installed near AOC-090 prior to the interim action soil removal. As part of the interim action, this well was decommissioned and the soil around it, including soil in the capillary zone impacted by LNAPL, was removed. In addition, other site soils that may have been contributing to the LNAPL at GW168 have been removed. Given that other risks from the VOCs and TPH in soils can be managed through institutional controls (discussed below) and that the remaining soils are either confined by the recently placed parking lot asphalt cover or are inaccessible due to the gas pipeline, no additional active measures are necessary to remediate soils.



16.4.3.1 *Institutional Controls*

Institutional controls for Alternative 3 will be similar to those discussed in Section 16.4.1.1 for Alternative 1.

16.4.3.2 *Soil Vapor Extraction*

The vapor extraction system for Alternative 3 would draw soil vapor from the soil through the perforated drainpipe that was installed during the interim action along the southern extent of the excavation area, parallel to the gas line on North 6th Street. The pipe (consisting of 4-inch wrapped drain tile) was placed directly against the native soil on the one to one sloping side of the southern wall of the excavation, approximately 3 feet bgs. The drainpipe (described in Section 16.4.2.2 for Alternative 2) has three legs and two access ports. The access ports would be connected to a vacuum blower system capable of removing at least 20 scfm from each port. The air would be routed for treatment through a combination GAC and permanganate unit in order to remove VOCs, including VC, prior to discharge to the atmosphere. Due to the fairly low permeability of the backfill placed in the 2004 excavation, it is expected that the SVE system would draw preferentially from the vadose zone soils along the southern side of the excavation that cannot be practicably excavated. Operation of the SVE would generate waste requiring off-site management (spent GAC and permanganate adsorbent).

16.4.3.3 *Monitored Attenuation*

Monitored attenuation for this alternative is intended to be a final “polishing” mechanism, following the active SVE, to ensure that cleanup levels for all COCs are met at the CPOC. With this alternative, it is assumed that MA would follow SVE and consist of the long-term groundwater monitoring for the same 13 wells described above for Alternative 1. Groundwater monitoring would be conducted semiannually for VOCs (contaminants and daughter products), TPH-D, TPH-G, TPH-MO, and a limited suite of geochemical parameters (dissolved oxygen, oxidation/reduction potential, temperature, and pH). To ensure plume control, all 13 monitoring wells would be analyzed once every 5 years for the entire list of analytes. It is assumed that monitoring would continue following active remediation for a total of 15 years of monitoring, and that annual reporting would be required for the duration. For cost estimation purposes, it was assumed that semiannual monitoring would be conducted for 15 years (during and after SVE operations) with annual reporting.

16.5 EVALUATION OF SITE REMEDIAL ALTERNATIVES

As previously discussed, all three alternatives developed for the site meet the MTCA minimum requirements for cleanup actions. This section compares and evaluates the alternatives based on the MTCA criteria described in Section 5.1. An analysis of each alternative with respect to the evaluation criteria is summarized in Table 16-1 and discussed below.

16.5.1 Protectiveness and Risk Reduction Evaluation

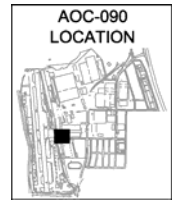
Protectiveness and risk reduction are gauged primarily by the time required for the alternative to reduce risk and meet cleanup levels. Alternative 3 provides permanent destruction of site COCs, either in situ or ex situ, when the adsorbent is regenerated. Of the three alternatives, it is expected to most quickly reduce the mass of COCs at the site. Alternatives 2 and 3 were rated medium high for this criterion.

16.5.2 Permanence

Permanence refers to the ability to reduce the toxicity, mobility, or volume of hazardous substances, including the permanent destruction of hazardous substances. All three Alternatives provide permanent destruction of COCs. Alternative 3 is rated highest for this criterion because the removal and destruction are more controlled and expected to occur at a faster rate for COCs remaining in vadose zone soils.

16.5.3 Cost

The cost evaluation includes all costs related to implementation of an alternative, including initial design and construction costs, operation and maintenance costs, monitoring costs, and reporting costs. The annual costs for operation, maintenance, monitoring, and reporting are recurring costs that occur in the future. The cost evaluation considers initial implementation costs and future recurring costs using NPV analysis. For NPV calculation, recurring costs were inflated 2% annually and a discount rate of 7% was used. Details regarding the cost estimates for the three alternatives are presented in Appendix B. The present value costs for the three alternatives, in 2007 dollars, are summarized below:



Alternative	Net Present Value
1: Monitored Attenuation	$579,000
2: Enhanced Bioremediation and Monitored Attenuation	$670,000
3: Soil Vapor Extraction and Monitored Attenuation	$718,000

As shown by these costs, Alternative 3 has the highest NPV cost, while Alternative 1 has the lowest. Therefore, Alternative 3 ranks lowest for cost, Alternative 1 ranks highest, and Alternative 2 is intermediate.

16.5.4 Long-Term Effectiveness

Long-term effectiveness includes the degree of certainty and reliability of the alternative and whether treatment residue remains from the alternative that will require management. Both Alternatives 1 and 2 are proven technologies, and neither produces residual wastes that would require ongoing management. Alternatives 1 and 2 were rated medium high for this criterion while Alternative 3 was rated medium low.

16.5.5 Management of Short-Term Risks

Short-term risk refers to the risk to human health and the environment during implementation of the alternative. Because the implementation of Alternative 1 is the simplest, does not require construction of a treatment system, and does not require handling of residuals, it is rated highest for this criterion. Alternative 3 is rated lowest, since it creates potential risks due to withdrawal of contaminated soil vapor.

16.5.6 Technical and Administrative Implementability

This criterion involves whether the alternative is technically possible relative to complexity, administrative/regulatory requirements, size, access, and integration with existing operations. Given that Alternative 1 is a small, simple system that integrates well with the Facility operations, it is rated highest. Alternative 3 is rated lowest, as it requires the highest level of permitting and operations.

16.5.7 Public Concerns

This criterion involves potential community concerns with the alternative. Since all three alternatives deal with an industrial site but have an impact upon the adjacent Cedar River Trail Park, they are rated the same.

16.5.8 Reasonable Restoration Time Frame

Restoration time frame involves the practicability of a shorter restoration time frame, with consideration given to a number of factors including site risks, site use and potential use, availability of alternative water supply, effectiveness and reliability of institutional controls, and toxicity of hazardous substances at the site. As a whole, these factors are a measure of the urgency of reducing risk and achieving cleanup goals for the site. Given that the site is industrial, the source has been removed to the extent practicable, and the risk to park users is low, all three alternatives are ranked medium low. However, Alternatives 2 and 3 would provide a shorter restoration time than Alternative 1.

16.6 SELECTION OF THE PREFERRED SITE REMEDIAL ALTERNATIVE

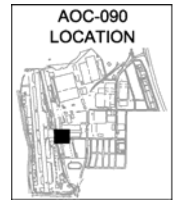
Selection of a preferred alternative under MTCA requires that a preference be given to alternatives that use permanent solutions (to the maximum extent practicable), provide for a reasonable restoration time frame, and consider public concerns. The analysis below defines the baseline alternative for AOC-090 and compares the other alternatives to the baseline alternative based on the degree of permanence, reasonable restoration time frame, and the degree to which it addresses potential public concerns. Based on this comparison, the preferred remedial alternative is identified and proposed for selection as the cleanup action to be implemented for the site.

16.6.1 Baseline Remedial Alternative

The evaluation of the three remedial alternatives for this site is summarized in Table 16-1. None of the alternatives is capable of attaining the standard POC at this site. As previously discussed, a high-pressure gas pipeline and North 6th Street are immediately south of the interim action soil excavation area. Based on the remedial alternative evaluation presented above and summarized on Table 16-1, the three remedial alternatives are ranked as follows for permanence:

1. Alternative 3: Soil Vapor Extraction and Monitored Attenuation
2. Alternative 2: Enhanced Bioremediation and Monitored Attenuation
3. Alternative 1: Monitored Attenuation

Based on this ranking, Alternative 3, Soil Vapor Extraction and Monitored Attenuation, is defined as the baseline remedial alternative. This alternative provides the greatest degree of mass removal and destruction for site COCs and is expected to accomplish this removal in the



shortest time. However, degradation of groundwater COCs would be slower under Alternative 3 than under Alternative 2. Both Alternatives 2 and 3 provide equivalent levels of removal and destruction of site COCs; however, Alternative 3 would provide for permanent destruction of volatile organic COCs through the SVE system and biodegradation. During SVE operations, VOCs present in extracted soil vapor would be adsorbed or oxidized on site by the permanganate and activated carbon adsorption system. The permanganate adsorber would destroy VC present in the soil gas. VOCs in the soil gas would be removed by the activated carbon; adsorbed organics would be permanently destroyed during off-site regeneration or disposal.

16.6.2 Comparison to Baseline Alternative

Alternative 3 has been defined as the baseline remedial alternative for this site. Alternatives 1 and 2 will be compared to the baseline alternative in the following subsections for selection of the preferred alternative. The purpose of this comparison is to assess the benefits and costs for Alternatives 1 and 2 relative to Alternative 3. The evaluation criteria presented above and in Table 16-1 were established in accordance with the MTCA requirements cited in WAC 173-340(3)(f). Costs for the alternatives will be based on the NPV, which reflects the total cost associated with each alternative over the 15-year time period evaluated. The evaluation of benefits will be qualitative.

The benefits to be assessed in this comparison and the relative rating for the alternatives are presented in Table 16-2. The rationale for this comparison is presented below:

- **Reduced risk to on-site worker health.** All three alternatives are equal in reducing long-term risk to site workers. Although the baseline alternative would remove volatile COCs within a few years, some short-term risks to workers would be created due to extraction of contaminated soil vapors. Potential risks to on-site workers would be the same for the other two alternatives. The institutional controls included in each of the alternatives have been proven effective in protecting worker health and would continue to be protective. The baseline alternative was rated moderate due to short-term worker risk; the other two alternatives were rated high.

- **Reduced risk to off-site human health.** Alternative 2 was rated high for this benefit, while the baseline alternative and Alternative 1 were rated moderate for reducing risks to off-site human health. All three would eventually attain the cleanup levels at the CPOCs, which are protective of human health and the environment. The institutional controls included in all alternatives that have proven to be protective of worker health on site would also be protective of human health in off-site areas affected by site COCs. However, the baseline alternative actively

withdraws volatile COCs from the subsurface, which creates the potential for emissions that may impact off-site receptors. Both the baseline alternative and Alternative 1 rely primarily upon MA for groundwater remediation, which will slowly attain the cleanup standard. Alternative 2 provides for the most rapid restoration of affected groundwater.

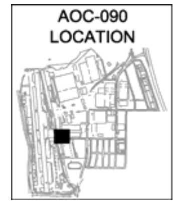
- **Reduced risk to the environment.** Alternatives 1 and 3 (the baseline alternative) were ranked lower than Alternative 2 for reducing potential risks to the environment. The active removal of volatile COCs using SVE that would result from the baseline alternative creates the potential for emissions to the atmosphere, which could migrate to off-site ecological receptors. All three alternatives would be protective of the aquatic environment because they would all attain the cleanup levels at the CPOCs; however, Alternative 2 is expected to provide the most rapid attainment of the cleanup standard.

- **Minimal adverse impact on Facility operations.** The baseline alternative was rated low for this benefit because it would impact Facility operations during installation of the above-ground SVE components and require long-term operation and periodic replacement of SVE system components. A high rating was given to Alternatives 1 and 2, which would have the least impact on Facility operations. The short duration impact to operations during injection events for Alternative 2 is not considered significant.

- **Minimal restrictions on Facility traffic and access.** The baseline alternative was rated low for this benefit because it would impact Facility traffic and access during installation of the SVE system. Additional impact would occur during periodic replacement or maintenance of SVE system components. Alternative 2 was rated moderate because periodic addition of substrate would disrupt traffic and access during these periods. Alternative 1 was given a high rating because it would affect traffic only during installation and sampling of monitoring wells, most of which would occur along the off-site CPOC, resulting in the least impact on Facility traffic and access.

- **Minimal adverse impact on Facility structures and utilities.** The baseline alternative was rated moderate for minimizing adverse impacts on facility structures and utilities because a new installation for the SVE blower system would be constructed. Alternatives 1 and 2 would have minimal impact on structures and utilities, and were rated high for this benefit.

The potential benefit evaluation for the three alternatives shows that Alternative 2, Enhanced Bioremediation and Monitored Attenuation, would provide the greatest benefit. Alternative 1 would provide the next highest benefit, and the baseline alternative (Alternative 3) ranks lowest for benefits.



The NPV costs for the three alternatives were presented in Section 16.5.3. The baseline alternative ranks last among the three alternatives, with the highest cost. Alternative 1 would have the lowest NPV cost (approximately 81% of the estimated cost for the baseline alternative). Alternative 2 would have the next lowest cost (approximately 93% of the cost for the baseline alternative). Alternative 1 is ranked highest for cost because it would have the lowest NPV.

16.6.3 Preferred Remedial Alternative

Alternative 2, Enhanced Bioremediation and Monitored Attenuation, provides the greatest benefit and has an intermediate cost; therefore, Alternative 2 is the preferred remedial alternative for the AOC-090 site. Alternative 3, as the baseline and the most permanent potential remedy, does not provide additional benefits that are commensurate with its disproportionate cost and potential risks. Ample evidence was collected during the RI to demonstrate that natural biodegradation of organic soil and groundwater COCs is active at this site. Subsequent experience after completing the 2004 and the 2007 interim action has shown substantial reduction in concentration of source area COCs as a result of enhanced bioremediation.

Affected soils have already been removed from AOC-090 to the extent practicable; existing underground utilities preclude additional soil removal. Under Alternative 2, the remaining affected soils would remain capped by either roads or other maintained pavement or tarmac, which would prevent direct contact, reduce potential runoff, and minimize infiltration of rainfall. Enhanced bioremediation would continue the rapid biodegradation of groundwater COCs that has been achieved as a result of the 2004 interim measure. Recent monitoring data indicate that groundwater COCs have exceeded the site-specific cleanup levels at the CPOCs defined for the shallow and intermediate zones. The active remediation program included in Alternative 2 is expected to reduce the downgradient concentrations within a reasonable time frame. Thus, the preferred alternative is expected to achieve compliance with MTCA requirements after allowing time to continue the ongoing remediation program.

While the affected soil and the affected groundwater plume extend beyond the property line, the off-site area is owned by the City of Renton and consists of a public road and the Cedar River Trail Park (also owned by the city). The City of Renton has indicated general agreement to allow a CPOC to be located on City property. Groundwater in the area is not used for any purpose, and potable water is readily available from the Renton public water system. The

institutional controls included in Alternative 2 have been implemented and proven by Boeing, who would continue to maintain overall responsibility for this site and ensure that the institutional controls are properly enforced. It is expected that similar institutional controls would be implemented by the City of Renton for adjacent off-site areas.

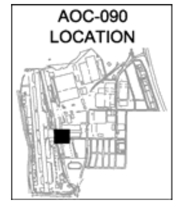
Enhanced bioremediation and monitored attenuation for this site would achieve the expectations for cleanup actions cited in the MTCA regulations at WAC 173-340-370 (1) – (8). Only those expectations relevant to large, complex sites are considered relevant to AOC-090. The relevant expectations are addressed as follows:

- **Implement Treatment at Sites with Liquid Wastes, High Contaminant Concentrations, Highly Mobile Materials, or Discrete Areas of Contamination.** Ecology expects that treatment will be emphasized for sites meeting these general criteria. A substantial amount of highly impacted soil was removed during the interim action. Boeing believes that while remaining soil COC levels exceed cleanup levels, they are not high enough to indicate that liquid wastes are present within the subsurface. Affected soil extends beneath the gas pipeline and North 6th Street, preventing access for practicable removal or treatment. Enhanced bioremediation would degrade or "treat" organic COCs over the long term using enhanced natural processes that result in nontoxic degradation products.

- **Destroy, Detoxify, or Remove Hazardous Substances.** Ecology expects that hazardous substances will be destroyed, detoxified, or removed to below cleanup levels. The substrate applied during the interim action has accelerated permanent destruction of site COCs. The additional application of electron donor included in Alternative 2 would continue to accelerate bioremediation and would ultimately destroy COCs, resulting in nontoxic degradation products.

- **Implement Engineering Controls for Low Contaminant Concentrations.** Ecology recognizes the need for containment for low concentrations of contaminants where treatment is impracticable. The preferred alternative would use active enhanced bioremediation to treat and destroy contaminants. The area would be covered by pavement, thereby providing an engineered barrier to limit the potential for direct contact with affected media and to limit surface water infiltration.

- **Prevent Runoff of Hazardous Substances.** Ecology expects that cleanup actions will include active measures to prevent precipitation from creating runoff that contains affected soil. This expectation would be met by the preferred alternative because the source area would be covered by the pavement in Boeing's parking area and by North 6th Street. In addition to preventing runoff from contacting hazardous substances, the pavement limits erosion and minimizes surface water infiltration,



thus resulting in decreased groundwater flow rates and increased time for groundwater to flow from the source area to the waterway.

- **Consolidate On-site Contaminants Exceeding Cleanup Levels.** Ecology expects that when contaminants exceeding cleanup levels are left on site they will be consolidated to the extent practicable. At this site, due to the location of the contaminants, it is not practicable to consolidate contaminants.

- **Prevent Runoff and Groundwater Discharge to Surface Water.** Ecology expects that the cleanup action would include active measures to prevent or minimize releases to adjacent surface water bodies via runoff or groundwater discharge, and that dilution will not be the sole method for attaining cleanup levels. Alternative 2 would meet this expectation. Available groundwater monitoring data indicate that biodegradation of organic COCs to nontoxic end-products is active and significant at this site. Addition of additional organic substrate would further accelerate these natural processes. The preferred alternative also includes a groundwater monitoring network and program that would confirm that cleanup levels were attained in groundwater less than 100 feet downgradient of the AOC and before groundwater can reach Lake Washington.

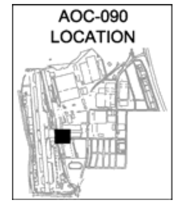
- **Ensure Appropriateness of Attenuation.** Ecology expects that natural attenuation may be appropriate if source control has been conducted to the maximum extent practicable; contaminants remaining on site do not pose unacceptable risks to human health and the environment; evidence indicates that degradation is occurring and will continue to occur at a reasonable rate; and appropriate monitoring is conducted. Alternative 2 does not rely solely on natural attenuation, as it would be designed to promote more rapid biodegradation. This alternative would, however, achieve all the expectations related to natural attenuation. Source excavation was conducted to the maximum extent practicable during the 2004 interim action. In addition, Boeing has proposed additional interim action to support enhanced bioremediation of affected groundwater. Effective institutional controls have been implemented for the Facility that have proven effective in protecting human health and the environment at this site. Groundwater monitoring data indicate that biodegradation of organic COCs is active at the site and can be accelerated through addition of organic substrate; coupled with the high organic fraction in site soil, additional substrate is expected to ensure conditions favorable to continued active biodegradation. Alternative 2 also includes a robust groundwater monitoring program designed to address EPA guidance for MNA of chlorinated VOCs. The monitoring system included in the preferred alternative would confirm that the site-specific cleanup levels are attained at the CPOCs established for this site within a reasonable time frame.

As noted above, due to the constituent migration that has occurred due to the historic releases at AOC-090, present COC concentrations at the CPOCs for AOC-090 exceed site-specific cleanup levels. Boeing has implemented interim actions to address the historic releases,

including removal of source area soils to the extent practicable and implementation of an enhanced bioremediation program directly beneath the source area. It is expected that the previously implemented interim measure, the currently proposed interim measure, and the additional remedial actions included in Alternative 2 will actively and permanently reduce the concentrations of COCs migrating from the AOC-090 source area. The reduced flux of COCs will reduce concentrations in the affected groundwater plume within a reasonable time. Thus, the preferred alternative will achieve the site-specific cleanup levels at the designated CPOCs within a reasonable time.

The preferred remedial alternative would be designed to comply with applicable regulations. Potentially applicable regulations are listed in Table 16-3. These regulations govern the design, installation, and operation of remediation systems. For the preferred alternative at AOC-090, regulatory requirements are expected to be minimal. Construction for the preferred alternative would be limited to installation of new monitoring and injection wells (as currently proposed as part of the interim action), some within 200 feet of the shoreline along the Cedar River Waterway.

The primary regulations governing the preferred alternative would be the MTCA regulations, the Washington well drilling regulations for monitoring wells, the underground injection control regulations, the solid waste disposal regulations, the dangerous waste regulations, the transportation regulations, the Shoreline Management Act, and the Department of Labor and Industries health and safety regulations. Well drilling rules specify well design and drilling requirements. The underground injection rules would address injection of electron donor to enhance bioremediation. The solid and dangerous waste regulations specify waste characterization, manifesting, and disposal requirements. Transportation regulations specify labeling and shipping requirements for wastes generated from implementation of the alternative. MTCA regulations specify remediation requirements and the cleanup standards to be attained. The Shoreline Management Act specifies standards for construction activities within 200 feet of the Cedar River Waterway. The preferred alternative would be designed and implemented to comply with these regulations.



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Geomatrix

TABLE 16-1

COMPARISON OF REMEDIAL ALTERNATIVES, AOC-090[1]

Boeing Renton Facility
Renton, Washington

Standards/Criteria		Alternatives: 1 - Monitored Attenuation	2 - Enhanced Bioremediation/MA	3 - Soil Vapor Extraction/MA
Protectiveness and Risk Reduction	Pros	Destroys COCs.	Fairly rapid COC destruction throughout plume.	Rapidly removes COCs; slow COC destruction within plume.
	Cons	Slow to achieve cleanup.		Requires off-site waste management.
	Rating	ML	MH	MH
Permanence	Pros	Natural carbon promotes MNA; Destroys COCs; No residuals.	Destroys COCs; No residuals; Reasonably rapid cleanup.	Removes COCs rapidly; Fastest to achieve cleanup levels in majority of plume.
	Cons	Slow degradation rates; Off-site CPOC.	Off-site CPOC.	Slow groundwater degradation rates; Off-site CPOC.
	Rating	ML	MH	H
Cost	Pros	Lowest cost.		
	Cons			Highest cost.
	Rating	MH	ML	L
Long-Term Effectiveness	Pros	Destroys COCs; Passive, natural process.	Destroys COCs.	Removes/Destroys COCs.
	Cons		Requires periodic injections.	Requires engineering controls; Requires off-site waste management.
	Rating	MH	MH	ML
Management of Short-Term Risks	Pros	Simplest implementation; No residuals.		
	Cons		Requires periodic injections.	Potential risks related to emissions and to handling of residuals.
	Rating	H	MH	ML
Technical and Administrative Implementability	Pros	Simple system.	Simple system.	Existing soil vapor collector.
	Cons	Off-site landowner permission needed.	Requires periodic injections; Off-site landowner permission needed; Injection permit required.	More complex system; Requires engineering controls; Requires air permitting; Active operations and maintenance; off-site landowner permission.
	Rating	H	MH	ML
Public Concerns	Pros	Industrial site.	Industrial site.	Industrial site.
	Cons	Requires City of Renton approval for CPOC.	Requires City of Renton approval for CPOC.	Requires City of Renton approval for CPOC.
	Rating	ML	ML	ML
Restoration Time Frame	Pros	Industrial site; Proven institutional controls; Alternative water available; Practicability of shorter time frame limited by facility operations.	Industrial site; Proven institutional controls; Alternative water available; Practicability of shorter time frame limited by facility operations.	Industrial site; Proven institutional controls; Alternative water available; Practicability of shorter time frame limited by facility operations.
	Cons			
	Rating	ML	ML	ML

Notes:

1. Comparison Ratings: H = Highest (if the decision were based solely on one criterion, an H score would indicate the alternative is the preferred alternative);
MH = Medium High;
ML = Medium Low;
L = Low.

TABLE 16-2

COMPARISON OF BENEFITS
AOC-090[1]
Boeing Renton Facility
Renton, Washington

Benefit	Alternative 1: Monitored Natural Attenuation	Alternative 2: Enhanced Bioremediation and Monitored Attenuation	Alternative 3: Soil Vapor Extraction and Monitored Attenuation
Reduced risk to on-site worker health	High	High	Moderate
Reduced risk to off-site human health	Moderate	High	Moderate
Reduced risk to the environment	Moderate	High	Moderate
Minimal adverse impact on Facility operations	High	High	Low
Minimal restrictions on Facility traffic and access	High	Moderate	Low
Minimal adverse impact on Facility structures and utilities	High	High	Moderate

Notes:
1. Benefits for each remedial alternative are rated as follows:
   High = high benefit;
   Moderate = moderate benefit;
   Low = low benefit.

TABLE 16-3

POTENTIALLY APPLICABLE REGULATIONS
AOC-090 PREFERRED REMEDIAL ALTERNATIVE
Boeing Renton Facility
Renton, Washington

Law/Regulation	Citation	Applicability
Chemical-Specific Laws and Regulations		
Washington Dangerous Waste Regulations	WAC 173-303	Waste management, permitting requirements
Washington Model Toxics Control Act Regulations	WAC 173-340	Establishment of cleanup levels and POCs
Action-Specific Laws and Regulations		
Washington State Environmental Policy Act Regulations	WAC 197-11	Permitting, EIA/EIS requirements[1]
Washington Industrial Safety and Health Act Regulations	WAC 296-24	Occupational health and safety
Transportation regulations	49 CFR Parts 100 & 177, WAC 446-50	Transportation for wastes and materials
Washington well drilling regulations	WAC 173-160 & -162	Well design and installation standards
Washington Underground Injection Control Regulations	WAC 173-218	Underground injection permitting
Washington solid waste disposal regulations	WAC 173-304	Disposal of nondangerous waste
Location-Specific Regulations		
Shoreline Management Act	RCW 90.58	Standards for construction within 200 ft of shoreline

Notes:
1. EIA = Environmental Impact Assessment; EIS = Environmental Impact Statement.

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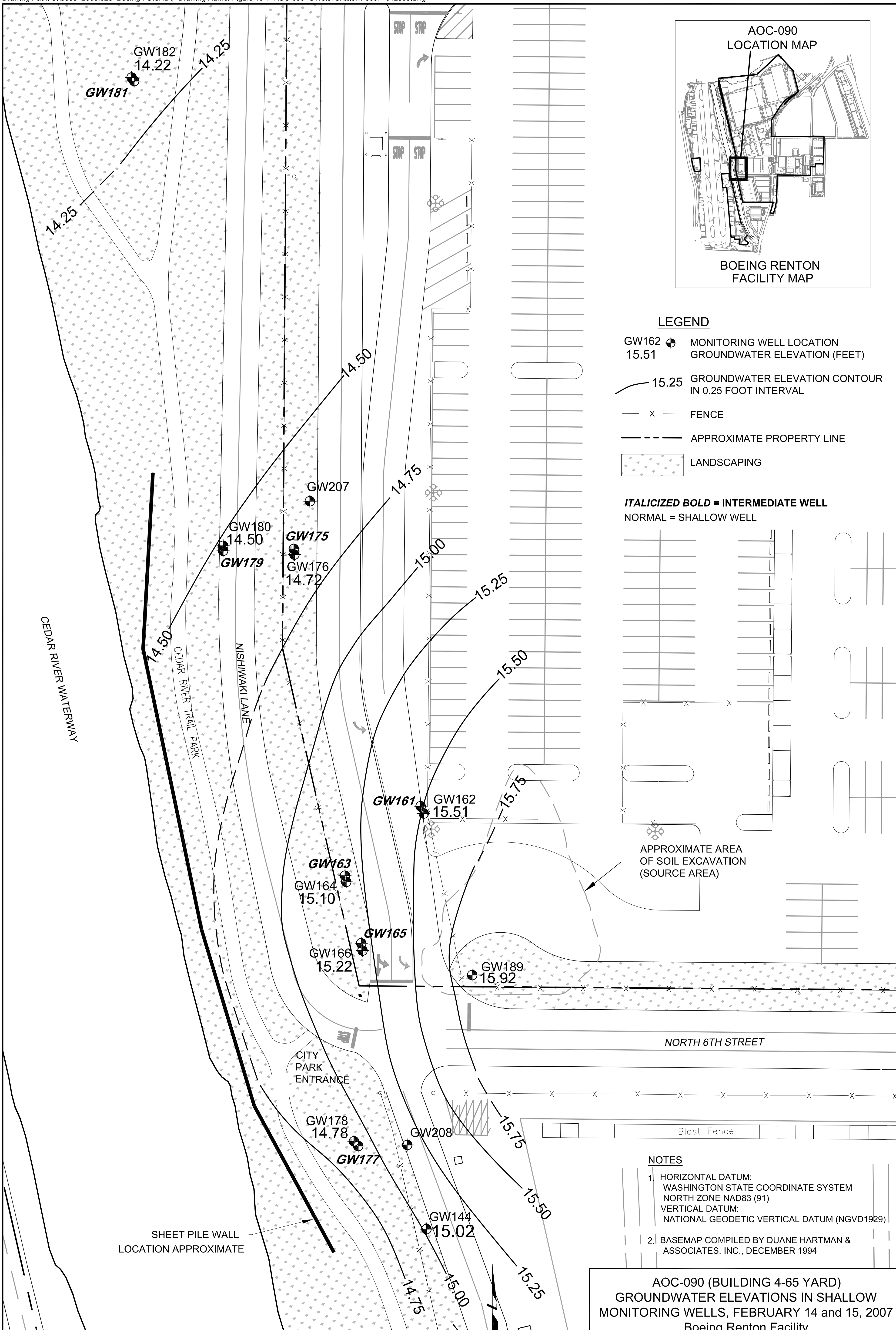


LEGEND

- GW162 15.51 — MONITORING WELL LOCATION, GROUNDWATER ELEVATION (FEET)
- 15.25 — GROUNDWATER ELEVATION CONTOUR IN 0.25 FOOT INTERVAL
- x — FENCE
- APPROXIMATE PROPERTY LINE
- LANDSCAPING

ITALICIZED BOLD **= INTERMEDIATE WELL**
NORMAL = SHALLOW WELL

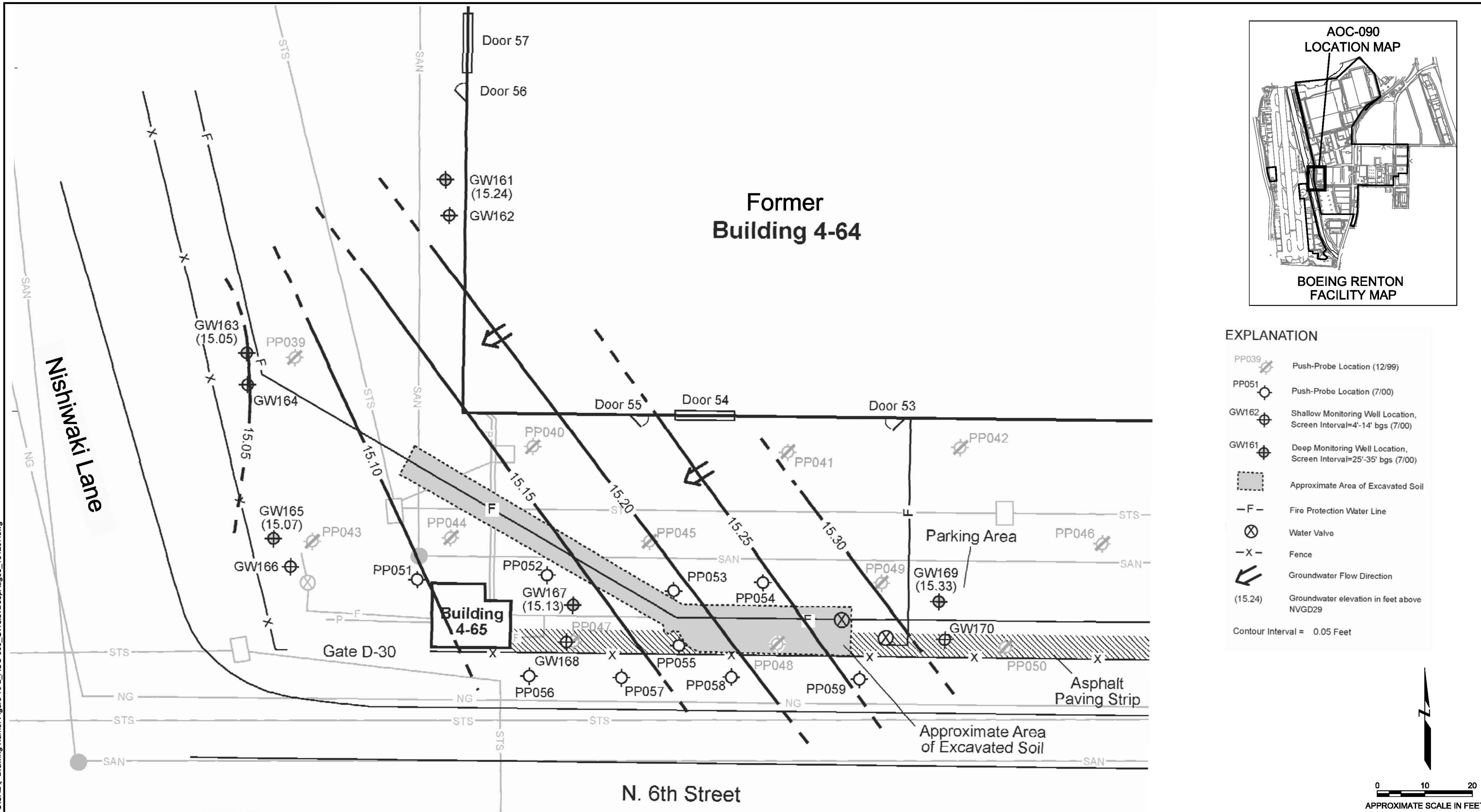
NOTES

1. HORIZONTAL DATUM:
   WASHINGTON STATE COORDINATE SYSTEM NORTH ZONE NAD83 (91)
   VERTICAL DATUM:
   NATIONAL GEODETIC VERTICAL DATUM (NGVD1929)
2. BASEMAP COMPILED BY DUANE HARTMAN & ASSOCIATES, INC., DECEMBER 1994

BOEING

AOC-090 (BUILDING 4-65 YARD)
GROUNDWATER ELEVATIONS IN SHALLOW MONITORING WELLS, FEBRUARY 14 and 15, 2007
Boeing Renton Facility
Renton, Washington

By: APS	Date: 05/28/08	Project No. 8888
Geomatrix		Figure 16-1



AOC-090 (BUILDING 4-65 YARD) RECENT GROUNDWATER ELEVATIONS IN INTERMEDIATE MONITORING WELLS, AUGUST 18, 2000
Boeing Renton Facility
Renton, Washington

By: APS | Date: 05/29/08 | Project No. 8888

Geomatrix | Figure **16-2**

NOTE:
FIGURE ADAPTED FROM FIGURE 5-17F FROM THE REMEDIAL INVESTIGATION REPORT, BOEING RENTON PLANT, RENTON, WA (WESTON, 2001a).

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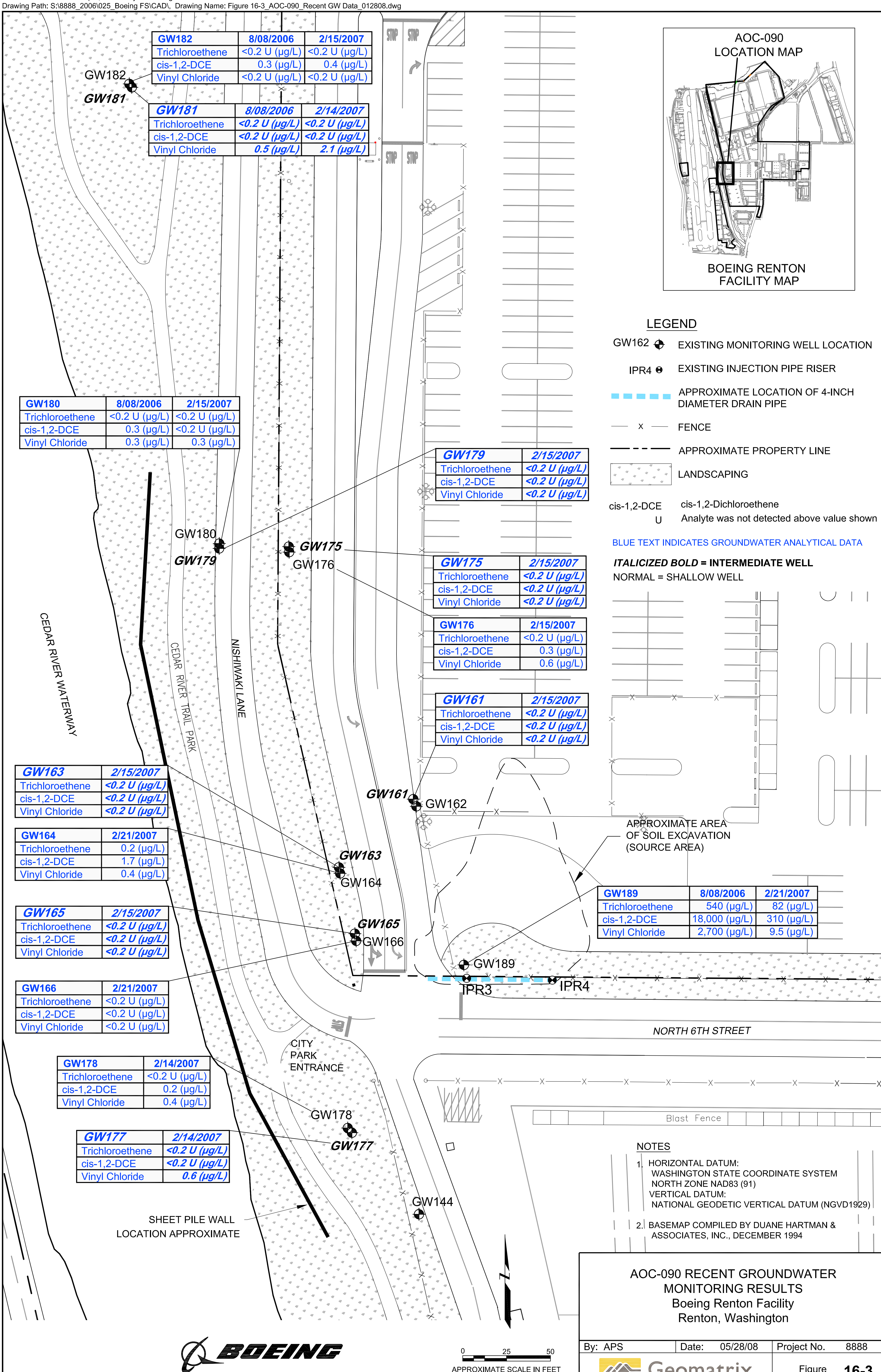

GW182	8/08/2006	2/15/2007
Trichloroethene	<0.2 U (µg/L)	<0.2 U (µg/L)
cis-1,2-DCE	0.3 (µg/L)	0.4 (µg/L)
Vinyl Chloride	<0.2 U (µg/L)	<0.2 U (µg/L)

GW181	***8/08/2006***	***2/14/2007***
Trichloroethene	***<0.2 U (µg/L)***	***<0.2 U (µg/L)***
cis-1,2-DCE	***<0.2 U (µg/L)***	***<0.2 U (µg/L)***
Vinyl Chloride	***0.5 (µg/L)***	***2.1 (µg/L)***

GW180	8/08/2006	2/15/2007
Trichloroethene	<0.2 U (µg/L)	<0.2 U (µg/L)
cis-1,2-DCE	0.3 (µg/L)	<0.2 U (µg/L)
Vinyl Chloride	0.3 (µg/L)	0.3 (µg/L)

GW179	***2/15/2007***
Trichloroethene	***<0.2 U (µg/L)***
cis-1,2-DCE	***<0.2 U (µg/L)***
Vinyl Chloride	***<0.2 U (µg/L)***

GW175	***2/15/2007***
Trichloroethene	***<0.2 U (µg/L)***
cis-1,2-DCE	***<0.2 U (µg/L)***
Vinyl Chloride	***<0.2 U (µg/L)***

GW176	2/15/2007
Trichloroethene	<0.2 U (µg/L)
cis-1,2-DCE	0.3 (µg/L)
Vinyl Chloride	0.6 (µg/L)

GW161	***2/15/2007***
Trichloroethene	***<0.2 U (µg/L)***
cis-1,2-DCE	***<0.2 U (µg/L)***
Vinyl Chloride	***<0.2 U (µg/L)***

GW163	***2/15/2007***
Trichloroethene	***<0.2 U (µg/L)***
cis-1,2-DCE	***<0.2 U (µg/L)***
Vinyl Chloride	***<0.2 U (µg/L)***

GW164	2/21/2007
Trichloroethene	0.2 (µg/L)
cis-1,2-DCE	1.7 (µg/L)
Vinyl Chloride	0.4 (µg/L)

GW165	***2/15/2007***
Trichloroethene	***<0.2 U (µg/L)***
cis-1,2-DCE	***<0.2 U (µg/L)***
Vinyl Chloride	***<0.2 U (µg/L)***

GW166	2/21/2007
Trichloroethene	<0.2 U (µg/L)
cis-1,2-DCE	<0.2 U (µg/L)
Vinyl Chloride	<0.2 U (µg/L)

GW189	8/08/2006	2/21/2007
Trichloroethene	540 (µg/L)	82 (µg/L)
cis-1,2-DCE	18,000 (µg/L)	310 (µg/L)
Vinyl Chloride	2,700 (µg/L)	9.5 (µg/L)

GW178	2/14/2007
Trichloroethene	<0.2 U (µg/L)
cis-1,2-DCE	0.2 (µg/L)
Vinyl Chloride	0.4 (µg/L)

GW177	***2/14/2007***
Trichloroethene	***<0.2 U (µg/L)***
cis-1,2-DCE	***<0.2 U (µg/L)***
Vinyl Chloride	***0.6 (µg/L)***

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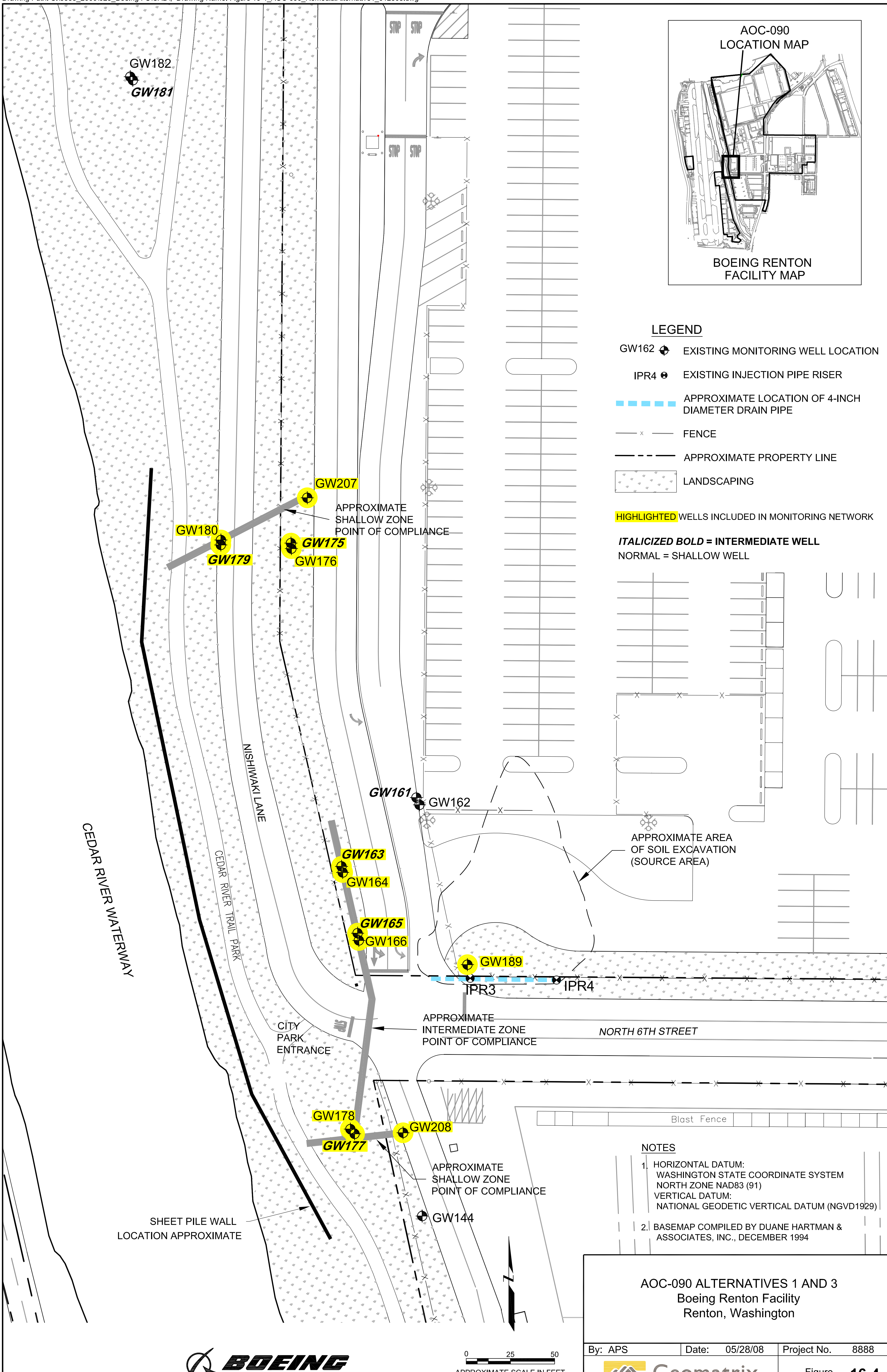

LEGEND

GW162 EXISTING MONITORING WELL LOCATION

IPR4 EXISTING INJECTION PIPE RISER

APPROXIMATE LOCATION OF 4-INCH DIAMETER DRAIN PIPE

FENCE

APPROXIMATE PROPERTY LINE

LANDSCAPING

HIGHLIGHTED WELLS INCLUDED IN MONITORING NETWORK

***ITALICIZED BOLD* = INTERMEDIATE WELL**

NORMAL = SHALLOW WELL

NOTES

1. HORIZONTAL DATUM:
WASHINGTON STATE COORDINATE SYSTEM
NORTH ZONE NAD83 (91)
VERTICAL DATUM:
NATIONAL GEODETIC VERTICAL DATUM (NGVD1929)

2. BASEMAP COMPILED BY DUANE HARTMAN & ASSOCIATES, INC., DECEMBER 1994

AOC-090 ALTERNATIVES 1 AND 3
Boeing Renton Facility
Renton, Washington

By: APS	Date: 05/28/08	Project No. 8888
Geomatrix		Figure 16-4

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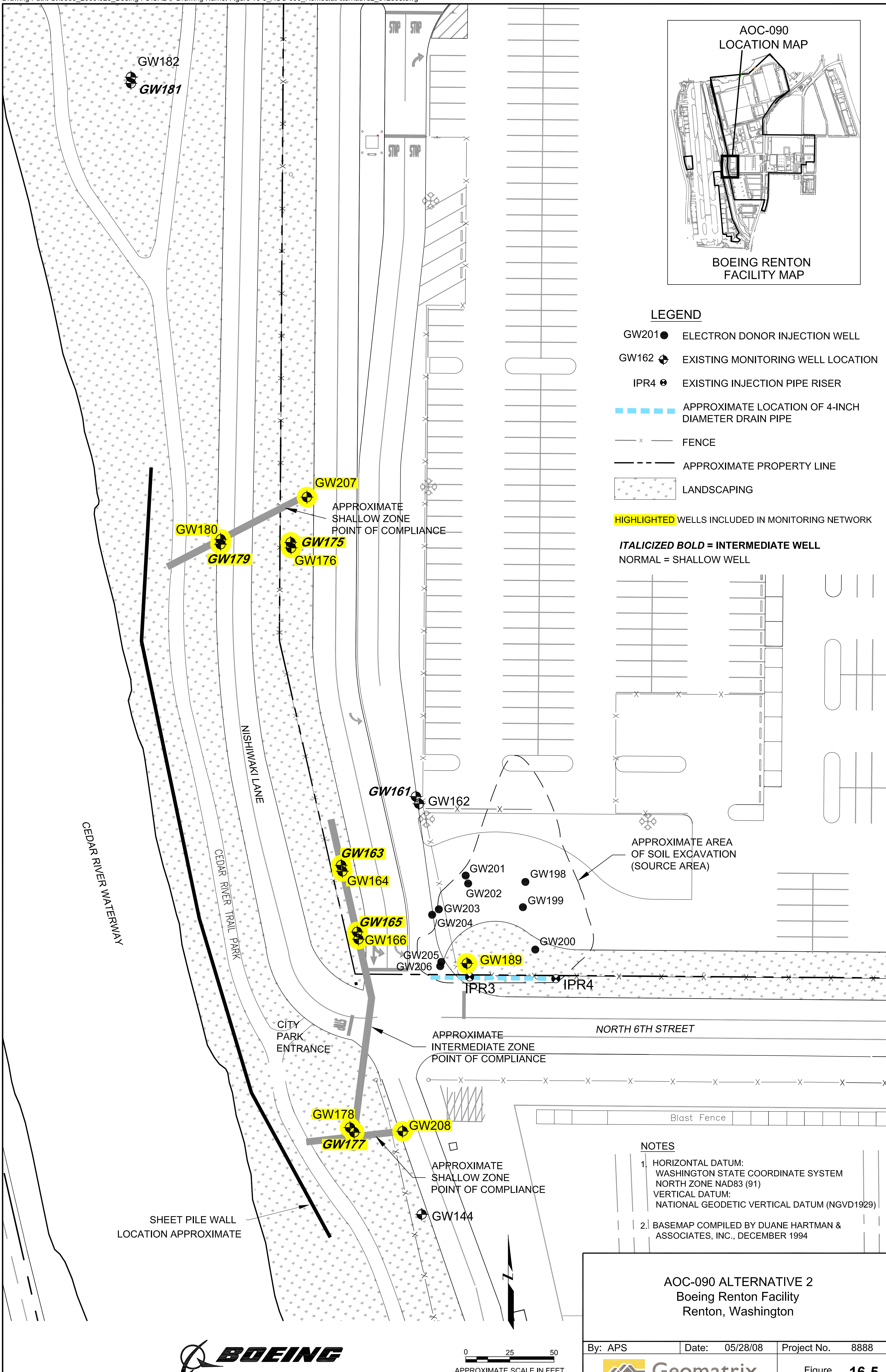


NOTES

1. HORIZONTAL DATUM:
WASHINGTON STATE COORDINATE SYSTEM
NORTH ZONE NAD83 (91)
VERTICAL DATUM:
NATIONAL GEODETIC VERTICAL DATUM (NGVD1929)
2. BASEMAP COMPILED BY DUANE HARTMAN & ASSOCIATES, INC., DECEMBER 1994

AOC-090 ALTERNATIVE 2
Boeing Renton Facility
Renton, Washington

By: APS	Date: 05/28/08	Project No. 8888
Geomatrix		Figure 16-5

17.0 DEVELOPMENT AND EVALUATION OF REMEDIAL ALTERNATIVES, AOC-092

In this section we discuss remediation objectives, identify and evaluate remedial alternatives, and describe the preferred remedial alternative for AOC-092.

17.1 SITE CHARACTERIZATION SUMMARY

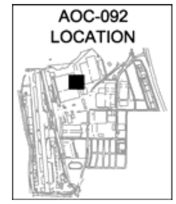
AOC-092 is located along the east side of Building 4-20 (see Figure 1-2). Soil impacted with petroleum hydrocarbons was discovered at this location during trenching activities for a new fire protection water line. During a preliminary investigation in February 2001, a soil sample (4-20-S4-E) collected at 5 feet bgs near column S-4 was analyzed for EPH, VPH, and TPH-G. Laboratory analysis identified detectable concentrations of EPH, VPH, and TPH-G in the sample. The sample was subsequently analyzed for BTEX, which resulted in detectable levels of toluene and xylene. The SVOC analysis (EPA Method 8270) detected naphthalene and 2-methylnaphthalene in the soil sample, but at concentrations below PCLs. Section 3.2 of the final FSWP presents the summary of the site characterization results for this AOC (Geomatrix, 2004c).

Subsequent investigation of AOC-092 was performed in November 2005 during facility improvements in the adjacent Building 4-20. The concrete slab floor inside Building 4-20 was removed and replaced. The portion of the floor that was removed was located northwest of the Building 4-20 Addition inside Building 4-20 (see Figure 17-1). In order to determine whether the affected soil related to the AOC-092 release extended underneath Building 4-20 in the area of slab removal, soil and groundwater samples were collected from six locations northwest of the known source area at AOC-092 via direct push borings. The locations of the borings and the analytical test results are shown on Figure 17-1

The site characterization results from the original site investigation and the follow-up investigation are summarized below (Weston, 2001a).

17.1.1 Historical, Present, and Future Site Use

This area was historically and is currently used for temporary outdoor storage of airplane parts and as a tow-path for partially completed aircraft. This area is currently used for industrial purposes, and is expected to remain in industrial use for the foreseeable future.



17.1.2 Previous Site Remedial Actions

There are no records of any soil removal associated with this AOC.

17.1.3 Site Hydrogeology

The direction of groundwater flow in the vicinity of AOC-92 is difficult to determine accurately since the local groundwater gradient was measured at less than 0.0001(Weston, 2001b). Historically, groundwater in the vicinity flows to the northwest toward Lake Washington, which is similar to the observed groundwater flow direction at the adjacent AOC-001 and AOC-002 area.

Based on the soil descriptions in the original investigation report, the predominant soil type in the vadose zone is gravelly sand, and the soil type dominating groundwater flow is silty sand (Weston, 2001b). Therefore, the dominant soil classification for the vadose zone is SW, and for the saturated zone is SM. The soil characteristics for the SW and SM soil will be used for relevant calculations in the FS for each of these zones, respectively.

17.1.4 Nature and Extent of Affected Soil

TPH-G was detected in a sample from the fire line excavation at 22,000 mg/kg. Samples collected away from this location were lower in concentration, but still above the TPH-G PCL of 30 mg/kg for soil affected by both benzene and gasoline. Aromatic hydrocarbons were also detected but below the soil PCLs. PP076 was installed at the same sample location where soil sample 4-20-S4-E was collected, but the sample did not contain TPH-G above the limit of detection (Weston, 2001b). TPH-G was also detected at PP073 at 150 mg/kg. The extent of TPH-G-affected soil has been defined to the northwest and northeast of the original soil sample. The Building 4-20 addition is present immediately to the south. The extent of TPH-G-affected soil was not defined to the southwest, south, or southeast of sample location 4-20-S4-E.

Soil samples were collected at 6 additional push-probe sampling locations installed approximately downgradient of the AOC-092 source area where the concrete slab was removed beneath Building 4-20. These soil results were summarized in a technical memorandum (Geomatrix, 2006e), and are posted on Figure 17-1. All soil sample results were non-detect for TPH-G and BTEX. Therefore, no affected soil was identified at the locations sampled during the additional investigation.

17.1.5 Nature and Extent of Affected Groundwater

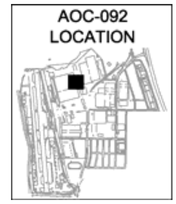
Benzene was detected above the PCL in groundwater samples collected from the push probes installed around the time of the fire line excavation at concentrations of up to 4.2 μg/L. TPH-G was also detected above the PCL in these samples at concentrations up to 8.7 mg/L. The nature and extent of groundwater affected by TPH-G and benzene were not defined during the February 2001 original investigation (Weston, 2001b). Additional groundwater samples from down-gradient push probes installed approximately 200 to 250 feet away at the north end of Building 4-20 did not contain TPH-G or benzene at concentrations above the detection limit.

Six groundwater samples were collected during the additional investigation in November 2005. Benzene and xylene were detected in the groundwater samples. Benzene in groundwater samples from four of the six push probe locations exceeded the PCL of 1.2 μg/L. The highest benzene concentration of 5.9 μg/L was detected at PP154, the southwesternmost boring closest to the AOC-092 source area. This benzene concentration is similar to the benzene concentrations observed in groundwater samples collected during the 2001 investigation. Figure 17-1 shows the location of the push-probe sample locations and their associated benzene and TPH-G analytical results.

17.2 CONCEPTUAL SITE MODEL

A preliminary conceptual model for migration of constituents present in affected soil and groundwater present at the Renton Facility was presented in Figure 2-6 of the FSWP (Geomatrix, 2004c). Based on the conceptual model and considerations presented in the FSWP plus information specific to this site, a site-specific conceptual site model is described below. This site-specific conceptual site model identifies the media and exposure pathways that must be addressed for the remedial alternatives that are potentially applicable to this site.

TPH-G is present in soil within the source area for AOC-092. As shown in the general facility conceptual model presented in the FSWP, TPH-G can migrate from the source areas via groundwater or vapor pathways. For this site, migration via groundwater will be most significant. Constituent transport via groundwater at this site is affected by soil/groundwater interactions and biodegradation. As groundwater flows through TPH-G-affected soil in the source area, adsorbed TPH-G and benzene may dissolve into groundwater, though no benzene was detected in soil samples collected at these push probes. Any dissolved TPH-G or benzene will move with groundwater, but at a different velocity due to continuing solute-soil interactions. This movement may create a plume extending downgradient from the source



areas; however, no such plume was detected in samples collected from the downgradient push probes PP090, PP095, and PP091 in 2003. However, benzene was detected in the groundwater samples collected from push probes PP-154 to PP-159 installed in November 2005 approximately 15 to 50 feet downgradient of the AOC-092 source area within Building 4-20. Benzene in groundwater is more likely to biodegrade than to volatilize.

The extent of groundwater affected by benzene is likely to be limited to the downgradient area near the source area. Benzene-affected groundwater may migrate to the northwest from the source area toward the most probable discharge area along the shoreline of Lake Washington. However, based on the results of BIOSCREEN modeling, the benzene at the concentrations present in the groundwater near AOC-092 will biodegrade below the benzene cleanup level before reaching the CPOCs proposed for both remedial alternatives considered. Volatilization of constituents from groundwater is not significant for most workers at this site, as noted in the conceptual model presented in the FSWP.

17.3 SITE REMEDIATION OBJECTIVES AND CLEANUP STANDARDS

The remediation objectives for the Renton Facility were presented in Section 2. Cleanup levels applicable to the Facility were proposed in the FSWP and subsequently approved by Ecology. The remedial alternatives developed and evaluated for this site will be capable of attaining the remediation objectives and cleanup standards presented in this section. As defined in the MTCA regulations, the cleanup standard consists of the cleanup level and the location or POC at which the cleanup level must be met. The remedial alternatives for this site, presented in Section 17.4, may have different points of compliance while fully addressing remediation objectives and meeting cleanup levels.

The groundwater and soil COCs exceeding the PCLs for AOC-092 were identified in FSWP Tables 5-1 and 5-3, respectively. These constituents were identified by comparing detected constituent concentrations to the PCLs identified in the original investigation report for this site; if a constituent concentration measured in any sample exceeded the PCL, the constituent was listed as a COC that must be addressed in the FS. Cleanup levels for both soil and groundwater meeting MTCA requirements were presented in the FSWP (Tables 5-6 and 5-2, respectively) and approved by Ecology. To confirm that the COCs listed in the FSWP included all constituents detected at concentrations exceeding the approved cleanup levels, the initial investigation soil and groundwater data were compared to the approved cleanup levels listed in the FSWP. If concentrations for constituents that were not identified as COCs exceeded

cleanup levels it would be necessary to include them as COCs. If concentrations for previously identified COCs were below the approved cleanup levels, the constituent should be removed as a COC. No new constituents were identified as COCs for this site, and no previously identified COCs were removed as a result of this comparison.

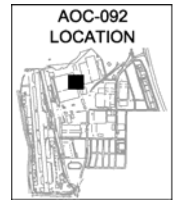
The soil and groundwater cleanup levels for the site COCs are listed in Tables 3-1 and 3-2, respectively. The soil cleanup levels are either MTCA Method A cleanup levels or site-specific MTCA Method C cleanup levels that are protective of groundwater at the CPOC and were calculated in accordance with the procedures described in the FSWP or in accordance with recent negotiations with Ecology. The groundwater cleanup levels listed in Table 3-2 were developed as described in Section 3 and in accordance with recent negotiations with Ecology. The cleanup levels are protective of surface water, human health, and the environment.

The cleanup levels allow for the degradation that would occur between the source area and the CPOC due to natural attenuation. Details concerning modeling and cleanup level calculations are included in Section 3 and Appendix A. These cleanup levels will be used in development and evaluation of remedial alternatives for AOC-092 that involve natural attenuation or enhanced in situ bioremediation.

17.4 DESCRIPTION OF SITE REMEDIAL ALTERNATIVES

AOC-092 is a gasoline-release location located just north of the Building 4-20 Addition. The TPH-G was found at this AOC during excavation and relocation of a fire water line. No gasoline-impacted soil was removed at the time of the original fire water line excavation from this area due to structural concerns regarding the building foundation (Boeing, 2001). Analytical data from the post-RI site investigation indicates that TPH-G and associated compounds were present in site soils and groundwater exceeding both the PCLs from the RI and cleanup levels from the FSWP. Soil sample results from a grab sample at location 4-20-S4-E had a TPH-G concentration of 22,000 mg/kg, and a soil sample from PP073 had a TPH-G concentration of 150 mg/kg (Boeing, 2001). TPH-G- and/or benzene-affected groundwater was found near and downgradient of the AOC-092 source area during a subsequent investigation.

MTCA requires that remedial alternatives selected for a site meet the MTCA threshold requirements for cleanup actions. The minimum threshold requirements specify that cleanup actions shall (1) protect human health and the environment, (2) comply with cleanup standards,



(3) comply with applicable state and federal law, and (4) provide for compliance monitoring. In order to be considered as a potential remedial alternative for the site, the technologies considered had to pass the screening evaluation of the remedial technologies described in Section 4. In addition, the alternatives had to meet the minimum threshold requirements established by MTCA and be consistent with overall site conditions.

Based on the screening evaluation, MTCA minimum threshold requirements, and the site considerations discussed above, two remedial alternatives addressing groundwater COCs were assembled for AOC-092:

- Alternative 1: Monitored Natural Attenuation
- Alternative 2: Source Area Excavation, Enhanced Bioremediation, and Monitored Attenuation

17.4.1 Alternative 1: Monitored Natural Attenuation

Alternative 1 is composed of two primary elements: institutional controls and MNA. The groundwater cleanup standard for this alternative will be the groundwater cleanup levels for AOC-092 COCs discussed in Section 17.3. Existing field data show that a benzene plume extends under Building 4-20 downgradient of the source area, and BIOSCREEN modeling suggests that the benzene plume would meet the cleanup standard at a CPOC located approximately 80 feet downgradient from the source area (Figure 17-2). Therefore a CPOC for Alternative 1 would need to be located in Building 4-20 approximately 80 to 100 feet downgradient of the source area (Figure 17-2). The soil cleanup standard will be the cleanup levels discussed in Section 17.3.2 and shown in Table 3-1.

The concentration of TPH-G of 22,000 mg/kg in the original grab sample collected at location 4-20-S4-E exceeded the residual saturation level of 1,697 mg/kg for gasoline in coarse sand and gravel (Brost and De Vaull, 2000). However, a soil sample collected from push probe PP076 installed adjacent to the same location as the original grab sample did not contain any detectable TPH-G or benzene above the PCLs. These results suggest that the affected soil exceeding the soil cleanup standard at this location may have been removed during installation of the fire water line, and that the affected soil had a limited extent. No NAPL has been discovered in any of these push probes.

Given that other risks from the TPH-G in soils can be managed through institutional controls (discussed below) and that the soils are confined by the existing pavement or tarmac, natural

attenuation should address remaining impacts; no additional active measures are necessary to remediate soils.

17.4.1.1 Institutional Controls

The following institutional controls are included in Alternative 1 to reduce the risk of human exposure to impacted soil or groundwater:

- Continued engineering controls, protocols, and monitoring previously established by Boeing to ensure that industrial workers inside buildings are protected and indoor air concentrations meet PELs established by the Washington Department of Labor and Industry;
- Continued engineering controls, protocols, and monitoring to ensure that temporary construction workers adhere to WAC 296-62-300, applicable Washington Labor and Industry standards, and OSHA HAZWOPER regulations (29 CFR 1919.120) for all construction work conducted in exposed areas of affected soil and groundwater; and
- Deed restrictions to limit development and use of the site.

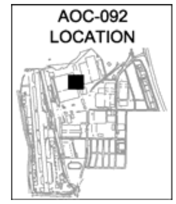
It is anticipated that deed restrictions would be established to limit future unrestricted land use without additional actions to attain compliance with appropriate soil and groundwater cleanup levels.

17.4.1.2 Monitored Natural Attenuation

Based on the POC approach presented in Section 6 of the FSWP, fate and transport groundwater modeling using BIOSCREEN was conducted to evaluate the efficacy of MNA as a final remedy for this AOC. The modeling followed the protocol established in the FSWP using approved model input parameters. The modeling results, presented in detail in Appendix A, are in agreement with the preliminary modeling conducted for the FSWP. The model results indicate that groundwater cleanup levels for all COCs fall rapidly with increased distance from the source and are met approximately 80 feet downgradient of the AOC-092 source area at a location underneath Building 4-20.

The development of a valid remedial approach for MNA at AOC-092 also requires a monitoring plan designed to verify the existence of and quantify the extent of enhanced and natural attenuation processes. In accordance with recent guidance and the approach discussed in Section 4.2.4, the conceptual monitoring program for AOC-092 is designed to:

- Demonstrate that natural attenuation is occurring according to expectations;



- Identify any potentially toxic and/or mobile transformation products;
- Verify that the plume is not expanding;
- Verify that cleanup levels are attained at the CPOC;
- Verify that there is no unacceptable impact to downgradient receptors;
- Detect new releases of COCs that could impact the effectiveness of the natural attenuation remedy;
- Demonstrate the efficacy of institutional controls put in place to protect potential receptors; and
- Verify attainment of remediation objectives.

The conceptual monitoring program for Alternative 1 at AOC-092 assumes that upon selection of this remedy, a detailed MNA Validation and Long-Term Sampling Work Plan would be developed to guide the process. This work plan would identify additional monitoring wells and monitoring analytes that would be required for both characterization/validation sampling and long-term groundwater monitoring. Characterization/validation sampling would be used to demonstrate the effectiveness of MNA with respect to contaminant mass reduction, attenuation rates, and temporal trends. Long-term groundwater monitoring would be used after characterization/validation monitoring to confirm that the contaminant plume is progressing toward containment or achievement of numerical goals.

For this conceptual design, it is assumed that characterization/validation sampling would consist of quarterly monitoring of three monitoring wells for a minimum of 1 year. Three new monitoring wells (all shallow) are assumed to be required to monitor plume migration. Monitoring parameters and analytes would consist of acetone, benzene, ethylbenzene, toluene, TPH-G, and the full suite of MNA geochemical parameters for hydrocarbon sites [dissolved oxygen, nitrate, Fe(II), sulfate, methane, temperature, pH, specific conductance, alkalinity, and oxidation/reduction potential]. It is assumed that reporting for characterization/validation sampling would follow each quarterly event.

It is further assumed that long-term groundwater monitoring would follow for an additional 13 to 14 years (15 total years of monitoring) and would include semiannual monitoring of three shallow wells for acetone, benzene, ethylbenzene, toluene, TPH-G, and a limited suite of geochemical parameters (dissolved oxygen, oxidation/reduction potential, temperature, and pH). To ensure plume control, all three wells would be analyzed once every 5 years for the entire characterization/validation list of analytes. It is assumed that annual reporting would be required for long-term groundwater monitoring.

17.4.2 Alternative 2: Source Area Excavation, Enhanced Bioremediation, and Monitored Attenuation

Alternative 2 includes three primary elements: institutional controls, source area soil excavation with enhanced bioremediation, and MA. The groundwater cleanup standard for this alternative will be the cleanup levels for AOC-092 groundwater COCs discussed in Section 17.3 and a CPOC as shown on Figure 17-3. The soil cleanup standard will be the cleanup levels discussed in Section 17.3 and shown in Table 3-1. The soil cleanup standard for TPH-G was exceeded by the original grab sample collected at 4-20-S4-E. This finding suggests that there may be a TPH-G source area exceeding the residual saturation limit and that the presence of LNAPL may be possible. This alternative includes source excavation, to the extent practicable given the location adjacent to Building 4-20, to remove contaminated soils in the source area and enhanced bioremediation to accelerate site cleanup.

17.4.2.1 Institutional Controls

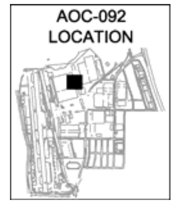
Institutional controls for Alternative 2 would be the same as those discussed in Section 17.4.1.1 for Alternative 1.

17.4.2.2 Source Area Excavation

Source area excavation for this alternative would consist of excavation and off-site disposal of TPH-G-contaminated soils from the area of the fire line. Excavation of affected soils would be conducted to the extent practicable, given the constraints imposed by the presence of the existing building and underground utilities. It has been assumed that the source area to be excavated is a relatively small area (6 feet by 17 feet) to a shallow depth. The volume of soil to be removed is estimated as approximately 30 cubic yards.

17.4.2.3 Enhanced Bioremediation

Enhanced bioremediation for AOC-092 would consist of injecting a TEA such as ORC, ammonium nitrate, or calcium nitrate into the source area groundwater to promote degradation of petroleum compounds. For cost estimation purposes, it was assumed that approximately 200 pounds of ORC would be applied to the open excavation after contaminated soil was



removed and prior to backfilling with clean soil. If a nitrate is selected, an equivalent dosage would be determined and applied in the same general manner as assumed for ORC.

17.4.2.4 Monitored Attenuation

Monitored attenuation for this alternative is intended to be a final "polishing" mechanism, following the active enhanced bioremediation, to ensure that cleanup levels for all COCs are met at the CPOC proposed for this alternative. With this alternative, it is assumed that MA would follow enhanced bioremediation and would consist of the long-term groundwater monitoring for three shallow wells located within and near the source area excavation for AOC-092, as shown on Figure 17-3. Groundwater monitoring would be conducted semiannually for benzene, ethylbenzene, toluene, TPH-G, and a limited suite of geochemical parameters (dissolved oxygen, oxidation/reduction potential, temperature, and pH). To ensure plume control, all three monitoring wells would be analyzed once every 5 years for the entire list of analytes. It is assumed that monitoring would continue following active remediation for a total of 15 years of monitoring and that annual reporting will be required for the duration.

17.5 EVALUATION OF SITE REMEDIAL ALTERNATIVES

As previously discussed, both alternatives developed for the AOC-092 site meet the MTCA minimum requirements for cleanup actions. This section compares and evaluates the alternatives based on the MTCA criteria described in Section 5.1. An analysis of each alternative with respect to the evaluation criteria is summarized in Table 17-1 and discussed below.

17.5.1 Protectiveness and Risk Reduction Evaluation

Protectiveness and risk reduction are gauged primarily on the time required for the alternative to reduce risk and meet cleanup levels. Although Alternative 2 would not destroy all of the COCs, of the two alternatives, it would be expected to reduce COCs in groundwater to cleanup levels more quickly and is therefore rated higher for this criterion.

17.5.2 Permanence

Permanence refers to the ability to reduce the toxicity, mobility, or volume of hazardous substances, including the permanent destruction of hazardous substances. Alternative 2 is rated higher for this criterion because the reduction of the hazardous waste volume from the site is expected to occur at a much faster rate.

17.5.3 Cost

The cost evaluation includes all costs related to implementation of an alternative, including initial design and construction costs, operation and maintenance costs, monitoring costs, and reporting costs. The annual costs for operation, maintenance, monitoring, and reporting are recurring costs that occur in the future. The cost evaluation considers initial implementation costs and future recurring costs using NPV analysis. For NPV calculation, recurring costs were inflated 2% annually, and a discount rate of 7% was used. Details regarding the cost estimates for the three alternatives are presented in Appendix B. The present value costs for the two alternatives, in 2007 dollars, are summarized below:

Alternative	Net Present Value
1: Monitored Natural Attenuation	$336,000
2: Source Area Excavation, Enhanced Bioremediation, and Monitored Attenuation	$364,000

As shown by these costs, Alternative 1 has the lower NPV cost, while Alternative 2 has the higher. Therefore, Alternative 1 ranks higher for cost and Alternative 2 ranks lower.

17.5.4 Long-Term Effectiveness

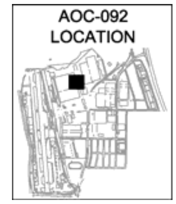
Long-term effectiveness includes the degree of certainty and reliability of the alternative and whether treatment residue remains from the alternative that would require management. Both Alternatives 1 and 2 are proven technologies, and Alternative 2 would produce some residual waste that would need to be disposed in a landfill. Therefore Alternative 1 is ranked higher than Alternative 2.

17.5.5 Management of Short-Term Risks

Short-term risk refers to the risk to human health and the environment during implementation of the alternative. Because the implementation of Alternative 1 is the simplest and does not require excavation or handling of contaminants, it is rated higher for this criterion.

17.5.6 Technical and Administrative Implementability

This criterion is gauged based on whether the alternative is technically possible relative to complexity, administrative/regulatory requirements, size, access, and integration with existing operations. Because Alternative 1 would require installing monitoring wells inside an active industrial building, it is rated low for this criterion.



17.5.7 Public Concerns

This criterion involves potential community concerns with the alternative. Since both alternatives deal with a large industrial site with limited public access, they are rated the same.

17.5.8 Reasonable Restoration Time Frame

Restoration time frame refers to the practicability of a shorter restoration time frame, with consideration given to a number of factors including site risks, site use and potential use, availability of alternative water supply, effectiveness and reliability of institutional controls, and toxicity of hazardous substances at the site. As a whole, these factors are a measure of the urgency of reducing risk and achieving cleanup goals for the site. Given that the site is industrial, has proven institutional controls, and the toxicity of contaminants is moderate, both alternatives are ranked medium low.

17.6 SELECTION OF THE PREFERRED SITE REMEDIAL ALTERNATIVE

Selection of a preferred alternative under MTCA requires that preference be given to alternatives that use permanent solutions (to the maximum extent practicable), provide for a reasonable restoration time frame, and consider public concerns. The analysis below defines the baseline alternative for AOC-092 and compares the other alternatives to the baseline alternative, based on the degree of permanence, reasonable restoration time frame, and the degree to which it addresses potential public concerns. Based on this comparison, the preferred remedial alternative is identified and proposed for selection as the cleanup action to be implemented for the site.

17.6.1 Baseline Remedial Alternative

The baseline remedial alternative for AOC-092 is Alternative 2. Although both alternatives could be considered to be permanent cleanup actions in the sense that cleanup standards would be met, this alternative is considered to have a higher degree of permanence, because hazardous substances would be permanently removed from the site and/or destroyed, and because it would likely provide for a shorter restoration time frame than Alternative 1.

The evaluation of both remedial alternatives for this site is summarized in Table 17-1. Neither of the alternatives is capable of attaining the standard POC at this site. Both alternatives are capable of attaining cleanup at an on-site CPOC; the CPOC for Alternative 1 would need to be located under Building 4-20, which would be very difficult at this time due to manufacturing

activities. The CPOC for the second alternative is located on site, approximately 8 feet from the source area, and would not be constrained by installing wells inside the building.

17.6.2 Comparison to Baseline Alternative

As noted above, Alternative 2 has been defined as the baseline remedial alternative for this site. Alternative 1 will be compared to the baseline alternative in this section for selection of the preferred alternative. The purpose of this comparison is to assess the benefits and costs for Alternative 2 relative to Alternative 1. The evaluation criteria presented above and in Table 17-1 were established in accordance with the MTCA requirements cited in WAC 173-340(3)(f). Costs for the alternatives will be based on the NPV, which reflects the total cost associated with each alternative over the 15-year time period evaluated. The evaluation of benefits will be qualitative.

The benefits to be assessed in this comparison and the relative rating for the alternatives are presented in Table 17-2. The rationale for this comparison is presented below.

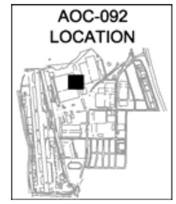
- **Reduced risk to on-site worker health.** Both alternatives are equal in reducing risk to site workers because they are both equally protective. Although the baseline alternative would remove volatile COCs within a few years, potential risks to on-site workers would not be changed substantially by the other alternative. The institutional controls included in each of the alternatives have been proven effective in protecting worker health and would continue to be protective.

- **Reduced risk to off-site human health.** Both alternatives were rated high for this benefit. Both would attain the cleanup level at their respective CPOCs, which is protective of human health and the environment. The institutional controls included in the alternatives that have proven to be protective of worker health on site would also be protective of human health in off-site areas located upgradient of the CPOCs for each alternative.

- **Reduced risk to the environment.** Both alternatives were rated high for this benefit. Both alternatives would be protective of the aquatic environment because they would attain the cleanup levels at their respective CPOCs.

- **Minimal adverse impact on Facility operations**. Alternative 2 was rated moderate for this benefit, because excavation would impact Facility operations. Alternative 1 was rated low since installing wells inside an active industrial building would severely disrupt ongoing industrial operations.

- **Minimal restrictions on Facility traffic and access.** The baseline alternative was rated moderate for this benefit because it would impact Facility traffic and access



during excavation of the source area. Alternative 1 was also given a moderate rating because it would affect Facility traffic and access to portions of the facility during installation of monitoring wells within an active building.

- **Minimal adverse impact on Facility structures and utilities**. The baseline alternative was rated moderate because excavation adjacent to Building 4-20 has the potential to affect the structural integrity of the building. Alternative 1 was rated moderate due to the need for installation and potential monitoring of CPOC monitoring wells inside of Building 4-20, which is an active manufacturing facility.

The potential benefit evaluation for the alternatives shows that Alternative 2 would provide a slightly higher benefit than Alternative 1.

The NPV costs for both alternatives were presented in Section 17.5.3. The baseline alternative ranks second among the alternatives and would have the higher cost (approximately 8% higher than the cost for Alternative 1).

17.6.3 Preferred Remedial Alternative

Alternative 2 is the preferred remedial alternative for the AOC-092 site. Alternative 2 would achieve the benefits of remediation sooner than Alternative 1 and does not have a disproportionate cost. Under Alternative 2, most affected soil would be removed. However, any affected soils under the adjacent building would remain and would be contained by the building and floor to prevent potential runoff and infiltration of rainfall. In addition, ORC introduced into the base of the excavation would promote further biodegradation of COCs. Groundwater in the area is not used for any purpose, and potable water is readily available from the Renton public water system. The institutional controls included in Alternative 2 have been implemented and proven by Boeing, who would continue to maintain overall responsibility for this site and ensure that the institutional controls are properly enforced.

Source area excavation, enhanced bioremediation, and MA for this site would achieve the expectations for cleanup actions cited in the MTCA regulations at WAC 173-340-370 (1) – (8). Only those expectations relevant to large, complex sites are considered relevant to AOC-092. The relevant expectations are addressed as follows:

- **Implement Treatment at Sites with Liquid Wastes, High Contaminant Concentrations, Highly Mobile Materials, or Discrete Areas of Contamination.** Ecology expects that treatment will be emphasized for sites meeting these general criteria. Boeing believes that while remaining COC levels are elevated, they are not high, and there is no evidence of liquid wastes at the site. The source area is

discrete but may extend beneath the building, preventing ready access for removal or treatment. Enhanced bioremediation would degrade or "treat" organic COCs over the long term using enhanced natural processes that result in nontoxic degradation products.

- **Destroy, Detoxify, or Remove Hazardous Substances.** Ecology expects that hazardous substances will be destroyed, detoxified, or removed to below cleanup levels. Most affected soil would be removed. Addition of ORC would ultimately destroy COCs resulting in nontoxic degradation products.

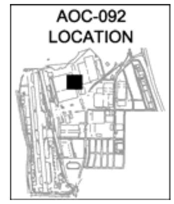
- **Implement Engineering Controls for Low Contaminant Concentrations.** Ecology recognizes the need for containment for low concentrations of contaminants where treatment is impracticable. This alternative uses treatment to enhance destruction of contaminants wherever practicable.

- **Prevent Runoff of Hazardous Substances.** Ecology expects that cleanup actions will include active measures to prevent precipitation from creating runoff that contains affected soil. This expectation would be met by the preferred alternative because the source area would be removed to the extent practicable, and the remaining source area would be covered by the building, tarmac or pavement. In addition to preventing runoff from contacting hazardous substances, the cover in this area minimizes surface water infiltration, thus resulting in decreased groundwater flow rates and increased time for groundwater to flow from the source area to the waterway.

- **Consolidate On-site Contaminants Exceeding Cleanup Levels.** Ecology expects that when contaminants are left on site exceeding cleanup levels they will be consolidated to the extent practicable. At this site, due to the location of any remaining contaminants, it is not practicable to consolidate contaminants.

- **Prevent Runoff and Groundwater Discharge to Surface Water.** Ecology expects that the cleanup action would include active measures to prevent or minimize releases to adjacent surface water bodies via runoff or groundwater discharge, and that dilution will not be the sole method for attaining cleanup levels. Alternative 2 would meet this expectation. Available groundwater monitoring data indicate that biodegradation of organic COCs is active and significant at this site. Addition of ORC will accelerate these natural processes. The cleanup alternative would also include a groundwater monitoring network and program that would confirm that cleanup levels are attained in groundwater at the CPOC downgradient of the AOC and before groundwater can reach Lake Washington.

- **Ensure Appropriateness of Attenuation.** Ecology expects that natural attenuation may be appropriate if source control has been conducted to the maximum extent practicable; contaminants remaining on site do not pose unacceptable risks to human health and the environment; evidence indicates that degradation is occurring



and will continue to occur at a reasonable rate; and appropriate monitoring is conducted. These expectations would all be achieved by Alternative 2. Most affected soil would be excavated and removed. For any remaining affected soil Boeing has implemented effective institutional controls that have proven effective in protecting human health and the environment at this site. Groundwater monitoring data indicate that biodegradation of organic COCs is active at the site and can be accelerated through addition of ORC. Alternative 2 also includes a robust groundwater monitoring program designed to address recent guidance for MNA. The monitoring system included in the preferred alternative would confirm that cleanup levels are attained prior to groundwater discharging to Lake Washington.

The preferred remedial alternative would be designed to comply with applicable regulations. Potentially applicable regulations are listed in Table 17-3. These regulations govern the design, installation, and operation of remediation systems. For the preferred alternative at AOC-092, regulatory requirements are expected to be minimal. Construction for the preferred alternative would be limited soil excavation and the installation of new monitoring wells. The primary regulations governing the preferred alternative would be the MTCA regulations, the Washington well drilling regulations for monitoring wells, the solid waste disposal regulations, the dangerous waste regulations, the transportation regulations, and the Department of Labor and Industries health and safety regulations. Well drilling rules specify well design and drilling requirements. The solid and dangerous waste regulations specify waste characterization, manifesting, and disposal requirements. Transportation regulations specify labeling and shipping requirements for wastes generated from implementation of the alternative. MTCA regulations specify remediation requirements and the cleanup standards to be attained. The preferred alternative would be designed and implemented to comply with these regulations.

TABLE 17-1

COMPARISON OF REMEDIAL ALTERNATIVES, AOC-092[1]

Boeing Renton Facility
Renton, Washington

Standards/Criteria		Alternatives: 1 - Monitored Natural Attenuation	Alternatives: 2 - Soil Excavation/Enhanced Bioremediation/MA
Protectiveness and Risk Reduction	Pros	Destroys COCs.	Removes some COCs, destroys some COCs.
	Cons	Slow to achieve cleanup.	
	Rating	ML	MH
Permanence	Pros	Destroys COCs; No residuals.	Destroys COCs; Excavated soil requires disposal; Reasonably rapid cleanup.
	Cons	Slow degradation rates.	
	Rating	MH	H
Cost	Pros	Low initial cost.	
	Cons	High long-term cost.	High initial cost.
	Rating	MH	ML
Long-Term Effectiveness	Pros	Destroys COCs; Passive, natural process.	Removes some COCs, destroys some COCs.
	Cons		Produces residuals requiring handling.
	Rating	MH	ML
Management of Short-Term Risks	Pros	Simplest implementation; No residuals.	
	Cons		Minor short-term risks during excavation.
	Rating	H	MH
Technical and Administrative Implementability	Pros	Simple system.	Simple system.
	Cons	Installation and monitoring of wells inside Building 4-20 extremely difficult due to manufacturing activities.	Requires off-site handling of excavated soils.
	Rating	L	MH
Public Concerns	Pros	Industrial site.	Industrial site.
	Cons		
	Rating	MH	MH
Restoration Time Frame	Pros	Industrial site; Proven institutional controls; Alternative water available; Practicability of shorter timeframe limited by facility operations.	Industrial site; Proven institutional controls; Alternative water available; Practicability of shorter timeframe limited by facility operations.
	Cons		
	Rating	ML	ML

Notes:
1. Comparison Ratings: H = Highest (if the decision were based solely on one criterion, an H score would indicate the alternative is the preferred alternative);
MH = Medium High;
ML = Medium Low;
L = Low.

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TABLE 17-2

COMPARISON OF BENEFITS[1]
AOC-092
Boeing Renton Facility
Renton, Washington

Benefit	Alternative 1: Monitored Natural Attenuation	Alternative 2: Source Area Excavation/Enhanced Bioremediation
Reduced risk to on-site worker health	High	High
Reduced risk to off-site human health	High	High
Reduced risk to the environment	High	High
Minimal adverse impact on Facility operations	Low	Moderate
Minimal restrictions on Facility traffic and access	Moderate	Moderate
Minimal adverse impact on Facility structures and utilities	Moderate	Moderate

Notes:
1. Benefits for each remedial alternative are rated as follows:
   High = high benefit;
   Moderate = moderate benefit;
   Low = low benefit.

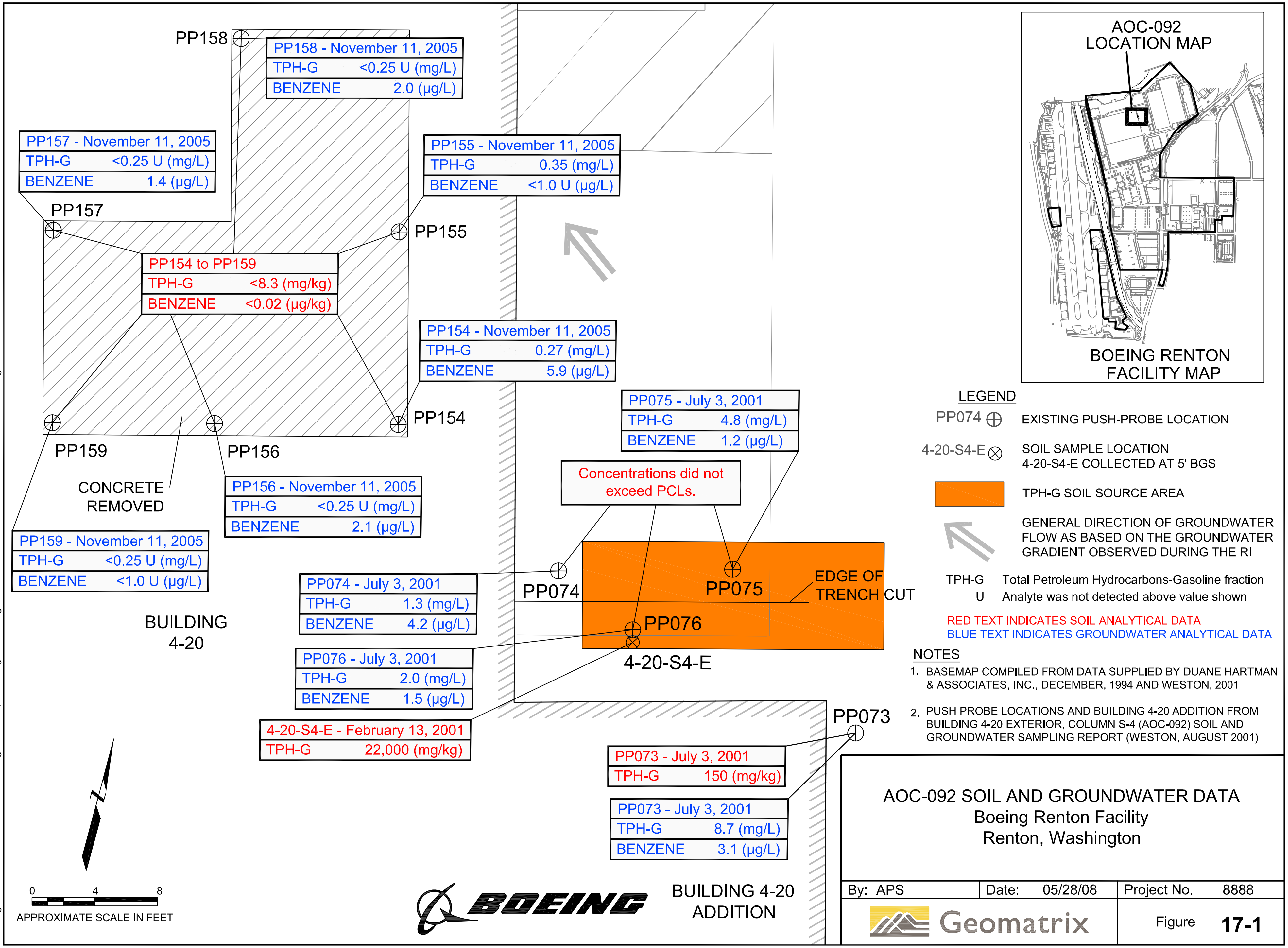
TABLE 17-3

POTENTIALLY APPLICABLE REGULATIONS
AOC-092 PREFERRED REMEDIAL ALTERNATIVE

Boeing Renton Facility
Renton, Washington

Law/Regulation	Citation	Applicability
Chemical-Specific Laws and Regulations		
Washington Dangerous Waste Regulations	WAC 173-303	Waste management, permitting requirements
Washington Model Toxics Control Act Regulations	WAC 173-340	Establishment of cleanup levels and POCs
Action-Specific Laws and Regulations		
Washington State Environmental Policy Act Regulations	WAC 197-11	Permitting, EIA/EIS[1] requirements
Washington Industrial Safety and Health Act Regulations	WAC 296-24	Occupational health and safety
Transportation regulations	49 CFR Parts 100 & 177, WAC 446-50	Transportation for wastes and materials
Washington well drilling regulations	WAC 173-160 & -162	Well design and installation standards
Washington solid waste disposal regulations	WAC 173-304	Disposal of nondangerous waste
Location-Specific Regulations		
Shoreline Management Act	RCW 90.58	Standards for construction within 200 ft of shoreline

Notes:
1. EIA = Environmental Impact Assessment; EIS = Environmental Impact Statement.



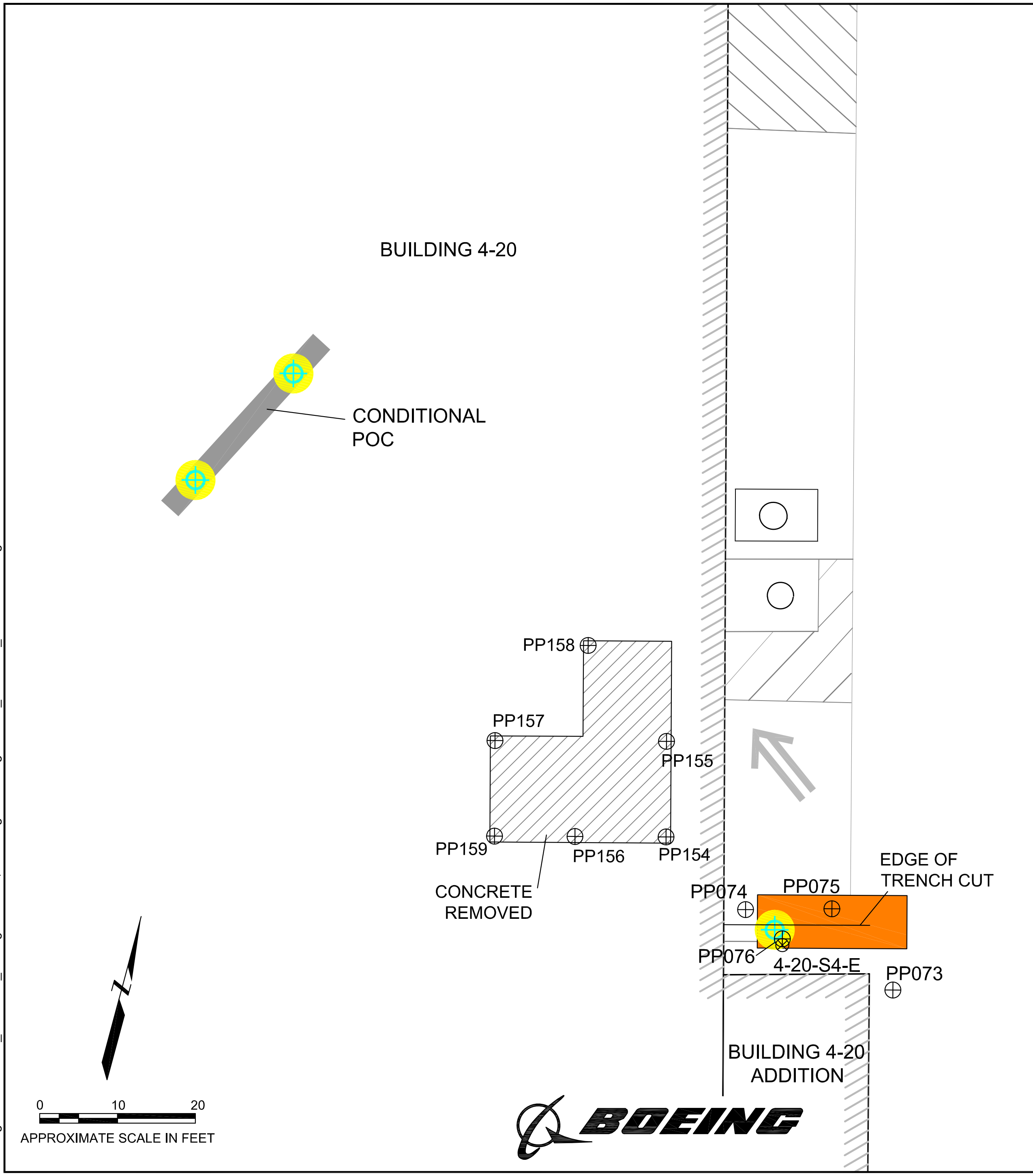
NOTES

1. BASEMAP COMPILED FROM DATA SUPPLIED BY DUANE HARTMAN & ASSOCIATES, INC., DECEMBER, 1994 AND WESTON, 2001
2. PUSH PROBE LOCATIONS AND BUILDING 4-20 ADDITION FROM BUILDING 4-20 EXTERIOR, COLUMN S-4 (AOC-092) SOIL AND GROUNDWATER SAMPLING REPORT (WESTON, AUGUST 2001)

AOC-092 SOIL AND GROUNDWATER DATA
Boeing Renton Facility
Renton, Washington

By: APS	Date: 05/28/08	Project No. 8888
Geomatrix		Figure 17-1

Plot Date: 05/28/08 - 2:15pm, Plotted by: astenberg
Drawing Path: S:\8888_2006\025_Boeing FS\CAD\, Drawing Name: Figure 17-1_AOC-092_Soil and GW Data_012808.dwg



LEGEND

PROPOSED SHALLOW MONITORING WELL

PP074 EXISTING PUSH-PROBE LOCATION

4-20-S4-E SOIL SAMPLE LOCATION
4-20-S4-E COLLECTED AT 5' BGS

TPH-G SOIL SOURCE AREA

GENERAL DIRECTION OF GROUNDWATER FLOW AS BASED ON THE GROUNDWATER GRADIENT OBSERVED DURING THE RI

HIGHLIGHTED WELLS INCLUDED IN MONITORING NETWORK

NOTES

1. BASEMAP COMPILED FROM DATA SUPPLIED BY DUANE HARTMAN & ASSOCIATES, INC., DECEMBER, 1994 AND WESTON, 2001

2. PUSH PROBE LOCATIONS AND BUILDING 4-20 ADDITION FROM BUILDING 4-20 EXTERIOR, COLUMN S-4 (AOC-092) SOIL AND GROUNDWATER SAMPLING REPORT (WESTON, AUGUST 2001)

AOC-092 ALTERNATIVE 1
Boeing Renton Facility
Renton, Washington

By: APS	Date: 05/29/08	Project No. 8888
Geomatrix		Figure 17-2

Plot Date: 05/29/08 - 5:16pm, Plotted by: astenberg
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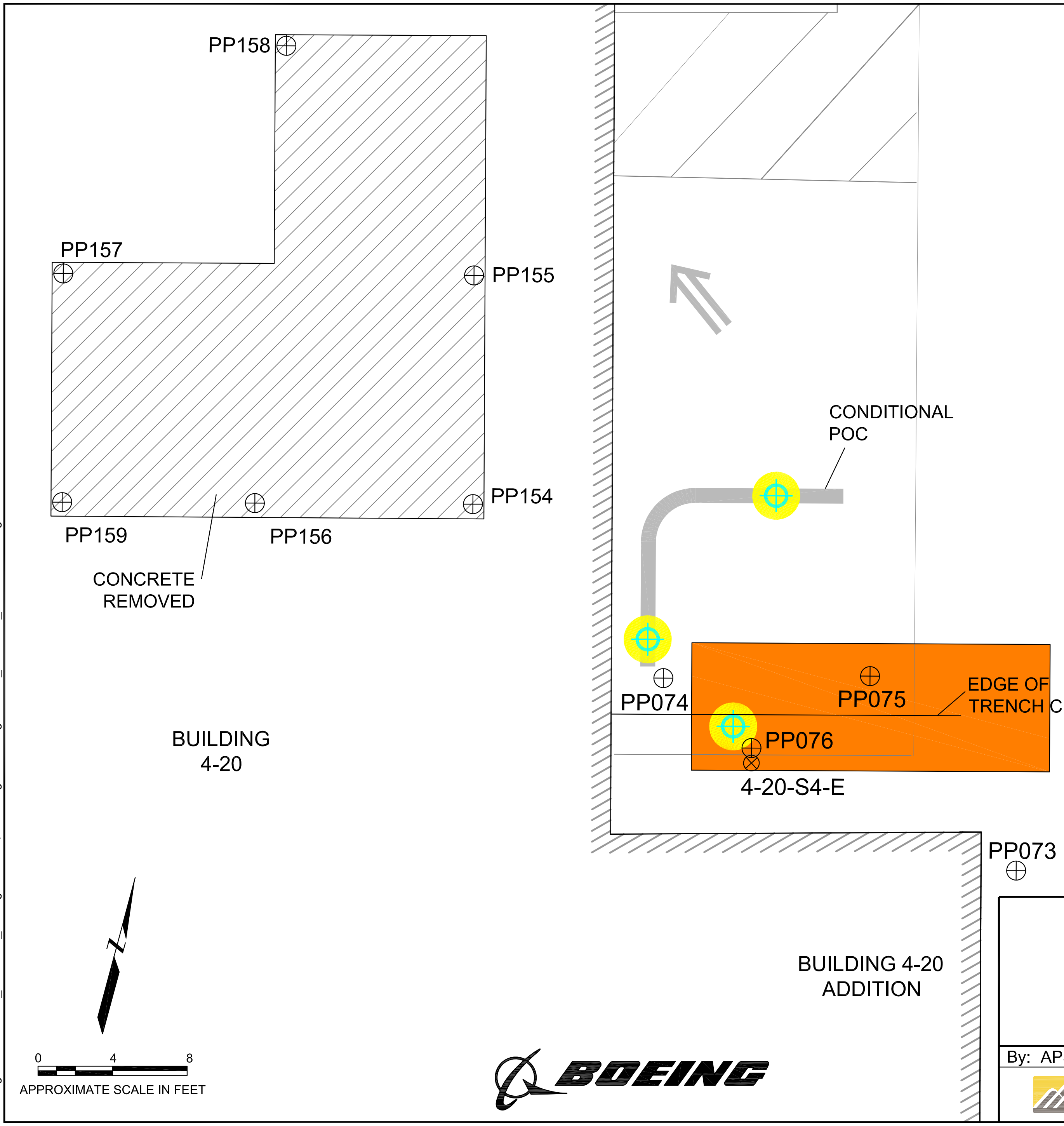
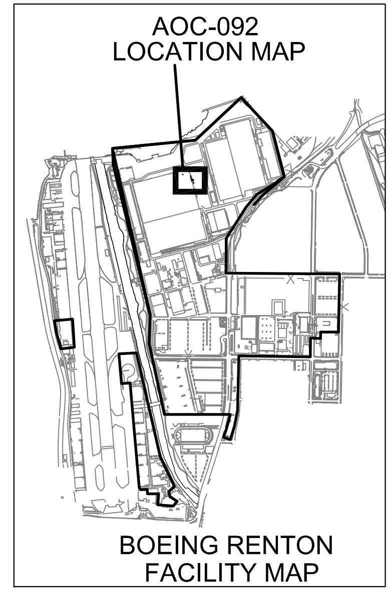




LEGEND

- PROPOSED SHALLOW MONITORING WELL
- PP074 ⊕ EXISTING PUSH-PROBE LOCATION
- 4-20-S4-E ⊗ SOIL SAMPLE LOCATION 4-20-S4-E COLLECTED AT 5' BGS
- TPH-G SOIL SOURCE AND EXCAVATION AREA
- GENERAL DIRECTION OF GROUNDWATER FLOW AS BASED ON THE GROUNDWATER GRADIENT OBSERVED DURING THE RI
- HIGHLIGHTED WELLS INCLUDED IN MONITORING NETWORK

NOTES

1. BASEMAP COMPILED FROM DATA SUPPLIED BY DUANE HARTMAN & ASSOCIATES, INC., DECEMBER, 1994 AND WESTON, 2001
2. PUSH PROBE LOCATIONS AND BUILDING 4-20 ADDITION FROM BUILDING 4-20 EXTERIOR, COLUMN S-4 (AOC-092) SOIL AND GROUNDWATER SAMPLING REPORT (WESTON, AUGUST 2001)

AOC-092 ALTERNATIVE 2
Boeing Renton Facility
Renton, Washington

By: APS	Date: 05/29/08	Project No. 8888
Geomatrix		Figure 17-3

Plot Date: 05/29/08 - 5:17pm, Plotted by: astenberg
Drawing Path: S:\8888_2006\025_Boeing FS\CAD\, Drawing Name: Figure 17-3_AOC-092_Alternative2.dwg

18.0 DEVELOPMENT AND EVALUATION OF REMEDIAL ALTERNATIVES, AOC-093

In this section we discuss remediation objectives, identify and evaluate remedial alternatives, and describe the preferred remedial alternative for AOC-093.

18.1 SITE CHARACTERIZATION SUMMARY

AOC-093 is located north of Building 4-20, near the shore of Lake Washington (see Figure 18-1 for the general location). During the installation of push probes to collect soil TOC samples downgradient of AOC-001, AOC-002, and AOC-003, soil affected by TPH-G was noted at PP081 near the water table. The soil sample contained 240 mg/kg of TPH-G. A groundwater sample collected at this location contained 67 µg/L of VC; however, the VC is attributed to AOC-001 and AOC-002, because AOC-093 is located downgradient from the primary source area for AOC-001 and AOC-002 and is about 45 feet from the shoreline. Subsequent to this sampling, three additional push probes were installed around PP081, and soil and groundwater samples from the shallow subsurface were collected and analyzed for TPH-G and VOCs. None of these soil or groundwater samples contained TPH or VOCs above the PCLs established in the final RI Report. Section 3.2 of the final FSWP presents the complete site characterization results for this unit (Geomatrix, 2004c). The site characterization results are summarized below.

18.1.1 Historical, Present, and Future Site Use

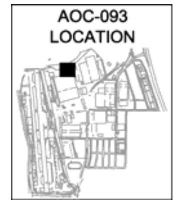
This area was historically and is currently used for temporary outdoor storage of airplane parts and is located within the tow path for partially completed aircraft. This location is in an area critical for ongoing airplane manufacturing operations. This area is currently used for industrial purposes and is expected to remain in industrial use for the foreseeable future.

18.1.2 Previous Site Remedial Actions

There are no records of any soil removal associated with AOC-093. There are also no known activities in the vicinity of this AOC that may have caused the release of TPH-G.

18.1.3 Site Hydrogeology

The general stratigraphy beneath this site consists of fill and alluvium. Fill materials consisted of brown fine- to medium-grained sand. Beneath the fill, alluvium consisted of greenish-gray clayey silt to silty clay with a high content of organic matter represented by wood fragments



and roots. Boring logs from the push probes indicate that the depth of the contact between hydraulic fill materials and alluvium ranges from approximately 0 to 2 feet bgs.

Groundwater was encountered in the push probes at 3 to 4.5 feet bgs. Groundwater in the vicinity of this AOC flows to the northwest toward Lake Washington at an average gradient of approximately 0.001 (based on the final RI Report for nearby AOC-001/002, and AOC-003). Slug test were conducted in wells GW049, GW050, and GW051 at nearby AOC-001/002 and AOC-003. These tests indicated that the hydraulic conductivity of the shallow aquifer ranged from 1.4×10^{-3} to 5.0×10^{-3} cm/s.

Based on a geologic cross-section from a push probe investigation in the vicinity of AOC-093, the predominant soil type in the limited vadose zone is silty sand with gravel, and the soil type dominating groundwater flow is also silty sand with isolated gravelly lenses (Geomatrix, 2004g). Therefore, the dominant soil classification for both the vadose and saturated zones is SM. Soil characteristics for SM soil will be used for relevant calculations and modeling for this site.

18.1.4 Nature and Extent of Affected Soil

The results of site sampling indicate that AOC-093 soils contain concentrations of TPH-G above the PCL as defined in the final RI Report. The analytical results from soil investigations conducted at this site are summarized on Figure 18-1. Only one sample collected from PP081 contained TPH-G above the PCL. Three additional push probes were installed around PP081 (PP097, PP098, and PP099). None of the soil samples from the three additional push probes contained TPH-G above the detection limit. The single sample of affected soil contained TPH-G at 240 mg/kg at a depth of 4.5 feet. No benzene was detected in the corresponding groundwater sample; therefore, the relevant soil cleanup level for TPH-G is 100 mg/kg. The nature and extent of TPH-G-affected soil have been defined at AOC-093, and affected soil is limited to a small area.

18.1.5 Nature and Extent of Affected Groundwater

There are no COCs for groundwater at this AOC since none of the groundwater samples collected from the push probes contained COCs that exceeded the PCLs. Groundwater samples collected from the four push probes did not exceed PCLs for TPH-G. VC and *cis*-1,2-DCE were detected in groundwater samples beneath this AOC, but these constituents are related to

affected groundwater from AOC-001/002 and will be addressed by remedial alternatives for that site (Section 11).

18.2 Conceptual Site Model

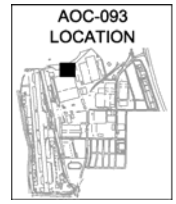
A preliminary conceptual model for migration of constituents present in affected soil and groundwater at the Renton Facility was shown in Figure 2-6 of the FSWP (Geomatrix, 2004c). Based upon the conceptual model and considerations presented in the FSWP plus information specific to this site, a site-specific conceptual site model is described below. This site-specific conceptual site model identifies the media and exposure pathways that must be addressed for remedial alternatives potentially applicable to this site.

TPH-G is present in soil within the source area for AOC-093. As shown in the Facility conceptual model presented in the FSWP, TPH-G can migrate from the source areas via groundwater or vapor pathways. For this site, migration via groundwater will be most significant; however, no TPH-G has been detected in groundwater near this AOC. Constituent transport via groundwater at this site would be affected by soil/groundwater interactions and biodegradation. As groundwater flows through TPH-G-affected soil in the source area, adsorbed TPH-G may dissolve into groundwater, though no TPH-G components were detected in groundwater samples collected. Any dissolved TPH-G would move with groundwater but at a different velocity due to continuing solute-soil interactions. This movement could create a plume extending downgradient from the source area; however, no such plume was detected in the adjacent push probes. If TPH-G is present in groundwater, it is more likely to biodegrade than to volatilize.

The extent of groundwater affected by dissolved TPH-G, if any, is limited to the area immediately adjacent to PP081. TPH-G-affected groundwater, if present, would migrate to the northwest from the source area toward Lake Washington. TPH-G constituents would likely biodegrade due to natural processes before reaching the lake shoreline. Volatilization of constituents from soil or groundwater is not significant for most workers at this site, as noted in the conceptual model presented in the FSWP.

18.3 Site Remediation Objectives and Cleanup Standards

The remediation objectives for the Renton Facility were presented in Section 2. Cleanup levels applicable to the Facility were proposed in the FSWP and were subsequently approved by Ecology. The remedial alternatives developed and evaluated for this site will be capable of



attaining the remediation objectives and cleanup standards presented in this section. As defined in the MTCA regulations, the cleanup standard consists of the cleanup level and the location or POC at which the cleanup level must be met. The remedial alternatives for this site, presented in Section 18.4, may have different points of compliance while fully addressing remediation objectives and meeting cleanup levels.

Characterization data for AOC-093 did not identify any groundwater contamination. The only soil constituent exceeding PCLs for AOC-093 is TPH-G, as listed in Table 5-3 of the FSWP. This constituent was identified by comparing detected constituent concentrations to the PCLs identified in the final RI Report; if a constituent concentration measured in any sample exceeded the PCL, the constituent was listed as a COC that must be addressed in the FS. The only COC associated with AOC-093 is TPH-G in soil. Therefore, TPH-G has been designated as a constituent that must be monitored in groundwater to determine if the site is causing a release to the environment. The groundwater cleanup level listed in Table 3-2 and in Table 5-2 of the FSWP for TPH-G with no benzene present is 1,000 µg/L (MTCA Method A). The MTCA Method A soil cleanup level for TPH-G with no benzene present is 100 mg/kg, as listed in Table 5-6 of the FSWP and in Table 3-1. The groundwater cleanup level for TPH-G of 1,000 µg/L would apply at the CPOC shown on Figure 18-1, which is located immediately downgradient of the affected soil area.

18.4 DESCRIPTION OF SITE REMEDIAL ALTERNATIVES

AOC-093 is an area of affected soil that was identified while delineating affected groundwater for AOCs-001 and -002. No activities are known that caused the release of TPH-G to site soil. Groundwater sampling conducted for this AOC did not identify any TPH-G constituents, which indicates that the affected soil is either not a source for groundwater or that the TPH-G constituents degrade very rapidly near the source area. This AOC is within the affected groundwater plume associated with AOCs-001 and -002 and is located about 45 feet from the Lake Washington shoreline. The one affected soil sample for AOC-093 (i.e., PP081) is located just downgradient of the CPOC defined for AOC-001/002 (see Figure 11-4).

This AOC is located near the Lake Washington shoreline. The site is also located within the tow path for partially assembled aircraft. The tow path is critical to the manufacture of aircraft at the Facility. Each aircraft produced at the Facility must be towed through the area where AOC-093 is located. Any remedial alternative implemented for AOC-093 must accommodate the movement of aircraft through the area; any interference with movement of the aircraft

would affect aircraft production and have significant cost implications. Due to the size of the aircraft produced at the Facility, no alternative tow path is available.

Based on the screening evaluation, MTCA minimum threshold requirements, and the site considerations discussed above, two remedial alternatives addressing the soil COC for AOC-093 were identified for evaluation in this FS:

- Alternative 1: Source Area Excavation and Monitored Natural Attenuation
- Alternative 2: Source Area Excavation, Enhanced Bioremediation, and Monitored Attenuation

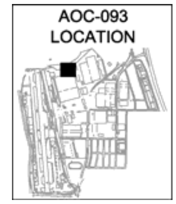
18.4.1 Alternative 1: Source Area Excavation and Monitored Natural Attenuation

Alternative 1 would consist of three primary elements: institutional controls, limited soil excavation, and MNA. Although no affected groundwater has been identified for this AOC, migration of constituents is the most significant potential exposure pathway for this site. The groundwater cleanup standard for this remedial alternative would be the groundwater cleanup level for TPH-G at a CPOC located just downgradient from the source area. Although the detected TPH-G in soil exceeds the applicable cleanup level, groundwater in the immediate vicinity of the source area is below the groundwater cleanup level for TPH-G. The soil sample collected from a depth of 4.5 feet at PP081 contained TPH-G at a concentration of 240 mg/kg, which exceeds the soil cleanup level of 100 mg/kg. Additional action, such as sampling and analysis for VPH/EPH or excavation of these shallow TPH-affected soils, will be done. For the purposes of evaluation of this alternative, limited excavation of TPH-G affected soils will be included as a conservative measure under this alternative.

18.4.1.1 Institutional Controls

The following institutional controls have been included in this alternative to reduce the risk of human exposure to impacted soil or groundwater:

- Deed recordation noting the nature and location of affected soil associated with this site;
- Continued engineering controls, protocols, and monitoring previously established by Boeing to ensure that industrial workers inside buildings are protected and indoor air concentrations meet PELs established by the Washington Department of Labor and Industry;



- Continued engineering controls, protocols, and monitoring to ensure that temporary construction workers adhere to WAC 296-62-300, applicable Washington Labor and Industry standards, and OSHA HAZWOPER regulations (29 CFR 1919.120) for all construction work conducted in exposed areas of affected soil and groundwater; and

- Deed restrictions to limit development and use of the site.

It is anticipated that deed restrictions would be established to limit future unrestricted land use without additional actions to attain compliance with appropriate soil and groundwater cleanup levels.

18.4.1.2 Monitored Natural Attenuation

Since shallow soils at PP081 exceed the MTCA Method A soil cleanup level of 100 mg/kg, limited soil excavation will be completed in the vicinity of PP081. The excavation will be completed to a depth of 5 feet if possible. It is assumed that soils from an area measuring 10 feet by 10 feet would be removed, and that the volume of soils excavated would be 15 yards. The excavated soil would be disposed off site. Although this site is not constrained by nearby buildings or other structures, excavation would be constrained because the excavation area would be located in the tow path used for movement of aircraft during production. This would make scheduling of the excavation very complex and difficult.

Although no groundwater COCs have been identified at this site, the soil contamination represents a potential source of groundwater constituents. Development of a valid remedial approach for MNA at AOC-093 requires a monitoring plan designed to verify the existence of and quantify the extent of enhanced and natural attenuation processes. In accordance with MNA guidance and the approach discussed in Section 4.2.4, the conceptual monitoring program for AOC-093 is designed to:

- Demonstrate that natural attenuation is occurring and that biodegradation of TPH constituents is the primary natural attenuation reaction;

- Identify any potentially toxic and/or mobile transformation products;

- Verify that the plume is not expanding;

- Verify that cleanup levels are attained at the CPOC;

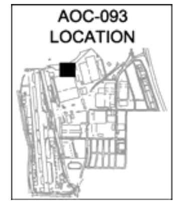
- Verify no unacceptable impact to downgradient receptors;

- Detect new releases of COCs that could impact the effectiveness of the natural attenuation remedy;
- Demonstrate the efficacy of institutional controls put in place to protect potential receptors; and
- Verify attainment of remediation objectives.

The conceptual monitoring program for Alternative 1 at AOC-093 assumes that upon selection of this remedy, a detailed MNA Validation and Long-Term Sampling Work Plan would be developed to guide the process. This work plan would identify additional monitoring wells and monitoring analytes that would be required for both characterization/validation sampling and long-term groundwater monitoring. Characterization/validation sampling would be used to demonstrate the effectiveness of MNA with respect to contaminant mass reduction, attenuation rates, and temporal trends. Long-term groundwater monitoring would be implemented after characterization/validation monitoring to confirm that the contaminant plume is in compliance with the cleanup standard.

For this conceptual program, it is assumed that characterization/validation sampling would consist of quarterly monitoring of one monitoring well for a minimum of 1 year. One new shallow monitoring well would be installed immediately downgradient of the source area, at the location shown in Figure 18-1. All samples collected from this well would be analyzed for TPH-G in addition to a limited suite of geochemical parameters (dissolved oxygen, pH, temperature, specific conductance, alkalinity, oxidation/reduction potential, and TOC). Quarterly data reporting would be done during the characterization/validation monitoring period.

It is further assumed that long-term groundwater monitoring would follow for an additional 13 to 14 years (15 total years of monitoring) and include semiannual monitoring of the shallow well for acetone, benzene, ethylbenzene, toluene, TPH-G, and a limited suite of geochemical parameters (dissolved oxygen, oxidation/reduction potential, temperature, and pH). To ensure plume control, the well would be analyzed once every 5 years for the entire characterization/validation list of analytes. It is assumed that annual reporting would be required for long-term groundwater monitoring. For cost estimation purposes, it was assumed that quarterly monitoring would be conducted for 2 years followed by 13 years of semiannual monitoring.



18.4.2 Alternative 2: Source Area Excavation, Enhanced Bioremediation, and Monitored Attenuation

Alternative 2 consists of the following three primary elements: institutional controls, source area soil excavation with enhanced bioremediation, and MA. The groundwater cleanup standard for this alternative would be the groundwater cleanup level for TPH-G of 1,000 µg/L and a CPOC as shown on Figure 18-1. The soil cleanup level of 100 mg/kg would be used for the soil excavation. This alternative includes source excavation (to the extent practicable given the location of the site within the tow path) to remove affected soils in the source area and enhanced bioremediation to accelerate site cleanup.

18.4.2.1 Institutional Controls

Institutional controls for Alternative 2 would be the same as those discussed in Section 18.4.1.1 for Alternative 1. For this alternative, however, institutional controls would be discontinued after monitoring and/or confirmation sampling showed that the site had been effectively remediated.

18.4.2.2 Source Area Excavation

As with Alternative 1, limited excavation of soil will be performed near PP081. This limited excavated would be the same for both alternatives.

18.4.2.3 Enhanced Bioremediation

Enhanced bioremediation for AOC-093 would consist of increasing oxygen in the subsurface aqueous system by adding approximately 200 pounds of ORC to the open excavation after the affected soil is removed and prior to backfilling with clean soil. The ORC would gradually release oxygen and promote biodegradation of any TPH constituents that may have leached to groundwater.

18.4.2.4 Monitored Attenuation

Monitored attenuation for this alternative would be a final “polishing” mechanism, following the active enhanced bioremediation, to ensure that cleanup levels would be met at the CPOC. With this alternative it is assumed that MA would follow enhanced bioremediation and consist of the same monitoring program described in Section 18.4.1.2 for Alternative 1.

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18.5 EVALUATION OF SITE REMEDIAL ALTERNATIVES

As previously discussed, both alternatives developed for the AOC-093 site meet the MTCA minimum requirements for cleanup actions. This section compares and evaluates the alternatives based on the MTCA criteria described in Section 5.1. An analysis of each alternative with respect to the evaluation criteria is summarized in Table 18-1 and discussed below.

18.5.1 Protectiveness and Risk Reduction Evaluation

Protectiveness and risk reduction are gauged primarily on the time required for the alternative to reduce risk and meet cleanup levels. The enhanced biodegradation included in Alternative 2 would promote more rapid biodegradation of remaining COCs. Therefore, Alternative 2 is expected to reduce the soil COC to cleanup levels more quickly than Alternative 1 and is rated higher for this criterion.

18.5.2 Permanence

Permanence refers to the ability to reduce the toxicity, mobility, or volume of hazardous substances, including the permanent destruction of hazardous substances. Both Alternatives 1 and 2 would permanently destroy COCs. Residuals would be generated from both Alternative 1 and Alternative 2 that would require management at an off-site facility. Alternative 2 is rated higher for this criterion because biodegradation of remaining affected soil would occur faster.

18.5.3 Cost

The cost evaluation includes all costs related to implementation of an alternative, including initial design and construction costs, operation and maintenance costs, monitoring costs, and reporting costs. The annual costs for operation, maintenance, monitoring, and reporting are recurring costs that occur in the future. The cost evaluation considers initial implementation costs and future recurring costs using NPV analysis. For NPV calculation, recurring costs were inflated 2% annually, and a discount rate of 7% was used. Details regarding the cost estimates for the three alternatives are presented in Appendix B. The present value costs for the two alternatives, in 2004 dollars, are summarized below:

Alternative	Net Present Value
1: Source Area Excavation and Monitored Natural Attenuation	$286,000
2: Source Area Excavation, Enhanced Bioremediation, and Monitored Attenuation	$316,000

As shown by these costs, Alternative 1 has the lower NPV cost, while Alternative 2 has the higher. Therefore, Alternative 2 ranks lower for cost and Alternative 1 ranks higher.

18.5.4 Long-Term Effectiveness

Long-term effectiveness includes the degree of certainty and reliability of the alternative and whether treatment residue remains from the alternative that would require management. Both Alternatives 1 and 2 are proven technologies, and both would produce residual wastes that would require off-site management. The two alternatives were rated equivalent for this criterion.

18.5.5 Management of Short-Term Risks

Short-term risk refers to the risk to human health and the environment during implementation of the alternative. Both alternatives would create minor short-term risks during implementation during excavation.

18.5.6 Technical and Administrative Implementability

This criterion is gauged based on whether the alternative is technically possible relative to complexity, administrative/regulatory requirements, size, access, and integration with existing operations. Both alternatives would impact site operations during excavation; therefore, both alternatives are rated equivalent for this criterion.

18.5.7 Public Concerns

This criterion involves potential community concerns with the alternatives. Since both alternatives deal with a large industrial site with limited public access, they are rated equivalent for this criterion.

18.5.8 Reasonable Restoration Time Frame

Restoration time frame refers to the practicability of a shorter restoration time frame with consideration given to a number of factors, including site risks, site use and potential use,

availability of alternative water supply, effectiveness and reliability of institutional controls, and toxicity of hazardous substances at the site. As a whole, these factors are a measure of the urgency of reducing risk and achieving cleanup goals for the site. The AOC-093 site is industrial, has proven institutional controls, and the toxicity of contaminants is moderate. Alternative 2 was rated higher for this criterion because it would have a shorter cleanup time through the addition of ORC or other TEA to the excavation.

18.6 SELECTION OF THE PREFERRED SITE REMEDIAL ALTERNATIVE

Selection of a preferred alternative under MTCA requires that preference be given to alternatives that use permanent solutions (to the maximum extent practicable), provide for a reasonable restoration time frame, and consider public concerns. The analysis below compares the baseline alternative (the alternative that provides the greatest degree of permanence) to the other alternatives based on degree of permanence, reasonable restoration time frame, and public concerns. According to MTCA (WAC 173-340-200), a permanent solution or permanent cleanup action means a cleanup action in which cleanup standards can be met without further action being required at the site involved, other than the approved disposal of any residue from the treatment of hazardous substances.

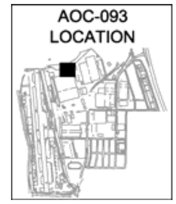
18.6.1 Baseline Remedial Alternative

The baseline remedial alternative for AOC-093 is Alternative 2. Although both alternatives could be considered to be permanent cleanup actions in the sense that cleanup standards would be met, this alternative is considered to have a higher degree of permanence because it would rely on a more aggressive approach to destroying hazardous substances and would likely provide for a shorter restoration time frame than Alternative 1.

The evaluation of both remedial alternatives for this site is summarized in Table 18-1. Neither of the alternatives is capable of attaining the standard POC at this site. However, both alternatives are capable of meeting the CPOC located on site and less than 25 feet from PP081.

18.6.2 Comparison to Baseline Alternative

As noted above, Alternative 2 has been defined as the baseline remedial alternative for this site. Alternative 1 will be compared to the baseline alternative in the following subsections for selection of the preferred alternative. The purpose of this comparison is to assess the benefits and costs for Alternative 1 relative to Alternative 2. The evaluation criteria presented above and in Table 18-1 were established in accordance with the MTCA requirements cited in



WAC 173-340(3)(f). Costs for the alternatives will be based on the NPV, which reflects the total cost associated with each alternative over the 15-year time period evaluated. The evaluation of benefits will be qualitative.

The benefits to be assessed in this comparison and the relative rating for the alternatives are presented in Table 18-2. The rationale for this comparison is presented below.

- **Reduced risk to on-site worker health.** Both alternatives are equal in reducing risk to site workers because they are both equally protective. Although the baseline alternative would remove volatile COCs within a few years, potential risks to on-site workers would not be changed substantially by the other alternative. The institutional controls included in each of the alternatives have been proven effective in protecting worker health and would continue to be protective.

- **Reduced risk to off-site human health.** Both alternatives were rated high for this benefit. Both would attain the cleanup level at the CPOC, which is protective of human health and the environment. The institutional controls included in the alternatives that have proven to be protective of worker health on site would also be protective of human health in off-site areas located upgradient of the CPOC.

- **Reduced risk to the environment.** Both alternatives were rated high for this benefit. Both alternatives would be protective of the aquatic environment because they would attain the cleanup levels at the CPOC.

- **Minimal adverse impact on Facility operations.** Both alternatives were rated moderate for this benefit because both would impact Facility operations during excavation of the source area.

- **Minimal restrictions on Facility traffic and access.** Both alternatives were rated moderate for this benefit because both would impact Facility traffic and access during excavation of the source area.

- **Minimal adverse impact on Facility structures and utilities.** Both alternatives were rated moderate because excavation would adversely affect use of the tow path.

The potential benefit evaluation for the alternatives shows that the alternatives are equivalent in terms of benefits.

The NPV costs for both alternatives were presented in Section 18.5.3. The baseline alternative ranks second among the alternatives and would have the higher cost (approximately 10% higher than the cost for Alternative 1).

18.6.3 Preferred Remedial Alternative

Alternative 1, Source Area Excavation and Monitored Natural Attenuation, is the preferred remedial alternative for the AOC-093 site. Alternative 2, as the baseline and the most permanent potential remedy, does not provide additional benefits at this AOC, where there are no identified groundwater COCs. Affected soils would remain covered by the pavement or tarmac, which would prevent potential runoff and infiltration of rainfall. Groundwater in the area is not used for any purpose, and potable water is readily available from the Renton public water system. The institutional controls included in Alternative 1 have been implemented and proven by Boeing, who would continue to maintain overall responsibility for this site and ensure that the institutional controls are properly enforced.

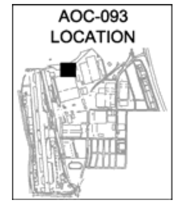
Institutional controls and MNA for this site would achieve the expectations for cleanup actions cited in the MTCA regulations at WAC 173-340-370 (1) – (8). Only those expectations relevant to large, complex sites are considered relevant to AOC-093. The relevant expectations are addressed as follows.

- **Implement Treatment at Sites with Liquid Wastes, High Contaminant Concentrations, Highly Mobile Materials, or Discrete Areas of Contamination.** Ecology expects that treatment will be emphasized for sites meeting these general criteria. Boeing believes that while remaining COC levels are elevated, they are not high, and there is no evidence of liquid wastes at the site.

- **Destroy, Detoxify, or Remove Hazardous Substances.** Ecology expects that hazardous substances will be destroyed, detoxified, or removed to below cleanup levels. Much of the affected soil would be removed. MNA would degrade or "treat" remaining organic COCs over the long term using natural processes that result in nontoxic degradation products.

- **Implement Engineering Controls for Low Contaminant Concentrations.** Ecology recognizes the need for containment for low concentrations of contaminants where treatment is impracticable. This alternative would use containment by pavement or tarmac to limit migration from soil to groundwater.

- **Prevent Runoff of Hazardous Substances.** Ecology expects that cleanup actions will include active measures to prevent precipitation from creating runoff that contains affected soil. This expectation would be met by the preferred alternative, because the source area would be removed to the extent practicable, and the remaining source area would be entirely covered by pavement or tarmac. In addition to preventing runoff from contacting hazardous substances, the site cover minimizes surface water infiltration, thus resulting in decreased groundwater flow



rates and increased time for groundwater to flow from the source area towards the lake.

- **Consolidate On-site Contaminants Exceeding Cleanup Levels.** Ecology expects that when contaminants are left on site exceeding cleanup levels that they will be consolidated to the extent practicable. At this site, due to the location of any remaining contaminants, it is not practicable to consolidate contaminants.

- **Prevent Runoff and Groundwater Discharge to Surface Water.** Ecology expects that the cleanup action would include active measures to prevent or minimize releases to adjacent surface water bodies via runoff or groundwater discharge, and that dilution will not be the sole method for attaining cleanup levels. Alternative 1 would meet this expectation. Available groundwater monitoring data indicate that biodegradation of organic COCs is active and significant at this site. The cleanup alternative also includes a groundwater monitoring network and program that would confirm that cleanup levels were attained in groundwater before groundwater could reach Lake Washington.

- **Ensure Appropriateness of Attenuation.** Ecology expects that natural attenuation may be appropriate if source control has been conducted to the maximum extent practicable; contaminants remaining on site do not pose unacceptable risks to human health and the environment; evidence indicates that degradation is occurring and will continue to occur at a reasonable rate; and appropriate monitoring is conducted. These expectations would all be achieved by Alternative 1. Most affected soil would be removed. Although affected soil and groundwater have been present at the site for a long time, Boeing has implemented effective institutional controls that have proven effective in protecting human health and the environment at this site. Groundwater monitoring data indicate that biodegradation of organic COCs is active at the site. Alternative 1 also includes a robust groundwater monitoring program designed to address recent guidance for MNA. The monitoring system included in the preferred alternative would confirm that cleanup levels were attained prior to groundwater discharging to Lake Washington.

The preferred remedial alternative would be designed to comply with applicable regulations. Potentially applicable regulations are listed in Table 18-3. These regulations govern the design, installation, and operation of remediation systems. For the preferred alternative at AOC-093, regulatory requirements are expected to be minimal. Construction for the preferred alternative would be limited to installation of a new groundwater monitoring well and excavation of affected soil, both within 200 feet of Lake Washington. The primary regulations governing the preferred alternative would be the MTCA regulations, the Washington state well drilling regulations for monitoring wells, the solid waste disposal regulations, the dangerous waste regulations, the transportation regulations, the Shoreline Management Act, and the Department of Labor and Industries health and safety regulations. Well drilling rules specify well design

and drilling requirements. The solid and dangerous waste regulations specify waste characterization, manifesting, and disposal requirements. Transportation regulations specify labeling and shipping requirements for wastes generated from implementation of the alternative. MTCA regulations specify remediation requirements and the cleanup standards to be attained. The Shoreline Management Act specifies standards for construction activities within 200 feet of the Lake Washington shoreline. The preferred alternative would be designed and implemented to comply with these regulations.

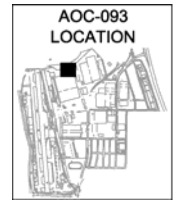


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TABLE 18-1

COMPARISON OF REMEDIAL ALTERNATIVES, AOC-093[1]

Boeing Renton Facility
Renton, Washington

Standards/Criteria		Alternatives	
		1 - Monitored Natural Attenuation	2 - Soil Excavation/Enhanced Bioremediation/MA
Protectiveness and Risk Reduction	Pros	Destroys organic constituents that may leach to groundwater. Appears to be active at site.	Removes soil COCs, destroys potential groundwater constituents.
	Cons	Slow to achieve cleanup.	
	Rating	MH	H
Permanence	Pros	Destroys potential groundwater constituents, No residuals.	Removes soil COCs, destroys potential groundwater constituents; Rapid cleanup.
	Cons	Slow degradation rates.	Residuals managed at off-site disposal facility.
	Rating	ML	MH
Cost	Pros	Low initial cost.	
	Cons		High initial cost.
	Rating	H	L
Long-Term Effectiveness	Pros	Destroys potential groundwater COCs; Passive, natural process.	Removes some COCs from site. Potential groundwater COCs would be destroyed.
	Cons		
	Rating	MH	MH
Management of Short-Term Risks	Pros	Simplest implementation; No residuals.	
	Cons	Minor short-term risks during excavation.	Minor short-term risks during excavation.
	Rating	MH	MH
Technical and Administrative Implementability	Pros	Simple, passive system. No permits required.	
	Cons	Excavation would interfere with site activities due to location in aircraft tow path.	Excavation would interfere with site activities due to location in aircraft tow path.
	Rating	ML	ML
Public Concerns	Pros	Industrial site.	Industrial site.
	Cons		
	Rating	MH	MH
Restoration Time Frame	Pros	Industrial site; Proven institutional controls; Alternative water available; Practicability of shorter time frame limited by facility operations	Industrial site; Proven institutional controls; Alternative water available; short cleanup time.
	Cons		
	Rating	ML	H

Notes:

1. Comparison Ratings: H = Highest (if the decision were based solely on one criterion, an H score would indicate the alternative is the preferred alternative);
MH =Medium High;
ML = Medium Low;
L = Low.

TABLE 18-2

COMPARISON OF BENEFITS, AOC-093[1]

Boeing Renton Facility
Renton, Washington

Benefit	Alternative 1: Monitored Natural Attenuation	Alternative 2: Source Area Excavation/ Enhanced Bioremediation/ Monitored Attenuation
Reduced risk to on-site worker health	High	High
Reduced risk to off-site human health	High	High
Reduced risk to the environment	High	High
Minimal adverse impact on Facility operations	Moderate	Moderate
Minimal restrictions on Facility traffic and access	Moderate	Moderate
Minimal adverse impact on Facility structures and utilities	Moderate	Moderate

Notes:
1. Benefits for each remedial alternative are rated as follows:
   High = high benefit;
   Moderate = moderate benefit;
   Low = low benefit.

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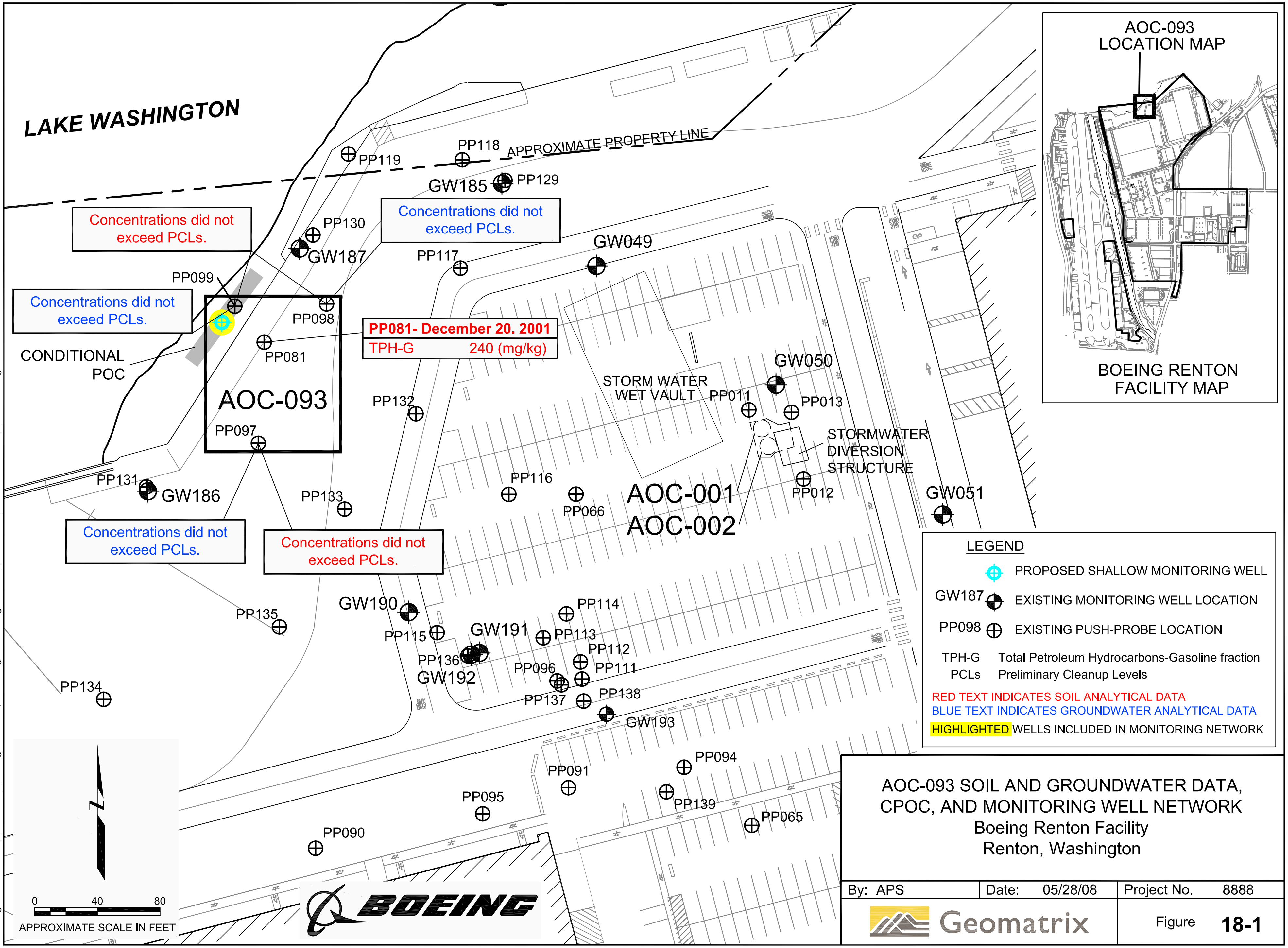
TABLE 18-3

POTENTIALLY APPLICABLE REGULATIONS
AOC-093 PREFERRED REMEDIAL ALTERNATIVE

Boeing Renton Facility
Renton, Washington

Law/Regulation	Citation	Applicability
Chemical-Specific Laws and Regulations		
Washington Dangerous Waste Regulations	WAC 173-303	Waste management, permitting requirements
Washington Model Toxics Control Act Regulations	WAC 173-340	Establishment of cleanup levels and POCs
Action-Specific Laws and Regulations		
Washington State Environmental Policy Act Regulations	WAC 197-11	Permitting, EIA/EIS[1] requirements
Washington Industrial Safety and Health Act Regulations	WAC 296-24	Occupational health and safety
Transportation regulations	49 CFR Parts 100 & 177, WAC 446-50	Transportation for wastes and materials
Washington well drilling regulations	WAC 173-160 & -162	Well design and installation standards
Washington solid waste disposal regulations	WAC 173-304	Disposal of nondangerous waste
Location-Specific Regulations		
Shoreline Management Act	RCW 90.58	Standards for construction within 200 ft of shoreline

Notes:
1. EIA = Environmental Impact Assessment; EIS = Environmental Impact Statement.



AOC-093 SOIL AND GROUNDWATER DATA, CPOC, AND MONITORING WELL NETWORK
Boeing Renton Facility
Renton, Washington

By: APS	Date: 05/28/08	Project No. 8888
Geomatrix		Figure 18-1

Plot Date: 05/28/08 - 2:16pm, Plotted by: astenberg
Drawing Path: S:\8888_2006\025_Boeing FS\CAD\, Drawing Name: Figure 18-1_AOC-093_Soil and GW Data_012808.dwg

19.0 DEVELOPMENT AND EVALUATION OF REMEDIAL ALTERNATIVES, AOC-094

In this section we describe current conditions and document the status of AOC-094.

19.1 SITE CHARACTERIZATION AND REMEDIAL ACTION SUMMARY

AOC-094 is located west of Building 5-08 on leased property at the Renton Municipal Airport (see Figure 1-2). AOC-094 was discovered during installation of an upgradient push probe near groundwater monitoring well GW084. A soil sample collected at 4.5 feet in depth contained TPH-G at a concentration that exceeded the PCL. Subsequently, a groundwater sample from GW084 was analyzed for VOCs and TPH-gasoline. No VOCs or TPH-G were detected in the groundwater sample.

As part of the Supplemental RI Data Collection field work, a second push probe was installed immediately next to PP089 and GW084 to collect a soil sample for analysis for EPH and VPH hydrocarbon fractionation for the FS.

19.1.1 Historical, Present, and Future Site Use

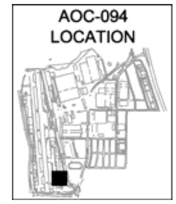
Building 5-08 and the adjacent area are owned by the City of Renton and are leased to Boeing. The Boeing-leased buildings and areas are currently used for industrial purposes supporting the manufacture of commercial airplanes and are expected to remain in industrial use for the foreseeable future.

19.1.2 Previous Site Remedial Actions

There are no documented records of any soil removal or other remedial actions associated with AOC-094.

19.1.3 Site Hydrogeology

The general stratigraphy at AOC-094 consists of an upper layer of sand and gravel fill material underlain by predominantly fine-grained alluvial deposits. Fill material consists mostly of sands and gravelly sands that extend to a depth of approximately 4 feet. The underlying alluvial deposits consist of interbedded greenish-gray, silty clay, clayey silt, and fine- to medium-grained silty sand with occasional gravelly lenses. Depth to groundwater ranges from approximately 4.5 to 11 feet bgs**.** Shallow groundwater in the vicinity of AOC-094 generally flows to the northeast, toward the Cedar River Waterway, with a hydraulic gradient ranging



from 0.003 to 0.006. The calculated hydraulic conductivity of the shallow aquifer at nearby SWMU-172/174 ranges from 4.6 x 10^{-5} to 4.2 x 10^{-3} cm/s.

19.1.4 Nature and Extent of Affected Soil

TPH-G was detected in a sample collected from a depth of 4.5 feet in PP089 (Figure 19-1) at a concentration of 590 mg/kg, which is above the PCL of 100 mg/kg (without benzene present) for TPH-G. A sample collected from the duplicate push probe PP110 contained TPH-G at a concentration of 1,400 mg/kg (Figure 19-1). A soil sample collected at a depth of 11 feet contained TPH-G at a concentration of 25 mg/kg, well below the TPH-G PCL.

19.1.5 Nature and Extent of Affected Groundwater

Groundwater samples collected from groundwater monitoring well GW084 (Figure 19-1) during the RI, and subsequently after the discovery of AOC-094, did not contain VOCs or TPH-G above the detection limit.

19.2 ATTAINMENT OF THE CLEANUP STANDARD

This section summarizes existing conditions at AOC-094 in relation to cleanup standards specified by the MTCA.

19.2.1 Site Constituents of Concern and Cleanup Standards

Unlike individual hazardous substances, petroleum hydrocarbon mixtures such as gasoline, diesel fuel, and lubricating oils are composed of thousands of chemical compounds. Typically, the concentration of these mixtures is analyzed as TPH, which represents the expected range of these materials such as the gasoline-range or the diesel-range (Ecology, 2001). The MTCA Cleanup Regulation allows for mixture-specific chemical characterization of released petroleum in order to develop a cleanup level tailored to the types of compounds actually present in soil or groundwater. This method, known as “TPH fractionation,” measures the concentration of 12 subgroups (or fractions) of TPH within the released mixture and is based on work by a consortium of national experts. These fraction groups are defined based on their relative average molecular size, with the lighter weight (and typically more volatile and soluble) compounds in one group, and heavier, less volatile and less soluble compounds, in others. The measured concentrations of each of the 12 groups are then assessed, together with their individual chemical and toxicological properties, to determine the appropriate cleanup level.

In order to assess the risk from TPH-G-affected soils within this AOC, the soil analytical data for the samples collected from PP110 (see Table 19-1) were input into the Ecology MTCATPH10 spreadsheet (Ecology, 2001) for determining soil cleanup levels for TPH at this site. The worksheets for determining the status of current risk of the soil and for calculating soil cleanup levels for the protection of groundwater were used. Toxicological, physical, and chemical properties of the chemicals input into the spreadsheet were found in the CLARC Database Version 3.1. Default exposure parameters were used. Default parameters were used for total soil porosity, volumetric water content, volumetric air content, dry soil bulk density, and the dilution factor. Fraction soil organic carbon was based on site-specific data for the soil type observed at the site. A fraction soil organic carbon value of 0.51% was used in the spreadsheet representing the SP/SW soil from the site. The results, provided in Tables 19-2 and 19-3, show that the risk for direct contact with the soil (Table 19-2) meets MTCA criteria and that the soil concentration is protective of potable groundwater (Table 19-3). No LNAPL has been identified in monitoring well GW084 installed near AOC-094. In addition, the soil TPH-G concentration of 1,400 mg/kg from the site is below the residual saturation level of 3,387 mg/kg for gasoline in a medium to coarse gravel (Brost and De Vaull, 2000), which suggests that accumulation of LNAPL is unlikely and the residual saturation requirement of MTCA has been met. Because the site is composed of clayey silt and silty sands with gravel, this value is likely conservative and the actual residual saturation levels for gasoline in this soil type may be higher.

19.2.2 No Further Action Recommendation

No further additional cleanup actions are necessary for AOC-094, because the soils and the groundwater at this site meet the site-specific cleanup levels for petroleum hydrocarbons in soil and groundwater calculated using the procedures identified in Section 5 of the approved FSWP (Geomatrix, 2004c). The standard POC for soil and groundwater cleanup levels has been met at AOC-094. AOC-094 will not be further evaluated during the FS.

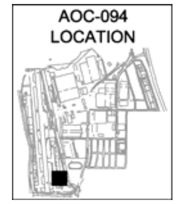


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TABLE 19-1

AOC-094 SOIL ANALYTICAL RESULTS[1]
SUPPLEMENTAL RI DATA COLLECTION[2]

Boeing Renton Facility
Renton, Washington

Sample ID	FS-SB-PP110-0040	FS-SB-PP110-1-0040	
Date Sampled	1/28/2003	1/28/2003	
Sample Depth (feet bgs) [3]	4.0	4.0	
Sample Type		duplicate	PCL [4]
VOCs [5] (µg/kg)			
Acetone	**60 [6]**	53 U [7]	3,270
Chloroform	11 U	**20 J [8]**	6,488
Ethylbenzene	**27 J**	**29 J**	30,090
m,p-xylene	**120**	**240 J**	640,000
o-xylene	**17 U**	**14 J**	694,600
1,3,5-Trimethylbenzene	**4,500**	**4,000**	NE [9]
1,2,4-Trimethylbenzene	**10,000**	**8,800**	NE
Isopropylbenzene	**250**	**210**	NE
n-Propylbenzene	**810 J**	**720 J**	NE
sec-Butylbenzene	**790 J**	**690 J**	NE
p-Isopropyltoluene	**1,800**	**1,600**	NE
Naphthalene	**180**	**150**	NE
TPH-Gasoline (mg/kg)	**1,400**	**1,200**	100
VPH [10] (µg/kg)			
C8-C10 Aromatics	**180**	n/a [11]	NE
C10-C12 Aromatics	**84**	n/a	NE
C12-C13 Aromatics	**6.8**	n/a	NE
C5-C6 Aliphatics	5 U	n/a	NE
C6-C8 Aliphatics	5 U	n/a	NE
C8-C10 Aliphatics	**69**	n/a	NE
C10-C12 Aliphatics	**180**	n/a	NE
EPH [12] (µg/kg)			
C8-C10 Aliphatics	**130,000**	n/a	NE
C8-C10 Aromatics	**13000**	n/a	NE
C10-C12 Aliphatics	**46,000**	n/a	NE
C10-C12 Aromatics	**8300**	n/a	NE
C12-C16 Aliphatics	**18,000**	n/a	NE
C12-C16 Aromatics	3700 U	n/a	NE
C16-C21 Aliphatics	**31,000**	n/a	NE
C16-C21 Aromatics	7700 U	n/a	NE
C21-C34 Aliphatics	**240,000**	n/a	NE
C21-C34 Aromatics	**120,000**	n/a	NE

Notes:
1. Concentrations in micrograms per kilogram (µg/kg).
2. Source: Geomatrix, 2004c.
3. bgs = below ground surface.
4. PCL = preliminary cleanup level.
5. VOCs = volatile organic compounds.
6. Results in **BOLD** exceed detection limit.
7. U = analyte not detected above the reporting limit.
8. J = Indicates a estimated value.
9. NE = not established.
10. VPH = Volatile Petroleum Hydrocarbons.
11. n/a = not analyzed.
12. EPH = Extractable Petroleum Hydrocarbons.

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TABLE 19-2

AOC-094 RESULTS
DIRECT CONTACT WITH SOIL
Boeing Renton Facility
Renton, Washington

Worksheet for Calculating Soil Cleanup Level for Soil Direct Contact Pathway: Method C-Industrial Land Use (Refer to MTCA WAC 173-340-745)

Date: 21-Aug-04
Site Name: Boeing Renton
Sample Name: FS-SB-PP110-0040

Chemical of Concern or EC Group	Measured Soil Conc dry basis	Exposure Parameters				Toxicity Parameters		Current Condition			Adjusted Condition			
		ABI	AF	ABS_d	GI	RfD_o	CPF_o	HQ	RISK	Pass or Fail?	Soil Conc being tested	HQ	RISK	Pass or Fail?
	mg/kg	unitless	mg/cm^2-day	unitless	unitless	mg/kg-day	kg-day/mg	unitless	unitless		mg/kg	unitless	unitless	
Petroleum EC Fraction														
AL_EC >5-6	0	1	0.2	0.03	0.8	5.7					0.00E+00			
AL_EC >6-8	0	1	0.2	0.03	0.8	5.7					0.00E+00			
AL_EC >8-10	130	1	0.2	0.03	0.8	0.03		2.98E-03			2.97E+02	6.82E-03		
AL_EC >10-12	46	1	0.2	0.03	0.8	0.03		1.05E-03			1.05E+02	2.41E-03		
AL_EC >12-16	18	1	0.2	0.1	0.5	0.03		9.00E-04			4.12E+01	2.06E-03		
AL_EC >16-21	31	1	0.2	0.1	0.5	2		2.33E-05			7.09E+01	5.32E-05		
AL_EC >21-34	240	1	0.2	0.1	0.5	2		1.80E-04			5.49E+02	4.12E-04		
AR_EC >8-10	12.853	1	0.2	0.03	0.8	0.05		1.77E-04			2.94E+01	4.04E-04		
AR_EC >10-12	8.12	1	0.2	0.03	0.8	0.05		1.12E-04			1.86E+01	2.55E-04		
AR_EC >12-16	1.85	1	0.2	0.1	0.5	0.05		5.55E-05			4.23E+00	1.27E-04		
AR_EC >16-21	3.85	1	0.2	0.1	0.5	0.03		1.93E-04			8.81E+00	4.40E-04		
AR_EC >21-34	120	1	0.2	0.1	0.5	0.03		6.00E-03			2.75E+02	1.37E-02		
Benzene	0	1	0.2	0.0005	0.95	0.003	0.055		0.00E+00		0.00E+00		0.00E+00	
Toluene	0	1	0.2	0.03	1	0.2					0.00E+00			
Ethylbenzene	0.027	1	0.2	0.03	0.92	0.1		1.79E-07			6.18E-02	4.10E-07		
Total Xylenes	0.12	1	0.2	0.03	0.9	2		4.00E-08			2.75E-01	9.15E-08		
Total Naphthalenes	0.18	1	0.2	0.13	0.89	0.02		1.11E-05			4.12E-01	2.53E-05		
n-Hexane	0	1	0.2	0.03	0.8	0.06					0.00E+00	0.00E+00		
MTBE	0										0.00E+00			
Ethylene Dibromide (EDB)	0	1	0.2	0.03	0.8	0.000057	85		0.00E+00		0.00E+00	0.00E+00	0.00E+00	
1,2 Dichloroethane (EDC)	0	1	0.2	0.03	0.8	0.03	0.091		0.00E+00		0.00E+00	0.00E+00	0.00E+00	
Benzo(a)anthracene	0	1	0.2	0.13	0.89		0.73		0.00E+00		0.00E+00		0.00E+00	
Benzo(b)fluoranthene	0	1	0.2	0.13	0.89		0.73		0.00E+00		0.00E+00		0.00E+00	
Benzo(k)fluoranthene	0	1	0.2	0.13	0.89		0.73		0.00E+00		0.00E+00		0.00E+00	
Benzo(a)pyrene	0	1	0.2	0.13	0.89		7.3		0.00E+00		0.00E+00		0.00E+00	
Chrysene	0	1	0.2	0.13	0.89		0.073		0.00E+00		0.00E+00		0.00E+00	
Dibenzo(a,h)anthracene	0	1	0.2	0.13	0.89		2.92		0.00E+00		0.00E+00		0.00E+00	
Indeno(1,2,3-cd)pyrene	0	1	0.2	0.13	0.89		0.73		0.00E+00		0.00E+00		0.00E+00	
Sum	**612**							1.17E-02	0.00E+00		1.40E+03	2.67E-02	0.00E+00	

a. "TPH Test" button below is for testing adjusted condition at a specified TPH concentration.
b. Check columns at left for Pass/Fail detail.

Current Condition	
TPH, mg/kg=	612.000
HI=	1.168E-02
Cancer RISK=	0.000E+00
Pass or Fail?	Pass

Adjusted Condition	
TPH, mg/kg=	1400.000
HI=	2.673E-02
Cancer RISK=	0.000E+00
Pass or Fail?	Pass
Check Residual Saturation (WAC340-747(10))	

Exposure Parameters		
for Non-carcinogens		Units
Average Body Weight, ABW	70	kg
Averaging Time, AT	20	yr
Exposure Frequency, EF	0.7	unitless
Exposure Duration, ED	20	year
Soil Ingestion Rate, SIR	50	mg/day
Dermal Surface Area, SA	2500	cm^2
for Carcinogens		
Parameters for Carcinogens		unit
Averaging time, AT_C	75	yr

TABLE 19-3

AOC-094 RESULTS
PROTECTION OF POTABLE GROUNDWATER

Boeing Renton Facility
Renton, Washington

Worksheet for Calculating Soil Cleanup Level for the Protection of Potable Ground Water (Refer to WAC 173-340-747)

Date: 8/21/04
Site Name: Boeing Renton
Sample Name: FS-SB-PP110-0040

Chemical of Concern or EC Group	Measured Soil Conc dry basis	Ground Water Cleanup Level Method A	Adjusted Condition: Soil Conc being tested	Adjusted Condition: Predicted Conc @Well	Adjusted Condition: HQ @ Well	Adjusted Condition: RISK @ Well	Adjusted Condition: Pass or Fail?
	mg/kg	ug/l	mg/kg	ug/l	unitless	unitless	
Petroleum EC Fraction							
AL_EC >5-6	0		0.00E+00	0.00E+00	0.00E+00	0.00E+00	
AL_EC >6-8	0		0.00E+00	0.00E+00	0.00E+00	0.00E+00	
AL_EC >8-10	130		2.97E+02	7.51E+00	3.13E-02	0.00E+00	
AL_EC >10-12	46		1.05E+02	1.78E-01	7.43E-04	0.00E+00	
AL_EC >12-16	18		4.12E+01	1.28E-03	2.66E-06	0.00E+00	
AL_EC >16-21	31		7.09E+01	2.73E-06	8.54E-11	0.00E+00	
AL_EC >21-34	240		5.49E+02	1.71E-10	5.35E-15	0.00E+00	
AR_EC >8-10	12.853		2.94E+01	7.58E+01	1.89E-01	0.00E+00	
AR_EC >10-12	8.12		1.86E+01	2.10E+01	5.24E-02	0.00E+00	
AR_EC >12-16	1.85		4.23E+00	1.17E+00	1.46E-03	0.00E+00	
AR_EC >16-21	3.85		8.81E+00	1.90E-01	3.95E-04	0.00E+00	
AR_EC >21-34	120		2.75E+02	6.26E-02	1.30E-04	0.00E+00	
Benzene	0	5	0.00E+00	0.00E+00	0.00E+00	0.00E+00	
Toluene	0	1000	0.00E+00	0.00E+00	0.00E+00	0.00E+00	
Ethylbenzene	0.027	700	6.18E-02	6.13E-01	7.66E-04	0.00E+00	
Total Xylenes	0.12	1000	2.75E-01	2.67E+00	1.67E-04	0.00E+00	
Total Naphthalenes	0.18	160	4.12E-01	6.62E-01	4.14E-03	0.00E+00	
n-Hexane	0		0.00E+00	0.00E+00	0.00E+00	0.00E+00	
MTBE	0	20	0.00E+00	0.00E+00	0.00E+00	0.00E+00	
Ethylene Dibromide (EDB)	0	0.01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	
1,2 Dichloroethane (EDC)	0	5	0.00E+00	0.00E+00	0.00E+00	0.00E+00	
Benzo(a)anthracene	0		0.00E+00	0.00E+00	0.00E+00	0.00E+00	*for*
Benzo(b)fluoranthene	0		0.00E+00	0.00E+00	0.00E+00	0.00E+00	*all*
Benzo(k)fluoranthene	0		0.00E+00	0.00E+00	0.00E+00	0.00E+00	*cPAHs*
Benzo(a)pyrene	0		0.00E+00	0.00E+00	0.00E+00	0.00E+00	
Chrysene	0		0.00E+00	0.00E+00	0.00E+00	0.00E+00	
Dibenzo(a,h)anthracene	0		0.00E+00	0.00E+00	0.00E+00	0.00E+00	
Indeno(1,2,3-cd)pyrene	0		0.00E+00	0.00E+00	0.00E+00	0.00E+00	
Sum	612.000		1.40E+03	1.10E+02	2.81E-01	0.00E+00	
Testing Total Soil Conc (mg/kg) is:			**1400.00**				

a. "TPH Test" button below is for testing adjusted condition at a specified TPH concentration.
b. Check columns at left for Pass/Fail detail.

Site-Specific Hydrogeological Characteristics

Item	Symbol	Value	Units
Total soil porosity: default is 0.43	n	0.43	unitless
Volumetric water content: default is 0.3	Θ_w	0.3	unitless
Initial volumetric air content: default is 0.13	Θ_a	0.13	unitless
Soil bulk density measured: default is 1.5	ρ_b	1.5	kg/l
Fraction Organic Carbon: default is 0.001	f_{oc}	0.0051	unitless
Dilution Factor: default is 20	DF	20	unitless

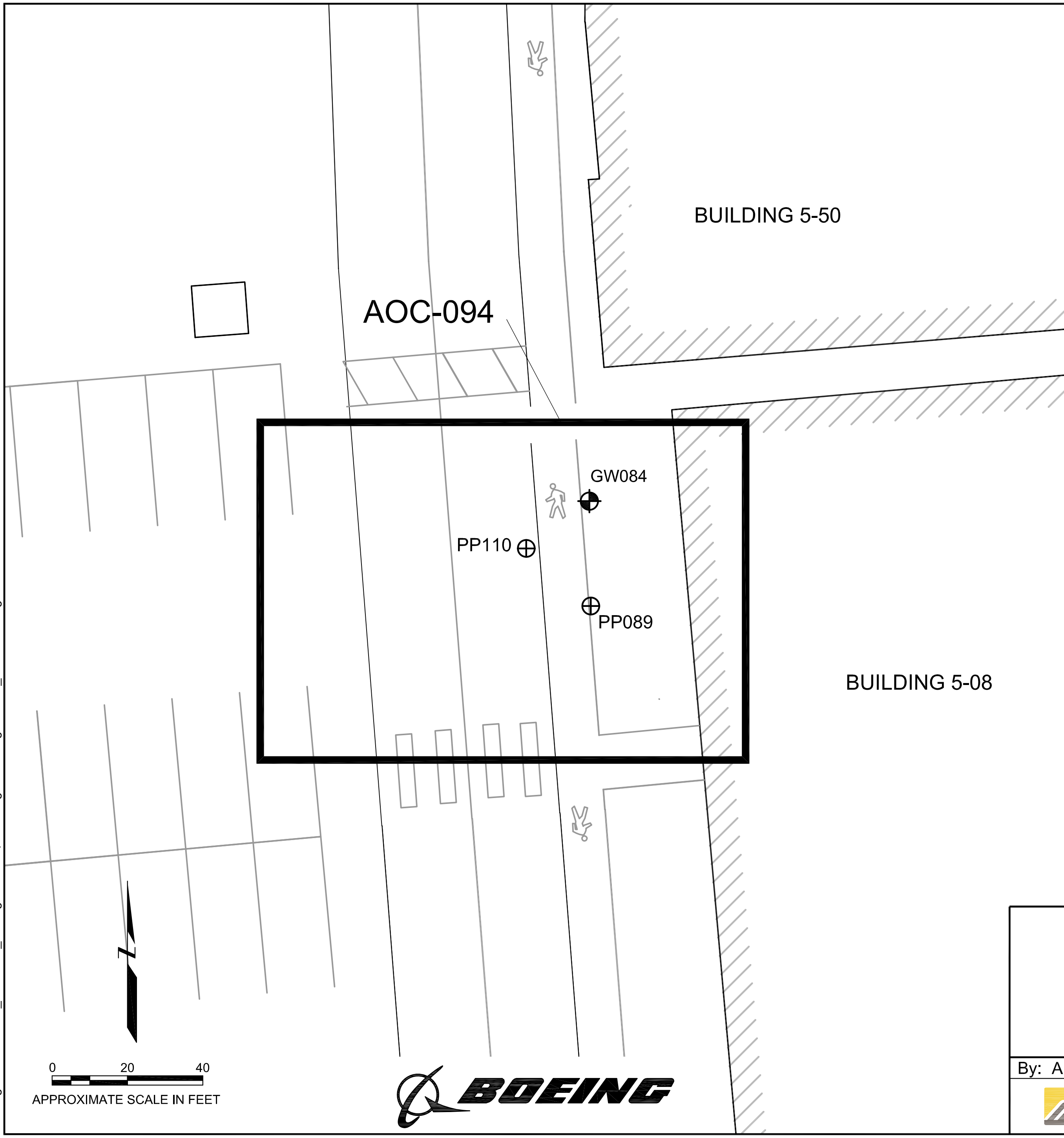
Back-Calculate Target Soil TPH Cleanup Levels

Based on HI=1.0 @Ground Water:
Based on total Cancer RISK =1.0E-5 @Ground Water:
Based on Benzene Ground Water Cleanup Level:

TPH OUTPUT

Total Soil Concentration (mg/kg) tested:	**1400.000**	
Pass or Fail?	**Pass**	*No carcxinogenic risk in the sample!*
Predicted TPH (ug/l) @Well:	**1.10E+02**	
Cancer Risk @ Well:	**0.00E+00**	
Hazard Index @Well:	**2.81E-01**	
Initial Weighted Average MW of NAPL (g/mol):	218.8	
Equilibrated Weighted Average MW of NAPL (g/mol):	224.2	
Initial Weighted Average Density of NAPL (kg/l):	0.841	
Volumetric NAPL Content, Θ_{NAPL} :	0.002	
NAPL Saturation (%), Θ_{NAPL}/n:	0.56%	
Type of model used for computation:	***4-Phase Model***	
Computation completed?	***Yes!***	
Mass Distribution Pattern @ 4-phase in soil pore system:		
Total Mass distributed in Water Phase:	0.03%	in Solid: 3.59%
Total Mass distributed in Air Phase:	0.08%	in NAPL: 96.30%

Please Check Soil Residual Saturation TPH Levels: Refer to Table 747-5!



LEGEND

GW084 EXISTING MONITORING WELL LOCATION

PP110 EXISTING PUSH-PROBE LOCATION

NOTES

1. BASEMAP COMPILED BY DUANE HARTMAN & ASSOCIATES, INC., DECEMBER, 1994
2. PUSH PROBE LOCATIONS FROM FINAL REMEDIAL INVESTIGATION REPORT (WESTON, 2001)

AOC-094 AREA AND LOCATION OF PP110
Boeing Renton Facility
Renton, Washington

By: APS	Date: 05/29/08	Project No. 8888
Geomatrix		Figure 19-1

Plot Date: 05/29/08 - 5:18pm, Plotted by: astenberg
Drawing Path: S:\8888_2006\025_Boeing FS\CAD\, Drawing Name: Figure 19-1_AOC-094.dwg

20.0 SUMMARY OF PREFERRED REMEDIAL ALTERNATIVES

Remedial alternatives were developed and evaluated for the 14 SWMU and AOC sites that were addressed in the focused FS presented in this report. Separate sections of this FS report summarize the site characterization data, previous remediation actions, site-specific remediation objectives, and potential remedial alternatives considered for the Facility. All potential remedial alternatives evaluated in this FS would be capable of attaining the remediation objectives identified in Sections 3 and 6 through 19. These remedial alternatives were evaluated relative to the criteria and regulatory standards presented in the approved FSWP. Sections 6 through 19 of this report identify the remedial alternatives preferred for each of the sites. The preferred remedial alternative for each of the 14 sites addressed in this FS report are summarized below. The key issues, preferred remedial alternatives, and estimated cost for the preferred remedial alternatives are summarized in Table 20-1. The total estimated NPV cost for implementation of all preferred remedial alternatives is about $6.5 million.

Many of the preferred remedial alternatives for the different SWMUs and AOCs utilize the same technologies and address similar constituents.

20.1 SWMU-168 (BUILDING 5-50)

Alternative 3, Enhanced Bioremediation and Monitored Attenuation, is the preferred remedial alternative for the SWMU-168 site, because it would provide the greatest benefit for the anticipated NPV cost. Under this alternative, affected soils would remain capped by a well-maintained pavement or tarmac, which would prevent potential runoff of affected soil and infiltration of rainfall into the affected area. In addition, enhanced biodegradation would promote rapid biodegradation of organic constituents, and institutional controls would be implemented to limit the potential for exposure. The low source area concentrations for site COCs and the limited area of affected groundwater support the selection of this alternative. Groundwater samples collected downgradient of the source areas show that groundwater COCs have not migrated to the Cedar River Waterway. Natural degradation of site COCs would attain all remediation objectives presented in Sections 2 and 6.3 of this FS report and would comply with applicable laws and regulations. The institutional controls included in this preferred alternative have been proven effective through prior implementation by Boeing, who would continue to maintain overall responsibility for this site and ensure that the institutional controls are properly maintained and enforced. The groundwater cleanup standard for this remedial alternative will be the groundwater cleanup levels cited in Table 3-2 and a CPOC located on leased property downgradient of the source area. As discussed in Section 6, an appropriate groundwater monitoring network would be implemented to support this remediation approach for SWMU-168.

20.2 SWMU-172/174 (BUILDING 5-08/5-09)

Alternative 2, Soil Vapor Extraction, Enhanced Bioremediation, and Monitored Attenuation, is the preferred remedial alternative for SWMU-172/174. This alternative is the baseline alternative for this site. SVE and enhanced bioremediation for this site would achieve the remediation objectives presented in Section 2 and Section 7.3. This alternative would also comply with applicable laws and regulations addressing cleanup and management of contaminated sites.

SVE and enhanced bioremediation would address the source areas to the extent practicable given site constraints. The buildings, tarmac, and pavement over much of the site minimize surface water infiltration, thus resulting in decreased groundwater flow rates and increased time for groundwater to flow from the source area to the waterway. The cap will remain over the site while SVE and enhanced bioremediation treat the site COCs. Groundwater COCs would be expected to attain cleanup levels at an on-site CPOC located upgradient of the Cedar River Waterway. East Perimeter Road and the retaining wall along the western shoreline of the waterway preclude development and minimize the potential for exposure to groundwater downgradient from the CPOC.

20.3 SWMU-179 (BUILDING 4-76)

No further remedial action is needed to attain remediation objectives for SWMU-179. The SWMU-179 cistern was removed in November 1990. After the buildings constraining the original excavation were demolished early in 2004, additional soil was removed and confirmation sampling was conducted, which confirmed that affected soil exceeding the approved cleanup levels in the FSWP had been removed from the site. In April 2004, a push probe groundwater sample was collected from this site to assess groundwater quality; site COCs in this groundwater sample were below PCLs and groundwater cleanup levels in the approved FSWP. This work confirmed that soil and groundwater COCs have been reduced to acceptable levels at SWMU-179.

Based on the recent cleanup action implemented for this site, no additional cleanup is necessary for SWMU-179 because the soil and groundwater COCs at this site meet the approved cleanup levels for soil and groundwater. The standard POC for soil and groundwater has been met at SWMU-179, and the site is currently in compliance with applicable environmental regulations.

20.4 BUILDING 4-78/79 SWMU/AOC GROUP

Alternative 2, SVE, Enhanced Bioremediation, Monitored Attenuation, and Monitored Natural Attenuation, is the preferred cleanup action for the Building 4-78/79 SWMU/AOC group. This alternative was defined as the baseline alternative for this site; the remediation costs for this alternative are not considered disproportionate and it would provide a more extensive and rapid remediation than the other alternatives considered. Remediation objectives established in Section 2 and Section 9.3 of this FS report would be attained by this alternative. This alternative would also comply with applicable laws and regulations addressing cleanup and management of contaminated sites.

The preferred alternative for this site is based on removal or destruction of site COCs. The SVE system would remove COCs from vadose zone soil within both source areas, resulting in permanent destruction of the volatile constituents. Enhanced bioremediation for the solvent source area and plume would promote rapid degradation of the solvents to nontoxic by-products. Natural attenuation for the benzene plume would degrade the petroleum hydrocarbons present in the plume prior to reaching the CPOC, as indicated by groundwater modeling conducted for the site. Monitored attenuation for the solvent plume and MNA for the benzene plume would ensure that cleanup standards are attained at the CPOC. The site would remain capped by the existing, well-maintained pavement, tarmac, and/or buildings, which would prevent runoff of affected soil and limit infiltration of surface water. This preferred remedial alternative would attain the cleanup standard required under MTCA regulations within a reasonable time frame.

20.5 FORMER FUEL FARM

Alternative 3, Monitored Natural Attenuation, has been selected as the preferred remedial alternative for the former Fuel Farm. This alternative would provide the greatest benefit at the lowest cost. The remediation objectives presented in Sections 2 and 10.3 would be attained by this alternative. This alternative would also comply with applicable laws and regulations addressing cleanup and management of contaminated sites. Groundwater samples collected downgradient from the source areas and upgradient from the Cedar River Waterway show that groundwater COCs have not migrated to the waterway, even though the release in the source area occurred many years ago, which indicates that natural attenuation is an active mechanism for this site. Preliminary groundwater modeling of natural attenuation confirms the downgradient observations and indicates that the groundwater cleanup levels would be attained at the off-lease CPOC located just west of East Perimeter Road. Operation of the interim measure at this site has created a relatively aerobic environment within the site subsurface, which would support biodegradation of the petroleum hydrocarbons released in the source area.

Under the preferred remedial alternative for this site, affected soils would remain capped by maintained pavement or tarmac, which would prevent potential runoff of affected soil and infiltration of rainfall. The off-site, downgradient area is owned by the City of Renton and consists of an adjoining industrial leased area, a public road, and a narrow strip of property along the western shoreline of the Cedar River Waterway. The other leased area buildings, tarmac, pavement, and roadway further limit infiltration of surface water. The City of Renton has indicated general agreement to allow a CPOC to be located on City property. The shoreline along the waterway is occupied by an above-grade retaining wall and is not suitable for development and use. Groundwater in the area is not used for any purpose, and potable water is readily available from the Renton public water system. The institutional controls included in the preferred alternative have been implemented and proven by Boeing, who would continue to maintain overall responsibility for this site and ensure that the institutional controls are properly enforced. This preferred remedial alternative would attain a cleanup standard consistent with the MTCA regulations.

20.6 AOCS-001 AND -002 (BUILDING 4-81)

Alternative 1, Enhanced Bioremediation and Monitored Attenuation, has been selected as the preferred alternative for AOCs-001 and -002. This remedial alternative was defined as the baseline alternative for this site. The remediation costs for this alternative are not considered disproportionate, and this alternative provides a more rapid restoration time frame than the other alternative considered. Remediation objectives established in Section 2 and Section 11.3 of this FS report would be attained by this alternative. This alternative would also comply with applicable laws and regulations addressing cleanup and management of contaminated sites. The previously implemented remedial measure has removed much of the affected soil exceeding soil cleanup levels from the source area. The cap provided by the existing, well-maintained concrete tarmac would eliminate runoff of affected soil and limit infiltration of surface water. Enhanced bioremediation would rapidly destroy constituents present in groundwater. The rigorous groundwater monitoring program would ensure that the cleanup standard is attained at the CPOC, which is located on site, upgradient from the Lake

Washington shoreline. The proven institutional controls would continue to be implemented to ensure that worker health and safety continue to be maintained. This alternative would attain a cleanup standard consistent with the MTCA regulations within a reasonable time frame.

20.7 AOC-003 (BUILDING 4-81)

Alternative 2, Enhanced Bioremediation and Monitored Attenuation, is the preferred remedial alternative for AOC-003. This alternative was defined as the baseline alternative for this site; the remediation costs for this alternative are not considered disproportionate; and this alternative provides more rapid remediation than the other alternative considered. Remediation objectives established in Section 2 and Section 12.3 of this FS report would be attained by this alternative. This alternative would also comply with applicable laws and regulations addressing cleanup and management of contaminated sites. Enhanced bioremediation would permanently degrade or "treat" organic COCs over the long term using enhanced natural processes that result in nontoxic degradation products. Affected soils would remain capped by the well-maintained tarmac or pavement to prevent potential runoff of affected soil and limit infiltration of rainfall. Groundwater in the area is not used for any purpose, and potable water is readily available from the Renton public water system. The institutional controls included in Alternative 2 have been implemented and proven by Boeing, who would continue to maintain overall responsibility for this site and ensure that the institutional controls are properly enforced.

The groundwater cleanup standard for this alternative will be the groundwater cleanup levels for AOC-003 COCs summarized in Table 3-2 and an on-site CPOC located downgradient of this site and upgradient of AOCs-001 and -002. The soil and groundwater cleanup levels would be attained by this remedial alternative within a reasonable time frame. Given that potential risks from the site COCs in soil and groundwater can be managed through institutional controls until bioremediation and MA attain cleanup levels, no other measures are required to attain remediation objectives and standards.

20.8 AOC-004 (BUILDING 4-21)

Alternative 2, Enhanced Bioremediation and Monitored Attenuation, was selected as the preferred alternative for AOC-004. This remedial alternative was defined as the baseline alternative for this site; the remediation costs for this alternative are not considered disproportionate; and this alternative provides more rapid remediation than the other alternative considered. Remediation objectives established in Section 2 and Section 13.3 of this FS report would be attained by this alternative. The preferred alternative would also comply with applicable laws and regulations addressing cleanup and management of contaminated sites. Under the preferred alternative, limited excavation of soil would be performed in the AOC-004 source area; however, some affected soils extending beneath the adjacent building would remain, because it is not practicable to excavate adjacent to or beneath the building. Remaining affected soil would be contained by the building and well-maintained tarmac or pavement, which would prevent runoff of affected soil and limit infiltration of rainfall. Enhanced bioremediation would degrade COCs over the long term using enhanced natural processes that result in nontoxic degradation products. Groundwater in the area is not used for any purpose, and potable water is readily available from the Renton public water system. The institutional controls included in Alternative 2 have been implemented and proven by Boeing, who would continue to maintain overall responsibility for this site and ensure that the institutional controls are properly enforced.

The soil and groundwater cleanup levels for AOC-004 were summarized in Tables 3-1 and 3-2. Given that potential risks from site COCs can be managed through institutional controls, no other measures are required. The preferred alternative for this site would attain a cleanup standard consistent with the MTCA regulations.

20.9 AOC-034/035 (BUILDING 4-41)

Alternative 2, Enhanced Bioremediation and Monitored Attenuation, is the preferred remedial alternative for AOC-034/035. This alternative was defined as the baseline alternative for this site; the remediation costs for this alternative are not considered disproportionate; and this alternative provides more rapid remediation than the other alternative considered. Remediation objectives established in Section 2 and Section 14.3 of this FS report would be attained by this alternative. This alternative would also comply with applicable laws and regulations addressing cleanup and management of contaminated sites. Affected soils would remain capped by the building and the adjacent pavement to prevent potential runoff of affected soil and limit infiltration of rainfall. Groundwater in the area is not used for any purpose, and potable water is readily available from the Renton public water system. The institutional controls included in Alternative 2 have been implemented and proven by Boeing, who would continue to maintain overall responsibility for this site and ensure that the institutional controls are properly enforced.

The groundwater cleanup standard for this alternative will be the groundwater cleanup levels for VC at AOC-034/035 summarized in Table 3-2 and an on-site CPOC located downgradient of this site. The soil and groundwater cleanup levels would be attained by this remedial alternative within a reasonable time frame. Given that potential risks from the site COCs in soil and groundwater can be managed through institutional controls until bioremediation and MA attain cleanup levels, no other measures are required to attain remediation objectives and standards.

20.10 AOC-060 (BUILDING 4-42)

Alternative 1, Monitored Natural Attenuation, was selected as the preferred remedial alternative for AOC-060, because it would provide the greatest benefit at the lowest cost. Substantial evidence was collected during the RI and subsequent quarterly monitoring to demonstrate that natural biodegradation of organic COCs is active at this site. Remediation objectives established in Section 2 of this FS report would be attained by this alternative. The preferred alternative would also comply with applicable laws and regulations addressing cleanup and management of contaminated sites. Groundwater samples collected downgradient of the source areas and upgradient of the Cedar River Waterway show that groundwater COCs have migrated off the Facility property but have not been detected in monitoring wells located close to the Cedar River Waterway since 2002. Modeling of natural attenuation at this site agrees with actual monitoring well data and indicates that groundwater cleanup levels would be attained at the off-site CPOC located in the Cedar River Trail Park within a reasonable time frame. Although groundwater COC concentrations have exceeded cleanup levels in a limited portion of the park, they would present no significant risks to park users.

Under Alternative 1, affected soils would remain capped by either buildings or the well-maintained site tarmac or pavement, which would prevent potential runoff of affected soil and limit infiltration of rainfall. The City of Renton is the property owner for the Cedar River Trail Park and Nishiwaki Lane; the City of Renton has indicated general agreement to allow a CPOC to be located in the park. Groundwater in the area is not used for any purpose, and potable water is readily available from the Renton public water system. The institutional controls included in the preferred alternative have been implemented and proven effective by Boeing, who would continue to maintain overall responsibility for this site and ensure that the institutional controls are properly enforced.

20.11 AOC-090 (BUILDING 4-65)

Alternative 2, Enhanced Bioremediation and Monitored Attenuation, would provide the greatest benefit and has an intermediate cost; therefore, Alternative 2 is the preferred remedial alternative for the AOC-090 site. Evidence from the final RI Report demonstrates that natural biodegradation of organic soil and groundwater COCs is active at this site. The 2004 interim action provided substantial reduction in concentration of source area COCs as a result of enhanced bioremediation. Affected soils have already been removed from AOC-090 to the extent practicable; existing underground utilities preclude additional soil removal. Enhanced bioremediation would continue the rapid biodegradation of groundwater COCs that has been achieved as a result of the 2004 interim measure. The active remediation program included in Alternative 2 would be expected to reduce the downgradient concentrations within a reasonable time frame. Thus, the preferred alternative is expected to achieve compliance with MTCA requirements after allowing time to continue the ongoing remediation program.

Remediation objectives established in Section 2 and Section 16.3 of this FS report would be attained by this alternative. Modeling shows active measures needed. The cleanup levels to be attained by this alternative are summarized in Tables 3-1 and 3-2. While the groundwater plume extends beyond the property line, the off-site area, owned by the City of Renton, consists of a public road and the Cedar River Trail Park (also owned by the City). The City of Renton has indicated that they are generally agreeable to allowing a CPOC to be located on City property. Groundwater in the area is not used for any purpose, and potable water is readily available from the Renton public water system. A risk assessment presented in the FSWP indicates that the VOCs present in groundwater beneath the park do not create a significant risk to park users.

20.12 AOC-092 (BUILDING 4-20)

Alternative 2, Source Area Excavation, Enhanced Bioremediation, and Monitored Attenuation, is the preferred remedial alternative for AOC-092. This alternative was defined as the baseline alternative for this site; the remediation costs for this alternative are not considered disproportionate; and this alternative provides more rapid remediation than the other alternative considered. Remediation objectives established in Section 2 and Section 17.3 of this FS report would be attained by this alternative. The preferred alternative would also comply with applicable laws and regulations addressing cleanup and management of contaminated sites.

Under this remediation approach, affected soils would be removed from the site to the extent practicable, and groundwater constituents would be actively degraded in situ using enhanced bioremediation. Affected soils under the adjacent building would remain beneath the building, which would contain the soils, prevent potential runoff of affected soil, and limit infiltration of rainfall to the source area. Groundwater in the area is not used for any purpose, and potable water is readily available from the Renton public water system. The institutional controls included in the preferred alternative have been implemented and proven by Boeing, who would continue to maintain overall responsibility for this site and ensure that the institutional controls are properly enforced. This remedial approach would attain cleanup standards consistent with the MTCA regulations.

20.13 AOC-093 (BUILDING 4-20)

Alternative 1, Source Area Excavation and Monitored Natural Attenuation, is the preferred remedial alternative for AOC 093. Limited excavation of soil would be performed; however, some affected soils would remain covered by tarmac or pavement, which would prevent potential runoff of affected soil and limit infiltration of rainfall. Remediation objectives established in Section 2 and Section 18.3 of this FS report would be attained by this alternative. The preferred alternative would also comply with applicable laws and regulations addressing cleanup and management of contaminated sites. Groundwater in the area is not used for any purpose, and potable water is readily available from the Renton public water system. The institutional controls included in this remedial alternative have been implemented and proven by Boeing, who would continue to maintain overall responsibility for this site and ensure that the institutional controls are properly enforced. Given that only TPH-G was detected in soil and no site COCs were detected in groundwater, risks from this site can be managed through institutional controls.

Groundwater monitoring data indicate that biodegradation of organic COCs is active at the site. The groundwater cleanup levels would be attained by this alternative at an on-site CPOC located immediately downgradient from AOC-093 within a reasonable time frame. A rigorous groundwater monitoring program would be implemented to ensure that this alternative attains the cleanup standard.

20.14 AOC-094 (BUILDING 5-08)

No remedial action is needed at AOC-094 to achieve compliance with applicable environmental regulations. The only COC identified at this site is TPH-G in soil; measured concentrations exceeded the MTCA Method A soil cleanup level. Site data indicate that groundwater has not been affected by the TPH-G present in soil. Therefore, only soil has been affected for AOC-094. Site-specific data for EPH and VPH were used to calculate soil cleanup levels for this site, as discussed in Section 19 of this FS report. The calculations were done in accordance with MTCA requirements and using calculation tools provided by Ecology. The results of these calculations indicate that the measured TPH-G concentration is below the MTCA Method B cleanup level. Therefore, the site is currently in compliance with MTCA regulations and no remedial action is necessary. The standard POC for soil and groundwater has been achieved at AOC-094.

TABLE 20-1

PREFERRED REMEDIAL ALTERNATIVES

Boeing Renton Facility
Renton, Washington

Site	Key Issues	Preferred Alternative	Initial Cost[1]	Net Present Value[1]
SWMU-168 (Building 5-50)	Small site on leased property. Soil COCs: methylene chloride (low concentration). Groundwater COCs: VC (low concentration).	**Alternative 3 - Enhanced Bioremediation and Monitored Attenuation:** Injected substrate to address groundwater COCs. Existing cap will stabilize COCs. On-site CPOC near leased property line.	$57,800	$409,000
SWMUs-172/174, (Buildings 5-08 & 5-09)	Moderate size site on leased property. Soil COCs: PCE, TCE, methylene chloride, benzene, metals. Groundwater COCs: PCE, TCE, 1,1-DCE, *cis* -1,2-DCE, methylene chloride, VC, chloromethane, benzene, *bis* -2-ethylhexyl phthalate, metals. Affected soils extend beneath bldg. Groundwater VOC plume extending to lease property line. Strong evidence of active natural biodegradation.	**Alternative 2 - Soil Vapor Extraction, Enhanced Bioremediation, Monitored Attenuation.** SVE addresses source area. Enhanced bioremediation for plume control. On-site CPOC near leased property line.	$354,600	$900,000
SWMU-179 (Building 4-76)	Small site; located on Facility property. Excavation and removal of affected soil completed in 2004. Confirmation sampling for soil and groundwater confirm attainment of cleanup levels.	Cleanup completed. No further action required.	$0	$0
Building 4-78/79 SWMU/AOC Group	Large site on Facility property. Two separate source areas for solvents (former container storage area) and TPH-G/benzene (fuel USTs and piping). Solvent source area beneath Bldg. 4-78. Two offset plumes with slight overlap. Soil COCs: TCE, *cis* -1,1-DCE, *cis* -1,2-DCE, VC, TPH-G, benzene. Groundwater COCs: TCE, 1,2-DCE, VC, TPH-G, benzene. Strong evidence of natural biodegradation.	**Alternative 2 - Soil Vapor Extraction, Enhanced Bioremediation, Monitored Attenuation, and Monitored Natural Attenuation:** SVE addresses both soil source areas. Enhanced bioremediation for solvent source area and plume. MNA for TPH-G/benzene plume. On-site CPOC.	$464,300	$1,140,000

TABLE 20-1

PREFERRED REMEDIAL ALTERNATIVES
Boeing Renton Facility
Renton, Washington

Site	Key Issues	Preferred Alternative	Initial Cost[1]	Net Present Value[1]
Former Fuel Farm	Large site located on leased property. Residual TPH remains at eastern edge of lease property. An air sparge/bioventing interim measure has been operated at site for about 9 years. Soil COCs: TPH-Jet Fuel, TPH-D, benzene, methylnaphthalene. Groundwater COCs: TPH-Jet Fuel, TPH-D. Absence of downgradient plume indicates biodegradation is active.	**Alternative 3 - Monitored Natural Attenuation:** BIOSCREEN modeling shows that MNA would be effective. On-site/Off-site CPOC.	$46,000	$482,000
AOCs-001 and -002 (Building 4-81)	Primary and secondary source areas; site is on Facility property. Soil COCs: TPH-G, *cis*-1,2-DCE, TCE, and VC. GW COCs: TCE, *cis*-1,2 DCE, and VC. Strong evidence of active natural biodegradation.	**Alternative 1 - Enhanced Bioremediation and Monitored Attenuation:** Primary source area to be excavated into shallow water table. Enhanced bioremediation for primary and secondary source areas. On-site CPOC.	$78,900	$524,000
AOC-003 (Building 4-81)	Small site; located on Facility property. Soil COCs: TCE (low concentration). GW COCs: PCE (low concentration) and VC (low concentration). Strong evidence of active natural biodegradation.	**Alternative 2 - Enhanced Bioremediation, and Monitored Attenuation:** Bioremediation for source area and plume. On-site CPOC upgradient of AOCs-001 and -002.	$67,400	$405,000
AOC-004 (Building 21)	Small site; located on Facility property. Soil COCs: benzene, ethylbenzene, toluene, acetone, TPH-G. Groundwater COCs: benzene (low concentrations), TPH-G (low concentrations), lead (low concentrations). Limited plume suggests active natural biodegradation.	**Alternative 2 - Enhanced Bioremediation and Monitored Attenuation:** Excavation of source area soil in vadose zone, enhanced bioremediation for source area groundwater. Monitored attenuation for groundwater plume. On-site CPOC.	$89,400	$382,000

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TABLE 20-1

PREFERRED REMEDIAL ALTERNATIVES
Boeing Renton Facility
Renton, Washington

Site	Key Issues	Preferred Alternative	Initial Cost[1]	Net Present Value[1]
AOC-034/035 (Building 4-41)	Small site; located on Facility property. Soil COCs: VC, *cis* -1,2-DCE. Groundwater COCs: VC, cis-1,1-DCE. Limited plume suggests active natural biodegradation.	**Alternative 2 - Enhanced Bioremediation and Monitored Attenuation:** Enhanced bioremediation for source area groundwater. Monitored attenuation for groundwater plume. On-site CPOC.	$61,000	$371,000
AOC-060 (Building 4-42)	Moderate site; source area on Facility property, plume extends off-site. Groundwater COCs: TCE, *cis* -1,2-DCE, VC. Plume presents no unacceptable risks to Cedar River Trail Park users. Strong evidence for natural biodegradation.	**Alternative 1 - Monitored Natural Attenuation:** BIOCHLOR modeling indicates that MNA would be effective in meeting remediation objectives. Off-site CPOC.	$32,300	$521,000
AOC-090	Large site; source area located on Facility property, plume extends off-site. Extensive source area soil excavation completed in 2004; enhanced bioremediation implemented for source area. Soil COCs: chlorinated solvents, petroleum hydrocarbons (gasoline, diesel, motor oil), metals. Groundwater COCs: chlorinated solvents, petroleum hydrocarbons (gasoline, diesel, motor oil). Strong evidence for active natural biodegradation of groundwater COCs.	**Alternative 2 - Enhanced Bioremediation and Monitored Attenuation:** Enhanced bioremediation implemented in Summer 2004 to be continued. Off-site CPOC.	$63,800	$670,000
AOC-092 (Building 4-20)	Small site; located on Facility property. Soil COCs: benzene, TPH-G. Groundwater COCs: benzene, TPH-G. Limited plume length suggests active natural biodegradation.	**Alternative 2 - Source Area Excavation, Enhanced Bioremediation, and Monitored Attenuation:** Excavate source area vadose zone soils. Enhanced bioremediation for source area with monitored attenuation for groundwater plume. On-site CPOC.	$58,200	$364,000

TABLE 20-1

PREFERRED REMEDIAL ALTERNATIVES

Boeing Renton Facility
Renton, Washington

Site	Key Issues	Preferred Alternative	Initial Cost[1]	Net Present Value[1]
AOC-093 (Building 4-20)	Small site located on Facility property. Soil COCs: TPH-G. No groundwater COCs detected. Located within groundwater plume for AOCs-001 and -002. Absence of groundwater COCs indicates active natural biodegradation.	**Alternative 1 - Source Area Excavation and Monitored Natural Attenuation:** Limited excavation and long-term monitoring, with monitoring program for AOCs-001 and -002 to confirm attainment of cleanup standard. On-site CPOC.	$29,700	$286,000
AOC-094	Small site; located on leased property. TPH-G detected in soil; no affected groundwater detected. Soil TPH-G is below cleanup level calculated using EPH/VPH data.	Preliminary assessment of TPH/EPH/VPH data indicate that soil TPH-G is below cleanup level. No remedial action is required.	$0	$0
		TOTAL	**$1,403,400**	**$6,454,000**

Notes:
1. Initial cost is the first year cost for implementation of the preferred alternative. Net Present Value cost is the present worth for full implementation of the alternative over a 15-year life with a 2% inflation rate and 7% discount rate. Details concerning the cost estimate are presented in Appendix B. All costs are in 2007 dollars.

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APPENDIX A

Groundwater Fate and Transport Modeling

GROUNDWATER FATE AND TRANSPORT MODELING
Boeing Renton Facility
Renton, Washington

A-1.0 INTRODUCTION

This appendix describes groundwater fate and transport modeling performed in support of evaluating potential remedial alternatives for the Feasibility Study (FS) at the Boeing Renton Facility. Geomatrix Consultants, Inc. (Geomatrix), performed modeling to predict concentrations of groundwater constituents of concern (COCs) at conditional points of compliance (CPOCs) that achieve Model Toxics Control Act (MTCA) cleanup levels protective of surface water. This modeling was done for the Solid Waste Management Units (SWMUs) and Areas of Concern (AOCs) addressed in the FS. These SWMUs and AOCs include eight sites with groundwater affected by chlorinated volatile organic compounds (VOCs) and five sites with groundwater affected by petroleum hydrocarbons. The modeling was performed to support development and evaluation of remedial alternatives considered in the FS and to establish proposed cleanup levels.

A-1.1 MODELING OBJECTIVES

The objectives of the fate and transport modeling were to:

- Predict the maximum groundwater COC concentrations at the CPOCs that would naturally attenuate to achieve applicable cleanup levels protective of surface waters at the point groundwater enters surface water; and
- Estimate MTCA Method C soil cleanup levels that are protective of groundwater for each SWMU and AOC addressed in the FS.

The groundwater modeling results were used to ensure that the CPOC groundwater cleanup levels proposed in the FS were protective of surface water (i.e., the proposed CPOC cleanup level cannot exceed the maximum modeled CPOC concentration that would attenuate to MTCA Method A or B criteria at surface water). The groundwater results were then applied during a subsequent stage of modeling to establish the maximum concentrations of COCs in soil that would be protective of the modeled maximum concentration in groundwater. The modeling results were used in the FS to establish the proposed groundwater cleanup levels applicable at the CPOC. This approach used to establish proposed soil and groundwater cleanup levels is described in Section 3 of the FS.

A-1.2 MODEL SELECTION

Natural attenuation modeling was performed using BIOCHLOR (ver. 2.2) and BIOSCREEN (ver. 1.4) software. These modeling programs were developed on behalf of the U.S. Air Force Center for Environmental Excellence by Groundwater Services, Inc., to assess natural attenuation of solutes in groundwater. The software has been accepted by the U.S. Environmental Protection Agency (EPA) and is available for download from the EPA CLU-IN web site (http://www.clu-in.org/).

BIOCHLOR simulates the natural attenuation of commonly found chlorinated solvents. BIOCHLOR is a Microsoft® Excel programmed spreadsheet that simulates one-dimensional advection, three-dimensional dispersion, linear adsorption, and biotransformation via reductive dechlorination for chlorinated solvents. BIOCHLOR was used to model SWMU/AOC groups in which chlorinated VOCs were the primary COCs.

BIOSCREEN simulates the degradation of dissolved petroleum hydrocarbons. BIOSCREEN is also a Microsoft Excel programmed spreadsheet that simulates one-dimensional advection, three-dimensional dispersion, linear adsorption, and both aerobic and anaerobic biological decay of petroleum hydrocarbons. BIOSCREEN was used to model SWMU/AOC groups in which fuel constituents and benzene were COCs.

A-2.0 MODELING APPROACH

Modeling was performed in four stages:

1. Model calibration, where possible.
2. Predicting maximum concentrations within the source areas and at the CPOCs that achieve cleanup levels proposed in this FS.
3. Natural attenuation screening.
4. Calculation of MTCA Method C soil cleanup levels protective of groundwater and surface water.

Each of these modeling stages is discussed in the following sections.

A-2.1 STAGE 1 - MODEL CALIBRATION

In the first stage, if sufficient downgradient groundwater quality data were available, models for each SWMU/AOC group were calibrated such that model-predicted concentrations of

COCs approximated concentrations measured in samples from site wells and/or push probes. The primary parameters adjusted to improve model calibration were degradation half-lives of the VOC and fuel constituent COCs. BIOCHLOR models for chlorinated VOCs that were calibrated to field data included SWMU-172/174, AOC-001/-002, AOC-060, and AOC-090. The BIOSCREEN model for total petroleum hydrocarbons, gasoline range (TPH-G) and benzene at AOC-092 was also calibrated to field data. Degradation half-lives used in the calibrated models were adjusted within the range of half-lives found in published literature (Table A-1). In two areas (AOC-001/-002 and AOC-060) the assumed time since release of COCs to groundwater at a given site was increased from 30 years before present to 50 years before present to achieve a better calibration. This change was considered reasonable, based on the long operational histories of these areas. Historical information indicates that these areas have been active since the 1940s.

If sufficient downgradient data were not available, model calibration was not performed and default degradation half-lives and release times specified in the Final Feasibility Study Work Plan (FSWP) were used (Geomatrix, 2004). Either the calibrated models or the default parameter value models (if calibration was not performed) were used in subsequent modeling, as described below. Input parameters for the models are provided in Tables A-2, A-3, and A-4. A summary of the measured and predicted concentrations from the calibrated models is presented for BIOCHLOR and BIOSCREEN in Tables A-5 and A-6, respectively.

A-2.2 STAGE 2 – MAXIMUM SOURCE AREA CONCENTRATIONS AND RESULTING CONCENTRATIONS AT THE CPOCS

Stage 2 modeling was done in support of establishing proposed groundwater cleanup levels for the CPOC that are protective of groundwater and to provide a basis for Stage 4 modeling to determine soil cleanup levels protective of groundwater and surface water. The proposed site-specific groundwater cleanup levels applicable at the CPOCs for each of the SWMUs and AOCs were established to achieve two criteria:

- Be protective of surface water by achieving MTCA Method A cleanup levels for TPH or MTCA Method B criteria for specific COCs (see FS Table 3-2) at the point groundwater enters surface water; and
- Achieve the total risk criteria specified in the MTCA regulations (i.e., total excess cancer risk of 10^{-5} and/or a Hazard Quotient of 1.0) at the CPOC.

Stage 2 modeling results, which determined the maximum concentration at the CPOC that would attenuate to MTCA Method B criteria, were used to determine if the CPOC cleanup levels would attenuate to achieve MTCA Method B criteria protective of surface water. The potential cleanup level was then set initially at the lower of the MTCA Method B criteria or the modeled maximum CPOC concentration protective of surface water. The initial potential cleanup level was then adjusted as appropriate to ensure the Hazard Quotient was not greater than 1.0 and the total cancer risk was not greater than 10^{-5}. The risk-adjusted potential cleanup levels were then compared to the practical quantitation limits (PQLs), and the greater value was established as the proposed cleanup level, in accordance with the MTCA regulations and guidance. Details of the approach used to establish the proposed groundwater cleanup levels applicable at the CPOC are described in Section 3 of the FS. Table 3-2 of the FS summarizes the criteria and approach used to establish the proposed cleanup levels.

Modeling in Stage 2 determined the maximum concentrations in groundwater at the source area and at the CPOC that were protective of MTCA Method A or Method B groundwater cleanup criteria cited in FS Table 3-2. The Method B criteria considered in modeling are as follows: tetrachloroethene (PCE), 0.08 micrograms per liter (µg/L); trichloroethene (TCE), 0.11 µg/L; *cis*-1,2-dichloroethene (*cis*-1,2-DCE), 70 µg/L; vinyl chloride (VC), 0.025 µg/L; and benzene, 0.8 µg/L. The MTCA Method A cleanup criteria used for Stage 2 modeling are TPH-G with benzene, 800 µg/L; total petroleum hydrocarbons, diesel range (TPH-D), 500 µg/L; and total petroleum hydrocarbons, Jet fuel A range (TPH-Jet A), 500 µg/L. As further noted in Section 3 of the FS, the Method B cleanup criteria were selected as the lowest criterion obtained from the CLARC website, taking into consideration the standard Method B formulae (carcinogens and noncarcinogens) and applicable or relevant and appropriate requirements (ARARs) for fresh surface water, groundwater, and drinking water. The MTCA Method A cleanup criteria are generally applicable to simple sites and are considered protective of surface water. Thus, the Method B and Method A criteria used in this modeling are protective of surface water.

Maximum source area groundwater concentrations protective of surface water were modeled by iteratively adjusting the source area groundwater concentrations input to the calibrated or default parameter models until predicted groundwater concentrations near the surface water receptor met the Method B or Method A cleanup criteria. These results are presented in Tables A-7 and A-8 for chlorinated and nonchlorinated COCs, respectively.

Using the maximum source area concentrations determined to be protective of surface water, the models were used to estimate maximum COC concentrations at the CPOCs (i.e., the modeled concentration at the CPOC using the maximum source area concentration) that are protective of surface water (i.e., would attenuate to the Method A or Method B cleanup criteria at the point groundwater enters surface water). The maximum CPOC concentrations protective of surface water are tabulated in Table A-7 for BIOCHLOR results and in Table A-8 for BIOSCREEN results.

A-2.3 STAGE 3 - NATURAL ATTENUATION SCREENING

The third modeling stage consisted of natural attenuation screening to evaluate whether natural attenuation is likely to reduce current source area groundwater COC concentrations to below proposed groundwater cleanup levels at the site CPOCs. Natural attenuation screening was performed by modeling groundwater COC concentrations at the CPOC locations using existing, measured source area concentrations as inputs into the default or calibrated models for each AOC or SWMU. The predicted COC concentrations at the CPOCs are presented in Tables A-7 and A-8. These predicted values were then compared to the site-specific proposed groundwater cleanup levels at the CPOCs established in Section 3 of the FS to evaluate whether natural attenuation would likely attain the proposed groundwater cleanup levels at the CPOCs. Results of this modeling are tabulated in Tables A-7 and A-8 and discussed further in Section A.4.

A-2.4 STAGE 4 – MTCA METHOD C SOIL CLEANUP LEVELS

Stage 4 modeling was used to determine Method C soil cleanup levels that are protective of groundwater. The soil cleanup levels were determined using partitioning models to calculate the soil concentration that is protective of the maximum protective groundwater concentration, considering attenuation between the source area and surface water.

In order to determine the maximum protective source area concentration, groundwater modeling was used to predict the maximum source area groundwater concentrations that would attenuate to the lower of:

- The proposed CPOC cleanup levels for groundwater; or
- The predicted maximum concentrations at the CPOC that are protective of surface water.

In some cases, the predicted maximum concentration at the CPOC that is protective of surface water (determined in Stage 2 modeling) was lower than the PQL, and the proposed cleanup level was based on the PQL. Stage 4 modeling was used to determine the maximum protective source area groundwater concentration by varying the source concentration iteratively until the predicted CPOC concentration met the lower of the above two criteria. The modeled maximum source area groundwater concentrations protective of groundwater at the CPOC are tabulated in the far right-hand column of Table A-9 and Table A-10. These source area concentrations are predicted to attain the cleanup levels and maximum concentrations protective of surface water at the CPOC.

MTCA Method C soil cleanup levels at each SWMU or AOC that are protective of groundwater at the CPOCs were then determined by partitioning calculations between soil and the maximum source area groundwater concentration protective of groundwater at the CPOCs. These calculations were completed using the MTCA three-phase partitioning model (Washington Administrative Code [WAC] Chapter 173-340-747). Modeling was completed using default values specified in MTCA, except for soil total organic carbon (TOC) content, which was based on site-specific data. TOC data are discussed further in Section A-3.1. The resulting Method C soil cleanup levels are tabulated in Table A-11.

At the Building 4-78/4-79 SWMU/AOC Group, the Former Fuel Farm, AOC-004, AOC-090, and AOC-092, the maximum predicted source area groundwater concentrations of TPH were unrealistically high (greater than 100,000 µg/L). In these cases, the maximum source area groundwater concentration used as input to the three-phase partitioning model was capped at 100,000 µg/L. Although source area soil concentrations for TPH constituents established through modeling and partitioning calculations are as high as 68,000 mg/kg, the soil cleanup levels proposed in the FS for TPH constituents must also consider residual saturation, MTCA requirements of no accumulation of free product, and potential human health impacts. The modeled source area concentrations for TPH were considered in establishing proposed soil cleanup levels in Section 3 of the FS. As noted in Section 3, proposed soil cleanup levels for TPH are based on MTCA Method A criteria for industrial properties.

A-3.0 MODEL INPUT PARAMETERS

This section describes selection of model input parameters for the BIOSCREEN and BIOCHLOR models. Input parameters common to both models are described first, followed by input parameters specific to the BIOCHLOR and BIOSCREEN models.

A-3.1 COMMON MODEL INPUT PARAMETERS

BIOCHLOR and BIOSCREEN utilize a number of the same input parameters describing hydrogeologic and chemical transport conditions. These parameters include hydraulic conductivity, hydraulic gradient, porosity, soil bulk density, and soil TOC. Values for these parameters common to both models are presented in Table A-2 and discussed further in the following sections.

A-3.1.1 Hydraulic Conductivity

Hydraulic conductivity values were based on the results of slug tests performed during the RI in wells completed in soil types similar to the predominant soil types at each AOC or SWMU. Table A-2 presents the predominant soil type at each AOC or SWMU and the associated hydraulic conductivity value. The hydraulic conductivity for sand (soil type SP) of 2.15 x 10^{-3} centimeters per second (cm/s) was calculated from the geometric mean of eight slug tests conducted in this soil type throughout the facility. The hydraulic conductivity for silty sand (soil type SM) of 8.96 x 10^{-4} cm/s was calculated from the geometric mean of 13 slug tests conducted in this soil type.

A-3.1.2 Hydraulic Gradient

Hydraulic gradient values were calculated based on contoured groundwater elevation data from each AOC or SWMU. Groundwater elevation contours for each AOC and SWMU are shown on Figures A-1 through A-11, and hydraulic gradients used in the models are presented on Table A-2. Except as noted below, groundwater elevation data collected in February 2007 at the Building 4-78/4-79 SWMU/AOC Group, AOC-001/002, AOC-003, AOC-060, and AOC-090 were used to calculate hydraulic gradients at these locations.

Three hydraulic gradient values were used in the models for AOC-090. In the shallow groundwater flow system two hydraulic gradient values were calculated which are representative of the generally northward and southward flow paths from the soil source area to the Cedar River. A third hydraulic gradient value was assigned for the intermediate-depth groundwater flow system based on the groundwater elevation map shown in Figure 16-2. This map is taken from the RI and is based on water level measurements collected on August 18, 2000 (Weston, 2001).

Groundwater elevation data are not routinely collected at SWMU-168, SWMU-172/174, AOC-004, AOC-034/035, and AOC-092. September 2000 groundwater elevation contours from the RI Report were used to calculate hydraulic gradients at these locations. With the exception of SWMU-172/174, few or no wells exist at these locations for measurement of groundwater elevations, and groundwater elevation contours are based instead on facility-wide contours of groundwater elevation data.

Due to the effects of an ongoing interim action, including an air sparge system, groundwater elevations measured at the Former Fuel Farm during normal groundwater sampling events are not representative of ambient groundwater conditions at this location. In November 2005 the air sparge system was temporarily shut down until water levels stabilized, and water level measurements were collected. These data are considered to be most representative of ambient groundwater flow conditions at the Former Fuel Farm and were used to calculate hydraulic gradients for this effort.

A-3.1.3 Porosity and Bulk Density

Default values specified in the MTCA three-phase partitioning model (WAC 173-340-747) were assigned for the parameters of soil bulk density (1.5 kilograms per liter [kg/L]) and soil porosity (0.43).

A-3.1.4 Total Organic Carbon

The soil TOC was based on a statistical evaluation of soil TOC values and soil type described in the FSWP (Geomatrix, 2004). Soil TOC values were assigned based on the predominant soil type at each AOC or SWMU, with values of 0.84 percent for silty sand (SM) and 0.46 percent for sand (SP).

A-3.2 BIOCHLOR INPUT PARAMETERS

Input parameters specific to the BIOCHLOR models include source area concentrations, degradation half-lives, model dimensions (source width and thickness, model length, distances to CPOC and surface water), and dispersivity. Values for these parameters are presented on Table A-3 and discussed further in the following sections.

A-3.2.1 Source Area Concentrations

For model calibration and natural attenuation screening, source area concentrations were generally taken as the maximum measured values as presented in the final RI Report (Weston, 2001) or from subsequent investigations reported in the FSWP, site-specific reports, and quarterly monitoring reports. Figures A-1 through A-8 and Table A-3 present source area concentration data from wells and push probes used in the modeling. These data are discussed further in Section A-4. At AOC-001/002 a soil removal interim action completed in 2005 has significantly reduced source area groundwater VOC concentrations. At this location data collected in 2003 and 2004, prior to the interim action, were used to calibrate the model, while February 2007 data were used for natural attenuation screening.

A-3.2.2 Degradation Half-Lives

For the models that were not calibrated, half-lives for PCE, TCE, *cis*-1,2-DCE, and VC were set by default at 1.97, 4.53, 1.00, and 7.88 years, respectively, as specified in the FSWP. The half-lives were adjusted as calibration parameters at SWMU-172/174, AOC-001/002, AOC-060, and AOC-090, where sufficient data were available to perform model calibration. Data used for calibration are shown on Table A-5 and Figures A-2, A-4, A-7, and A-8. Default and final calibrated half-lives (Table A-3) are within the range of published degradation half-lives (Aronson and Howard, 1997; Wiedemeier et al., 1999), as shown on Table A-1. Model calibration to establish calibrated half-lives is discussed further in Section A-4.

A-3.2.3 Model Dimensions

The source area dimensions were based on figures in the final RI Report and final FSWP. Distances to the on-site and off-site CPOCs, as appropriate, and to surface water are based on Figures A-1 through A-11 and were used to establish the model dimensions. The model run time during calibration was generally set to 30 years, based on an assumed time before present when a release to groundwater may have occurred. During calibration, model run time at AOC-001/002 and AOC-060 was increased to 50 years in order to improve the calibration. Both of these areas were active areas of the facility more than 50 years ago, and a 50-year-old potential release date is a reasonable assumption. Predictive simulations for natural attenuation screening, for determining maximum concentrations in source area groundwater protective of surface water, and for determining concentrations at the CPOC protective of surface water used a run time of 1,000 years in order to reach steady-state conditions.

A-3.2.4 Dispersivity

Dispersivity was assigned a value of one-tenth the total flow path length from the source area to the surface water receptor (Table A-3). Within each AOC or SWMU the same dispersivity value was used regardless of whether the model run was used to predict concentrations between the source area and the CPOC or the source area and surface water.

A-3.3 BIOSCREEN Input Parameters

Input parameters specific to the BIOSCREEN models include source area concentrations, degradation half-lives, model dimensions (source width and thickness, model length, distances to CPOC), and dispersivity. Values for key parameters are presented on Table A-4 and discussed further in the following sections.

A-3.3.1 Source Area Concentrations

For model calibration and natural attenuation screening, source area concentrations were taken as the maximum measured values as presented in the final RI Report (Weston, 2001) or from subsequent investigations reported in the final FSWP, site-specific reports, and quarterly monitoring reports. Figure A-3, Figures A-8 through A-11, and Table A-4 present source area concentration data from wells and push probes used in the modeling.

A-3.3.2 Degradation Half-Lives

For the models that were not calibrated, the degradation half-lives were the default values in BIOSCREEN. The half-lives were adjusted as calibration parameters at AOC-092, where sufficient data were available to perform model calibration. Data used in model calibration for AOC-092 are shown on Table A-6 and on Figure A-11.

A-3.3.3 Model Dimensions

The source area dimensions were based on figures in the final RI Report and final FSWP. Distances to the on-site and off-site CPOCs, as appropriate, and to surface water are based on Figures A-3 and A-8 through A-11 and were used to establish the model dimensions. The model run time during calibration was set to 30 years, based on an assumed time before present when a release to groundwater may have occurred. Predictive simulations for natural attenuation screening and determining maximum source area concentrations and cleanup levels at the CPOC protective of surface water used a run time of 1,000 years in order to reach steady-state conditions.

A-3.3.4 Dispersivity

Dispersivity was assigned a value of one-tenth the total flow path length from the source area to the surface water receptor. Within each AOC or SWMU the same dispersivity value was used regardless of whether the model run was used to predict concentrations between the source area and the CPOC or the source area and surface water.

A-4.0 MODEL IMPLEMENTATION AND RESULTS

This section presents results of BIOCHLOR chlorinated VOC and BIOSCREEN TPH and benzene modeling and calculation of source area soil cleanup levels.

A-4.1 BIOCHLOR Chlorinated VOC Model Results

Results of BIOCHLOR model calibration are shown in Table A-5. In general, model calibration significantly improved the accuracy of predicted groundwater concentrations at downgradient wells. Modeled maximum source area groundwater concentrations that are predicted to meet the Method B cleanup criteria at surface water (as listed in Table 3-2 of this FS), predicted concentrations at the CPOCs that are protective of surface water, and natural attenuation screening results based on current source area concentrations are presented in Table A-7. BIOCHLOR model implementation and results for each SWMU and AOC are discussed in the following sections.

A-4.1.1 SWMU-168

Downgradient water quality data were not available to calibrate the model for SWMU-168 (Figure A-1). For this site, the default degradation half-lives of 1.97, 4.53, 1.00, and 7.88 years for PCE, TCE, *cis*-1,2-DCE, and VC, respectively, were used in the model. Source area groundwater quality data for natural attenuation screening were selected as the maximum concentration from four push probe groundwater samples collected in 1999. VC, at a concentration of 2.1µg/L, was the only chlorinated VOC detected at SWMU-168.

The CPOC is located approximately 30 feet downgradient from the source area and 95 feet upgradient from the Cedar River Waterway. Model results indicate that a maximum source area VC concentration of 0.23 µg/L and concentration at the CPOC of 0.11 µg/L would attenuate to below Method B cleanup criteria protective of surface water prior to reaching the waterway. The proposed CPOC cleanup level for this SWMU is 0.11 µg/L. The modeling suggests that the source area concentration of 2.1 µg/L is not likely to attenuate to below the proposed cleanup level before reaching the CPOC (Table A-7). Active remedial actions to reduce source area concentrations at this SWMU have been evaluated in the FS.

A-4.1.2 SWMU-172/174

Source area concentrations for this model were taken as the maximum of June 1999 and August 2000 data from well GW152 and calibrated using August 2000 data from well GW172 as a downgradient calibration target (Figure A-2). Data from push probes were also reviewed for use as source area (PP006) and downgradient (PP061) water quality data for calibration. PCE concentrations at PP006 (300 µg/L) were higher than at GW152 (53 µg/L). The higher concentrations at PP006 were not used in model calibration, because a higher source area concentration would result in lower calibrated degradation half-lives (i.e., more rapid degradation), which would result in a greater degree of degradation predicted in model runs. As a conservative measure, source area data were instead limited to well GW152. Downgradient push probe PP061 shows higher concentrations than the source area and was not used for model calibration. Wells GW152 and GW172 appear to be on a groundwater flow path, while push probe PP061 is cross-gradient. Based on these data, GW152 was selected as the source area and GW172 as the downgradient calibration target.

Table A-5 presents model calibration results between GW152 and GW172 using default and calibrated degradation half-lives. Table A-3 presents the calibrated degradation half-lives. The default and calibrated models give similar results for *cis*-1,2-DCE and VC; however, the calibrated model significantly improves the match between observed and predicted PCE and TCE groundwater concentrations.

The CPOC is located approximately 85 feet downgradient from the source area and 60 feet upgradient from the Cedar River Waterway. Model results indicate that maximum source area concentrations of PCE, TCE, *cis*-1,2-DCE, and VC of 0.4, 0.4, 0.4, and 0.5 µg/L, respectively, would attenuate to below Method B cleanup criteria protective of surface water prior to reaching the waterway. Modeled COC concentrations at the CPOC that are protective of surface water range from less than 0.01 µg/L for PCE and TCE to 0.11 µg/L for VC (see Table A-7). The modeling suggests that the current source area concentrations are not likely to attenuate to below these concentrations before reaching the CPOC (Table A-7). Active remedial actions to reduce source area concentrations at SWMU-172/174 have been evaluated in the FS.

A-4.1.3 Building 4-78/4-79 SWMU/AOC Group

Available downgradient water quality data were not used to calibrate the model for this SWMU/AOC group (Figure A-3). A hydraulic containment interim action operated at this SWMU/AOC group from 1991 through November 2003, and water quality data collected from the apparent downgradient direction may not be representative of ambient fate and transport conditions at the site. Instead of model calibration, the conservative, default degradation half-lives were used for modeling natural attenuation at this site. Source area groundwater quality data for natural attenuation screening were selected as November 2006 data from well GW033, which has historically shown the highest chlorinated VOC concentrations.

The CPOC is located along the property line approximately 215 feet downgradient from the source area and 185 feet upgradient from the Cedar River Waterway. For modeling purposes, the distance from the CPOC to the source area was set conservatively at 215 feet, given that the highest concentration of chlorinated VOCs was present in samples from GW033. Model results (Table A-7) indicate that maximum source area concentrations of TCE, *cis*-1,2-DCE, and VC of 20, 120, and 120 µg/L, respectively, would attenuate to below Method B cleanup criteria protective of surface water prior to reaching the waterway. Modeled COC concentrations at the CPOC that are predicted to attain Method B cleanup criteria at surface water for TCE, *cis*-1,2-DCE, and VC are 0.8, 0.9, and 0.26 µg/L, respectively. The modeling suggests that current source area concentrations are not likely to attenuate to below these concentrations before reaching the CPOC (Table A-7). Active remedial actions to reduce source area concentrations at this SWMU/AOC group have been evaluated in the FS.

A-4.1.4 AOC-001/002

Source area and downgradient concentrations for model calibration were taken from push probe data collected between 2001 and 2004 (Figure A-4), prior to implementation of a soil removal interim action in November 2005. Source area concentrations were taken as the maximum concentrations from push probes completed in or near the soil source area. Push probes PP133 and PP098 lay generally on a flow path from the source area to Lake Washington and were used as downgradient calibration targets.

Table A-5 presents model calibration results between the source area and PP133 and PP098 using default and calibrated degradation half lives. Table A-3 presents the calibrated degradation half-lives. Only minor changes to the default degradation rates for TCE, *cis*-1,2-DCE, and VC were made. The model run time was also increased from 30 years to 50 years to improve the calibration. The calibrated model slightly overpredicts concentrations at PP098 and slightly underpredicts concentrations at PP133.

The CPOC is located approximately 285 feet downgradient from the source area and 60 feet upgradient from Lake Washington. Model results (Table A-7) indicate that maximum source area concentrations of TCE, *cis*-1,2-DCE, and VC of 1, 1, and 2 µg/L, respectively would attenuate to below Method B cleanup criteria protective of surface water prior to reaching the lake. Modeled COC concentrations at the CPOC that are protective of surface water range from 0.002 µg/L for TCE and *cis*-1,2-DCE to 0.05 µg/L for VC.

Source area concentrations used for natural attenuation screening were selected from post-soil removal interim action water quality data collected from wells in February 2007 (Figure A-5 and Table A-7). These data are expected to be more representative than historic data for predicting future fate and transport at this AOC. Based on the model results (Table A-7), the current source area concentrations are not likely to attenuate to below these concentrations for *cis*-1,2-DCE and VC before reaching the CPOC. Active remedial actions to reduce source area concentrations at AOC-001/002 have been evaluated in the FS.

A-4.1.5 AOC-003

At AOC-003 groundwater quality data are limited to four push probes completed in 1999 and one downgradient monitoring well which has been sampled since 2004 (see text Figure 12-1 for data). Because the downgradient monitoring well was installed 5 years after the push probe data were collected this well was not used for calibration purposes. Instead, the default degradation half-lives were used in this model. Source area groundwater data for natural attenuation screening are shown on Figure A-4.

The CPOC is located approximately 150 feet downgradient from the source area and 635 feet upgradient from Lake Washington. Model results (Table A-7) indicate that maximum source area concentrations of PCE, TCE, *cis*-1,2-DCE, and VC of 50, 50, 20, and 10 µg/L, respectively, would attenuate to below Method B cleanup criteria protective of surface water prior to reaching the lake. Modeled COC concentrations at the CPOC that are protective of surface water for PCE, TCE, *cis*-1,2-DCE, and VC are 0.54, 4.0, 0.78, and 4.6 µg/L, respectively. Existing source area groundwater concentrations of these constituents are expected to attenuate to below these concentrations prior to reaching the CPOC (Table A-7).

A-4.1.6 AOC-034/035

Downgradient water quality data were not available to calibrate the model for AOC-034/035; therefore, the default degradation half-lives were used in this model. Source area concentrations were selected as the maximum values from groundwater samples collected from push probes in December 2006 (Figure A-6). Only *cis*-1,2-DCE (maximum concentration of 0.5 µg/L) and VC (maximum concentration of 2.7 µg/L) were detected above the detection limits in these samples.

The CPOC is located approximately 60 feet downgradient from the source area and 290 feet upgradient from the Cedar River Waterway. Model results (Table A-7) indicate that maximum source area concentrations of *cis*-1,2-DCE and VC of 450 and 500 µg/L, respectively, would attenuate to below Method B cleanup criteria protective of surface water prior to reaching the waterway. Predicted COC concentrations at the CPOC that are protective of surface water for *cis*-1,2-DCE and VC are 0.65 and 80 µg/L, respectively. Existing source area groundwater concentrations of these constituents are expected to attenuate to below these concentrations prior to reaching the CPOC (Table A-7).

A-4.1.7 AOC-060

Source area and downgradient concentrations for model calibration were taken from groundwater samples collected from wells in February 2007 (Figure A-7). Source area concentrations were taken from well GW012, which had the highest COC concentrations. Monitoring wells GW148, GW149, and GW159 lay generally on a flow path from the source area to the Cedar River Waterway and were used as downgradient calibration targets.

Table A-5 presents model calibration results between the source area and downgradient wells GW148, GW149, and GW159 using default and calibrated degradation half-lives. Table A-3 presents the calibrated degradation half-lives. The *cis*-1,2-DCE half-life was increased and the VC half-life was decreased from the default values. The model run time was also increased from 30 years to 50 years to improve the calibration.

The CPOC is located approximately 160 feet downgradient from the source area and 85 feet upgradient from the Cedar River Waterway. Model results (Table A-7) indicate that maximum source area concentrations of TCE, *cis*-1,2-DCE, and VC of 0.3, 10, and 27 µg/L, respectively, would attenuate to below Method B cleanup criteria protective of surface water prior to reaching the waterway. Predicted COC concentrations at the CPOC that are protective of surface water for TCE, *cis*-1,2-DCE, and VC are 0.01, 0.08, and 0.26 µg/L, respectively. The current source area concentrations are likely to attenuate to below these concentrations before reaching the CPOC (Table A-7).

A-4.1.8 AOC-090 - Shallow

For this AOC there are indications of shallow and intermediate groundwater impacts, so two depth intervals (AOC-090 shallow and AOC-090 intermediate) were modeled. In the shallow interval groundwater flow is affected by the presence of a sheet pile wall along the Cedar River Waterway, resulting in a northward flow path and a southward flow path from the source area, around the wall, to the waterway. Source area and downgradient concentrations for model calibration were selected from shallow depth data collected in April 2003 and February 2004, prior to implementation of a soil removal and enhanced bioremediation interim action at the AOC-090 source area (Figure A-8). More recent data were not used for calibration since the interim action has likely altered site conditions. Data from well GW168 were used for the source area concentrations, and downgradient wells GW164 and GW180 along the northward flow path were used as calibration targets.

Table A-5 presents model calibration results between the source area and wells GW164 and GW180 using default and calibrated degradation half-lives. Table A-3 presents the calibrated degradation half-lives. The calibration for this model was poor, due to the very rapid decline in VOC concentrations between the source area near well GW168 and downgradient well GW164; however the calibrated results are a significant improvement over the results using the default half-lives. Calibrated model results overpredict concentrations at GW164, but are consistent with the nondetected concentrations at well GW180.

The calibrated model was used to evaluate maximum source area groundwater concentrations and cleanup levels at the CPOCs for the northward and southward flow paths. Along the northward flow path the CPOC is located approximately 260 feet downgradient from the source area and 150 feet upgradient from the Cedar River Waterway. Model results (Table A-7) indicate that maximum source area concentrations for PCE, TCE, *cis*-1,2-DCE, and VC of 190,000 µg/L each would attenuate to below Method B cleanup criteria protective of surface water prior to reaching the waterway along this flow path. Predicted COC concentrations at the northern CPOC that are protective of surface water for PCE, TCE, *cis*-1,2-DCE, and VC are 0.39, 0.5, 9.5, and 9.9 µg/L, respectively.

Along the southward flow path the CPOC is located approximately 110 feet downgradient from the source area and 125 feet upgradient from the waterway. The hydraulic gradient along this flow path (0.008) is also higher than along the northward flow path (0.005). Model results (Table A-7) indicate that maximum source area concentrations of PCE, TCE, *cis*-1,2-DCE, and VC of 20, 90, 100, and 100 µg/L, respectively, would attenuate to below Method B cleanup criteria protective of surface water prior to reaching the waterway along this flow path. Predicted COC concentrations at the southern CPOC that are protective of surface water for PCE, TCE, *cis*-1,2-DCE, and VC are 0.11, 0.21, 2.4, and 2.1 µg/L, respectively.

Natural attenuation screening (Table A-7) indicates the current source area concentrations are not likely to attenuate to below the proposed site-specific cleanup levels before reaching the southern CPOC, but are likely to attenuate to below these concentrations before reaching the northern CPOC. Active remedial actions to reduce source area concentrations at this AOC have been evaluated in the FS.

A-4.1.9 AOC-090 - Intermediate

There are not sufficient downgradient data to calibrate the model for the intermediate interval. Degradation in the intermediate interval was assumed to be the same as the shallow interval even though they have different soil matrices. Source area concentrations for the intermediate interval were assumed to be the same as for the shallow interval model.

For the intermediate interval, the CPOC is located approximately 35 feet downgradient from the source area and 120 feet upgradient from the waterway. Model results (Table A-7) indicate that maximum source area concentrations of PCE, TCE, *cis*-1,2-DCE, and VC of 60, 60, 60, and 100 µg/L, respectively, would attenuate to below Method B cleanup criteria protective of surface water prior to reaching the waterway along this flow path. Predicted COC concentrations at the intermediate depth interval CPOC that are protective of surface water for PCE, TCE, *cis*-1,2-DCE, and VC are 5, 5.9, 19, and 15 µg/L, respectively. Natural attenuation screening (Table A-7) indicates the current source area concentrations are not likely to attenuate to below the proposed site-specific cleanup levels before reaching the CPOC. Active remedial actions to reduce source area concentrations have been evaluated in the FS for the intermediate interval.

A-4.2 BIOSCREEN TPH AND BENZENE MODEL RESULTS

Water quality data downgradient from identified source areas were not sufficient to calibrate the BIOSCREEN models, except at AOC-092. Calibration results are shown on Table A-6. Model results for the other AOCs and SWMUs presented in this section are based on default model inputs. Modeled maximum source area groundwater concentrations that are predicted to meet MTCA cleanup criteria at surface water, predicted concentrations at the CPOCs that achieve MTCA cleanup criteria protective of surface water, and natural attenuation screening results based on current source area concentrations are presented in Table A-8. Results for each SWMU and AOC are discussed in the following sections.

A-4.2.1 Building 4-78/4-79 SWMU/AOC Group

Source area groundwater quality data for natural attenuation screening were selected as the maximum TPH-G and benzene concentrations from wells GW031 and GW033 collected in November 2006 (Figure A-3). These wells have historically shown the highest TPH and benzene concentrations.

The CPOC is located approximately 100 feet downgradient from the source area and 300 feet upgradient from the Cedar River Waterway. Model results (Table A-8) indicate that the source area concentration of TPH-G and benzene will attenuate to the proposed cleanup levels before reaching the on-site CPOC. The modeled source area benzene and TPH-G groundwater concentrations expected to attenuate to below proposed cleanup levels before reaching the CPOC are greater than 100,000 µg/L.

A-4.2.2 Former Fuel Farm

Source area groundwater quality data for natural attenuation screening were selected as the maximum TPH-Jet A and TPH-D concentrations from push probes completed in 2002 and 2003 (Figure A-9). Model results (Table A-8) indicate that the source area concentration of TPH-Jet A and TPH-D will attenuate to below proposed cleanup levels before reaching the CPOC. Modeled maximum source area groundwater concentrations of TPH-Jet A and TPH-D expected to attenuate to below proposed cleanup levels before reaching the CPOC are greater than 100,000 µg/L.

A-4.2.3 AOC-004

Source area groundwater quality data for natural attenuation screening were selected as the maximum TPH-G and benzene concentrations from push probes completed in 1999 (Figure A-10). Model results (Table A-8) indicate that the source concentration of TPH-G and benzene will attenuate to below proposed cleanup levels before reaching the CPOC, which is located approximately 40 feet north of the source area. Modeled maximum source area concentrations for TPH-G and benzene expected to attenuate to below proposed cleanup levels before reaching the CPOC are greater than 100,000 µg/L.

A-4.2.4 AOC-090

Model results (Table A-8) indicate that the source area concentration of TPH-G, TPH-D, and benzene will attenuate to below cleanup levels before reaching the CPOC. Modeled source area benzene groundwater concentrations expected to attenuate to below proposed cleanup levels before reaching the CPOC are 3,400 µg/L for shallow southward flow and greater than 100,000 µg/L for shallow northward flow. Calculated source area TPH-G and TPH-D groundwater concentrations expected to attenuate to below proposed cleanup levels before reaching the CPOC are greater than 100,000 µg/L for the southward flow. For the northward flow, the maximum source area concentrations protective of surface water are predicted to be greater than 100,000 µg/L for TPH-G, TPH-D, and benzene. For both flow paths, existing concentrations are predicted to attenuate to below proposed cleanup levels for all three COCs before reaching the CPOCs.

A-4.2.5 AOC-092

Source area and downgradient TPH-G and benzene concentrations for model calibration were taken from push probe data collected in 2001 and 2005 (Figure A-11). Source area concentrations were taken as the maximum concentrations from push probes completed in or near the soil source area (PP073, PP074, and PP075). Push probes PP155 and PP158 lay generally on a flow path from the source area toward Lake Washington and were used as downgradient calibration targets.

Table A-6 presents model calibration results between the source area and push probes PP155 and PP158 using default and calibrated degradation half-lives. Table A-4 presents the calibrated degradation half-lives. The calibrated model is an improvement over the default degradation half-lives, and either matches or overpredicts concentrations at the downgradient calibration targets.

Model results using the calibrated model (Table A-8) indicate that the source area concentration of TPH-G and benzene will attenuate to below proposed cleanup levels before reaching the CPOC. Modeled maximum source area concentrations of benzene and TPH-G expected to attenuate to below proposed cleanup levels before reaching the CPOC are greater than 100,000 µg/L.

A-4.3 MTCA METHOD C SOIL CLEANUP LEVELS

Source area soil concentrations protective of groundwater at the CPOC were calculated using the predicted maximum source area groundwater concentrations protective of the CPOC. As noted above, the predicted source area groundwater concentrations would attenuate to the lower of proposed CPOC cleanup levels or CPOC concentrations protective of surface water by the time groundwater reaches the CPOC. The MTCA three-phase partitioning model (WAC 173-340-747) was used for the partitioning calculations. These calculations were performed following the procedures and input parameters outlined in the FSWP for calculating Method C soil cleanup levels protective of groundwater; calculations were done for vadose zone soil for soil COCs for each SWMU and AOC. These soil cleanup levels would be applicable to the source areas for the soil COCs at the SWMUs or AOCs that were modeled.

The maximum, protective source area groundwater concentrations were modeled as described above (Stage 4 modeling). The modeled concentration predicted to attenuate to the lower of the proposed CPOC cleanup level or the predicted CPOC concentration that is protective of surface water was used for the partitioning calculations. The maximum protective source area chlorinated VOC concentrations are shown on Table A-9, and the maximum protective source area TPH and benzene concentrations are shown on Table A-10. In several cases, the predicted maximum source area groundwater concentrations for specific constituents were unrealistically high, particularly with TPH compounds. In cases where predicted maximum source area TPH concentrations in groundwater were greater than 100,000 µg/L, a value of 100,000 µg/L was used in the three-phase partitioning model calculations. The soil concentrations calculated in this way would be protective of groundwater at the designated CPOC. The resulting soil cleanup levels are shown on Table A-11. Finally, the soil concentration protective of groundwater was compared to the MTCA criteria for direct worker contact (see Table A-11); the lower of the concentration protective of groundwater and direct worker contact was selected as the concentration protective of human health and the environment for each area. The source area soil concentrations that would be protective of groundwater and direct worker contact were considered in establishing the proposed soil cleanup levels in Section 3 of the FS.

A-5.0 REFERENCES

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Wiedemeier, T.H., C.J. Newell, H.S. Rifai and J.T. Wilson, 1999, Natural Attenuation of Fuels and Chlorinated Solvents in the Subsurface, John Wiley and Sons, Inc., New York, New York.

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TABLE A-1

BIODEGRADATION RATE LITERATURE VALUES[1]

Boeing Renton Facility
Renton, Washington

Degradation Parent and Daughter Product	Half-Life in Years		
	Minimum	**Maximum**	**Default**
PCE to TCE[2]	0.056	10	1.97
TCE to *cis*- 1,2-DCE[2]	0.31	13.6	4.53
cis -1,2-DCE to VC[3]	0.21	3.8	1.00
VC to ETH[2]	0.022	5.8	7.88

Notes:
1. PCE = tetrachlorethene;
   TCE = trichloroethene;
   cis -1,2-DCE = *cis* -1,2-dichloroethene;
   VC = vinyl chloride;
   ETH = ethene.
2. First-order decay half-lives are the minimum and maximum presented in Aronson & Howard, 1997.
3. First-order decay half-life is the range of representative decay constants for field studies cited in Table 6.6 in Wiedemeier et al., 1999.

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TABLE A-2

GENERAL INPUT PARAMETERS
Boeing Renton Facility
Renton, Washington

SWMU/AOC	Predominant Soil Type in Transmissive Zone (USCS)[1]	Hydraulic Conductivity (cm/s)[2]	Total Organic Carbon (percent)[2]	Hydraulic Gradient (unitless)[3]	Porosity (unitless)[4]	Soil Bulk Density (kg/L)[4]
SWMU-168	Silty Sand (SM)	8.96E-04	0.84	0.004	0.43	1.5
SWMU-172/174	Sand (SP)	2.15E-03	0.46	0.004	0.43	1.5
Bldg 4-78/4-79 SWMU/AOC Group	Silty Sand (SM)	8.96E-04	0.84	0.001	0.43	1.5
Former Fuel Farm	Silty Sand (SM)	8.96E-04	0.84	0.003	0.43	1.5
AOC-001/002	Silty Sand (SM)	8.96E-04	0.84	0.003	0.43	1.5
AOC-003	Silty Sand (SM)	8.96E-04	0.84	0.003	0.43	1.5
AOC-004	Silty Sand (SM)	8.96E-04	0.84	0.002	0.43	1.5
AOC-034/035	Silty Sand (SM)	8.96E-04	0.84	0.001	0.43	1.5
AOC-060	Sand (SP)	2.15E-03	0.46	0.001	0.43	1.5
AOC-090 (shallow northward flow)	Silty Sand (SM)	8.96E-04	0.84	0.005	0.43	1.5
AOC-090 (shallow southward flow)	Silty Sand (SM)	8.96E-04	0.84	0.008	0.43	1.5
AOC-090 (intermediate)	Sand (SP)	2.15E-03	0.46	0.002	0.43	1.5
AOC-092	Silty Sand (SM)	8.96E-04	0.84	0.001	0.43	1.5

Notes:
1. Predominant soil types are from the RI Report (Weston, 2001). USCS = Unified Soil Classification System.
2. Hydraulic conductivity (in units of centimeters per second [cm/s]) and total organic carbon for each soil type were specified in the FS Work Plan (Geomatrix, 2004) and updated with more recent data when available.
3. Hydraulic gradients are based on available groundwater elevation data as discussed in Section A-3.1.2.
4. Porosity and bulk density (in units of kilograms per liter [kg/L]) are default values specified in 173-340-747 WAC.

TABLE A-3

BIOCHLOR INPUT PARAMETERS AND SITE MODEL DESCRIPTIONS[1]

Boeing Renton Facility
Renton, Washington

SWMU/AOC	Source Area Concentrations (µg/L)[2]				Half-Lives (Years)[3]				Note
	PCE	TCE	*cis*-1,2-DCE	VC	PCE to TCE	TCE to *cis*-1,2-DCE	*cis*-1,2-DCE to VC	VC to ETH	
SWMU-168	ND[4]	ND	ND	2.1	NA[5]	NA	NA	7.88	Default
SWMU-172/174	53	93	270	2.8	0.50	0.31	0.49	0.90	Calibrated
Bldg 4-78/4-79 SWMU/AOC Group	ND	20	2,800	750	NA	4.53	1.00	7.88	Default
AOC-001/002	3.6	1,400	52,000	28,000	1.97	3.00	1.60	7.00	Calibrated
AOC-003	8.3	1.3	5.4	5.7	1.97	4.53	1.00	7.88	Default
AOC-034/035	ND	ND	0.5	2.7	NA	NA	1.00	7.88	Default
AOC-060	ND	ND	10	27	NA	4.53	3.00	2.70	Calibrated
AOC-090 (shallow and intermediate)	55	37,000	15,100	392	0.50	0.31	0.60	0.40	Calibrated

SWMU/AOC	Distance to On-Site CPOC (feet)[6]	Distance to Off-Site CPOC (feet)[6]	Distance from Source Area to Surface Waters (feet)	Source Width (feet)	Source Submerged Thickness (feet)	Model Length (feet)	Dispersivity (feet)	Model Width (feet)
SWMU-168	30	NA	125	15	5	125	12.5	50
SWMU-172/174	85	NA	145	30	20	145	14.5	150
Bldg 4-78/4-79 SWMU/AOC Group	215	NA	400	100	20	400	40	100
AOC-001/002	285	NA	345	30	5	345	34.5	100
AOC-003	150	NA	785	30	5	785	78.5	100
AOC-034/035	60	NA	350	20	15	250	25	50
AOC-060	NA	160	245	40	10	245	24.5	150
AOC-090 (shallow northward flow)	NA	260	410	30	15	410	41	100
AOC-090 (shallow southward flow)	NA	110	235	30	15	235	23.5	100
AOC-090 (intermediate)	35	NA	155	30	15	155	15.5	100

Notes:
1. PCE = tetrachlorethene; TCE = trichloroethene; *cis*-1,2-DCE = *cis*-1,2-dichloroethene; VC = vinyl chloride; ETH = ethene.
2. Source area concentrations are from the RI Report (Weston, 2001) or supplemental sampling results presented in the FS Work Plan (Geomatrix, 2004), or more recent monitoring data post voluntary site cleanup actions. Unit are in micrograms per liter (µg/L).
3. Default half-lives are from Appendix B of Wiedemeier et al., 1999.
4. ND = Not detected.
5. NA = Not applicable.
6. CPOC = conditional point of compliance. Distances to CPOCs are from current site figures. For sites with multiple paths the shortest path to the CPOC and surface water was modeled. Source area dimensions and model domain are based on data in the RI Report.

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TABLE A-4

BIOSCREEN INPUT PARAMETERS[1]

Boeing Renton Facility
Renton, Washington

SWMU/AOC	Source Area Concentrations[2]				Half-Lives (Years)[3]				Note
	TPH-G (mg/L)	TPH-D (mg/L)	Jet-A (mg/L)	Benzene (µg/L)	TPH-G	TPH-D	Jet-A	Benzene	
Bldg 4-78/4-79 SWMU/AOC Group	0.46	ND[4]	ND	66	2	NA[5]	NA	2	Default
Former Fuel Farm	ND	18	30	ND	NA	2	2	NA	Default
AOC-004	0.93	ND	ND	29	2	NA	NA	2	Default
AOC-090 (shallow)	19	170	ND	12	2	2	NA	2	Default
AOC-092	8.7	ND	ND	5.9	28	NA	NA	22	Calibrated

SWMU/AOC	Distance to On-Site CPOC (feet)[6]	Distance to Off-Site CPOC (feet)[6]	Distance from Source Area to Surface Waters (feet)	Source Width (feet)[7]	Source Submerged Thickness (feet)[7]	Model Length (feet)[7]	Model Width (feet)[7]
Bldg 4-78/4-79 SWMU/AOC Group	100	NA	400	80	10	100	150
Former Fuel Farm[8]	120	NA	220	150	5	120	150
AOC-004	40	NA	1,100	5	5	30	25
AOC-090 (shallow northward flow)	NA	260	410	40	15	410	150
AOC-090 (shallow southward flow)	NA	110	235	40	15	235	150
AOC-092	8	NA	600	8	10	40	15

Notes:

1. TPH-G = total petroleum hydrocarbons, gasoline range; TPH-D = total petroleum hydrocarbons, diesel range; Jet-A = Jet Fuel A.
2. Source area concentrations are from the RI Report (Weston, 2001) or supplemental sampling results presented in the FS Work Plan (Geomatrix, 2004). Source area concentrations are given in milligrams per liter (mg/L) or micrograms per liter (µg/L).
3. Default half-lives are from the FS Work Plan.
4. ND = Not detected.
5. NA = Not applicable.
6. CPOC = conditional point of compliance. Distances to CPOCs are from the FS Work Plan.
7. Source area dimensions and model domain are based on data in the RI Report.
8. A portion of the CPOC for the Former Fuel Farm is off lease.

TABLE A-5

BIOCHLOR MODEL CALIBRATION[1]

Boeing Renton Facility
Renton, Washington

Concentrations are in micrograms per liter (µg/L)

SWMU/AOC	Note	Downgradient Well or Push Probe Used for Calibration	Distance from Source Area (Feet)	Measured Concentration at Downgradient Well or Push Probe (µg/L)				Model Predicted Concentration at Downgradient Well or Push Probe (µg/L)			
				PCE	TCE	*cis*- 1,2-DCE	VC	PCE	TCE	*cis*- 1,2-DCE	VC
SWMU-172/174	Default Model	GW172	40	8.6	8.6	34	34	25	72	39	36
	Calibrated Model	GW172	40	8.6	8.6	34	34	8.4	13	34	34
AOC-001/002	Default Model	PP133	180	<20 [2]	<20	<20	1,100	0.01	17	11	1,245
	Calibrated Model	PP133	180	<20	<20	<20	1,100	0.01	8	57	1,478
	Default Model	PP098	290	<1	<1	7.7	67	0	0.5	0.1	39
	Calibrated Model	PP098	290	<1	<1	7.7	67	0	0.2	0.8	46
AOC-060	Default Model	GW148	100	<0.2	<0.2	0.4	<0.2	0	0	0.1	4.8
	Calibrated Model	GW148	100	<0.2	<0.2	0.4	<0.2	0	0	0.4	1.4
	Default Model	GW149	150	<0.2	<0.2	<0.2	0.3	0	0	0.01	2.8
	Calibrated Model	GW149	150	<0.2	<0.2	<0.2	0.3	0	0	0.09	0.31
	Default Model	GW159	230	<0.2	<0.2	<0.2	<0.2	0	0	0.001	1.1
	Calibrated Model	GW159	230	<0.2	<0.2	<0.2	<0.2	0	0	0.01	0.02
AOC-090 Northward Flow	Default Model	GW164	80	<1	1.4	5.5	2	6.6	7,976	2,055	4,068
	Calibrated Model	GW164	80	<1	1.4	5.5	2	0.7	136	1,048	670
	Default Model	GW180	260	<1	<1	<1	<1	0.1	198	43	205
	Calibrated Model	GW180	260	<1	<1	<1	<1	0	0.002	0.5	0.6

Notes:
1. PCE = tetrachlorethene; TCE = trichloroethene; *cis* -1,2-DCE = *cis* -1,2-dichloroethene; VC = vinyl chloride.
2. < = Not detected at practical quantitation limit indicated.

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TABLE A-6

BIOSCREEN MODEL CALIBRATION

Boeing Renton Facility
Renton, Washington

Concentrations are in micrograms per liter (µg/L)

SWMU/AOC	Note	Downgradient Well or Push Probe Used for Calibration	Distance from Source Area (Feet)	Measured Concentration at Downgradient Well or Push Probe (µg/L)		Model Predicted Concentration at Downgradient Well or Push Probe (µg/L)	
				TPH-G[1]	Benzene	TPH-G	Benzene
AOC-092	Default Model	PP155	24	350	ND[2]	0	0.02
	Default Model	PP158	40	ND	2.0	0	0
	Calibrated Model	PP155	24	350	ND	355	3.2
	Calibrated Model	PP158	40	ND	2.0	95	2.1

Notes:
1. TPH-G = total petroleum hydrocarbons, gasoline range.
2. ND = Not detected.

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TABLE A-7

BIOCHLOR NATURAL ATTENUATION MODEL RESULTS[1]

Boeing Renton Facility
Renton, Washington

Concentrations are in micrograms per liter (µg/L)

SWMU/AOC	Note	Source Area Concentrations (µg/L)				Predicted CPOC Concentration Based on Source Area Concentrations (µg/L)				Predicted Maximum Source Concentration Protective of Surface Water (µg/L)				Predicted Maximum CPOC Concentration Protective of Surface Water (µg/L)			
		PCE	TCE	*cis*-1,2-DCE	VC	PCE	TCE	*cis*-1,2-DCE	VC	PCE	TCE	*cis*-1,2-DCE	VC	PCE	TCE	*cis*-1,2-DCE	VC
SWMU-168	Default Half-Lives	ND[2]	ND	ND	2.1	NA[3]	NA	NA	1.0	NA	NA	NA	0.23	NA	NA	NA	0.11
SWMU-172/174	Calibrated Half-Lives	53	93	270	2.8	1.0	0.9	9.1	27.7	0.4	0.4	0.4	0.5	0.008	0.009	0.03	0.11
Bldg 4-78/4-79 SWMU/AOC Group	Default Half-Lives	ND	20	2,800	750	NA	0.02	0.004	20	NA	20	120	120	NA	0.80	0.900	0.26
AOC-001/002[4]	Calibrated Half-Lives	ND	ND	94	310	NA	0	0.003	4.4	NA	1	1	2	NA	0.002	0.002	0.05
AOC-003	Default Half-Lives	8.3	1.3	5.4	5.7	0.09	0.38	0.08	0.92	50	50	20	10	0.54	4.0	0.78	4.6
AOC-034/035	Default Half-Lives	ND	ND	0.5	2.7	NA	NA	0.0007	0.30	NA	NA	450	500	NA	NA	0.65	80
AOC-060	Calibrated Half-Lives	ND	ND	10	27	NA	NA	0.07	0.25	NA	0.3	10	27	NA	0.01	0.08	0.26
AOC-090 (shallow) Northward Flow	Calibrated Half-Lives	55	37,000	15,100	392	0.0	0.0	0.5	0.6	190,000	190,000	190,000	190,000	0.39	0.50	9.5	9.9
AOC-090 (shallow) Southward Flow	Calibrated Half-Lives	55	37,000	15,100	392	0.3	39	598	468	20	90	100	100	0.11	0.21	2.4	2.1
AOC-090 (intermediate)	Calibrated Half-Lives	55	37,000	15,100	392	4.62	1,345	5,800	2,918	60	60	60	100	5	5.9	19	15

Notes:
1. PCE = tetrachloroethene; TCE = trichloroethene; *cis*-1,2-DCE = *cis*-1,2-dichloroethene; VC = vinyl chloride.
   CPOC = Conditional point of compliance.
2. ND = Not detected.
3. NA = Not applicable.
4. Source area concentration data are based on post-interim measure monitoring well samples collected in February 2007.

TABLE A-8

BIOSCREEN NATURAL ATTENUATION MODEL RESULTS[1]

Boeing Renton Facility
Renton, Washington

Concentrations are in micrograms per liter (µg/L)

SWMU/AOC	Note	Source Area Concentrations (µg/L)				Predicted CPOC Concentration based on Source Area Concentrations (µg/L)				Predicted Maximum Source Concentration Protective of Surface Water (µg/L)				Predicted Maximum CPOC Concentration Proctective of Surface Water (µg/L)			
		TPH-G	TPH-D	Jet-A	Benzene	TPH-G	TPH-D	Jet-A	Benzene	TPH-G	TPH-D	Jet-A	Benzene	TPH-G	TPH-D	Jet-A	Benzene
Bldg 4-78/4-79 AOC/SWMU Group	Default Half-Lives	460	ND[2]	ND	66	0	NA[3]	NA	0.00	>100,000 [4]	NA	NA	>100,000	>100,000	NA	NA	>100,000
Former Fuel Farm	Default Half-Lives	ND	18,000	30,000	ND	NA	0	0	NA	NA	>100,000	>100,000	NA	NA	>100,000	>100,000	NA
AOC-004	Default Half-Lives	930	ND	ND	29	0	NA	NA	0.38	>100,000	NA	NA	>100,000	>100,000	NA	NA	>100,000
AOC-090 (shallow northward flow) [5]	Default Half-Lives	19,000	170,000	ND	12	0.0	0.0	NA	0.01	>100,000	>100,000	NA	>100,000	>100,000	>100,000	NA	430
AOC-090 (shallow southward flow)	Default Half-Lives	19,000	170,000	ND	12	0.001	0.0	NA	0.22	>100,000	>100,000	NA	3,400	>100,000	>100,000	NA	61
AOC-092	Calibrated Half-Lives	8,700	ND	ND	5.9	1,696	NA	NA	5.01	>100,000	NA	NA	>100,000	>100,000	NA	NA	>100,000

Notes:
1. TPH-G = total petroleum hydrocarbons, gasoline range; TPH-D = total petroleum hydrocarbons, diesel range; Jet-A = Jet fuel A range.
   CPOC = Conditional point of compliance.
2. ND = Not detected.
3. NA = Not applicable.
4. > = Modeled concentration is greater than value indicated.
5. No modeling was completed for AOC-90 at the intermediate depth as TPH-G, TPH-D, Jet-A, and BTEX were not identified as COCs at the intermediate depth.

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TABLE A-9

BIOCHLOR MODEL RESULTS
SOURCE AREA GROUNDWATER CONCENTRATIONS PROTECTIVE OF SURFACE WATER AND THE CPOC[1]

Boeing Renton Facility
Renton, Washington

Concentrations are in micrograms per liter (µg/L)

		Predicted Maximum CPOC Concentration Protective of Surface Water (µg/L)				Proposed CPOC Cleanup Level[2] (µg/L)				CPOC Water Quality Criteria for Stage 4 Modeling[3] (µg/L)				Predicted Source Concentration Protective of Groundwater[4] (µg/L)			
SWMU/AOC	**Note**	**PCE**	**TCE**	***cis*- 1,2-DCE**	**VC**	**PCE**	**TCE**	***cis*- 1,2-DCE**	**VC**	**PCE**	**TCE**	***cis*- 1,2-DCE**	**VC**	**PCE**	**TCE**	***cis*- 1,2-DCE**	**VC**
SWMU-168	Default Half-Lives	NA[5]	NA	NA	0.11	NA	NA	NA	0.11	NA	NA	NA	0.11	NA	NA	NA	0.23
SWMU-172/174	Calibrated Half-Lives	0.008	0.009	0.03	0.11	0.02	0.02	0.03	0.11	0.008	0.009	0.03	0.11	0.4	0.4	0.4	0.5
Bldg 4-78/4-79 SWMU/AOC Group	Default Half-Lives	NA	0.8	0.9	0.26	NA	0.23	0.9	0.20	NA	0.23	0.9	0.20	NA	3	26	6
AOC-001/-002	Calibrated Half-Lives	NA	0.002	0.002	0.05	NA	0.02	0.02	0.05	NA	0.002	0.002	0.05	NA	1	1	2
AOC-003	Default Half-Lives	0.54	4.0	0.78	4.6	0.02	0.16	0.78	0.24	0.02	0.16	0.78	0.24	0.05	4	0.7	1
AOC-034/035	Default Half-Lives	NA	NA	0.65	80	NA	NA	0.65	0.29	NA	NA	0.65	0.29	NA	NA	4.5	4.5
AOC-060	Calibrated Half-Lives	NA	0.01	0.08	0.26	NA	0.02	0.08	0.26	NA	0.01	0.08	0.26	NA	0.3	10	27
AOC-090 (shallow) Northward Flow	Calibrated Half-Lives	0.39	0.50	9.5	9.9	0.05	0.08	2.4	0.13	0.05	0.08	2.4	0.13	2,500	2,500	2,500	2,500
AOC-090 (shallow) Southward Flow	Calibrated Half-Lives	0.11	0.21	2.4	2.1	0.05	0.08	2.4	0.13	0.05	0.08	2.4	0.13	4	4	4	5
AOC-090 (intermediate)	Calibrated Half-Lives	5.0	5.9	19	15	0.05	0.08	2.4	0.13	0.05	0.08	2.4	0.13	0.6	0.6	0.6	0.6

Notes:
1. PCE = tetrachlorethene; TCE = trichloroethene; *cis* -1,2-DCE = *cis*- 1,2-dichloroethene; VC = vinyl chloride.
   CPOC = Conditional point of compliance.
2. Proposed cleanup level applicable at the CPOC as presented on Table 3-2, Section 3 of the FS.
3. CPOC water quality criteria are the lower of the predicted maximum CPOC concentrations protective of surface water and the proposed CPOC cleanup levels.
4. Maximum source concentration predicted to attenuate to achieve the CPOC water quality criteria at the CPOC.
5. NA = Not applicable.

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TABLE A-10

BIOSCREEN MODEL RESULTS
MAXIMUM SOURCE AREA GROUNDWATER CONCENTRATIONS[1]

Boeing Renton Facility
Renton, Washington

Concentrations are in micrograms per liter (µg/L)

SWMU/AOC	Note	Predicted Maximum CPOC Concentration Protective of Surface Water (µg/L)				Proposed CPOC Cleanup Level[2] (µg/L)				CPOC Water Quality Criteria for Stage 4 Modeling[3] (µg/L)				Predicted Source Concentration Protective of Groundwater[4] (µg/L)			
		TPH-G	TPH-D	Jet-A	Benzene	TPH-G	TPH-D	Jet-A	Benzene	TPH-G	TPH-D	Jet-A	Benzene	TPH-G	TPH-D	Jet-A	Benzene
Bldg 4-78/4-79 AOC/SWMU Group	Default Half-Lives	>100,000	NA[5]	NA	>100,000	800	NA	NA	0.8	800	0	0	0.8	>100,000	NA	NA	1,200
Former Fuel Farm	Default Half-Lives	NA	>100,000	>100,000	NA	NA	500	500	NA	0	500	500	0	NA	>100,000	>100,000	NA
AOC-004	Default Half-Lives	>100,000	NA	NA	>100,000	800	NA	NA	8	800	0	0	8	>100,000	NA	NA	610
AOC-090 (shallow northward flow)	Default Half-Lives	>100,000	>100,000	NA	430	800	500	NA	0.8	800	500	0	1	>100,000	>100,000	NA	30,000
AOC-090 (shallow southward flow)	Default Half-Lives	>100,000	>100,000	NA	61	800	500	NA	0.8	800	500	0	1	>100,000	>100,000	NA	45
AOC-092	Calibrated Half-Lives	>100,000	NA	NA	>100,000	800	NA	NA	8	800	0	0	8	>100,000	NA	NA	9.5

Notes:

1. TPH-G = total petroleum hydrocarbons, gasoline range; TPH-D = total petroleum hydrocarbons, diesel range; Jet-A = Jet fuel A range.
   CPOC = Conditional point of compliance.
2. Proposed cleanup level applicable at the CPOC as presented on Table 3-2, Section 3 of the FS.
3. CPOC water quality criteria are the lower of the predicted maximum CPOC concentrations protective of surface water and the proposed CPOC cleanup levels.
4. Maximum source concentration predicted to attenuate to achieve the CPOC water quality criteria at the CPOC.
5. NA = Not applicable.

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TABLE A-11

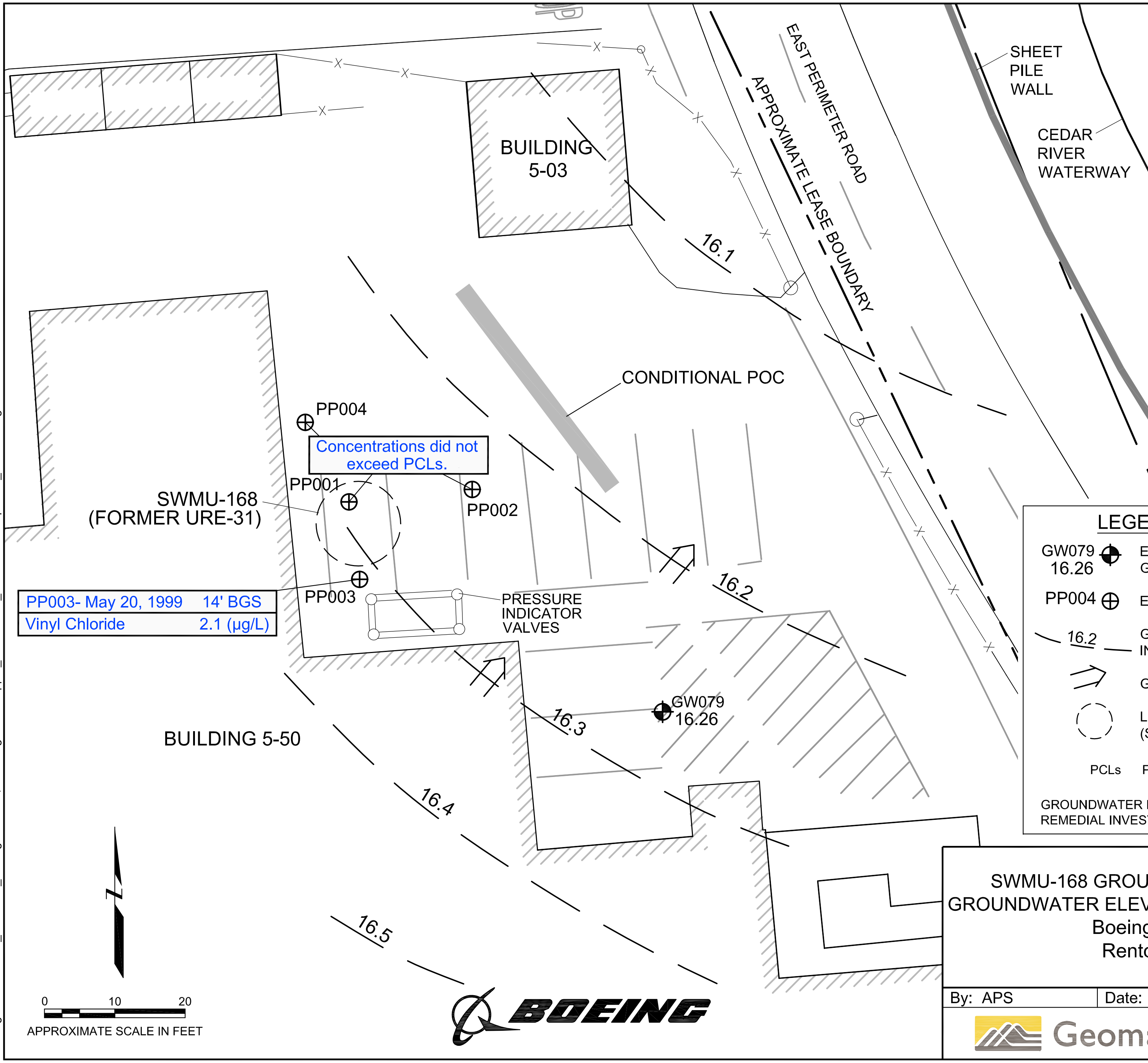
SOIL CONCENTRATIONS PROTECTIVE OF GROUNDWATER[1]

Boeing Renton Facility
Renton, Washington

SWMU/AOC	Constituent[2]	Maximum Measured Concentration in Source Area Groundwater[3] (μg/L)	Predicted Source Concentration Protective of Groundwater[4] (μg/L)	Basis for Source Area Groundwater Concentration	Calculated Soil Concentration Protective of Groundwater (mg/kg)	MTCA[5,6] Method C Direct Contact Criteria (mg/kg)	Soil Concentration Protective of Groundwater and Direct Contact (mg/kg)
SWMU-172/174	PCE	53	0.4	Modeled	0.01	240	0.01
	TCE	93	0.4	Modeled	0.006	330	0.006
Bldg 4-78/4-79 SWMU/AOC Group	Benzene	66	1,200	Observed	19	2,400	19
	TPH-G w/ benzene	460	100,000	Observed	14,840	NA[7]	14,840
	TCE	20	3	Modeled	0.1	330	0.1
	cis-1,2 DCE	2,800	26	Modeled	0.3	35,000[8]	0.3
	VC	750	6	Modeled	0.1	88	0.1
Former Fuel Farm	TPH-D	18,000	100,000	Observed	68,840	NA	68,840
	TPH-Jet-A	30,000	100,000	Observed	68,840	NA	68,840
AOC-001/002	TCE	0.1	1	Modeled	0.02	330	0.02
	cis-1,2 DCE	94	1	Modeled	0.01	35,000[8]	0.01
	VC	310	2	Modeled	0.02	88	0.02
AOC-003	TCE	1.3	4.0	Modeled	0.09	330	0.09
AOC-004	Benzene	29	610	Modeled	9.5	2,400	9.5
	TPH-G w/ benzene	930	100,000	Observed	14,840	NA	14,840
AOC-034/035	*cis*-1,2 DCE	0.5	4.5	Modeled	0.05	35,000[8]	0.05
	VC	2.7	4.5	Modeled	0.04	88	0.04
AOC-090[9]	PCE	55	0.6	Modeled	0.03	240	0.03
	TCE	37,000	0.6	Modeled	0.01	330	0.01
	cis-1,2 DCE	15,100	0.6	Modeled	0.006	35,000[8]	0.006
	VC	392	0.6	Modeled	0.006	88	0.006
	TPH-G	19,000	100,000	Observed	14,840	NA	14,840
	TPH-D	170,000	100,000	Observed	68,840	NA	68,840
	Benzene	12	45	Modeled	0.7	2,400	0.7
AOC-092	TPH-G	8,700	100,000	Modeled	14,840	NA	14,840
	Benzene	5.9	9.5	Modeled	0.15	2,400	0.15

Notes:

1. Concentrations are given in micrograms per liter (μg/L) for groundwater or milligrams per kilogram (mg/kg) for soil.
2. PCE = tetrachlorethene; TCE = trichloroethene; TPH-G = total petroleum hydrocarbons, gasoline range; *cis*-1,2 DCE = *cis*-1,2-dichloroethene; VC = vinyl chloride; TPH-D = total petroleum hydrocarbons, diesel range; TPH-Jet A = total petroleum hydrocarbons, Jet fuel A range.
3. For constituents reported as ND, tabulated concentrations are half of the reporting limit.
4. Modeled source area concentration from the last column of Tables A-9 and A-10.
5. MTCA = Model Toxics Control Act.
6. Except where noted, values are for carcinogens, from the CLARC database at https://fortress.wa.gov/ecy/clarc/Reporting/ChemicalQuery.aspx, accessed October 2007.
7. NA = Not applicable.
8. Value is for noncarcinogenic *cis*-1,2 DCE from CLARC database at https://fortress.wa.gov/ecy/clarc/Reporting/ChemicalQuery.aspx, accessed October 2007
9. Predicted source concentrations protective of groundwater are based on the lowest predicted values from the shallow and intermediate pathways.



LEGEND

GW079 16.26	EXISTING MONITORING WELL LOCATION GROUNDWATER ELEVATION (FEET)
PP004	EXISTING PUSH-PROBE LOCATION
16.2	GROUNDWATER ELEVATION CONTOUR IN 0.1 FOOT INTERVAL (SEPTEMBER 2000)
	GROUNDWATER FLOW DIRECTION
	LIMITS OF FORMER EXCAVATION (SECOR 1994)
PCLs	Preliminary Cleanup Levels

GROUNDWATER ELEVATION CONTOURS FROM FINAL REMEDIAL INVESTIGATION (WESTON, 2001)

SWMU-168 GROUNDWATER QUALITY DATA, GROUNDWATER ELEVATION CONTOURS, AND CPOC
Boeing Renton Facility
Renton, Washington

By: APS | Date: 05/28/08 | Project No. 8888

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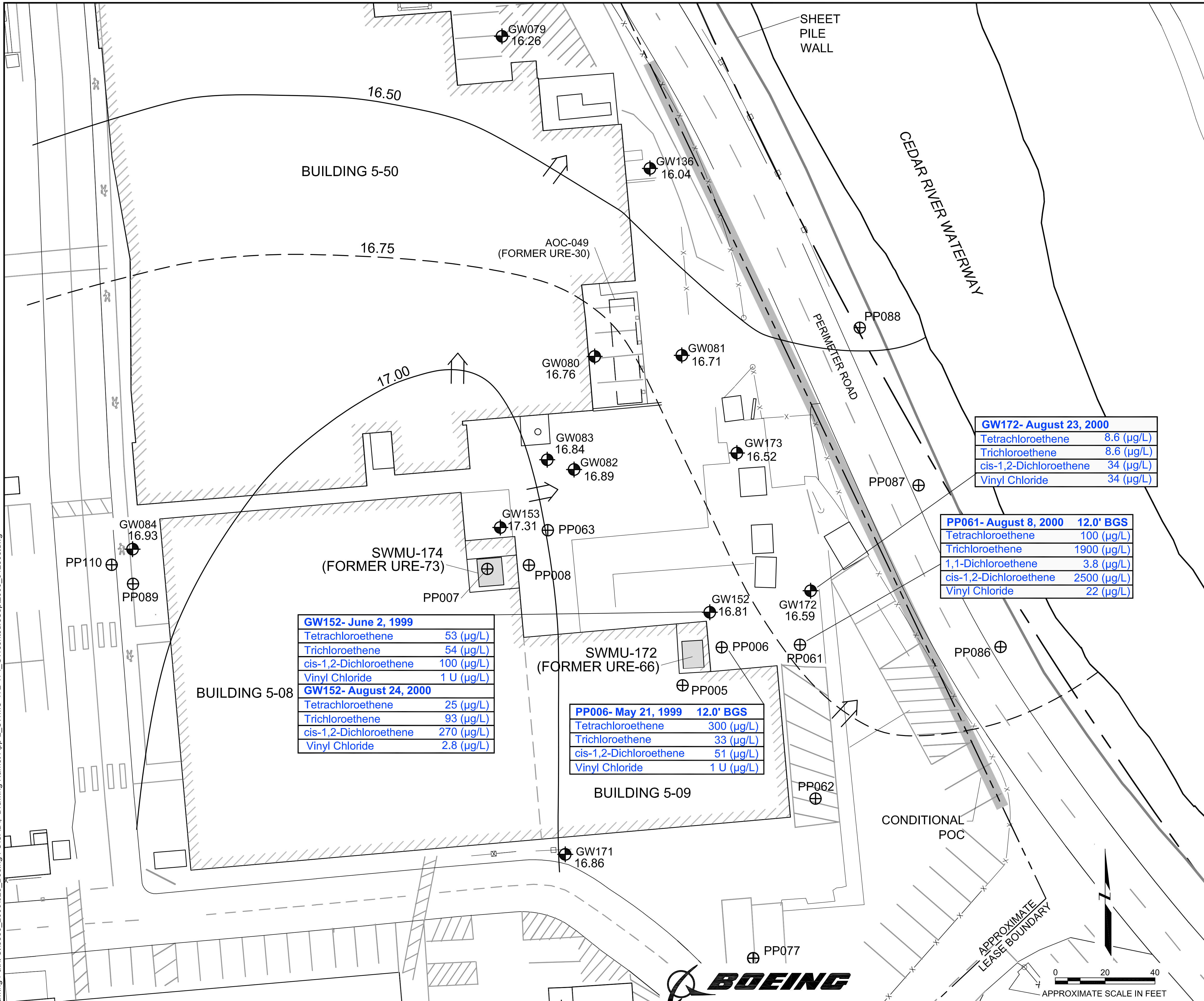
Figure **A-1**

Plot Date: 05/28/08 - 9:23am, Plotted by: astenberg
Drawing Path: S:\8888_2006\025_Boeing FS\CAD\, Drawing Name: App-1_SWMU-168_GWcontoursSept2000_012508.dwg



GW172- August 23, 2000	
Tetrachloroethene	8.6 (µg/L)
Trichloroethene	8.6 (µg/L)
cis-1,2-Dichloroethene	34 (µg/L)
Vinyl Chloride	34 (µg/L)

PP061- August 8, 2000	12.0' BGS
Tetrachloroethene	100 (µg/L)
Trichloroethene	1900 (µg/L)
1,1-Dichloroethene	3.8 (µg/L)
cis-1,2-Dichloroethene	2500 (µg/L)
Vinyl Chloride	22 (µg/L)

GW152- June 2, 1999	
Tetrachloroethene	53 (µg/L)
Trichloroethene	54 (µg/L)
cis-1,2-Dichloroethene	100 (µg/L)
Vinyl Chloride	1 U (µg/L)
GW152- August 24, 2000	
Tetrachloroethene	25 (µg/L)
Trichloroethene	93 (µg/L)
cis-1,2-Dichloroethene	270 (µg/L)
Vinyl Chloride	2.8 (µg/L)

PP006- May 21, 1999	12.0' BGS
Tetrachloroethene	300 (µg/L)
Trichloroethene	33 (µg/L)
cis-1,2-Dichloroethene	51 (µg/L)
Vinyl Chloride	1 U (µg/L)

LEGEND

GW152 16.81 — EXISTING MONITORING WELL LOCATION GROUNDWATER ELEVATION (FEET)

PP061 — EXISTING PUSH-PROBE LOCATION

16.50 — GROUNDWATER ELEVATION CONTOUR IN 0.25 FOOT INTERVAL (SEPTEMBER 2000)

GROUNDWATER FLOW DIRECTION

U — Analyte was not detected above value shown

NOTES

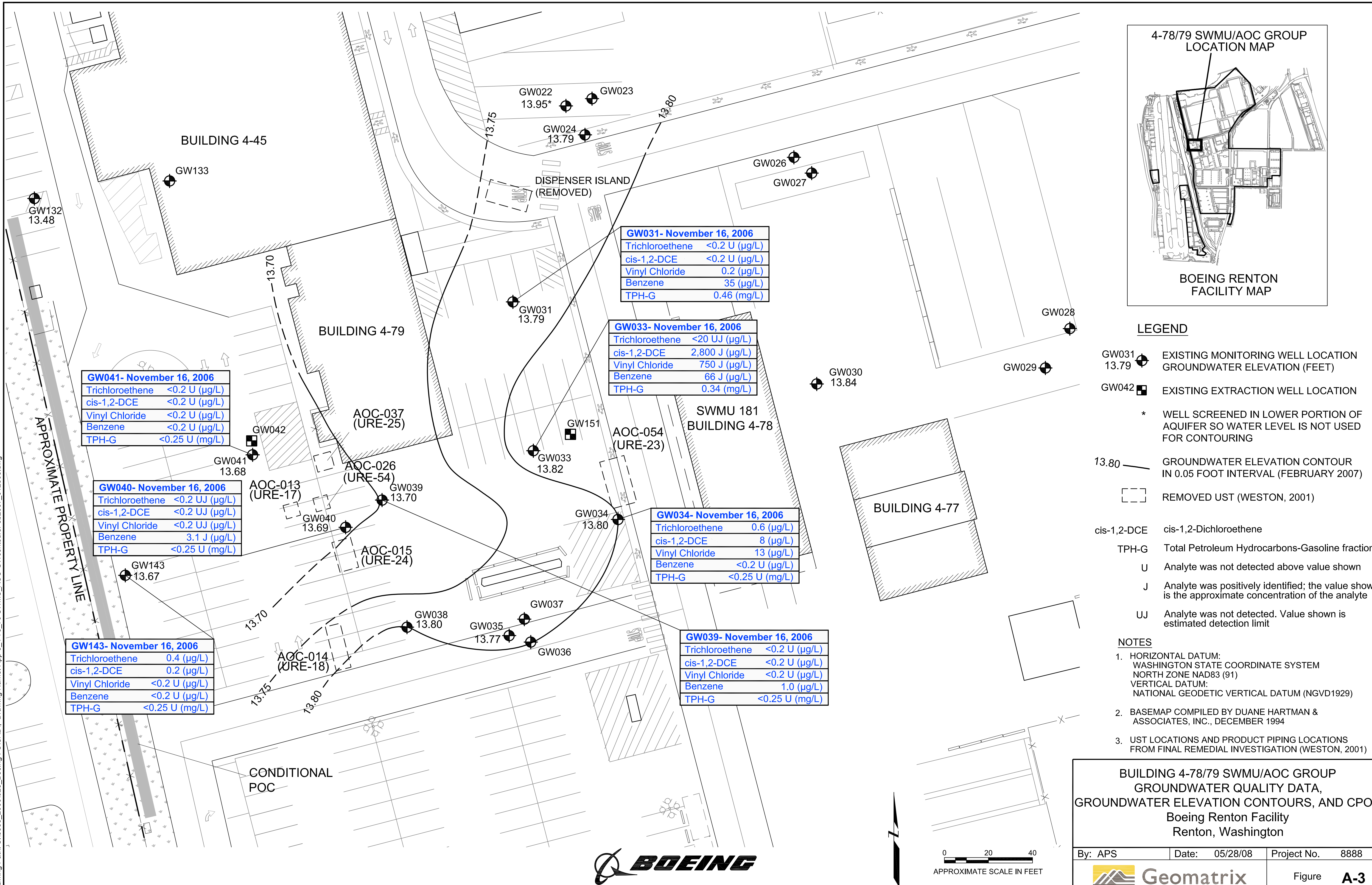
1. HORIZONTAL DATUM: WASHINGTON STATE COORDINATE SYSTEM NORTH ZONE NAD83 (91)
VERTICAL DATUM: NATIONAL GEODETIC VERTICAL DATUM (NGVD1929)
2. BASEMAP COMPILED BY DUANE HARTMAN & ASSOCIATES, INC., DECEMBER, 1994
3. GROUNDWATER ELEVATION CONTOURS AND PUSH PROBE LOCATIONS FROM FINAL REMEDIAL INVESTIGATION REPORT (WESTON, 2001)

SWMU-172 and SWMU-174 GROUNDWATER QUALITY DATA, GROUNDWATER ELEVATION CONTOURS, AND CPOC
Boeing Renton Facility
Renton, Washington

By: APS | Date: 05/28/08 | Project No. 8888

Geomatrix | Figure A-2

Plot Date: 05/28/08 - 9:23am, Plotted by: astenberg
Drawing Path: S:\8888_2006\025_Boeing FS\CAD\, Drawing Name: App-2_SWMU-172-174_GWcontoursSept2000_012508.dwg



GW031- November 16, 2006	
Trichloroethene	<0.2 U (µg/L)
cis-1,2-DCE	<0.2 U (µg/L)
Vinyl Chloride	0.2 (µg/L)
Benzene	35 (µg/L)
TPH-G	0.46 (mg/L)

GW033- November 16, 2006	
Trichloroethene	<20 UJ (µg/L)
cis-1,2-DCE	2,800 J (µg/L)
Vinyl Chloride	750 J (µg/L)
Benzene	66 J (µg/L)
TPH-G	0.34 (mg/L)

GW041- November 16, 2006	
Trichloroethene	<0.2 U (µg/L)
cis-1,2-DCE	<0.2 U (µg/L)
Vinyl Chloride	<0.2 U (µg/L)
Benzene	<0.2 U (µg/L)
TPH-G	<0.25 U (mg/L)

GW040- November 16, 2006	
Trichloroethene	<0.2 UJ (µg/L)
cis-1,2-DCE	<0.2 UJ (µg/L)
Vinyl Chloride	<0.2 UJ (µg/L)
Benzene	3.1 J (µg/L)
TPH-G	<0.25 U (mg/L)

GW034- November 16, 2006	
Trichloroethene	0.6 (µg/L)
cis-1,2-DCE	8 (µg/L)
Vinyl Chloride	13 (µg/L)
Benzene	<0.2 U (µg/L)
TPH-G	<0.25 U (mg/L)

GW143- November 16, 2006	
Trichloroethene	0.4 (µg/L)
cis-1,2-DCE	0.2 (µg/L)
Vinyl Chloride	<0.2 U (µg/L)
Benzene	<0.2 U (µg/L)
TPH-G	<0.25 U (mg/L)

GW039- November 16, 2006	
Trichloroethene	<0.2 U (µg/L)
cis-1,2-DCE	<0.2 U (µg/L)
Vinyl Chloride	<0.2 U (µg/L)
Benzene	1.0 (µg/L)
TPH-G	<0.25 U (mg/L)

LEGEND

- GW031 13.79 — EXISTING MONITORING WELL LOCATION GROUNDWATER ELEVATION (FEET)
- GW042 — EXISTING EXTRACTION WELL LOCATION
- * — WELL SCREENED IN LOWER PORTION OF AQUIFER SO WATER LEVEL IS NOT USED FOR CONTOURING
- 13.80 — GROUNDWATER ELEVATION CONTOUR IN 0.05 FOOT INTERVAL (FEBRUARY 2007)
- REMOVED UST (WESTON, 2001)
- cis-1,2-DCE — cis-1,2-Dichloroethene
- TPH-G — Total Petroleum Hydrocarbons-Gasoline fraction
- U — Analyte was not detected above value shown
- J — Analyte was positively identified; the value shown is the approximate concentration of the analyte
- UJ — Analyte was not detected. Value shown is estimated detection limit

NOTES

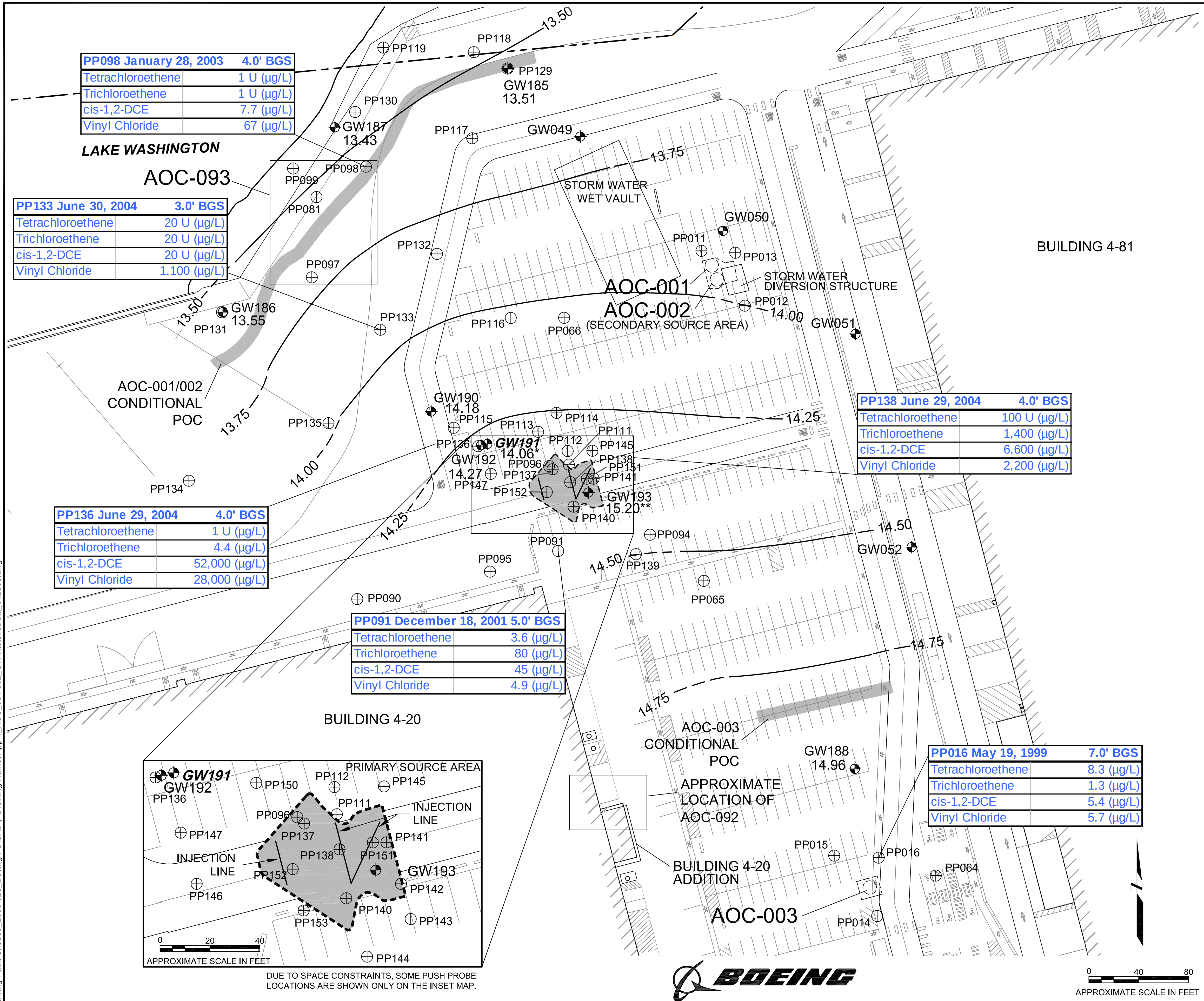
1. HORIZONTAL DATUM: WASHINGTON STATE COORDINATE SYSTEM NORTH ZONE NAD83 (91)
   VERTICAL DATUM: NATIONAL GEODETIC VERTICAL DATUM (NGVD1929)
2. BASEMAP COMPILED BY DUANE HARTMAN & ASSOCIATES, INC., DECEMBER 1994
3. UST LOCATIONS AND PRODUCT PIPING LOCATIONS FROM FINAL REMEDIAL INVESTIGATION (WESTON, 2001)

BUILDING 4-78/79 SWMU/AOC GROUP
GROUNDWATER QUALITY DATA,
GROUNDWATER ELEVATION CONTOURS, AND CPOC
Boeing Renton Facility
Renton, Washington

By: APS | Date: 05/28/08 | Project No. 8888

Geomatrix | Figure A-3

Plot Date: 05/28/08 - 9:24am, Plotted by: astenberg
Drawing Path: S:\8888_2006\025_Boeing FS\CAD\, Drawing Name: App-3_4-78_79 SWMU_AOC-GWcontoursFeb2007_012508.dwg



DUE TO SPACE CONSTRAINTS, SOME PUSH PROBE LOCATIONS ARE SHOWN ONLY ON THE INSET MAP.

PP098 January 28, 2003	4.0' BGS
Tetrachloroethene	1 U (µg/L)
Trichloroethene	1 U (µg/L)
cis-1,2-DCE	7.7 (µg/L)
Vinyl Chloride	67 (µg/L)

PP133 June 30, 2004	3.0' BGS
Tetrachloroethene	20 U (µg/L)
Trichloroethene	20 U (µg/L)
cis-1,2-DCE	20 U (µg/L)
Vinyl Chloride	1,100 (µg/L)

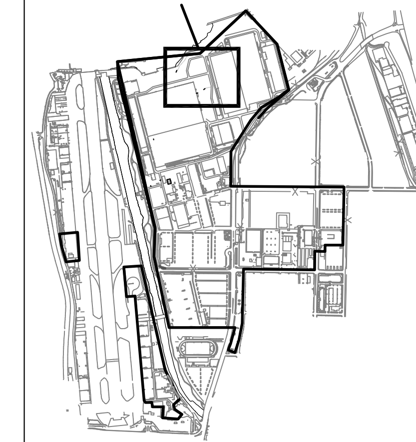
PP136 June 29, 2004	4.0' BGS
Tetrachloroethene	1 U (µg/L)
Trichloroethene	4.4 (µg/L)
cis-1,2-DCE	52,000 (µg/L)
Vinyl Chloride	28,000 (µg/L)

PP091 December 18, 2001	5.0' BGS
Tetrachloroethene	3.6 (µg/L)
Trichloroethene	80 (µg/L)
cis-1,2-DCE	45 (µg/L)
Vinyl Chloride	4.9 (µg/L)

PP138 June 29, 2004	4.0' BGS
Tetrachloroethene	100 U (µg/L)
Trichloroethene	1,400 (µg/L)
cis-1,2-DCE	6,600 (µg/L)
Vinyl Chloride	2,200 (µg/L)

PP016 May 19, 1999	7.0' BGS
Tetrachloroethene	8.3 (µg/L)
Trichloroethene	1.3 (µg/L)
cis-1,2-DCE	5.4 (µg/L)
Vinyl Chloride	5.7 (µg/L)

AOC-001 AND AOC-002
LOCATION MAP



BOEING RENTON
FACILITY MAP

LEGEND

GW190 14.18	EXISTING MONITORING WELL LOCATION GROUNDWATER ELEVATION (FEET)
PP011	EXISTING PUSH PROBE LOCATION
*	WELL SCREENED IN LOWER PORTION OF AQUIFER SO WATER LEVEL IS NOT USED FOR CONTOURS
**	WATER LEVEL IS ANOMALOUS SO IT WAS NOT INCLUDED WITH CONTOURS
14.50	GROUNDWATER ELEVATION CONTOUR IN 0.25 FOOT INTERVAL (FEBRUARY 2007)
	APPROXIMATE PROPERTY LINE
	APPROXIMATE NOVEMBER 2005 EXCAVATION AREA, SHOWING EXISTING REMEDIATION PORTS AND LINES.
cis-1,2-DCE	cis-1,2-Dichloroethene
U	Analyte was not detected above value shown

***ITALICIZED BOLD* = DEEP ZONE**
NORMAL = SHALLOW ZONE

NOTES

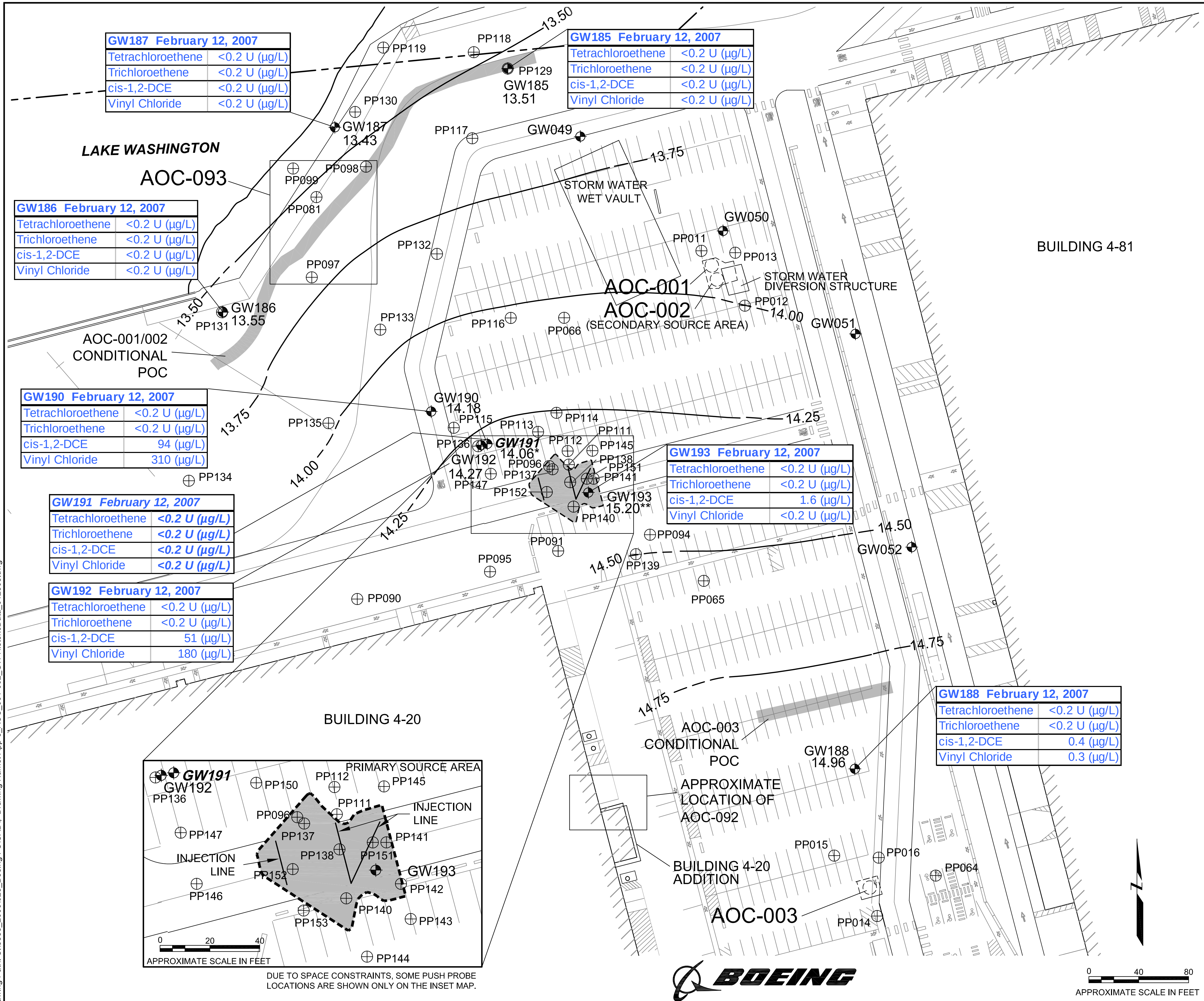
1. HORIZONTAL DATUM:
   WASHINGTON STATE COORDINATE SYSTEM
   NORTH ZONE NAD83 (91)
   VERTICAL DATUM:
   NATIONAL GEODETIC VERTICAL DATUM (NGVD1929)
2. BASEMAP COMPILED BY DUANE HARTMAN & ASSOCIATES INC., DECEMBER 1994

AOC-001 AND AOC-002 GROUNDWATER
PRE-INTERIM ACTION CONCENTRATIONS
Boeing Renton Facility
Renton, Washington

By: APS | Date: 05/28/08 | Project No. 8888

Geomatrix | Figure A-4

Plot Date: 05/28/08 - 9:25am, Plotted by: astenberg
Drawing Path: S:\8888_2006\025_Boeing FS\CAD\, Drawing Name: App-4_AOC_001-002_GW HistoricData_012508.dwg



GW187 February 12, 2007	
Tetrachloroethene	<0.2 U (µg/L)
Trichloroethene	<0.2 U (µg/L)
cis-1,2-DCE	<0.2 U (µg/L)
Vinyl Chloride	<0.2 U (µg/L)

GW185 February 12, 2007	
Tetrachloroethene	<0.2 U (µg/L)
Trichloroethene	<0.2 U (µg/L)
cis-1,2-DCE	<0.2 U (µg/L)
Vinyl Chloride	<0.2 U (µg/L)

GW186 February 12, 2007	
Tetrachloroethene	<0.2 U (µg/L)
Trichloroethene	<0.2 U (µg/L)
cis-1,2-DCE	<0.2 U (µg/L)
Vinyl Chloride	<0.2 U (µg/L)

GW190 February 12, 2007	
Tetrachloroethene	<0.2 U (µg/L)
Trichloroethene	<0.2 U (µg/L)
cis-1,2-DCE	94 (µg/L)
Vinyl Chloride	310 (µg/L)

GW191 February 12, 2007	
Tetrachloroethene	***<0.2 U (µg/L)***
Trichloroethene	***<0.2 U (µg/L)***
cis-1,2-DCE	***<0.2 U (µg/L)***
Vinyl Chloride	***<0.2 U (µg/L)***

GW192 February 12, 2007	
Tetrachloroethene	<0.2 U (µg/L)
Trichloroethene	<0.2 U (µg/L)
cis-1,2-DCE	51 (µg/L)
Vinyl Chloride	180 (µg/L)

GW193 February 12, 2007	
Tetrachloroethene	<0.2 U (µg/L)
Trichloroethene	<0.2 U (µg/L)
cis-1,2-DCE	1.6 (µg/L)
Vinyl Chloride	<0.2 U (µg/L)

GW188 February 12, 2007	
Tetrachloroethene	<0.2 U (µg/L)
Trichloroethene	<0.2 U (µg/L)
cis-1,2-DCE	0.4 (µg/L)
Vinyl Chloride	0.3 (µg/L)

LEGEND

GW190 14.18 — EXISTING MONITORING WELL LOCATION GROUNDWATER ELEVATION (FEET)

PP011 — EXISTING PUSH PROBE LOCATION

* — WELL SCREENED IN LOWER PORTION OF AQUIFER SO WATER LEVEL IS NOT USED FOR CONTOURS

** — WATER LEVEL IS ANOMALOUS SO IT WAS NOT INCLUDED WITH CONTOURS

14.50 — GROUNDWATER ELEVATION CONTOUR IN 0.25 FOOT INTERVAL (FEBRUARY 2007)

— APPROXIMATE PROPERTY LINE

— APPROXIMATE NOVEMBER 2005 EXCAVATION AREA, SHOWING EXISTING REMEDIATION PORTS AND LINES.

cis-1,2-DCE — cis-1,2-Dichloroethene

U — Analyte was not detected above value shown

***ITALICIZED BOLD* = DEEP ZONE**

NORMAL = SHALLOW ZONE

NOTES

1. HORIZONTAL DATUM:
   WASHINGTON STATE COORDINATE SYSTEM
   NORTH ZONE NAD83 (91)
   VERTICAL DATUM:
   NATIONAL GEODETIC VERTICAL DATUM (NGVD1929)
2. BASEMAP COMPILED BY DUANE HARTMAN & ASSOCIATES, INC., DECEMBER 1994

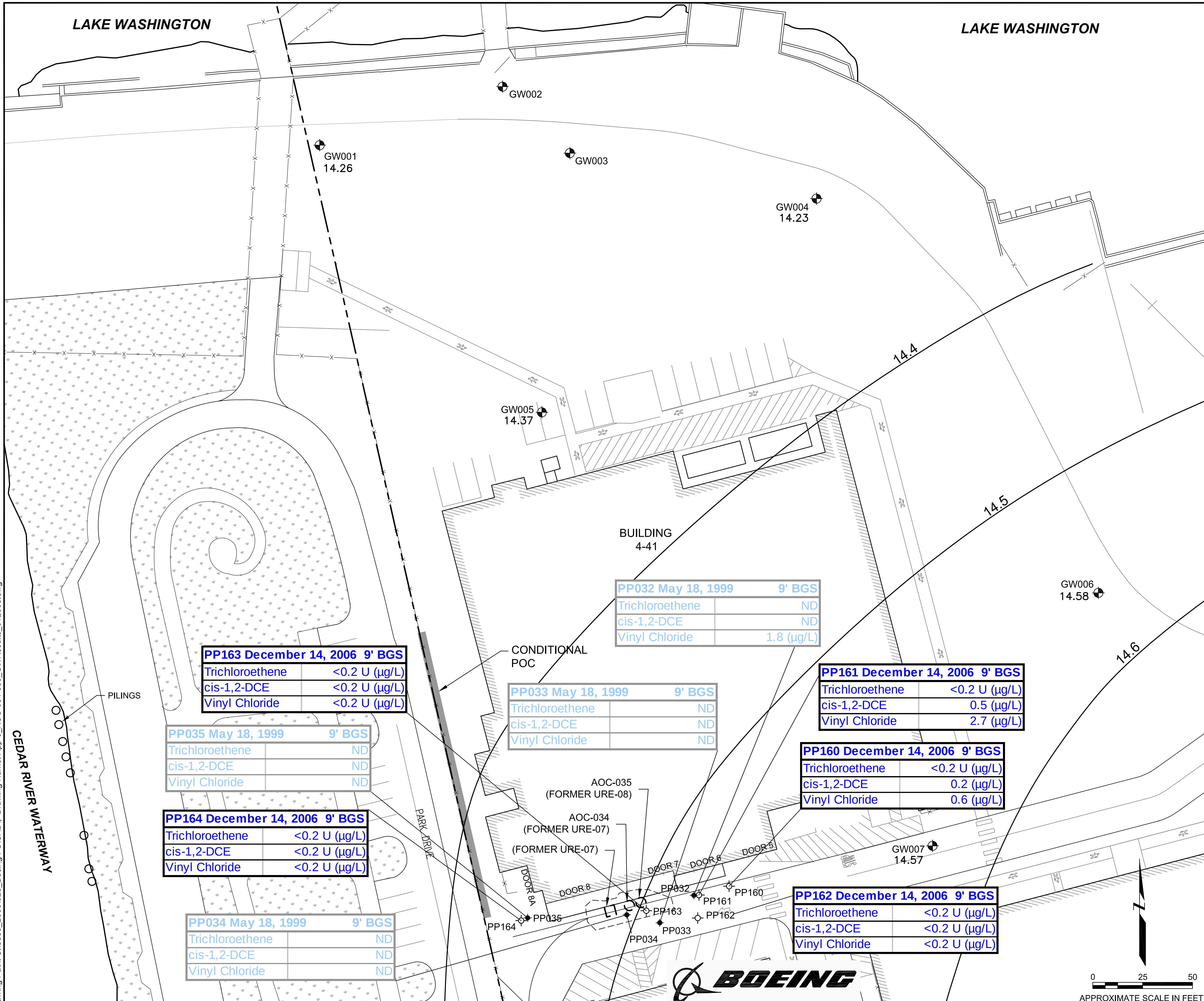
AOC-001/002 AND AOC-003 GROUNDWATER QUALITY DATA, GROUNDWATER ELEVATION CONTOURS, AND CPOC
Boeing Renton Facility
Renton, Washington

By: APS | Date: 05/28/08 | Project No. 8888

Geomatrix

Figure A-5

Plot Date: 05/28/08 - 9:26am, Plotted by: astenberg
Drawing Path: S:\8888_2006\025_Boeing FS\CAD\, Drawing Name: App-5_AOC_001-002_GW HistoricData_012508.dwg



PP163 December 14, 2006	9' BGS
Trichloroethene	<0.2 U (µg/L)
cis-1,2-DCE	<0.2 U (µg/L)
Vinyl Chloride	<0.2 U (µg/L)

PP035 May 18, 1999	9' BGS
Trichloroethene	ND
cis-1,2-DCE	ND
Vinyl Chloride	ND

PP164 December 14, 2006	9' BGS
Trichloroethene	<0.2 U (µg/L)
cis-1,2-DCE	<0.2 U (µg/L)
Vinyl Chloride	<0.2 U (µg/L)

PP034 May 18, 1999	9' BGS
Trichloroethene	ND
cis-1,2-DCE	ND
Vinyl Chloride	ND

PP032 May 18, 1999	9' BGS
Trichloroethene	ND
cis-1,2-DCE	ND
Vinyl Chloride	1.8 (µg/L)

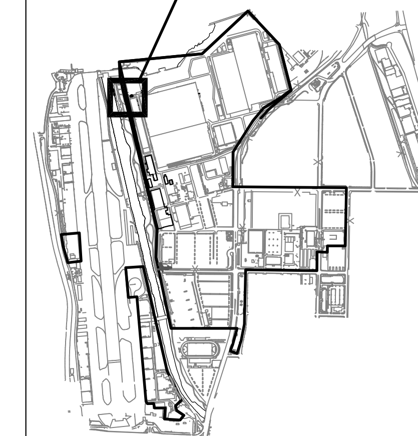
PP033 May 18, 1999	9' BGS
Trichloroethene	ND
cis-1,2-DCE	ND
Vinyl Chloride	ND

PP161 December 14, 2006	9' BGS
Trichloroethene	<0.2 U (µg/L)
cis-1,2-DCE	0.5 (µg/L)
Vinyl Chloride	2.7 (µg/L)

PP160 December 14, 2006	9' BGS
Trichloroethene	<0.2 U (µg/L)
cis-1,2-DCE	0.2 (µg/L)
Vinyl Chloride	0.6 (µg/L)

PP162 December 14, 2006	9' BGS
Trichloroethene	<0.2 U (µg/L)
cis-1,2-DCE	<0.2 U (µg/L)
Vinyl Chloride	<0.2 U (µg/L)

AOC-034 and AOC-035
LOCATION MAP



BOEING RENTON
FACILITY MAP

LEGEND

- GW006 14.58 — MONITORING WELL LOCATION GROUNDWATER ELEVATION (FEET)
- PP162 — 12/14/2006 PUSH-PROBE SOIL AND GROUNDWATER SAMPLE LOCATION
- PP032 — HISTORICAL PUSH-PROBE LOCATION
- LIMITS OF PREVIOUS EXCAVATION (HART CROWSER 1987)
- FORMER UST LOCATION
- FENCE
- 14.5 — GROUNDWATER ELEVATION CONTOUR IN 0.1 FOOT INTERVAL (SEPTEMBER 2000)
- cis-1,2-DCE — cis-1,2-Dichloroethene
- U — Analyte was not detected above value shown
- ND — Not Detected

NOTES

1. HORIZONTAL DATUM:
   WASHINGTON STATE COORDINATE SYSTEM
   NORTH ZONE NAD83 (91)
   VERTICAL DATUM:
   NATIONAL GEODETIC VERTICAL DATUM (NGVD1929)
2. BASEMAP COMPILED BY DUANE HARTMAN & ASSOCIATES, INC., DECEMBER, 1994
3. GROUNDWATER ELEVATION CONTOURS AND HISTORIC PUSH PROBE LOCATIONS FROM FINAL REMEDIAL INVESTIGATION REPORT (WESTON, 2001)

BOEING

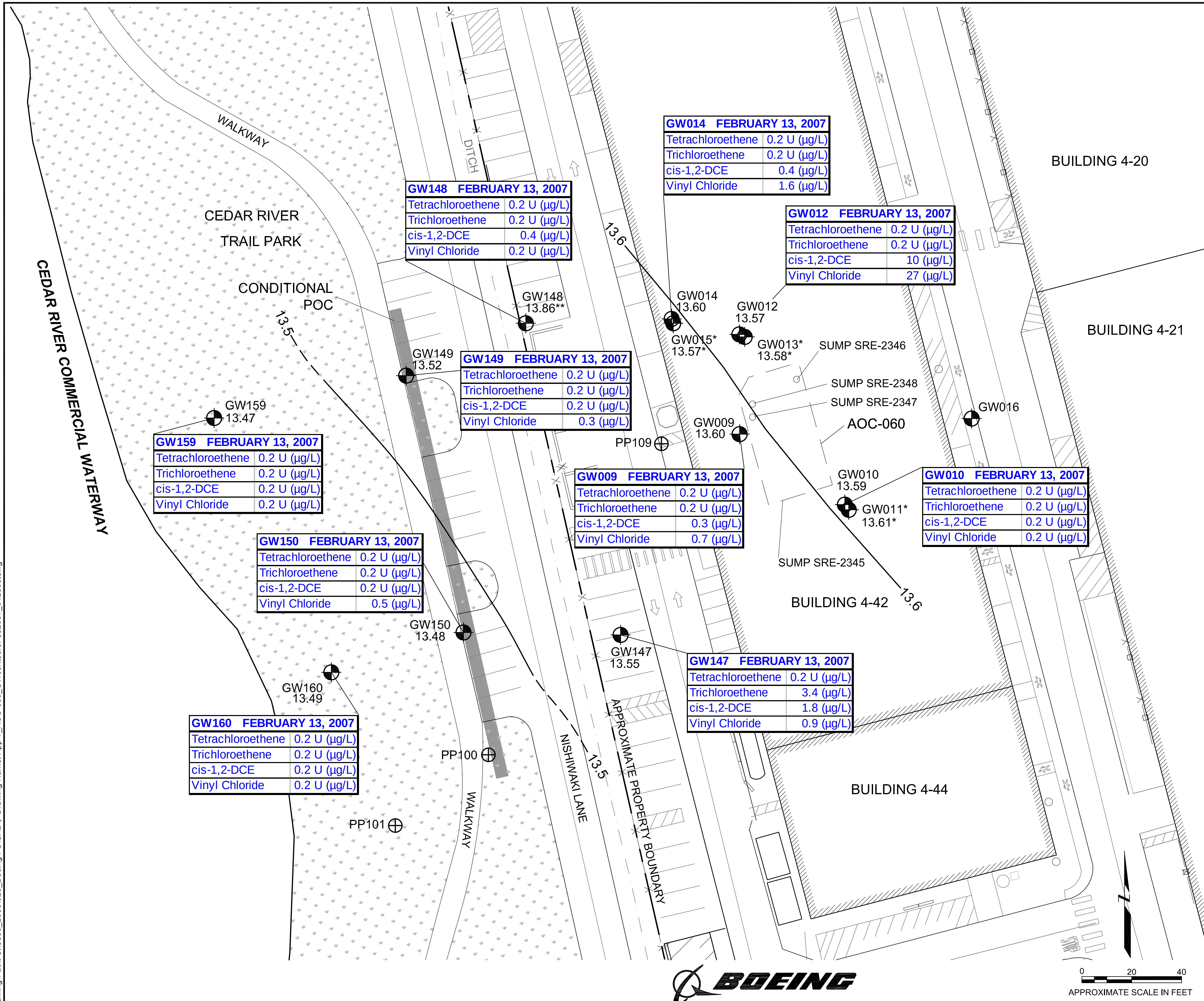
AOC-034 and AOC-035 GROUNDWATER QUALITY DATA, GROUNDWATER ELEVATIONS, AND CPOC

Boeing Renton Facility
Renton, Washington

By: APS | Date: 05/28/08 | Project No. 8888

Geomatrix | Figure A-6

Plot Date: 05/28/08 - 9:28am, Plotted by: astenberg
Drawing Path: S:\8888_2006\025_Boeing FS\CAD\, Drawing Name: App-6_AOC-034-035_GWResults_012508.dwg



GW014	FEBRUARY 13, 2007
Tetrachloroethene	0.2 U (µg/L)
Trichloroethene	0.2 U (µg/L)
cis-1,2-DCE	0.4 (µg/L)
Vinyl Chloride	1.6 (µg/L)

GW148	FEBRUARY 13, 2007
Tetrachloroethene	0.2 U (µg/L)
Trichloroethene	0.2 U (µg/L)
cis-1,2-DCE	0.4 (µg/L)
Vinyl Chloride	0.2 U (µg/L)

GW012	FEBRUARY 13, 2007
Tetrachloroethene	0.2 U (µg/L)
Trichloroethene	0.2 U (µg/L)
cis-1,2-DCE	10 (µg/L)
Vinyl Chloride	27 (µg/L)

GW149	FEBRUARY 13, 2007
Tetrachloroethene	0.2 U (µg/L)
Trichloroethene	0.2 U (µg/L)
cis-1,2-DCE	0.2 U (µg/L)
Vinyl Chloride	0.3 (µg/L)

GW159	FEBRUARY 13, 2007
Tetrachloroethene	0.2 U (µg/L)
Trichloroethene	0.2 U (µg/L)
cis-1,2-DCE	0.2 U (µg/L)
Vinyl Chloride	0.2 U (µg/L)

GW009	FEBRUARY 13, 2007
Tetrachloroethene	0.2 U (µg/L)
Trichloroethene	0.2 U (µg/L)
cis-1,2-DCE	0.3 (µg/L)
Vinyl Chloride	0.7 (µg/L)

GW010	FEBRUARY 13, 2007
Tetrachloroethene	0.2 U (µg/L)
Trichloroethene	0.2 U (µg/L)
cis-1,2-DCE	0.2 U (µg/L)
Vinyl Chloride	0.2 U (µg/L)

GW150	FEBRUARY 13, 2007
Tetrachloroethene	0.2 U (µg/L)
Trichloroethene	0.2 U (µg/L)
cis-1,2-DCE	0.2 U (µg/L)
Vinyl Chloride	0.5 (µg/L)

GW147	FEBRUARY 13, 2007
Tetrachloroethene	0.2 U (µg/L)
Trichloroethene	3.4 (µg/L)
cis-1,2-DCE	1.8 (µg/L)
Vinyl Chloride	0.9 (µg/L)

GW160	FEBRUARY 13, 2007
Tetrachloroethene	0.2 U (µg/L)
Trichloroethene	0.2 U (µg/L)
cis-1,2-DCE	0.2 U (µg/L)
Vinyl Chloride	0.2 U (µg/L)

LEGEND

GW150 13.48	EXISTING MONITORING WELL LOCATION GROUNDWATER ELEVATION (FEET)
PP109	EXISTING SUPPLEMENTAL RI PUSH PROBE
*	WELL SCREENED IN LOWER PORTION OF AQUIFER SO WATER LEVEL IS NOT USED FOR CONTOURING
**	WATER LEVEL IS ANOMALOUS SO IT WAS NOT INCLUDED WITH CONTOURS
13.6	GROUNDWATER ELEVATION CONTOUR IN 0.1 FOOT INTERVAL (FEBRUARY 2007)
x	FENCE
	APPROXIMATE PROPERTY LINE
cis-1,2-DCE	cis-1,2-Dichloroethene
U	Analyte was not detected above value shown

NOTES

1. HORIZONTAL DATUM:
   WASHINGTON STATE COORDINATE SYSTEM
   NORTH ZONE NAD83 (91)
   VERTICAL DATUM:
   NATIONAL GEODETIC VERTICAL DATUM (NGVD1929)
2. BASEMAP COMPILED BY DUANE HARTMAN & ASSOCIATES, INC., DECEMBER, 1994

BOEING

AOC-060 (BUILDING 4-42)
GROUNDWATER QUALITY DATA, GROUNDWATER ELEVATION CONTOURS, AND CPOC
Boeing Renton Facility
Renton, Washington

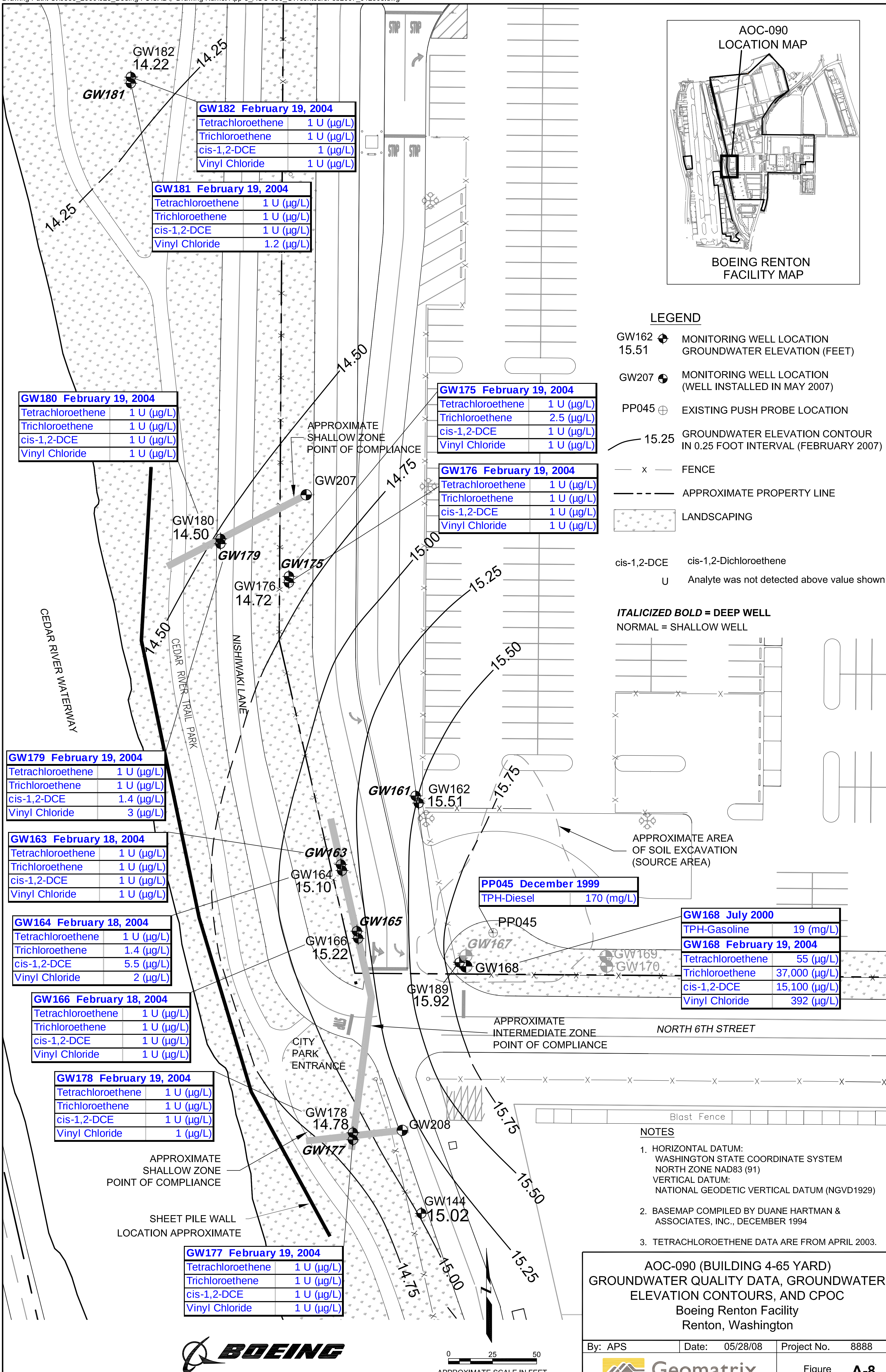
By: APS | Date: 05/28/08 | Project No. 8888

Geomatrix

Figure A-7

Plot Date: 05/28/08 - 9:29am, Plotted by: astenberg
Drawing Path: S:\8888_2006\025_Boeing FS\CAD\, Drawing Name: App-7_AOC-060_GWcontoursFeb2007_012508.dwg

Plot Date: 05/28/08 - 9:19am, Plotted by: astenberg
Drawing Path: S:\8888_2006\025_Boeing FS\CAD\, Drawing Name: App-8_AOC-090_GWcontoursFeb2007_012508.dwg



GW182 February 19, 2004	
Tetrachloroethene	1 U (µg/L)
Trichloroethene	1 U (µg/L)
cis-1,2-DCE	1 (µg/L)
Vinyl Chloride	1 U (µg/L)

GW181 February 19, 2004	
Tetrachloroethene	1 U (µg/L)
Trichloroethene	1 U (µg/L)
cis-1,2-DCE	1 U (µg/L)
Vinyl Chloride	1.2 (µg/L)

GW180 February 19, 2004	
Tetrachloroethene	1 U (µg/L)
Trichloroethene	1 U (µg/L)
cis-1,2-DCE	1 U (µg/L)
Vinyl Chloride	1 U (µg/L)

GW175 February 19, 2004	
Tetrachloroethene	1 U (µg/L)
Trichloroethene	2.5 (µg/L)
cis-1,2-DCE	1 U (µg/L)
Vinyl Chloride	1 U (µg/L)

GW176 February 19, 2004	
Tetrachloroethene	1 U (µg/L)
Trichloroethene	1 U (µg/L)
cis-1,2-DCE	1 U (µg/L)
Vinyl Chloride	1 U (µg/L)

GW179 February 19, 2004	
Tetrachloroethene	1 U (µg/L)
Trichloroethene	1 U (µg/L)
cis-1,2-DCE	1.4 (µg/L)
Vinyl Chloride	3 (µg/L)

GW163 February 18, 2004	
Tetrachloroethene	1 U (µg/L)
Trichloroethene	1 U (µg/L)
cis-1,2-DCE	1 U (µg/L)
Vinyl Chloride	1 U (µg/L)

PP045 December 1999	
TPH-Diesel	170 (mg/L)

GW168 July 2000	
TPH-Gasoline	19 (mg/L)
GW168 February 19, 2004	
Tetrachloroethene	55 (µg/L)
Trichloroethene	37,000 (µg/L)
cis-1,2-DCE	15,100 (µg/L)
Vinyl Chloride	392 (µg/L)

GW164 February 18, 2004	
Tetrachloroethene	1 U (µg/L)
Trichloroethene	1.4 (µg/L)
cis-1,2-DCE	5.5 (µg/L)
Vinyl Chloride	2 (µg/L)

GW166 February 18, 2004	
Tetrachloroethene	1 U (µg/L)
Trichloroethene	1 U (µg/L)
cis-1,2-DCE	1 U (µg/L)
Vinyl Chloride	1 U (µg/L)

GW178 February 19, 2004	
Tetrachloroethene	1 U (µg/L)
Trichloroethene	1 U (µg/L)
cis-1,2-DCE	1 U (µg/L)
Vinyl Chloride	1 (µg/L)

GW177 February 19, 2004	
Tetrachloroethene	1 U (µg/L)
Trichloroethene	1 U (µg/L)
cis-1,2-DCE	1 U (µg/L)
Vinyl Chloride	1 U (µg/L)

LEGEND

- GW162 15.51 — MONITORING WELL LOCATION, GROUNDWATER ELEVATION (FEET)
- GW207 — MONITORING WELL LOCATION (WELL INSTALLED IN MAY 2007)
- PP045 — EXISTING PUSH PROBE LOCATION
- 15.25 — GROUNDWATER ELEVATION CONTOUR IN 0.25 FOOT INTERVAL (FEBRUARY 2007)
- x — FENCE
- APPROXIMATE PROPERTY LINE
- LANDSCAPING

cis-1,2-DCE — cis-1,2-Dichloroethene

U — Analyte was not detected above value shown

ITALICIZED BOLD **= DEEP WELL**

NORMAL = SHALLOW WELL

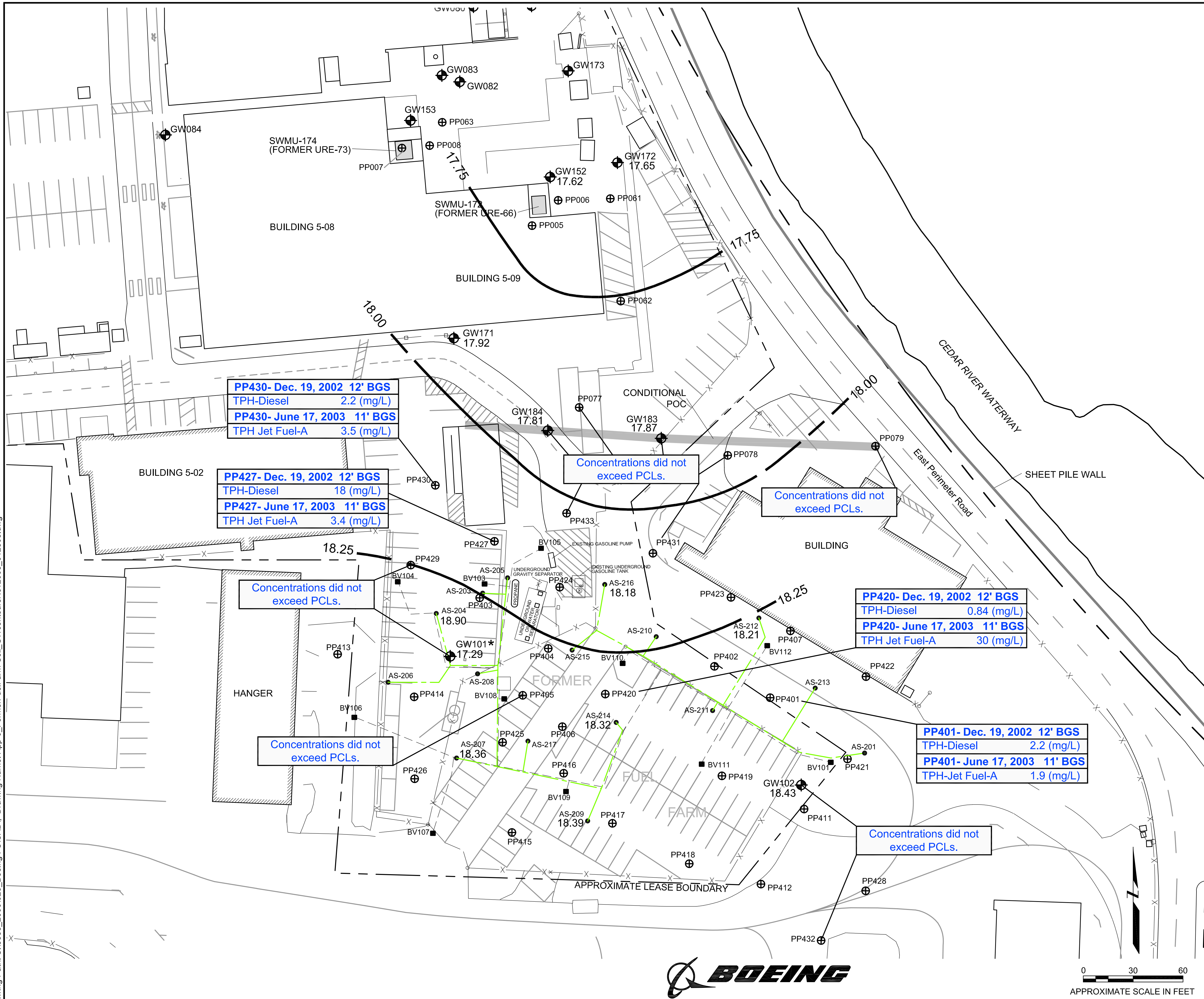
NOTES

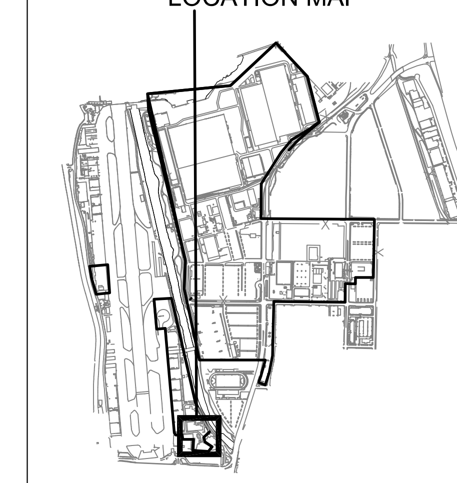
1. HORIZONTAL DATUM: WASHINGTON STATE COORDINATE SYSTEM NORTH ZONE NAD83 (91)
   VERTICAL DATUM: NATIONAL GEODETIC VERTICAL DATUM (NGVD1929)
2. BASEMAP COMPILED BY DUANE HARTMAN & ASSOCIATES, INC., DECEMBER 1994
3. TETRACHLOROETHENE DATA ARE FROM APRIL 2003.

BOEING

AOC-090 (BUILDING 4-65 YARD)
GROUNDWATER QUALITY DATA, GROUNDWATER
ELEVATION CONTOURS, AND CPOC
Boeing Renton Facility
Renton, Washington

By: APS	Date: 05/28/08	Project No. 8888
Geomatrix		Figure A-8





LEGEND

GW152 17.62	EXISTING MONITORING WELL LOCATION GROUNDWATER ELEVATION (FEET)
PP433	EXISTING PUSH PROBE LOCATION
AS-204	EXISTING UNDERGROUND AIR SPARGING WELL
BV112	EXISTING UNDERGROUND BIOVENTING WELL
	UNDERGROUND BIOVENTING LINE
	UNDERGROUND AIR SPARGING LINE
	FENCE
18.25	GROUNDWATER ELEVATION CONTOUR IN 0.25 FOOT INTERVAL (NOVEMBER 7, 2005)
GW101*	Anomalous Water Level; Water Level in Monitoring Well influenced by Air Sparge Operation
TPH	Total Petroleum Hydrocarbons
PCLs	Preliminary Cleanup Levels

NOTES

1. HORIZONTAL DATUM:
   WASHINGTON STATE COORDINATE SYSTEM
   NORTH ZONE NAD83 (91)
   VERTICAL DATUM:
   NATIONAL GEODETIC VERTICAL DATUM (NGVD1929)
2. BASEMAP COMPILED BY DUANE HARTMAN & ASSOCIATES, INC., DECEMBER, 1994
3. PUSH PROBE LOCATIONS FROM FINAL REMEDIAL INVESTIGATION REPORT (WESTON, 2001)
4. PIPING LOCATIONS APPROXIMATE
5. ALL SOIL AND GROUNDWATER DATA FOR THE PUSH PROBES ARE THE MOST RECENT DATA AVAILABLE

FORMER FUEL FARM AOC GROUP GROUNDWATER QUALITY DATA, GROUNDWATER ELEVATION CONTOURS, AND CPOC

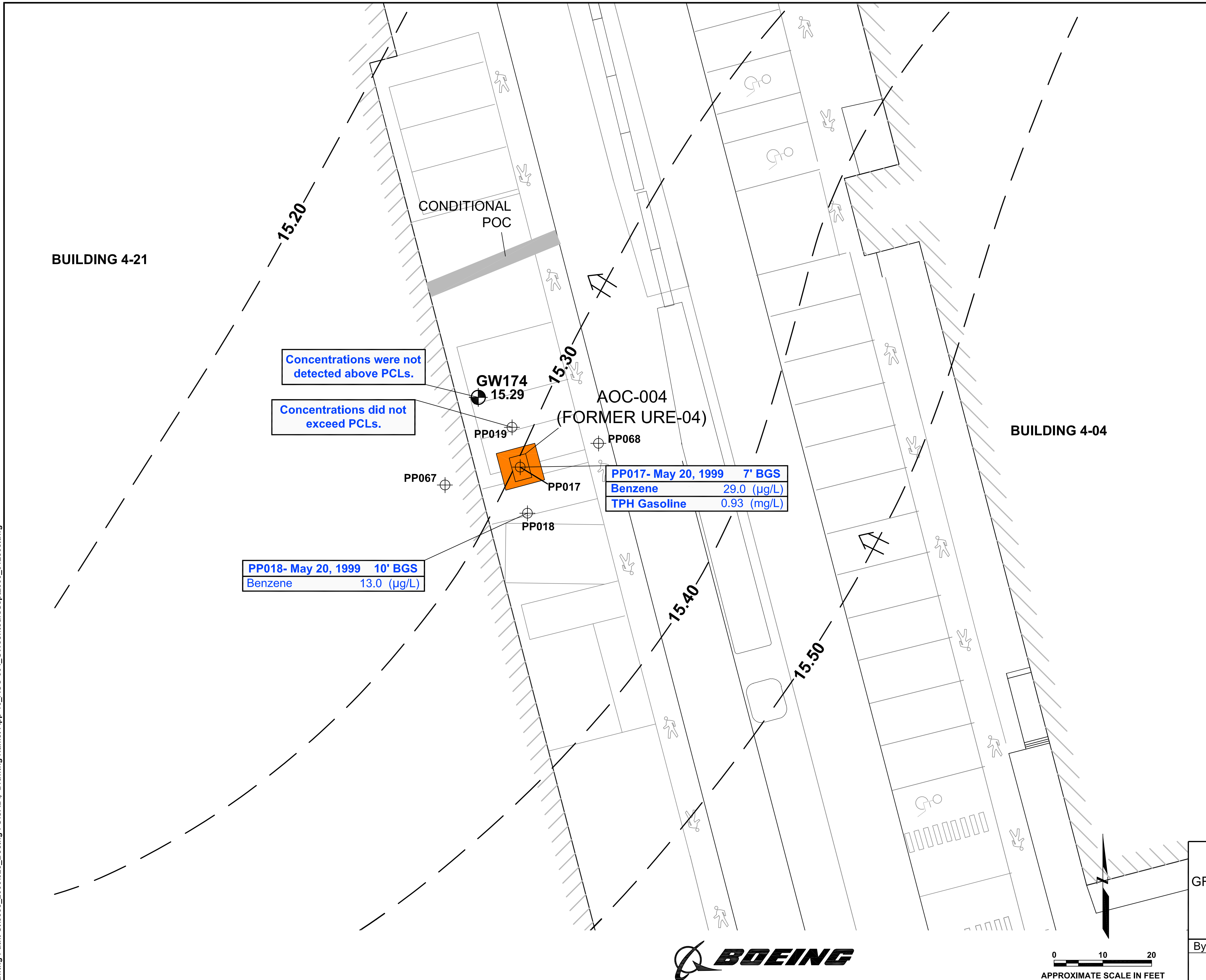
Boeing Renton Facility
Renton, Washington

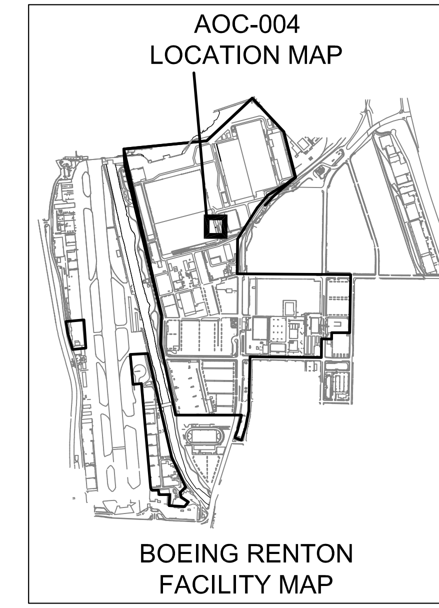
By: APS | Date: 05/28/08 | Project No. 8888

Geomatrix | Figure A-9

BOEING

Plot Date: 05/28/08 - 9:18am, Plotted by: astenberg
Drawing Path: S:\8888_2006\025_Boeing FS\CAD\, Drawing Name: App-9_FormerFuelFarm-Soil_GWcontoursNov2005_012508.dwg





LEGEND

GW174 15.29	EXISTING MONITORING WELL LOCATION GROUNDWATER ELEVATION (FEET)
PP018	EXISTING PUSH-PROBE LOCATION
	FORMER UST LOCATION
	APPROXIMATE AOC-004 SOURCE AREA
15.50	GROUNDWATER ELEVATION CONTOUR IN 0.10 FOOT INTERVAL (SEPTEMBER 7, 2000)
TPH	Total Petroleum Hydrocarbons
PCLs	Preliminary Cleanup Levels

NOTES

1. HORIZONTAL DATUM:
   WASHINGTON STATE COORDINATE SYSTEM
   NORTH ZONE NAD83 (91)
   VERTICAL DATUM:
   NATIONAL GEODETIC VERTICAL DATUM (NGVD1929)
2. BASEMAP COMPILED BY DUANE HARTMAN & ASSOCIATES, INC., DECEMBER, 1994
3. PUSH PROBE LOCATIONS FROM FINAL REMEDIAL INVESTIGATION REPORT (WESTON, 2001)
4. ALL SOIL AND GROUNDWATER DATA FOR THE PUSH PROBES ARE THE MOST RECENT DATA AVAILABLE

BOEING

AOC-004 GROUNDWATER QUALITY DATA, GROUNDWATER ELEVATION CONTOURS, AND CPOC
Boeing Renton Facility
Renton, Washington

By: APS | Date: 05/28/08 | Project No. 8888

Geomatrix | Figure A-10

Plot Date: 05/28/08 - 9:16am, Plotted by: astenberg
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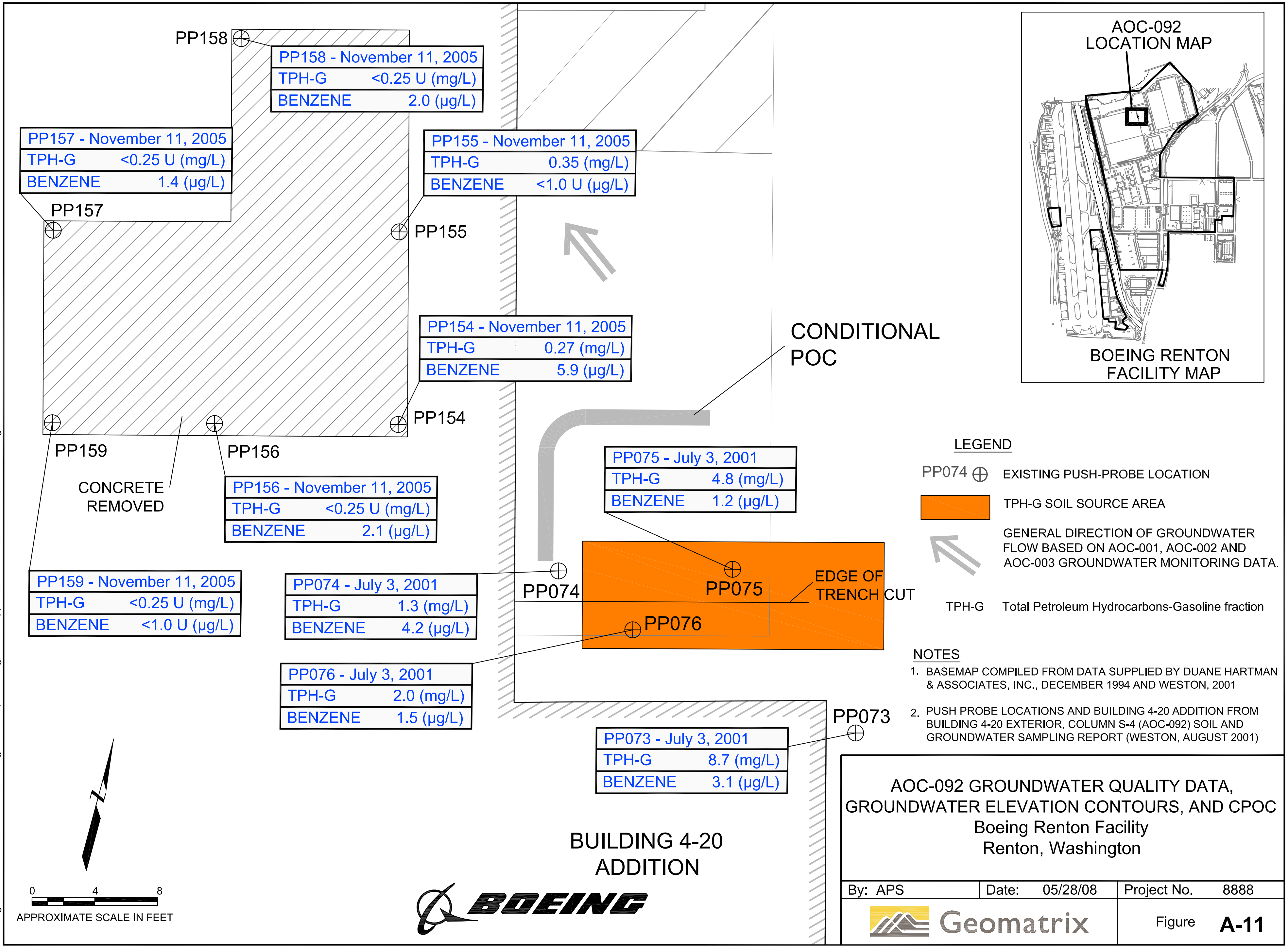

NOTES
1. BASEMAP COMPILED FROM DATA SUPPLIED BY DUANE HARTMAN & ASSOCIATES, INC., DECEMBER 1994 AND WESTON, 2001
2. PUSH PROBE LOCATIONS AND BUILDING 4-20 ADDITION FROM BUILDING 4-20 EXTERIOR, COLUMN S-4 (AOC-092) SOIL AND GROUNDWATER SAMPLING REPORT (WESTON, AUGUST 2001)

AOC-092 GROUNDWATER QUALITY DATA, GROUNDWATER ELEVATION CONTOURS, AND CPOC
Boeing Renton Facility
Renton, Washington

By: APS	Date: 05/28/08	Project No. 8888
Geomatrix		Figure A-11

Plot Date: 05/28/08 - 9:22am, Plotted by: astenberg
Drawing Path: S:\8888_2006\025_Boeing FS\CAD\, Drawing Name: App-11_AOC-092_GW Data_012508.dwg

APPENDIX B

Cost Estimating Summary

COST ESTIMATING SUMMARY

Boeing Renton Facility
Renton, Washington

The cost estimates for the different alternatives for each Area of Concern (AOC) or SMWU, referred to hereafter as "site," were developed based on the conceptual designs for the alternatives described in the report. The general approach is based on the U.S. Environmental Protection Agency's (EPA's) "A Guide to Developing and Documenting Cost Estimates During the Feasibility Study" (EPA, 2000). The subsurface conditions used are those described in the final "Remedial Investigation Report" (Weston, 2001).

There are a total of 12 sites with cost estimates completed for each site. For ease of reference and comparison, the costs of the different alternatives for each site have been presented on separate pages. The cost estimates for each site consist of three separate tables. The first table (e.g., Table B1-1) presents the initial costs of the alternatives, which includes the design and installation of the alternatives. The second table (e.g., Table B1-2) presents the recurring cost which covers the costs associated with operation and maintenance (e.g., equipment replacement) of the alternatives. The third table for each site (e.g., Table B1-3) presents the Net Present Value (NPV) for all the costs for the duration of the project. The costs on all three tables are in 2007 dollars.

The quantities were estimated based on the anticipated scope of work for each conceptual design using available site data and maps. Reasonable assumptions based on professional judgment were made as appropriate to complete the estimate. The quantities are, therefore, preliminary estimates and are not suitable for final design.

The unit prices for each line item were taken from "Building Construction Cost Data" (RSMeans, 2005a); Environmental Remediation Cost Data-Unit Price" (RSMeans, 2005b); vendor quotes, or based on actual experience and engineering judgment. In developing the unit prices, the following general assumptions were made and may appear as footnotes to the cost estimate tables:

- Production rates and prices are based on a standard 40-hour work week; no overtime or shift differentials have been included.
- The personal protective equipment (PPE) will be level D, unless otherwise noted.

- The waste generated will be non-hazardous solid waste, except as otherwise noted.
- Surface asphalt and concrete are assumed to have not been impacted and will be recycled.
- No unique or specialty equipment or approaches have been considered unless otherwise noted.
- Costs for power and water have not been estimated, unless otherwise noted.
- No security guards will be required.
- Work will be performed continuously without interruptions or multiple mobilizations and setups.
- The estimates are accurate to +50% and -30%.
- Sales tax will be 8.8%.
- No prevailing wage or union standby labor have been included.

The initial cost tables present the consultant's cost separately as a percentage of the contractor cost. The specific line items have been divided into investigation, design, permitting, project management, and construction management. The assigned percentages were obtained from the EPA guide (EPA, 2000) and from previous experience.

The recurring costs have also been generalized for simplicity. The unit prices include the cost of the consultant as well as any contractor costs. A separate line item for project management has been added at a fixed unit price of $1,000 per month for all sites and alternatives; the actual project management cost will vary. Project durations of 15 years have been assumed for all sites and alternatives, unless otherwise noted.

The NPV table presents the calculated project present value based on an annual inflation rate of 2% and discount (interest) rate of 7%. A column has been added to the recurring cost tables for annualized costs to accommodate the NPV calculations.

REFERENCES

EPA, 2000, A Guide to Developing and Documenting Cost Estimates During the Feasibility Study, July.

RSMeans, 2005a, Building Construction Cost Data, 18th Annual Edition.

RSMeans, 2005b, Environmental Remediation Cost Data-Unit Price, 11th Annual Edition.

Weston, 2001, Remedial Investigation Report, Boeing Renton Plant, Renton, Washington: Prepared for The Boeing Company, Boeing Shared Services Group, Energy and Environmental Affairs, August 10.

Geomatrix

TABLE B1-1
IMPLEMENTATION COST ESTIMATE
INITIAL COSTS
SWMU-168
Boeing Renton Facility
Renton, Washington

					ALTERNATIVE 1		ALTERNATIVE 2		ALTERNATIVE 3	
INITIAL COSTS					**MNA**		**SVE, Monitored Attenuation**		**Enhanced Bioremediation, Monitored Attenuation**	
CONTRACTOR			**Unit**	**Unit Cost**	**Quantity**	**Cost**	**Quantity**	**Cost**	**Quantity**	**Cost**
1	**Mobilization/Demobilization**									
		Mobilization/Demobilization	lump sum	$10,000	0.1	$1,000	0.5	$5,000	0	$1,000
2	**Health and Safety**									
		Health and Safety Officer	hour	$75	4	$300	20	$1,500	4	$300
		Equipment	month	$2,000	0	$0	1	$2,000	0	$0
		PPE	day	$100	1	$100	3	$300	1	$100
3	**Site Preparation**									
		Utility Locates	hour	$85	4	$340	4	$340	4	$340
		Site Security	linear foot	$4	100	$400	200	$800	100	$400
		Temporary Facilities	month	$3,000	0	$0	1	$3,000	0	$0
		Traffic Control	lump sum	$1,000	1	$1,000	1	$1,000	1	$1,000
		Erosion Control	linear foot	$5	100	$500	200	$1,000	100	$500
		Storm water Management	day	$500	0	$0	1	$500	0	$0
4	**Surveying**									
		Surveying	day	$1,500	1	$1,500	3	$4,500	1	$1,500
5	**Monitoring Wells**									
		Monitoring Well Installation (2" PVC)	linear foot	$75	75	$5,630	75	$5,630	75	$5,630
		Base Price Per Well	each	$500	4	$2,000	4	$2,000	4	$2,000
		Waste Disposal	drum	$150	14	$2,100	14	$2,100	14	$2,100
6	**SVE**									
		Soil Vapor Extraction Well Installation (4" PVC)	linear foot	$100	0	$0	5	$500	0	$0
		Base Price Per Well	each	$300	0	$0	1	$300	0	$0
		Waste Disposal	drum	$150	0	$0	1	$150	0	$0
		Knock out pot	each	$2,000	0	$0	1	$2,000	0	$0
		Vacuum Blower	each	$2,500	0	$0	1	$2,500	0	$0
		Granular Activated Carbon	each	$3,000	0	$0	2	$6,000	0	$0
		Permanganate Unit	each	$1,500	0	$0	1	$1,500	0	$0
		Valves	each	$85	0	$0	1	$90	0	$0
		Gauges	each	$25	0	$0	1	$30	0	$0
		Treatment Center	lump sum	$12,000	0	$0	0.5	$6,000	0.0	$0
		Electrical Service	lump sum	$10,000	0	$0	0.5	$5,000	0.0	$0
		Electrical Connections	lump sum	$5,000	0	$0	1	$5,000	0	$0
7	**Enhanced Bioremediation**									
		Direct Push	day	$2,000	0	$0	0	$0	2	$4,000
		Additive	lb	$5.00	0	$0	0	$0	325	$1,630
		Equipment	day	$400	0	$0	0	$0	2	$800
Subtotal						**$14,870**		**$58,740**		**$21,300**
Sales Tax (8.8%)						**$1,310**		**$5,170**		**$1,870**
Subtotal						**$16,180**		**$63,910**		**$23,170**
Contingency (30%)						**$4,850**		**$19,170**		**$6,950**
Subtotal, Contractor						**$21,000**		**$83,100**		**$30,100**
PROFESSIONAL TECHNICAL SERVICES										
		Investigation (Confirmation Sampling)	lump sum	$7,200	1	$7,200	1.8	$12,600	1.8	$12,600
		Permitting	%	5%	$21,000	$1,050	$83,100	$4,160	$30,100	$1,510
		Engineering design costs	%	20%	$21,000	$4,200	$83,100	$16,620	$30,100	$6,020
		Construction Management	%	15%	$21,000	$3,150	$83,100	$12,470	$30,100	$4,520
		Project Management	%	10%	$21,000	$2,100	$83,100	$8,310	$30,100	$3,010
Subtotal, Professional Services						**$17,700**		**$54,160**		**$27,660**
TOTAL INITIAL COST						**$38,700**		**$137,260**		**$57,800**

Notes:
1. 2007 Dollars.
2. Costs are +50% -30%.
3. 40 hour work week.
4. Level D PPE.
5. Waste disposal is non-hazardous solid waste.
6. Soil 1 cubic yard = 1.6 tons.
7. Concrete/Asphalt 1 cubic yard = 2 tons.
8. Installation of 2 shallow monitoring wells and 1 intermediate monitoring well, all alternatives.
9. Installation of 1 SVE well at location PP001, Alternatives 2 and 3.
10. No pilot test for SVE.
11. Enhanced Bioremediation will require a single application, Alternative 3.
12. Investigation (Confirmation Sampling) will include 3 push probe locations with 3 sample depths per location.

Geomatrix

TABLE B1-2
IMPLEMENTATION COST ESTIMATE
RECURRING COSTS
SWMU-168
Boeing Renton Facility
Renton, Washington

	RECURRING COSTS	Unit	Unit Cost	ALTERNATIVE 1 MNA				ALTERNATIVE 2 SVE, Monitored Attenuation				ALTERNATIVE 3 Enhanced Bioremediation, Monitored Attenuation			
				Annual Quantity	Annual Cost	Lifetime Quantity	Lifetime Cost	Annual Quantity	Annual Cost	Lifetime Quantity	Lifetime Cost	Annual Quantity	Annual Cost	Lifetime Quantity	Lifetime Cost
1	**OPERATION AND MAINTENANCE**														
	Monitoring SVE	annual	$15,000	0	$0	0	$0	1	$15,000	5	$75,000	0	$0	5	$75,000
	Air Sampling SVE	per well	$450	0	$0	0	$0	1	$450	5	$2,250	0	$0	5	$2,250
	Electricity	monthly	$400	0	$0	0	$0	12	$4,800	60	$24,000	0	$0	0	$0
	Carbon Replacement	pound	$2	0	$0	0	$0	600	$1,200	3000	$6,000	0	$0	0	$0
	Permanganate Replacement	pound	$2	0	$0	0	$0	700	$1,400	3500	$7,000	0	$0	0	$0
	Maintenance SVE	lump sum	$5,000	0	$0	0	$0	1	$5,000	5	$25,000	0	$0	5	$25,000
	Monitoring Well Maintenance	per well	$500	3	$1,500	15	$7,500	3	$1,500	15	$7,500	0	$0	15	$7,500
Subtotal					**$1,500**		**$7,500**		**$29,350**		**$146,750**		**$0**		**$109,750**
2	**QUARTERLY GW MONITORING (Years 1,2)**														
	Sampling	each well	$600	16	$9,600	32	$19,200	16	$9,600	32	$19,200	32	$19,200	24	$14,400
	Analysis	each well	$500	16	$8,000	32	$16,000	16	$8,000	32	$16,000	32	$16,000	24	$12,000
	Reporting	per round	$5,000	4	$20,000	8	$40,000	4	$20,000	8	$40,000	4	$20,000	8	$40,000
Subtotal					**$37,600**		**$75,200**		**$37,600**		**$75,200**		**$55,200**		**$66,400**
3	**SEMIANNUAL GW MONITORING (Years 3-15)**														
	Sampling	each well	$600	8	$4,800	104	$62,400	8	$4,800	104	$62,400	8	$4,800	104	$62,400
	Analysis	each well	$200	8	$1,600	104	$20,800	8	$1,600	104	$20,800	8	$1,600	104	$20,800
	Reporting	per round	$5,000	2	$10,000	26	$130,000	2	$10,000	26	$130,000	2	$10,000	26	$130,000
Subtotal					**$16,400**		**$213,200**		**$16,400**		**$213,200**		**$16,400**		**$213,200**
4	**FIVE YEAR GW MONITORING (Years 5,10,15)**														
	Sampling	each well	$600	4	$2,400	9	$5,400	4	$2,400	9	$5,400	4	$2,400	9	$5,400
	Analysis	each well	$500	4	$2,000	9	$4,500	4	$2,000	9	$4,500	4	$2,000	9	$4,500
	Reporting	per round	$5,000	1	$5,000	3	$15,000	1	$5,000	3	$15,000	1	$5,000	3	$15,000
Subtotal					**$9,400**		**$24,900**		**$9,400**		**$24,900**		**$9,400**		**$24,900**
5	**PROJECT MANAGEMENT**														
	Project Management	year	$12,000	1	$12,000	15	$180,000	1	$12,000	15	$180,000	1	$12,000	15	$180,000
Subtotal					**$12,000**		**$180,000**		**$12,000**		**$180,000**		**$12,000**		**$180,000**

Notes:
1. 2007 Dollars.
2. Costs are +50% -30%.
3. 40 hour work week.
4. Sales tax of 8.8% included in unit price.
5. SVE system runs for 5 years, Alternatives 2 and 3.
6. Monitoring Well Operation and Maintenance for 15 years, all alternatives.

TABLE B1-3
IMPLEMENTATION COST ESTIMATE
NET PRESENT VALUE
SWMU-168
Boeing Renton Facility
Renton, Washington

	ALTERNATIVE 1					ALTERNATIVE 2					ALTERNATIVE 3				
	MNA					SVE, Monitored Attenuation					Enhanced Bioremediation & Monitored Attenuation				
Year	**Initial Costs**	**O&M**	**PM**	**GW Mon.**	**Total**	**Initial Costs**	**O&M**	**PM**	**GW Mon.**	**Total**	**Initial Costs**	**O&M**	**PM**	**GW Mon.**	**Total**
0	$38,700				$38,700	$137,260				$137,260	$57,800				$57,800
1		$1,530	$12,200	$38,400	$52,130		$29,900	$12,200	$38,400	$80,500		$0	$12,200	$56,300	$68,500
2		$1,560	$12,400	$39,200	$53,160		$30,500	$12,400	$39,200	$82,100		$0	$12,400	$57,400	$69,800
3		$1,590	$12,600	$17,400	$31,590		$31,100	$12,600	$17,400	$61,100		$0	$12,600	$17,400	$30,000
4		$1,620	$12,900	$17,700	$32,220		$31,700	$12,900	$17,700	$62,300		$0	$12,900	$17,700	$30,600
5		$1,650	$13,200	$19,400	$34,250		$32,300	$13,200	$19,400	$64,900		$0	$13,200	$19,400	$32,600
6		$1,680	$13,500	$18,500	$33,680		$1,680	$13,500	$18,500	$33,680		$1,680	$13,500	$18,500	$33,680
7		$1,710	$13,800	$18,900	$34,410		$1,710	$13,800	$18,900	$34,410		$1,710	$13,800	$18,900	$34,410
8		$1,740	$14,100	$19,300	$35,140		$1,740	$14,100	$19,300	$35,140		$1,740	$14,100	$19,300	$35,140
9		$1,770	$14,400	$19,700	$35,870		$1,770	$14,400	$19,700	$35,870		$1,770	$14,400	$19,700	$35,870
10		$1,810	$14,700	$21,500	$38,010		$1,810	$14,700	$21,500	$38,010		$1,810	$14,700	$21,500	$38,010
11		$1,850	$15,000	$20,400	$37,250		$1,850	$15,000	$20,400	$37,250		$1,850	$15,000	$20,400	$37,250
12		$1,890	$15,300	$20,800	$37,990		$1,890	$15,300	$20,800	$37,990		$1,890	$15,300	$20,800	$37,990
13		$1,930	$15,600	$21,200	$38,730		$1,930	$15,600	$21,200	$38,730		$1,930	$15,600	$21,200	$38,730
14		$1,970	$15,900	$21,600	$39,470		$1,970	$15,900	$21,600	$39,470		$1,970	$15,900	$21,600	$39,470
15		$2,010	$16,200	$23,700	$41,910		$2,010	$16,200	$23,700	$41,910		$2,010	$16,200	$23,700	$41,910
TOTAL	$38,700	$26,300	$211,800	$337,700	$614,500	$137,300	$173,900	$211,800	$337,700	$860,600	$57,800	$18,400	$211,800	$373,800	$661,800
				Net Present Value	$367,000				**Net Present Value**	$572,000				**Net Present Value**	$409,000

Notes:
1. Inflated at a rate of 2% annually.
2. Discount rate of 7%.

TABLE B2-1
IMPLEMENTATION COST ESTIMATE
INITIAL COSTS
SWMU-172&174
Boeing Renton Facility
Renton, Washington

INITIAL COSTS				ALTERNATIVE 1 Source Area Excavation, Enhanced Bioremediation		ALTERNATIVE 2 SVE, Enhanced Bioremediation		ALTERNATIVE 3 MNA	
CONTRACTOR		**Unit**	**Unit Cost**	**Quantity**	**Cost**	**Quantity**	**Cost**	**Quantity**	**Cost**
1	**Mobilization/Demobilization**								
	Mobilization/Demobilization	lump sum	$10,000	3	$30,000	1.5	$15,000	0.1	$1,000
2	**Health and Safety**								
	Health and Safety Officer	hour	$75	120	$9,000	24	$1,800	4	$300
	Equipment	month	$2,000	1	$2,000	1	$2,000	0	$0
	PPE	day	$100	30	$3,000	10	$1,000	2	$200
3	**Site Preparation**								
	Utility Locates	hour	$85	8	$680	6	$510	2	$170
	Site Security	linear foot	$4	400	$1,600	100	$400	0	$0
	Temporary Facilities	month	$3,000	2	$6,000	1	$3,000	0	$0
	Traffic Control	lump sum	$1,000	2	$2,000	1	$1,000	1	$1,000
	Erosion Control	linear foot	$5	400	$2,000	100	$500	0	$0
	Storm water Management	day	$500	20	$10,000	2	$1,000	0	$0
4	**Surveying**								
	Surveying	day	$1,500	4	$6,000	4	$6,000	1	$1,500
5	**Monitoring Wells**								
	Well Abandonment	linear foot	$25	86	$2,150	56	$1,400	56	$1,400
	Base Price Per Well Abandonment	each	$200	5	$1,000	3	$600	3	$600
	Monitoring Well Installation (2" PVC)	linear foot	$75	95	$7,130	95	$7,130	95	$7,130
	Base Price Per Well	each	$500	5	$2,500	5	$2,500	5	$2,500
	Waste Disposal	drum	$150	23	$3,380	23	$3,450	23	$3,450
6	**Source Area Excavation**								
	Saw Cut Asphalt (6")	linear foot	$3	300	$900	0	$0	0	$0
	Excavation	cubic yard	$14	1,200	$16,800	0	$0	0	$0
	Waste Transportation/Disposal (non-hazardous)	ton	$40	706	$28,260	0	$0	0	$0
	Waste Transportation/Disposal (hazardous)	ton	$180	1,400	$252,000	0	$0	0	$0
	Backfill	ton	$14	1,600	$22,400	0	$0	0	$0
	Groundwater Management	gallon	$3	6,000	$18,000	0	$0	0	$0
	Asphalt Paving (6")	square foot	$4	4,500	$18,000	0	$0	0	$0
7	**SVE**								
	Pilot Test	lump sum	$20,000	0	$0	1	$20,000	0	$0
	Soil Vapor Extraction Well Installation (4" PVC)	linear foot	$100	0	$0	15	$1,500	0	$0
	Base Price Per Well	each	$300	0	$0	3	$900	0	$0
	Waste Disposal	drum	$150	0	$0	4	$600	0	$0
	Knock out pot	each	$2,000	0	$0	1	$2,000	0	$0
	Vacuum Blower	each	$2,500	0	$0	1	$2,500	0	$0
	Granular Activated Carbon	each	$3,000	0	$0	2	$6,000	0	$0
	Permanganate Unit	each	$1,500	0	$0	1	$1,500	0	$0
	Valves	each	$85	0	$0	8	$680	0	$0
	Gauges	each	$25	0	$0	8	$200	0	$0
	Treatment Center	lump sum	$12,000	0	$0	1	$12,000	0	$0
	Electrical Service	lump sum	$10,000	0	$0	1	$10,000	0	$0
	Electrical Connections	lump sum	$5,000	0	$0	2	$10,000	0	$0
8	**Trenching**								
	Saw Cut Asphalt (6")	linear foot	$3	0	$0	300	$900	0	$0
	Excavation	cubic yard	$10	0	$0	120	$1,200	0	$0
	Waste Transportation/Disposal (non-hazardous)	ton	$40	0	$0	120	$4,800	0	$0
	Waste Transportation/Disposal (hazardous)	ton	$160	0	$0	80	$12,800	0	$0
	Backfill	ton	$12	0	$0	200	$2,400	0	$0
	Piping	linear foot	$25	0	$0	150	$3,750	0	$0
	Asphalt Paving (6")	square foot	$4	0	$0	450	$1,800	0	$0
9	**Enhanced Bioremediation**								
	Injection Wells (4" PVC)	linear foot	$100	180	$18,000	180	$18,000	0	$0
	Base Price Per Well	each	$300	12	$3,600	12	$3,600	0	$0
	Waste Disposal	drum	$150	18	$2,700	18	$2,700	0	$0
Subtotal					**$469,100**		**$167,120**		**$19,250**
Sales Tax (8.8%)					**$41,280**		**$14,710**		**$1,690**
Subtotal					**$510,380**		**$181,830**		**$20,940**
Contingency (30%)					**$153,110**		**$54,550**		**$6,280**
Subtotal, Contractor					**$663,500.0**		**$236,400**		**$27,200**
PROFESSIONAL TECHNICAL SERVICES									
	Permitting	%	5%	$663,500	$33,180	$236,400	$11,820	$27,200	$1,400
	Engineering design costs	%	20%	$663,500	$132,700	$236,400	$47,280	$27,200	$5,400
	Construction Management	%	15%	$663,500	$99,530	$236,400	$35,460	$27,200	$4,100
	Project Management	%	10%	$663,500	$66,350	$236,400	$23,640	$27,200	$2,700
Subtotal, Professional Services					**$331,760**		**$118,200**		**$13,600**
TOTAL INITIAL COST					**$995,300**		**$354,600**		**$40,800**

Notes:
1. 2007 Dollars.
2. Costs are +50% -30%.
3. 40 hour work week.
4. Level C PPE.
5. Waste disposal 40% hazardous and 60% non-hazardous solid waste.
6. Soil 1 cubic yard = 1.6 tons
7. Concrete/Asphalt 1 cubic yard = 2 tons
8. Backfill costs assume delivered and placed.
9. Install 4 shallow monitoring wells and 3 intermediate monitoring wells, all alternatives.
10. Install 12 injection wells for enhanced bioremediation, Alternatives 1 and 2.
11. Install 3 soil vapor extraction wells, Alternative 2.
12. Excavation would require abandonment of GW153 and GW152, Alternative 1.

TABLE B2-2
IMPLEMENTATION COST ESTIMATE
RECURRING COSTS
SWMU-172&174
Boeing Renton Facility
Renton, Washington

	RECURRING COSTS			ALTERNATIVE 1 Source Area Excavation, Enhanced Bioremediation				ALTERNATIVE 2 SVE, Enhanced Bioremediation				ALTERNATIVE 3 MNA			
		Unit	**Unit Cost**	**Annual Quantity**	**Annual Cost**	**Lifetime Quantity**	**Lifetime Cost**	**Annual Quantity**	**Annual Cost**	**Lifetime Quantity**	**Lifetime Cost**	**Annual Quantity**	**Annual Cost**	**Lifetime Quantity**	**Lifetime Cost**
1	**ENHANCED BIOREMEDIATION (Years 1,2,3)**														
	Additive	lb	$5	1600	$8,000	3,200	$16,000	2,000	$10,000	4,000	$20,000	0	$0	0	$0
	Application (labor and equipment)	per well	$700	24	$16,800	48	$33,600	24	$16,800	48	$33,600	0	$0	0	$0
	Well abandonment (Year 3)	linear foot	$25	180	$4,500	180	$4,500	180	$4,500	180	$4,500	0	$0	0	$0
	Base Price per Well abandonment (Year 3)	each	$200	12	$2,400	12	$2,400	12	$2,400	12	$2,400	0	$0	0	$0
	Waste Disposal (Year 3)	drum	$150	18	$2,700	18	$2,700	18	$2,700	18	$2,700	0	$0	0	$0
Subtotal					**$34,400**		**$59,200**		**$36,400**		**$63,200**		**$0**		**$0**
2	**OPERATION AND MAINTENANCE**														
	Monitoring SVE	annual	$15,000	0	$0	0	$0	1	$15,000	2	$30,000	0	$0	0	$0
	Air Sampling SVE	per well	$450	0	$0	0	$0	4	$1,800	8	$3,600	0	$0	0	$0
	Electricity	monthly	$400	0	$0	0	$0	12	$4,800	24	$9,600	0	$0	0	$0
	Maintenance SVE	lump sum	$5,000	0	$0	0	$0	1	$5,000	2	$10,000	0	$0	0	$0
	Monitoring Well Maintenance	per well	$500	8	$4,000	120	$60,000	8	$4,000	120	$60,000	8	$4,000	120	$60,000
Subtotal					**$4,000**		**$60,000**		**$30,600**		**$113,200**		**$4,000**		**$60,000**
3	**GRANULAR ACTIVATED CARBON (Years 1,2)**														
	Carbon Replacement	pound	$2	0	$0	0	$0	1200	$2,400	18,000	$36,000	0	$0	0	$0
	Permanganate Replacement	pound	$2	0	$0	0	$0	1400	$2,800	21,000	$42,000	0	$0	0	$0
Subtotal					**$0**		**$0**		**$5,200**		**$78,000**		**$0**		**$0**
4	**SVE Confirmation Sampling (Year 3)**														
	Analytical	each	$200	0	$0	0	$0		$0	15	$3,000	0	$0	0	$0
	Drill Rig	day	$2,000	0	$0	0	$0		$0	2	$4,000	0	$0	0	$0
	Labor	hr	$85	0	$0	0	$0		$0	26	$2,210	0	$0	0	$0
Subtotal					**$0**		**$0**		**$0**		**$9,210**		**$0**		**$0**
5	**SVE Well Abandonment (Year 3)**														
	Well abandonment	linear foot	$25	0	$0	0	$0	15	$380	15	$380	0	$0	0	$0
	Base Price per Well abandonment	each	$200	0	$0	0	$0	3	$600	3	$600	0	$0	0	$0
	Waste Disposal	drum	$150	0	$0	0	$0	4	$600	4	$600	0	$0	0	$0
Subtotal					**$0**		**$0**		**$1,580**		**$1,580**		**$0**		**$0**
6	**QUARTERLY GW MONITORING (Years 1,2)**														
	Sampling	each well	$600	44	$26,400	88	$52,800	52	$31,200	104	$62,400	52	$31,200	104	$62,400
	Analysis	each well	$500	44	$22,000	64	$32,000	52	$26,000	104	$52,000	52	$26,000	104	$52,000
	Reporting	per round	$5,000	4	$20,000	8	$40,000	4	$20,000	8	$40,000	4	$20,000	8	$40,000
Subtotal					**$68,400**		**$124,800**		**$77,200**		**$154,400**		**$77,200**		**$154,400**
7	**SEMIANNUAL GW MONITORING (Years 3-15)**														
	Sampling	each well	$600	10	$6,000	130	$78,000	10	$6,000	130	$78,000	10	$6,000	130	$78,000
	Analysis	each well	$200	10	$2,000	130	$26,000	10	$2,000	130	$26,000	10	$2,000	130	$26,000
	Reporting	per round	$5,000	2	$10,000	26	$130,000	2	$10,000	26	$130,000	2	$10,000	26	$130,000
Subtotal					**$18,000**		**$234,000**		**$18,000**		**$234,000**		**$18,000**		**$234,000**
8	**FIVE YEAR GW MONITORING (Years 5,10,15)**														
	Sampling	each well	$600	11	$6,600	33	$19,800	13	$7,800	39	$23,400	13	$7,800	39	$23,400
	Analysis	each well	$500	11	$5,500	33	$16,500	13	$6,500	39	$19,500	13	$6,500	39	$19,500
	Reporting	per round	$5,000	1	$5,000	3	$15,000	1	$5,000	3	$15,000	1	$5,000	3	$15,000
Subtotal					**$17,100**		**$51,300**		**$19,300**		**$57,900**		**$19,300**		**$57,900**
9	**PROJECT MANAGEMENT**														
	Project Management	year	$12,000	1	$12,000	15	$180,000	1	$12,000	15	$180,000	1	$12,000	15	$180,000
Subtotal					**$12,000**		**$180,000**		**$12,000**		**$180,000**		**$12,000**		**$180,000**

Notes:
1. 2007 Dollars.
2. Costs are +50% -30%.
3. 40 hour work week.
4. Sales tax of 8.8% included in unit price.
5. Enhanced Bioremediation using 500 gallons of sodium lactate per event, Alternatives 1 and 2.
6. Enhanced Bioremediation 4 injections over 2 years (the first injection included as initial cost), Alternatives 1 and 2.
7. Emissions Control 2 years with Rented Catalytic Oxidizer and the following years with Granular Activated Carbon with Permanganate Unit, Alternative 2.

TABLE B2-3
IMPLEMENTATION COST ESTIMATE
NET PRESENT VALUE
SWMU-172&174

Boeing Renton Facility
Renton, Washington

Year	ALTERNATIVE 1						ALTERNATIVE 2								ALTERNATIVE 3				
	Source Area Excavation, Enhanced Bioremediation						SVE, Enhanced Bioremediation								MNA				
	Initial Costs	O&M	Enh. Bio.	PM	GW Mon.	Total	Initial Costs	O&M	Enh. Bio.	SVE Emissions Control	SVE Conf. and Aband.	PM	GW Mon.	Total	Initial Costs	O&M	PM	GW Mon.	Total
0	$995,300					$995,300	$354,600							$354,600	$40,800				$40,800
1		$4,100	$25,300	$12,200	$69,800	$111,400		$31,200	$25,300	$5,300		$12,200	$78,700	$152,700		$4,100	$12,200	$78,700	$95,000
2		$4,200	$25,800	$12,400	$71,200	$113,600		$31,800	$25,800	$5,300		$12,400	$80,300	$155,600		$4,200	$12,400	$80,300	$96,900
3		$4,300	$10,200	$12,600	$19,100	$46,200		$4,300	$10,200		$11,500	$12,600	$19,100	$57,700		$4,300	$12,600	$19,100	$36,000
4		$4,400		$12,900	$19,500	$36,800		$4,400				$12,900	$19,500	$36,800		$4,400	$12,900	$19,500	$36,800
5		$4,500		$13,200	$28,800	$46,500		$4,500				$13,200	$31,200	$48,900		$4,500	$13,200	$31,200	$48,900
6		$4,600		$13,500	$20,300	$38,400		$4,600				$13,500	$20,300	$38,400		$4,600	$13,500	$20,300	$38,400
7		$4,700		$13,800	$20,700	$39,200		$4,700				$13,800	$20,700	$39,200		$4,700	$13,800	$20,700	$39,200
8		$4,800		$14,100	$21,100	$40,000		$4,800				$14,100	$21,100	$40,000		$4,800	$14,100	$21,100	$40,000
9		$4,900		$14,400	$21,500	$40,800		$4,900				$14,400	$21,500	$40,800		$4,900	$14,400	$21,500	$40,800
10		$5,000		$14,700	$31,800	$51,500		$5,000				$14,700	$34,500	$54,200		$5,000	$14,700	$34,500	$54,200
11		$5,100		$15,000	$22,400	$42,500		$5,100				$15,000	$22,400	$42,500		$5,100	$15,000	$22,400	$42,500
12		$5,200		$15,300	$22,800	$43,300		$5,200				$15,300	$22,800	$43,300		$5,200	$15,300	$22,800	$43,300
13		$5,300		$15,600	$23,300	$44,200		$5,300				$15,600	$23,300	$44,200		$5,300	$15,600	$23,300	$44,200
14		$5,400		$15,900	$23,800	$45,100		$5,400				$15,900	$23,800	$45,100		$5,400	$15,900	$23,800	$45,100
15		$5,500		$16,200	$35,100	$56,800		$5,500				$16,200	$38,100	$59,800		$5,500	$16,200	$38,100	$59,800
TOTAL	$995,300	$72,000	$61,300	$211,800	$451,200	$1,791,600	$354,600	$126,700	$61,300	$10,600	$11,500	$211,800	$477,300	$1,253,800	$40,800	$72,000	$211,800	$477,300	$801,900
					Net Present Value	$1,416,000							Net Present Value	$900,000				Net Present Value	$492,000

Notes:
1. Inflated at a rate of 2% annually.
2. Discount rate of 7%.

TABLE B3-1
IMPLEMENTATION COST ESTIMATE
INITIAL COSTS
Building 4-78/79
Boeing Renton Facility
Renton, Washington

				ALTERNATIVE 1 Source Area Excavation, Enhanced Bioremediation, Monitored Attenuation		**ALTERNATIVE 2** SVE, Enhanced Bioremediation, Monitored Attenuation		**ALTERNATIVE 3** Source Area Excavation, MNA	
INITIAL COSTS									
CONTRACTOR		**Unit**	**Unit Cost**	**Quantity**	**Cost**	**Quantity**	**Cost**	**Quantity**	**Cost**
1	**Mobilization/Demobilization**								
	Mobilization/Demobilization	lump sum	$10,000	4	$40,000	1	$10,000	4	$40,000
2	**Health and Safety**								
	Health and Safety Officer	hour	$75	80	$6,000	20	$1,500	80	$6,000
	Equipment	month	$2,000	2	$4,000	1	$2,000	2	$4,000
	PPE	day	$100	20	$2,000	10	$1,000	20	$2,000
3	**Site Preparation**								
	Utility Locates	hour	$85	20	$1,700	20	$1,700	16	$1,360
	Site Security	linear foot	$4	1,000	$4,000	1,000	$4,000	1,000	$4,000
	Temporary Facilities	month	$3,000	1	$3,000	1	$3,000	1	$3,000
	Traffic Control	lump sum	$1,000	3	$3,000	3	$3,000	3	$3,000
	Erosion Control	linear foot	$5	1,000	$5,000	500	$2,500	1,000	$5,000
	Storm water Management	day	$500	10	$5,000	5	$2,500	10	$5,000
4	**Surveying**								
	Surveying	day	$1,500	3	$4,500	3	$4,500	3	$4,500
5	**Monitoring Wells**								
	Well Abandonment	linear foot	$40	40	$1,600	0	$0	40	$1,600
	Base Price Per Well Abandonment	each	$200	2	$400	0	$0	2	$400
	Monitoring Well Installation (2" PVC)	linear foot	$75	210	$15,750	210	$15,750	210	$15,750
	Base Price Per Well	each	$500	9	$4,500	9	$4,500	9	$4,500
	Waste Disposal	drum	$150	24	$3,600	20	$3,000	24	$3,600
6	**Source Area Excavation**								
	Saw Cut Asphalt (6")	linear foot	$3	1,100	$3,300	0	$0	1,100	$3,300
	Excavation	cubic yard	$12	1,150	$13,800	0	$0	1,150	$13,800
	Waste Transportation/Disposal (non-hazardous)	ton	$40	1,900	$76,000	0	$0	1,900	$76,000
	Backfill	ton	$10	1,900	$19,000	0	$0	1,900	$19,000
	Groundwater Management	gallon	$1	6,000	$6,000	0	$0	6,000	$6,000
	ORC into Excavation	pound	$15	800	$12,000	0	$0	0	$0
	Asphalt Paving (6")	square foot	$4	5,500	$22,000	0	$0	5,500	$22,000
7	**SVE**								
	Pilot Test	lump sum	$20,000	0	$0	1	$20,000	0	$0
	Soil Vapor Extraction Well Installation (4" PVC)	linear foot	$100	0	$0	240	$24,000	0	$0
	Base Price Per Well	each	$300	0	$0	16	$4,800	0	$0
	Waste Disposal	drum	$150	0	$0	40	$6,000	0	$0
	Knock out pot	each	$2,000	0	$0	1	$2,000	0	$0
	Vacuum Blower	each	$3,500	0	$0	3	$10,500	0	$0
	Granular Activated Carbon	each	$3,000	0	$0	1	$3,000	0	$0
	Permanganate Unit	each	$1,500	0	$0	1	$1,500	0	$0
	Valves	each	$85	0	$0	20	$1,700	0	$0
	Gauges	each	$25	0	$0	20	$500	0	$0
	Treatment Center	lump sum	$12,000	0	$0	1	$12,000	0	$0
	Electrical Service	lump sum	$10,000	0	$0	1	$10,000	0	$0
	Electrical Connections	lump sum	$5,000	0	$0	3	$15,000	0	$0
8	**Trenching**								
	Saw Cut Asphalt (6")	linear foot	$3	0	$0	900	$2,700	0	$0
	Excavation	cubic yard	$1	0	$0	130	$130	0	$0
	Waste Transportation/Disposal (non-hazardous)	ton	$40	0	$0	205	$8,200	0	$0
	Backfill	ton	$12	0	$0	205	$2,460	0	$0
	Piping	linear foot	$25	0	$0	450	$11,250	0	$0
	Asphalt Paving (6")	square foot	$4	0	$0	1,530	$6,120	0	$0
9	**Enhanced Bioremediation**								
	Injection Wells (4" PVC)	linear foot	$100	210	$21,000	210	$21,000	0	$0
	Base Price Per Well	each	$300	7	$2,100	7	$2,100	0	$0
	Waste Disposal	drum	$150	35	$5,250	35	$5,250	0	$0
	Additive	lb	$5	600	$3,000	600	$3,000	0	$0
	Application (labor and equipment)	per well	$700	7	$4,900	7	$4,900	0	$0
Subtotal					**$292,400**		**$237,060**		**$243,810**
Sales Tax (8.8%)					**$25,730**		**$20,860**		**$21,460**
Subtotal					**$318,130**		**$257,920**		**$265,270**
Contingency (30%)					**$95,440**		**$51,580**		**$79,580**
Subtotal, Contractor					**$413,600**		**$309,500**		**$344,900**
PROFESSIONAL TECHNICAL SERVICES									
	Soil Confirmation Sampling	lump sum	$26,800	1	$26,800	0	$0	1	$26,800
	Permitting	%	5%	$413,600	$20,680	$309,500	$15,480	$344,900	$17,200
	Engineering design costs	%	20%	$413,600	$82,720	$309,500	$61,900	$344,900	$69,000
	Construction Management	%	15%	$413,600	$62,040	$309,500	$46,430	$344,900	$51,700
	Project Management	%	10%	$413,600	$41,360	$309,500	$30,950	$344,900	$34,500
Subtotal, Professional Services					**$233,600**		**$154,760**		**$199,200**
TOTAL INITIAL COST					**$647,200**		**$464,260**		**$544,100**

Notes:
1. 2007 Dollars.
2. Costs are +50% -30%.
3. 40 hour work week.
4. Level C PPE.
5. Waste disposal is non-hazardous solid waste.
6. Soil 1 cubic yard = 1.6 tons
7. Concrete/Asphalt 1 cubic yard = 2 tons
8. Backfill costs assume delivered and placed.
9. Install 3 shallow monitoring wells, 4 intermediate monitoring wells, 1 deep monitoring well, all alternatives.
10. Install 7 injection wells for enhanced bioremediation, Alternatives 1 and 2.
11. SVE would require 16 SVE wells, Alternative 2.
12. Excavation would require abandonment of GW040 and GW031, Alternatives 1 and 3.
13. Excavation costs include AOC-013, AOC-015, AOC-026, AOC-054, and pipeline area, Alternatives 1 and 3.
14. The contingency for Alternative 2 was reduced to 20% to reflect the lower level of uncertainty in this estimate.

TABLE B3-2
IMPLEMENTATION COST ESTIMATE
RECURRING COSTS
Building 4-78/79
Boeing Renton Facility
Renton, Washington

RECURRING COSTS	Unit	Unit Cost	ALTERNATIVE 1 — Source Area Excavation, Enhanced Bioremediation, Monitored Attenuation: Annual Quantity	Annual Cost	Lifetime Quantity	Lifetime Cost	ALTERNATIVE 2 — SVE, Enhanced Bioremediation, Monitored Attenuation: Annual Quantity	Annual Cost	Lifetime Quantity	Lifetime Cost	ALTERNATIVE 3 — Source Area Excavation, MNA: Annual Quantity	Annual Cost	Lifetime Quantity	Lifetime Cost
1 ENHANCED BIOREMEDIATION (Years 1,2,3)														
Additive	lb	$5	1200	$6,000	2,400	$12,000	1200	$6,000	2,400	$12,000	0	$0	0	$0
Application (labor and equipment)	per well	$700	14	$9,800	28	$19,600	14	$9,800	28	$19,600	0	$0	0	$0
Well abandonment (Year 3)	linear foot	$25	210	$5,250	210	$5,250	210	$5,250	210	$5,250	0	$0	0	$0
Base Price per Well abandonment (Year 3)	each	$200	7	$1,400	7	$1,400	7	$1,400	7	$1,400	0	$0	0	$0
Waste Disposal (Year 3)	drum	$150	35	$5,250	35	$5,250	35	$5,250	35	$5,250	0	$0	0	$0
Subtotal				**$27,700**		**$43,500**		**$27,700**		**$43,500**		**$0**		**$0**
2 OPERATION AND MAINTENANCE														
Monitoring SVE	annual	$15,000	0	$0	0	$0	1	$15,000	5	$75,000	0	$0	0	$0
Air Sampling SVE	per well	$450	0	$0	0	$0	10	$4,500	50	$22,500	0	$0	0	$0
Electricity	monthly	$400	0	$0	0	$0	12	$4,800	60	$24,000	0	$0	0	$0
Carbon Replacement	pound	$2	0	$0	0	$0	600	$1,200	3,000	$6,000	0	$0	0	$0
Permanganate Replacement	pound	$2	0	$0	0	$0	700	$1,400	3,500	$7,000	0	$0	0	$0
Maintenance SVE	lump sum	$5,000	0	$0	0	$0	1	$5,000	5	$25,000	0	$0	0	$0
Monitoring Well Maintenance	per well	$500	12	$6,000	180	$90,000	12	$6,000	180	$90,000	12	$6,000	180	$90,000
Subtotal				**$6,000**		**$90,000**		**$37,900**		**$249,500**		**$6,000**		**$90,000**
3 SVE Confirmation Sampling (Year 6)														
Analytical	lump	$9,000	0	$0	0	$0	1	$9,000	1	$9,000	0	$0	0	$0
Drill Rig	day	$2,000	0	$0	0	$0	3	$6,000	3	$6,000	0	$0	0	$0
Labor	hr	$85	0	$0	0	$0	48	$4,080	48	$4,080	0	$0	0	$0
Subtotal				**$0**		**$0**		**$19,080**		**$19,080**		**$0**		**$0**
4 SVE Well Abandonment (Year 6)														
Well abandonment	linear foot	$25	0	$0	0	$0	240	$6,000	240	$6,000	0	$0	0	$0
Base Price per Well abandonment	each	$200	0	$0	0	$0	16	$3,200	16	$3,200	0	$0	0	$0
Waste Disposal	drum	$150	0	$0	0	$0	40	$6,000	40	$6,000	0	$0	0	$0
Subtotal				**$0**		**$0**		**$15,200**		**$15,200**		**$0**		**$0**
5 QUARTERLY GW MONITORING (Years 1,2)														
Sampling	each well	$600	56	$33,600	112	$67,200	56	$33,600	112	$67,200	56	$33,600	112	$67,200
Analysis	each well	$500	56	$28,000	112	$56,000	56	$28,000	112	$56,000	56	$28,000	112	$56,000
Reporting	per round	$5,000	4	$20,000	8	$40,000	4	$20,000	8	$40,000	4	$20,000	8	$40,000
Subtotal				**$81,600**		**$163,200**		**$81,600**		**$163,200**		**$81,600**		**$163,200**
6 SEMIANNUAL GW MONITORING (Years 3-15)														
Sampling	each well	$600	6	$3,600	78	$46,800	6	$3,600	78	$46,800	6	$3,600	78	$46,800
Analysis	each well	$200	6	$1,200	78	$15,600	6	$1,200	78	$15,600	6	$1,200	78	$15,600
Reporting	per round	$5,000	2	$10,000	26	$130,000	2	$10,000	26	$130,000	2	$10,000	26	$130,000
Subtotal				**$14,800**		**$192,400**		**$14,800**		**$192,400**		**$14,800**		**$192,400**
7 FIVE YEAR GW MONITORING (Years 5,10,15)														
Sampling	each well	$600	14	$8,400	42	$25,200	14	$8,400	42	$25,200	14	$8,400	42	$25,200
Analysis	each well	$500	14	$7,000	42	$21,000	14	$7,000	42	$21,000	14	$7,000	42	$21,000
Reporting	per round	$5,000	1	$5,000	3	$15,000	1	$5,000	3	$15,000	1	$5,000	3	$15,000
Subtotal				**$20,400**		**$61,200**		**$20,400**		**$61,200**		**$20,400**		**$61,200**
8 PROJECT MANAGEMENT														
Project Management	year	$12,000	1.0	$12,000	15	$180,000	2.0	$24,000	15	$180,000	1	$12,000	15	$180,000
Subtotal				**$12,000**		**$180,000**		**$24,000**		**$180,000**		**$12,000**		**$180,000**

1. Based on 2007 Dollars.
2. Costs are +50% -30%.
3. Assumed 40 hour work week.
4. Sales tax of 8.8% included in unit price.
5. Enhanced Biodegradation four injections over two years, first event is in implementation costs, Alternatives 1 and 2.

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TABLE B3-3
IMPLEMENTATION COST ESTIMATE
NET PRESENT VALUE
Building 4-78/79
Boeing Renton Facility
Renton, Washington

	ALTERNATIVE 1						ALTERNATIVE 2							ALTERNATIVE 3				
	Source Area Excavation, Enhanced Bioremediation, Monitored Attenuation						SVE, Enhanced Bioremediation, Monitored Attenuation							Source Area Excavation, MNA				
Year	Initial Costs	O&M	Enh. Bio.	PM	GW Mon.	Total	Initial Costs	O&M	SVE Conf. & Aband.	Enh. Bio.	PM	GW Mon.	Total	Initial Costs	O&M	PM	GW Mon.	Total
0	$647,200					$647,200	$464,260						$464,260	$544,100				$544,100
1		$6,100	$16,100	$12,200	$83,200	$117,600		$38,700		$16,100	$24,500	$83,200	$162,500		$6,100	$12,200	$83,200	$101,500
2		$6,200	$16,400	$12,400	$84,900	$119,900		$39,500		$16,400	$25,000	$84,900	$165,800		$6,200	$12,400	$84,900	$103,500
3		$6,300	$12,600	$12,600	$15,700	$47,200		$40,300		$12,600	$25,500	$15,700	$94,100		$6,300	$12,600	$15,700	$34,600
4		$6,400		$12,900	$16,000	$35,300		$41,100			$26,000	$16,000	$83,100		$6,400	$12,900	$16,000	$35,300
5		$6,500		$13,200	$30,700	$50,400		$41,900			$26,500	$30,700	$99,100		$6,500	$13,200	$30,700	$50,400
6		$6,600		$13,500	$16,700	$36,800		$6,600	$38,600		$27,000	$16,700	$88,900		$6,600	$13,500	$16,700	$36,800
7		$6,700		$13,800	$17,000	$37,500		$6,700			$13,800	$17,000	$37,500		$6,700	$13,800	$17,000	$37,500
8		$6,800		$14,100	$17,300	$38,200		$6,800			$14,100	$17,300	$38,200		$6,800	$14,100	$17,300	$38,200
9		$6,900		$14,400	$17,600	$38,900		$6,900			$14,400	$17,600	$38,900		$6,900	$14,400	$17,600	$38,900
10		$7,000		$14,700	$33,900	$55,600		$7,000			$14,700	$33,900	$55,600		$7,000	$14,700	$33,900	$55,600
11		$7,100		$15,000	$18,400	$40,500		$7,100			$15,000	$18,400	$40,500		$7,100	$15,000	$18,400	$40,500
12		$7,200		$15,300	$18,800	$41,300		$7,200			$15,300	$18,800	$41,300		$7,200	$15,300	$18,800	$41,300
13		$7,300		$15,600	$19,200	$42,100		$7,300			$15,600	$19,200	$42,100		$7,300	$15,600	$19,200	$42,100
14		$7,400		$15,900	$19,600	$42,900		$7,400			$15,900	$19,600	$42,900		$7,400	$15,900	$19,600	$42,900
15		$7,500		$16,200	$37,400	$61,100		$7,500			$16,200	$37,400	$61,100		$7,500	$16,200	$37,400	$61,100
TOTAL	$647,200	$102,000	$45,100	$211,800	$446,400	$1,452,500	$464,300	$272,000	$38,600	$45,100	$289,500	$446,400	$1,555,900	$544,100	$102,000	$211,800	$446,400	$1,304,300
					Net Present Value	$1,100,000						Net Present Value	$1,140,000				Net Present Value	$966,000

Notes:
1. Inflated at a rate of 2% annually.
2. Discount rate of 7%.

TABLE B4-1
IMPLEMENTATION COST ESTIMATE
INITIAL COSTS
Former Fuel Farm
Boeing Renton Facility
Renton, Washington

INITIAL COSTS				ALTERNATIVE 1 Existing BS/BV, Monitored Attenuation		ALTERNATIVE 2 Upgrade Existing System, Monitored Attenuation		ALTERNATIVE 3 MNA	
CONTRACTOR		Unit	Unit Cost	Quantity	Cost	Quantity	Cost	Quantity	Cost
1	**Mobilization/Demobilization**								
	Mobilization/Demobilization	lump sum	$10,000	0.1	$1,000	1	$10,000	0.1	$1,000
2	**Health and Safety**								
	Health and Safety Officer	hour	$75	4	$300	8	$600	4	$300
	Equipment	month	$2,000	0	$0	1	$2,000	0	$0
	PPE	day	$100	2	$200	8	$800	2	$200
3	**Site Preparation**								
	Utility Locates	hour	$85	4	$340	12	$1,020	4	$340
	Site Security	linear foot	$4	100	$400	250	$1,000	100	$400
	Temporary Facilities	month	$3,000	0	$0	1	$3,000	0	$0
	Traffic Control	lump sum	$1,000	1	$1,000	3	$3,000	1	$1,000
	Erosion Control	linear foot	$5	0	$0	250	$1,250	0	$0
	Storm water Management	day	$500	0	$0	4	$2,000	0	$0
4	**Surveying**								
	Surveying	day	$1,500	2	$3,000	2	$3,000	2	$3,000
5	**Monitoring Wells**								
	Monitoring Well Installation (2" PVC)	linear foot	$75	115	$8,630	115	$8,630	115	$8,630
	Base Price Per Well	each	$500	7	$3,500	7	$3,500	7	$3,500
	Waste Disposal	drum	$150	22	$3,300	22	$3,300	22	$3,300
6	**Upgrade Existing System**								
	Air Sparge Installation (2" PVC)	linear foot	$100	0	$0	195	$19,500	0	$0
	Base Price Per Well	each	$300	0	$0	13	$3,900	0	$0
	Waste Disposal	drum	$150	0	$0	46	$6,830	0	$0
	Blower	each	$5,000	0	$0	1	$5,000	0	$0
	Saw Cut Asphalt (6")	linear foot	$3	0	$0	600	$1,800	0	$0
	Excavation	cubic yard	$10	0	$0	370	$3,700	0	$0
	Waste Transportation/Disposal (non-hazardous)	ton	$40	0	$0	450	$18,000	0	$0
	Backfill	ton	$12	0	$0	450	$5,400	0	$0
	Piping	linear foot	$25	0	$0	300	$7,500	0	$0
	Asphalt Paving (6")	square foot	$4	0	$0	1,000	$4,000	0	$0
Subtotal					**$21,670**		**$118,730**		**$21,670**
Sales Tax (8.8%)					**$1,910**		**$10,450**		**$1,910**
Subtotal					**$23,580**		**$129,180**		**$23,580**
Contingency (30%)					**$7,070**		**$38,750**		**$7,070**
Subtotal, Contractor					**$30,700**		**$167,900**		**$30,700**
PROFESSIONAL TECHNICAL SERVICES									
	Permitting	%	5%	$30,700	$1,540	$167,900	$8,400	$30,700	$1,500
	Engineering design costs	%	20%	$30,700	$6,140	$167,900	$33,580	$30,700	$6,100
	Construction Management	%	15%	$30,700	$4,610	$167,900	$25,190	$30,700	$4,600
	Project Management	%	10%	$30,700	$3,070	$167,900	$16,790	$30,700	$3,100
Subtotal, Professional Services					**$15,360**		**$84,000**		**$15,300**
TOTAL INITIAL COST					**$46,060**		**$251,900**		**$46,000**

Notes:
1. 2007 Dollars.
2. Costs are +50% -30%.
3. 40 hour work week.
4. Level D PPE
5. Waste disposal is non-hazardous solid waste.
6. Boeing providing water.
7. Soil 1 cubic yard = 1.6 tons
8. Concrete/Asphalt 1 cubic yard = 2 tons
9. Backfill costs assume delivered and placed.
10. Installation of 1 new shallow monitoring well and 1 new intermediate monitoring well.

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TABLE B4-2
IMPLEMENTATION COST ESTIMATE
RECURRING COSTS
Former Fuel Farm
Boeing Renton Facility
Renton, Washington

	RECURRING COSTS			ALTERNATIVE 1 Existing BS/BV, Monitored Attenuation				ALTERNATIVE 2 Upgrade Existing System, Monitored Attenuation				ALTERNATIVE 3 MNA			
		Unit	Unit Cost	Annual Quantity	Annual Cost	Lifetime Quantity	Lifetime Cost	Annual Quantity	Annual Cost	Lifetime Quantity	Lifetime Cost	Annual Quantity	Annual Cost	Lifetime Quantity	Lifetime Cost
1	**OPERATION AND MAINTENANCE**														
	BS/BV Operation and Maintenance	year	$45,000	1	$45,000	15	$675,000	1	$45,000	15	$675,000	0	$0	0	$0
	Monitoring Well Maintenance	per well	$500	9	$4,500	135	$67,500	9	$4,500	135	$67,500	9	$4,500	135	$67,500
Subtotal					**$49,500**		**$742,500**		**$49,500**		**$742,500**		**$4,500**		**$67,500**
2	**FIVE YEAR REPLACEMENT COSTS**														
	Blower	each	$5,000	1	$5,000	3	$15,000	1	$5,000	3	$15,000	0	$0	0	$0
Subtotal					**$5,000**		**$15,000**		**$5,000**		**$15,000**		**$0**		**$0**
3	**TEN YEAR REPLACEMENT COSTS**														
	Piping	linear foot	$25	200	$5,000	200	$5,000	300	$7,500	300	$7,500	0	$0	0	$0
Subtotal					**$5,000**		**$5,000**		**$7,500**		**$7,500**		**$0**		**$0**
4	**QUARTERLY GW MONITORING (Years 1,2)**														
	Sampling	each well	$600	28	$16,800	56	$33,600	28	$16,800	56	$33,600	28	$16,800	56	$33,600
	Analysis	each well	$500	28	$14,000	56	$28,000	28	$14,000	56	$28,000	28	$14,000	56	$28,000
	Reporting	per round	$5,000	4	$20,000	8	$40,000	4	$20,000	8	$40,000	4	$20,000	8	$40,000
Subtotal					**$50,800**		**$101,600**		**$50,800**		**$101,600**		**$50,800**		**$101,600**
5	**SEMIANNUAL GW MONITORING (Years 3-15)**														
	Sampling	each well	$600	16	$9,600	208	$124,800	16	$9,600	208	$124,800	16	$9,600	208	$124,800
	Analysis	each well	$200	16	$3,200	208	$41,600	16	$3,200	208	$41,600	16	$3,200	208	$41,600
	Reporting	per round	$5,000	2	$10,000	26	$130,000	2	$10,000	26	$130,000	2	$10,000	26	$130,000
Subtotal					**$22,800**		**$296,400**		**$22,800**		**$296,400**		**$22,800**		**$296,400**
6	**FIVE YEAR GW MONITORING (Years 5,10,15)**														
	Sampling	each well	$600	9	$5,400	27	$16,200	9	$5,400	27	$16,200	9	$5,400	27	$16,200
	Analysis	each well	$500	9	$4,500	27	$13,500	9	$4,500	27	$13,500	9	$4,500	27	$13,500
	Reporting	per round	$5,000	1	$5,000	3	$15,000	1	$5,000	3	$15,000	1	$5,000	3	$15,000
Subtotal					**$14,900**		**$44,700**		**$14,900**		**$44,700**		**$14,900**		**$44,700**
7	**PROJECT MANAGEMENT**														
	Project Management	year	$12,000	1	$12,000	15	$180,000	1	$12,000	15	$180,000	1	$12,000	15	$180,000
Subtotal					**$12,000**		**$180,000**		**$12,000**		**$180,000**		**$12,000**		**$180,000**

Notes:
1. 2007 Dollars.
2. Costs are +50% -30%.
3. 40 hour work week.
4. Sales tax of 8.8% included in unit price.

Geomatrix

TABLE B4-3
IMPLEMENTATION COST ESTIMATE
NET PRESENT VALUE
Former Fuel Farm
Boeing Renton Facility
Renton, Washington

	ALTERNATIVE 1						ALTERNATIVE 2						ALTERNATIVE 3				
	Existing BS/BV, Monitored Attenuation						Upgrade Existing System, Monitored Attenuation						MNA				
Year	Initial Costs	O&M	Five and Ten Year Replacement Costs	PM	GW Mon.	Total	Initial Costs	O&M	Five and Ten Year Replacement Costs	PM	GW Mon.	Total	Initial Costs	O&M	PM	GW Mon.	Total
0	$46,060					$46,060	$251,900					$251,900	$46,000				$46,000
1		$50,500		$12,200	$51,800	$114,500		$50,500		$12,200	$51,800	$114,500		$4,600	$12,200	$51,800	$68,600
2		$51,500		$12,400	$52,800	$116,700		$51,500		$12,400	$52,800	$116,700		$4,700	$12,400	$52,800	$69,900
3		$52,500		$12,600	$24,200	$89,300		$52,500		$12,600	$24,200	$89,300		$4,800	$12,600	$24,200	$41,600
4		$53,600		$12,900	$24,700	$91,200		$53,600		$12,900	$24,700	$91,200		$4,900	$12,900	$24,700	$42,500
5		$54,700	$5,500	$13,200	$29,000	$102,400		$54,700	$5,500	$13,200	$29,000	$102,400		$5,000	$13,200	$29,000	$47,200
6		$55,800		$13,500	$25,700	$95,000		$55,800		$13,500	$25,700	$95,000		$5,100	$13,500	$25,700	$44,300
7		$56,900		$13,800	$26,200	$96,900		$56,900		$13,800	$26,200	$96,900		$5,200	$13,800	$26,200	$45,200
8		$58,000		$14,100	$26,700	$98,800		$58,000		$14,100	$26,700	$98,800		$5,300	$14,100	$26,700	$46,100
9		$59,200		$14,400	$27,200	$100,800		$59,200		$14,400	$27,200	$100,800		$5,400	$14,400	$27,200	$47,000
10		$60,400	$15,200	$14,700	$32,100	$122,400		$60,400	$15,200	$14,700	$32,100	$122,400		$5,500	$14,700	$32,100	$52,300
11		$61,600		$15,000	$28,300	$104,900		$61,600		$15,000	$28,300	$104,900		$5,600	$15,000	$28,300	$48,900
12		$62,800		$15,300	$28,900	$107,000		$62,800		$15,300	$28,900	$107,000		$5,700	$15,300	$28,900	$49,900
13		$64,100		$15,600	$29,500	$109,200		$64,100		$15,600	$29,500	$109,200		$5,800	$15,600	$29,500	$50,900
14		$65,400		$15,900	$30,100	$111,400		$65,400		$15,900	$30,100	$111,400		$5,900	$15,900	$30,100	$51,900
15		$66,700	$6,700	$16,200	$35,400	$125,000		$66,700	$6,700	$16,200	$35,400	$125,000		$6,000	$16,200	$35,400	$57,600
TOTAL	$46,100	$873,700		$211,800	$472,600	$1,631,600	$251,900	$873,700	$27,400	$211,800	$472,600	$1,837,400	$46,000	$79,500	$211,800	$472,600	$809,900
					Net Present Value	$934,000					Net Present Value	$1,127,000				Net Present Value	$482,000

Notes:
1. Inflated at a rate of 2% annually.
2. Discount rate of 7%.

TABLE B5-1
IMPLEMENTATION COST ESTIMATE
INITIAL COSTS
AOC-001,002
Boeing Renton Facility
Renton, Washington

INITIAL COSTS					ALTERNATIVE 1 Enhanced Bioremediation, Monitored Attenuation		ALTERNATIVE 2 Monitored Natural Attenuation	
CONTRACTOR			**Unit**	**Unit Cost**	**Quantity**	**Cost**	**Quantity**	**Cost**
1	**Mobilization/Demobilization**							
		Mobilization/Demobilization	lump sum	$10,000	1	$10,000	0.5	$5,000
2	**Health and Safety**							
		Health and Safety Officer	hour	$75	8	$600	4	$300
		Equipment	month	$2,000	0.5	$1,000	0	$0
		PPE	day	$100	5	$500	0	$0
3	**Site Preparation**							
		Utility Locates	hour	$85	8	$680	8	$680
		Site Security	linear foot	$4	100	$400	100	$400
		Temporary Facilities	month	$3,000	0	$0	0	$0
		Traffic Control	lump sum	$1,000	0	$0	0	$0
		Erosion Control	linear foot	$5	100	$500	100	$500
		Storm water Management	day	$500	0	$0	0	$0
4	**Surveying**							
		Surveying	day	$1,500	1	$1,500	1	$1,500
5	**Monitoring Wells**							
		Concrete Coring	day	$1,500	1	$1,500	1	$1,500
		Monitoring Well Installation (2" PVC)	linear foot	$75	120	$9,000	120	$9,000
		Base Price Per Well	each	$500	4	$2,000	4	$2,000
		Waste Disposal	drum	$150	16	$2,400	16	$2,400
6	**Enhanced Bioremediation**							
		Injection Wells (4" PVC)	linear foot	$100	50	$5,000	0	$0
		Base Price Per Well	each	$300	3	$900	0	$0
		Waste Disposal	drum	$150	8	$1,200	0	$0
Subtotal						**$37,180**		**$23,280**
Sales Tax (8.8%)						**$3,270**		**$2,050**
Subtotal						**$40,450**		**$25,330**
Contingency (30%)						**$12,140**		**$7,600**
Subtotal, Contractor						**$52,600**		**$32,900**
PROFESSIONAL TECHNICAL SERVICES								
		Investigation	lump sum	$9,000	0	$0	0	$0
		Permitting	%	5%	$52,600	$2,630	$32,900	$1,650
		Engineering design costs	%	20%	$52,600	$10,520	$32,900	$6,580
		Construction Management	%	15%	$52,600	$7,890	$32,900	$4,940
		Project Management	%	10%	$52,600	$5,260	$32,900	$3,290
Subtotal, Professional Services						**$26,300**		**$16,500**
TOTAL INITIAL COST						**$78,900**		**$49,400**

Notes:
1. 2007 Dollars.
2. Costs are +50% -30%.
3. 40 hour work week.
4. Level B PPE.
5. Waste disposal is 60% hazardous and 40% non-hazardous solid waste.
6. Soil 1 cubic yard = 1.6 tons
7. Concrete/Asphalt 1 cubic yard = 2 tons
8. Backfill costs assume delivered and placed.
9. Installation of 2 shallow monitoring wells and 4 deep monitoring wells, all alternatives.

TABLE B5-2
IMPLEMENTATION COST ESTIMATE
RECURRING COSTS
AOC-001,002
Boeing Renton Facility
Renton, Washington

	RECURRING COSTS			ALTERNATIVE 1 Enhanced Bioremediation, Monitored Attenuation				ALTERNATIVE 2 Monitored Natural Attenuation			
		Unit	Unit Cost	Annual Quantity	Annual Cost	Lifetime Quantity	Lifetime Cost	Annual Quantity	Annual Cost	Lifetime Quantity	Lifetime Cost
1	**ENHANCED BIOREMEDIATION (Years 1,2,3, and 4)**										
	Additive (wells)	lbs	$4.50	3,600	$16,200	3,600	$16,200	0	$0	0	$0
	Application (labor and equipment)	per well	$700	3	$2,100	9	$6,300	0	$0	0	$0
	Additive (horizontal pipes)	lbs	$4.50	400	$1,800	1,200	$5,400	0	$0	0	$0
	Application (labor and equipment)	per well	$700	4	$2,800	4	$2,800	0	$0	0	$0
	Injection Well Abandonment (year 4)	linear ft	$25	50	$1,250	50	$1,250	0	$0	0	$0
	Base price per well abandonment (year 4)	each	$300	3	$900	3	$900	0	$0	0	$0
	Waste Disposal (year 4)	drum	$150	8	$1,200	8	$1,200	0	$0	0	$0
Subtotal					**$26,250**		**$34,050**		**$0**		**$0**
2	**OPERATION AND MAINTENANCE**										
	Monitoring Well Maintenance	per well	$500	9	$4,500	135	$67,500	9	$4,500	135	$67,500
Subtotal					**$4,500**		**$67,500**		**$4,500**		**$67,500**
3	**QUARTERLY GW MONITORING (Years 1-2)**										
	Sampling	each well	$600	36	$21,600	72	$43,200	36	$21,600	72	$43,200
	Analysis	each well	$500	36	$18,000	72	$36,000	36	$18,000	72	$36,000
	Reporting	per round	$5,000	4	$20,000	8	$40,000	4	$20,000	8	$40,000
Subtotal					**$59,600**		**$119,200**		**$59,600**		**$119,200**
4	**SEMIANNUAL GW MONITORING (Years 3-15)**										
	Sampling	each well	$600	10	$6,000	130	$78,000	10	$6,000	130	$78,000
	Analysis	each well	$200	10	$2,000	130	$26,000	10	$2,000	130	$26,000
	Reporting	per round	$5,000	2	$10,000	26	$130,000	2	$10,000	26	$130,000
Subtotal					**$18,000**		**$234,000**		**$18,000**		**$234,000**
5	**FIVE YEAR GW MONITORING (Years 5,10,15)**										
	Sampling	each well	$600	9	$5,400	27	$16,200	9	$5,400	27	$16,200
	Analysis	each well	$500	9	$4,500	27	$13,500	9	$4,500	27	$13,500
	Reporting	per round	$5,000	1	$5,000	3	$15,000	1	$5,000	3	$15,000
Subtotal					**$14,900**		**$44,700**		**$14,900**		**$44,700**
6	**PROJECT MANAGEMENT**										
	Project Management	year	$12,000	1	$12,000	15	$180,000	1	$12,000	15	$180,000
Subtotal					**$12,000**		**$180,000**		**$12,000**		**$180,000**

1. 2007 Dollars.
2. Costs are +50% -30%.
3. 40 hour work week.
4. Sales tax of 8.8% included in unit price.
5. Enhanced Biodegradation 10 injections over 5 years (first injection as part of implementation costs), Alternative 1.

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TABLE B5-3
IMPLEMENTATION COST ESTIMATE
NET PRESENT VALUE
AOC-001,002
Boeing Renton Facility
Renton, Washington

Year	ALTERNATIVE 1 Enhanced Bioremediation, Monitored Attenuation						ALTERNATIVE 2 Monitored Natural Attenuation				
	Initial Costs	O&M	Enh. Bio.	PM	GW Mon.	Total	Initial Costs	O&M	PM	GW Mon.	Total
0	$78,900					$78,900	$49,400				$49,400
1		$4,600	$23,400	$12,200	$60,800	$101,000		$4,600	$12,200	$60,800	$77,600
2		$4,700	$4,800	$12,400	$62,000	$83,900		$4,700	$12,400	$62,000	$79,100
3		$4,800	$4,900	$12,600	$19,100	$41,400		$4,800	$12,600	$19,100	$36,500
4		$4,900	$3,600	$12,900	$19,500	$40,900		$4,900	$12,900	$19,500	$37,300
5		$5,000		$13,200	$26,400	$44,600		$5,000	$13,200	$26,400	$44,600
6		$5,100		$13,500	$20,300	$38,900		$5,100	$13,500	$20,300	$38,900
7		$5,200		$13,800	$20,700	$39,700		$5,200	$13,800	$20,700	$39,700
8		$5,300		$14,100	$21,100	$40,500		$5,300	$14,100	$21,100	$40,500
9		$5,400		$14,400	$21,500	$41,300		$5,400	$14,400	$21,500	$41,300
10		$5,500		$14,700	$29,100	$49,300		$5,500	$14,700	$29,100	$49,300
11		$5,600		$15,000	$22,400	$43,000		$5,600	$15,000	$22,400	$43,000
12		$5,700		$15,300	$22,800	$43,800		$5,700	$15,300	$22,800	$43,800
13		$5,800		$15,600	$23,300	$44,700		$5,800	$15,600	$23,300	$44,700
14		$5,900		$15,900	$23,800	$45,600		$5,900	$15,900	$23,800	$45,600
15		$6,000		$16,200	$32,200	$54,400		$6,000	$16,200	$32,200	$54,400
TOTAL	$78,900	$79,500	$36,700	$211,800	$425,000	$831,900	$49,400	$79,500	$211,800	$425,000	$765,700
					Net Present Value	$524,000				**Net Present Value**	$466,000

Notes:
1. Inflated at a rate of 2% annually.
2. Discount rate of 7%.

TABLE B6-1
IMPLEMENTATION COST ESTIMATE
INITIAL COSTS
AOC-003
Boeing Renton Facility
Renton, Washington

INITIAL COSTS					ALTERNATIVE 1 MNA		ALTERNATIVE 2 Enhanced Bioremediation, Monitored Attenuation	
CONTRACTOR			Unit	Unit Cost	Quantity	Cost	Quantity	Cost
1	**Mobilization/Demobilization**							
		Mobilization/Demobilization	lump sum	$10,000	0.1	$1,000	0.3	$3,000
2	**Health and Safety**							
		Health and Safety Officer	hour	$75	0	$0	8	$600
		PPE	day	$100	0	$0	2	$200
3	**Site Preparation**							
		Utility Locates	hour	$85	4	$340	4	$340
		Site Security	linear foot	$4	0	$0	100	$400
		Erosion Control	linear foot	$5	0	$0	100	$500
4	**Surveying**							
		Surveying	day	$1,500	1	$1,500	1	$1,500
5	**Monitoring Wells**							
		Concrete Coring	day	$1,500	1	$1,500	1	$1,500
		Monitoring Well Installation (2" PVC)	linear foot	$75	58	$4,350	58	$4,350
		Base Price Per Well	each	$500	3	$1,500	2	$1,000
		Waste Disposal	drum	$150	8	$1,200	8	$1,200
6	**Enhanced Bioremediation**							
		Concrete Coring	day	$1,500	0	$0	1	$1,500
		Injection Wells (2" PVC)	linear foot	$100	0	$0	80	$8,000
		Base Price Per Well	each	$500	0	$0	4	$2,000
		Waste Disposal	drum	$150	0	$0	8	$1,200
		Additive	lbs	$5	0	$0	330	$1,650
		Application (labor and equipment)	per well	$700	0	$0	4	$2,800
Subtotal						**$11,390**		**$31,740**
Sales Tax (8.8%)						**$1,000**		**$2,790**
Subtotal						**$12,390**		**$34,530**
Contingency (30%)						**$3,720**		**$10,360**
Subtotal, Contractor						**$16,100**		**$44,900**
PROFESSIONAL TECHNICAL SERVICES								
		Permitting	%	5%	$16,100	$810	$44,900	$2,250
		Engineering design costs	%	20%	$16,100	$3,220	$44,900	$8,980
		Construction Management	%	15%	$16,100	$2,420	$44,900	$6,740
		Project Management	%	10%	$16,100	$1,610	$44,900	$4,490
Subtotal, Professional Services						**$8,100**		**$22,460**
TOTAL INITIAL COST						**$24,200**		**$67,360**

Notes:
1. 2007 Dollars.
2. Costs are +50% -30%.
3. 40 hour work week.
4. Level D PPE.
5. Waste disposal is solid waste.
6. Soil 1 cubic yard = 1.6 tons
7. Concrete/Asphalt 1 cubic yard = 2 tons
8. Backfill costs assume delivered and placed.
9. Install 1 shallow monitoring well and 1 intermediate monitoring well, all alternatives.
10. Assume no pilot test for enhanced biodegradation, Alternative 2.

TABLE B6-2
IMPLEMENTATION COST ESTIMATE
RECURRING COSTS
AOC-003

Boeing Renton Facility
Renton, Washington

RECURRING COSTS				ALTERNATIVE 1 MNA				ALTERNATIVE 2 Enhanced Bioremediation, Monitored Attenuation			
		Unit	Unit Cost	Annual Quantity	Annual Cost	Lifetime Quantity	Lifetime Cost	Annual Quantity	Annual Cost	Lifetime Quantity	Lifetime Cost
1	**ENHANCED BIODEGRADATION (Years 1,2,3)**										
	Additive	lbs	$5	0	$0	0	$0	330	$1,650	660	$3,300
	Application (labor and equipment	per well	$700	0	$0	0	$0	4	$2,800	8	$5,600
	Well abandonment (year 3)	linear foot	$25	0	$0	0	$0	80	$2,000	80	$2,000
	Base price per well abandonment (year 3)	each	$200	0	$0	0	$0	4	$800	4	$800
	Waste Disposal (year 3)	drum	$150	0	$0	0	$0	8	$1,200	8	$1,200
Subtotal					**$0**		**$0**		**$8,450**		**$12,900**
2	**OPERATION AND MAINTENANCE**										
	Monitoring Well Maintenance	per well	$500	3	$1,500	45	$22,500	3	$1,500	45	$22,500
Subtotal					**$1,500**		**$22,500**		**$1,500**		**$22,500**
3	**QUARTERLY GW MONITORING (Years 1,2)**										
	Sampling	each well	$600	16	$9,600	32	$19,200	16	$9,600	32	$19,200
	Analysis	each well	$500	16	$8,000	32	$16,000	16	$8,000	32	$16,000
	Reporting	per round	$5,000	4	$20,000	8	$40,000	4	$20,000	8	$40,000
Subtotal					**$37,600**		**$75,200**		**$37,600**		**$75,200**
4	**SEMIANNUAL GW MONITORING (Years 3-15)**										
	Sampling	each well	$600	8	$4,800	104	$62,400	8	$4,800	104	$62,400
	Analysis	each well	$200	8	$1,600	104	$20,800	8	$1,600	104	$20,800
	Reporting	per round	$5,000	2	$10,000	26	$130,000	2	$10,000	26	$130,000
Subtotal					**$16,400**		**$213,200**		**$16,400**		**$213,200**
5	**FIVE YEAR GW MONITORING (Years 5,10,15)**										
	Sampling	each well	$600	4	$2,400	12	$7,200	4	$2,400	12	$7,200
	Analysis	each well	$500	4	$2,000	12	$6,000	4	$2,000	12	$6,000
	Reporting	per round	$5,000	1	$5,000	3	$15,000	1	$5,000	3	$15,000
Subtotal					**$9,400**		**$28,200**		**$9,400**		**$28,200**
6	**PROJECT MANAGEMENT**										
	Project Management	year	$12,000	1	$12,000	15	$180,000	1	$12,000	15	$180,000
Subtotal					**$12,000**		**$180,000**		**$12,000**		**$180,000**

Notes:
1. 2007 Dollars.
2. Costs are +50% -30%.
3. 40 hour work week.
4. Sales tax of 8.8% included in unit price.
5. Single application of Enhanced Biodegradation, Alternative 2.

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TABLE B6-3
IMPLEMENTATION COST ESTIMATE
NET PRESENT VALUE
AOC-003
Boeing Renton Facility
Renton, Washington

Year	ALTERNATIVE 1					ALTERNATIVE 2					
	MNA					Enhanced Bioremediation, Monitored Attenuation					
	Initial Costs	O&M	PM	GW Mon.	Total	Initial Costs	O&M	Enh. Bio.	PM	GW Mon.	Total
0	$24,200				$24,200	$67,360					$67,360
1		$1,500	$12,200	$38,400	$52,100		$1,500	$4,500	$12,200	$38,400	$56,600
2		$1,530	$12,400	$39,200	$53,130		$1,530	$4,600	$12,400	$39,200	$57,730
3		$1,560	$12,600	$17,400	$31,560		$1,560	$4,200	$12,600	$17,400	$35,760
4		$1,590	$12,900	$17,700	$32,190		$1,590		$12,900	$17,700	$32,190
5		$1,620	$13,200	$19,400	$34,220		$1,620		$13,200	$19,400	$34,220
6		$1,650	$13,500	$18,500	$33,650		$1,650		$13,500	$18,500	$33,650
7		$1,680	$13,800	$18,900	$34,380		$1,680		$13,800	$18,900	$34,380
8		$1,710	$14,100	$19,300	$35,110		$1,710		$14,100	$19,300	$35,110
9		$1,740	$14,400	$19,700	$35,840		$1,740		$14,400	$19,700	$35,840
10		$1,770	$14,700	$21,500	$37,970		$1,770		$14,700	$21,500	$37,970
11		$1,810	$15,000	$20,400	$37,210		$1,810		$15,000	$20,400	$37,210
12		$1,850	$15,300	$20,800	$37,950		$1,850		$15,300	$20,800	$37,950
13		$1,890	$15,600	$21,200	$38,690		$1,890		$15,600	$21,200	$38,690
14		$1,930	$15,900	$21,600	$39,430		$1,930		$15,900	$21,600	$39,430
15		$1,970	$16,200	$23,700	$41,870		$1,970		$16,200	$23,700	$41,870
TOTAL	$24,200	$25,800	$211,800	$337,700	$599,500	$67,400	$25,800	$13,300	$211,800	$337,700	$656,000
				Net Present Value	$353,000					**Net Present Value**	$405,000

Notes:
1. Inflated at a rate of 2% annually.
2. Discount rate of 7%.

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TABLE B7-1
IMPLEMENTATION COST ESTIMATE
INITIAL COSTS
AOC-004

Boeing Renton Facility
Renton, Washington

INITIAL COSTS					ALTERNATIVE 1 MNA		ALTERNATIVE 2 Enhanced Bioremediation and Monitored Attenuation	
CONTRACTOR			**Unit**	**Unit Cost**	**Quantity**	**Cost**	**Quantity**	**Cost**
1	**Mobilization/Demobilization**							
		Mobilization/Demobilization	lump sum	$10,000	0.1	$1,000	0.5	$5,000
2	**Health and Safety**							
		Health and Safety Officer	hour	$75	0	$0	8	$600
		Equipment	month	$2,000	0	$0	1	$2,000
		PPE	day	$100	0	$0	8	$800
3	**Site Preparation**							
		Utility Locates	hour	$85	4	$340	8	$680
		Site Security	linear foot	$4	100	$400	200	$800
		Temporary Facilities	month	$3,000	0	$0	0.5	$1,500
		Traffic Control	lump sum	$1,000	0	$0	2	$2,000
		Erosion Control	linear foot	$5	100	$500	200	$1,000
		Storm water Management	day	$500	0	$0	2	$1,000
4	**Source Area Excavation**							
		Saw Cut Concrete (12")	linear foot	$7	40	$280	40	$280
		Excavation	cubic yard	$12	15	$180	15	$180
		Waste Transportation/Disposal	ton	$40	26	$1,040	26	$1,040
		Backfill	ton	$12	26	$310	26	$310
		Groundwater Management	gallon	$3	1,000	$3,000	1,000	$3,000
		Concrete (12") with rebar	square foot	$15	100	$1,500	100	$1,500
5	**Surveying**							
		Surveying	day	$1,500	1	$1,500	2	$3,000
6	**Monitoring Wells**							
		Monitoring Well Installation (2" PVC)	linear foot	$75	55	$4,130	55	$4,130
		Base Price Per Well	each	$500	3	$1,500	3	$1,500
		Waste Disposal	drum	$150	12	$1,800	12	$1,800
7	**Enhanced Bioremediation**							
		Direct Push Rig	day	$2,000	0	$0	1	$2,000
		Coring	day	$1,500	0	$0	2	$3,000
		Chemical	pound	$15	0	$0	300	$4,500
		Application (equipment)	day	$500	0	$0	1	$500
Subtotal						**$17,480**		**$42,120**
Sales Tax (8.8%)						**$1,540**		**$3,710**
Subtotal						**$19,020**		**$45,830**
Contingency (30%)						**$5,710**		**$13,750**
Subtotal, Contractor						**$24,700**		**$59,600**
PROFESSIONAL TECHNICAL SERVICES								
		Permitting	%	5%	$24,700	$1,240	$59,600	$2,980
		Engineering design costs	%	20%	$24,700	$4,940	$59,600	$11,920
		Construction Management	%	15%	$24,700	$3,710	$59,600	$8,940
		Project Management	%	10%	$24,700	$2,470	$59,600	$6,000
Subtotal, Professional Services						**$12,360**		**$29,800**
TOTAL INITIAL COST						**$37,100**		**$89,400**

Notes:
1. 2007 Dollars.
2. Costs are +50% -30%.
3. 40 hour work week.
4. Leve D PPE.
5. Waste disposal is solid waste.
6. Soil 1 cubic yard = 1.6 tons
7. Concrete/Asphalt 1 cubic yard = 2 tons
8. Backfill costs assume delivered and placed.
9. Installation of 2 shallow monitoring wells and 1 intermediate monitoring well, all alternatives.

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TABLE B7-2
IMPLEMENTATION COST ESTIMATE
RECURRING COSTS
AOC-004
Boeing Renton Facility
Renton, Washington

RECURRING COSTS				ALTERNATIVE 1 MNA				ALTERNATIVE 2 Enhanced Bioremediation and Monitored Attenuation			
		Unit	Unit Cost	Annual Quantity	Annual Cost	Lifetime Quantity	Lifetime Cost	Annual Quantity	Annual Cost	Lifetime Quantity	Lifetime Cost
1	**OPERATION AND MAINTENANCE**										
	Monitoring Well Maintenance	per well	$500	3	$1,500	45	$22,500	3	$1,500	45	$22,500
Subtotal					**$1,500**		**$22,500**		**$1,500**		**$22,500**
2	**QUARTERLY GW MONITORING (Years 1,2)**										
	Sampling	each well	$600	12	$7,200	24	$14,400	12	$7,200	24	$14,400
	Analysis	each well	$500	12	$6,000	24	$12,000	12	$6,000	24	$12,000
	Reporting	per round	$5,000	4	$20,000	8	$40,000	4	$20,000	8	$40,000
Subtotal					**$33,200**		**$66,400**		**$33,200**		**$66,400**
3	**SEMIANNUAL GW MONITORING (Years 3-15)**										
	Sampling	each well	$600	4	$2,400	52	$31,200	4	$2,400	52	$31,200
	Analysis	each well	$200	4	$800	52	$10,400	4	$800	52	$10,400
	Reporting	per round	$5,000	2	$10,000	26	$130,000	2	$10,000	26	$130,000
Subtotal					**$13,200**		**$171,600**		**$13,200**		**$171,600**
4	**FIVE YEAR GW MONITORING (Years 5,10,15)**										
	Sampling	each well	$600	3	$1,800	9	$5,400	3	$1,800	9	$5,400
	Analysis	each well	$500	3	$1,500	9	$4,500	3	$1,500	9	$4,500
	Reporting	per round	$5,000	1	$5,000	3	$15,000	1	$5,000	3	$15,000
Subtotal					**$8,300**		**$24,900**		**$8,300**		**$24,900**
5	**PROJECT MANAGEMENT**										
	Project Management	year	$12,000	1	$12,000	15	$180,000	1	$12,000	15	$180,000
Subtotal					**$12,000**		**$180,000**		**$12,000**		**$180,000**

Notes:
1. 2007 Dollars.
2. Costs are +50% -30%.
3. 40 hour work week.
4. Sales tax of 8.8% included in unit price.

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TABLE B7-3
IMPLEMENTATION COST ESTIMATE
NET PRESENT VALUE
AOC-004

Boeing Renton Facility
Renton, Washington

	ALTERNATIVE 1					ALTERNATIVE 2				
	MNA					Enhanced Bioremediation and Monitored Attenuation				
Year	**Initial Costs**	**O&M**	**PM**	**GW Mon.**	**Total**	**Initial Costs**	**O&M**	**PM**	**GW Mon.**	**Total**
0	$37,100				$37,100	$89,400				$89,400
1		$1,530	$12,200	$33,900	$47,630		$1,530	$12,200	$33,900	$47,630
2		$1,560	$12,400	$34,600	$48,560		$1,560	$12,400	$34,600	$48,560
3		$1,590	$12,600	$14,000	$28,190		$1,590	$12,600	$14,000	$28,190
4		$1,620	$12,900	$14,300	$28,820		$1,620	$12,900	$14,300	$28,820
5		$1,650	$13,200	$16,500	$31,350		$1,650	$13,200	$16,500	$31,350
6		$1,680	$13,500	$14,900	$30,080		$1,680	$13,500	$14,900	$30,080
7		$1,710	$13,800	$15,200	$30,710		$1,710	$13,800	$15,200	$30,710
8		$1,740	$14,100	$15,500	$31,340		$1,740	$14,100	$15,500	$31,340
9		$1,770	$14,400	$15,800	$31,970		$1,770	$14,400	$15,800	$31,970
10		$1,810	$14,700	$18,200	$34,710		$1,810	$14,700	$18,200	$34,710
11		$1,850	$15,000	$16,400	$33,250		$1,850	$15,000	$16,400	$33,250
12		$1,890	$15,300	$16,700	$33,890		$1,890	$15,300	$16,700	$33,890
13		$1,930	$15,600	$17,000	$34,530		$1,930	$15,600	$17,000	$34,530
14		$1,970	$15,900	$17,300	$35,170		$1,970	$15,900	$17,300	$35,170
15		$2,010	$16,200	$20,100	$38,310		$2,010	$16,200	$20,100	$38,310
TOTAL	$37,100	$26,300	$211,800	$280,400	$555,600	$89,400	$26,300	$211,800	$280,400	$607,900
				Net Present Value	$333,000				**Net Present Value**	$382,000

Notes:
1. Inflated at a rate of 2% annually.
2. Discount rate of 7%.

Geomatrix

TABLE B8-1
IMPLEMENTATION COST ESTIMATE
INITIAL COSTS
AOC-034/035
Boeing Renton Facility
Renton, Washington

INITIAL COSTS					ALTERNATIVE 1 MNA		ALTERNATIVE 2 Enhanced Bioremediation, Monitored Attenuation	
CONTRACTOR			**Unit**	**Unit Cost**	**Quantity**	**Cost**	**Quantity**	**Cost**
1	**Mobilization/Demobilization**							
		Mobilization/Demobilization	lump sum	$10,000	0.1	$1,000	0.3	$3,000
2	**Health and Safety**							
		Health and Safety Officer	hour	$75	4	$300	8	$600
		PPE	day	$100	1	$100	2	$200
3	**Site Preparation**							
		Utility Locates	hour	$85	4	$340	4	$340
		Site Security	linear foot	$4	100	$400	100	$400
		Erosion Control	linear foot	$5	100	$500	100	$500
4	**Surveying**							
		Surveying	day	$1,500	1	$1,500	1	$1,500
5	**Monitoring Wells**							
		Concrete Coring	day	$1,500	1	$1,500	1	$1,500
		Monitoring Well Installation (2" PVC)	linear foot	$75	60	$4,500	60	$4,500
		Base Price Per Well	each	$500	4	$2,000	4	$2,000
		Waste Disposal	drum	$150	14	$2,100	14	$2,100
6	**Enhanced Bioremediation**							
		Concrete Coring	day	$1,500	0	$0	2	$3,000
		Injection Wells (2" PVC)	linear foot	$100	0	$0	60	$6,000
		Base Price Per Well	each	$500	0	$0	4	$2,000
		Waste Disposal	drum	$150	0	$0	8	$1,200
Subtotal						**$14,200**		**$28,800**
Sales Tax (8.8%)						**$1,250**		**$2,530**
Subtotal						**$15,450**		**$31,330**
Contingency (30%)						**$4,640**		**$9,400**
Subtotal, Contractor						**$20,100**		**$40,700**
PROFESSIONAL TECHNICAL SERVICES								
		Permitting	%	5%	$20,100	$1,010	$40,700	$2,000
		Engineering design costs	%	20%	$20,100	$4,020	$40,700	$8,100
		Construction Management	%	15%	$20,100	$3,020	$40,700	$6,100
		Project Management	%	10%	$20,100	$2,010	$40,700	$4,100
Subtotal, Professional Services						**$10,060**		**$20,300**
TOTAL INITIAL COST						**$30,160**		**$61,000**

Notes:
1. 2007 Dollars.
2. Costs are +50% -30%.
3. 40 hour work week.
4. Level D PPE.
5. Waste disposal is solid waste.
6. Soil 1 cubic yard = 1.6 tons
7. Concrete/Asphalt 1 cubic yard = 2 tons
8. Backfill costs assume delivered and placed.
9. Install 1 shallow monitoring well and 1 intermediate monitoring well, all alternatives.
10. Assume no pilot test for enhanced biodegradation, Alternative 2.

TABLE B8-2
IMPLEMENTATION COST ESTIMATE
RECURRING COSTS
AOC-034/035
Boeing Renton Facility
Renton, Washington

	RECURRING COSTS			ALTERNATIVE 1 MNA				ALTERNATIVE 2 Enhanced Bioremediation, Monitored Attenuation			
		Unit	Unit Cost	Annual Quantity	Annual Cost	Lifetime Quantity	Lifetime Cost	Annual Quantity	Annual Cost	Lifetime Quantity	Lifetime Cost
1	**ENHANCED BIODEGRADATION (Years 1,2,3)**										
	Additive	lbs	$5	0	$0	0	$0	330	$1,650	660	$3,300
	Application (labor and equipment	per well	$700	0	$0	0	$0	4	$2,800	8	$5,600
	Well abandonment (year 3)	linear foot	$25	0	$0	0	$0	60	$1,500	60	$1,500
	Base price per well abandonment (year 3)	each	$200	0	$0	0	$0	4	$800	4	$800
	Waste Disposal (year 3)	drum	$150	0	$0	0	$0	8	$1,200	8	$1,200
Subtotal					**$0**		**$0**		**$7,950**		**$12,400**
2	**OPERATION AND MAINTENANCE**										
	Monitoring Well Maintenance	per well	$500	2	$1,000	30	$15,000	2	$1,000	30	$15,000
Subtotal					**$1,000**		**$15,000**		**$1,000**		**$15,000**
3	**QUARTERLY GW MONITORING (Years 1,2)**										
	Sampling	each well	$600	16	$9,600	32	$19,200	16	$9,600	32	$19,200
	Analysis	each well	$500	16	$8,000	32	$16,000	16	$8,000	32	$16,000
	Reporting	per round	$5,000	4	$20,000	8	$40,000	4	$20,000	8	$40,000
Subtotal					**$37,600**		**$75,200**		**$37,600**		**$75,200**
4	**SEMIANNUAL GW MONITORING (Years 3-15)**										
	Sampling	each well	$600	4	$2,400	52	$31,200	4	$2,400	52	$31,200
	Analysis	each well	$200	4	$800	52	$10,400	4	$800	52	$10,400
	Reporting	per round	$5,000	2	$10,000	26	$130,000	2	$10,000	26	$130,000
Subtotal					**$13,200**		**$171,600**		**$13,200**		**$171,600**
5	**FIVE YEAR GW MONITORING (Years 5,10,15)**										
	Sampling	each well	$600	4	$2,400	12	$7,200	4	$2,400	12	$7,200
	Analysis	each well	$500	4	$2,000	12	$6,000	4	$2,000	12	$6,000
	Reporting	per round	$5,000	1	$5,000	3	$15,000	1	$5,000	3	$15,000
Subtotal					**$9,400**		**$28,200**		**$9,400**		**$28,200**
6	**PROJECT MANAGEMENT**										
	Project Management	year	$12,000	1	$12,000	15	$180,000	1	$12,000	15	$180,000
Subtotal					**$12,000**		**$180,000**		**$12,000**		**$180,000**

Notes:
1. 2007 Dollars.
2. Costs are +50% -30%.
3. 40 hour work week.
4. Sales tax of 8.8% included in unit price.
5. Single application of Enhanced Biodegradation, Alternative 2.

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TABLE B8-3
IMPLEMENTATION COST ESTIMATE
NET PRESENT VALUE
AOC-034/035

Boeing Renton Facility
Renton, Washington

Year	ALTERNATIVE 1					ALTERNATIVE 2					
	MNA					Enhanced Bioremediation, Monitored Attenuation					
	Initial Costs	O&M	PM	GW Mon.	Total	Initial Costs	O&M	Enh. Bio.	PM	GW Mon.	Total
0	$30,160				$30,160	$61,000					$61,000
1		$1,000	$12,200	$38,400	$51,600		$1,000	$4,500	$12,200	$38,400	$56,100
2		$1,020	$12,400	$39,200	$52,620		$1,020	$4,600	$12,400	$39,200	$57,220
3		$1,040	$12,600	$14,000	$27,640		$1,040	$3,700	$12,600	$14,000	$31,340
4		$1,060	$12,900	$14,300	$28,260		$1,060		$12,900	$14,300	$28,260
5		$1,080	$13,200	$17,700	$31,980		$1,080		$13,200	$17,700	$31,980
6		$1,100	$13,500	$14,900	$29,500		$1,100		$13,500	$14,900	$29,500
7		$1,120	$13,800	$15,200	$30,120		$1,120		$13,800	$15,200	$30,120
8		$1,140	$14,100	$15,500	$30,740		$1,140		$14,100	$15,500	$30,740
9		$1,160	$14,400	$15,800	$31,360		$1,160		$14,400	$15,800	$31,360
10		$1,180	$14,700	$19,500	$35,380		$1,180		$14,700	$19,500	$35,380
11		$1,200	$15,000	$16,400	$32,600		$1,200		$15,000	$16,400	$32,600
12		$1,220	$15,300	$16,700	$33,220		$1,220		$15,300	$16,700	$33,220
13		$1,240	$15,600	$17,000	$33,840		$1,240		$15,600	$17,000	$33,840
14		$1,260	$15,900	$17,300	$34,460		$1,260		$15,900	$17,300	$34,460
15		$1,290	$16,200	$21,500	$38,990		$1,290		$16,200	$21,500	$38,990
TOTAL	$30,200	$17,100	$211,800	$293,400	$552,500	$61,000	$17,100	$12,800	$211,800	$293,400	$596,100
				Net Present Value	$331,000					Net Present Value	$371,000

Notes:
1. Inflated at a rate of 2% annually.
2. Discount rate of 7%.

Geomatrix

TABLE B9-1
IMPLEMENTATION COST ESTIMATE
INITIAL COSTS
AOC-060
Boeing Renton Facility
Renton, Washington

INITIAL COSTS					ALTERNATIVE 1 MNA		ALTERNATIVE 2 Enhanced Bioremediation, Monitored Attenuation		ALTERNATIVE 3 Air Sparge, SVE, Monitored Attenuation	
CONTRACTOR			**Unit**	**Unit Cost**	**Quantity**	**Cost**	**Quantity**	**Cost**	**Quantity**	**Cost**
1	**Mobilization/Demobilization**									
		Mobilization/Demobilization	lump sum	$10,000	0.2	$2,000	0.5	$5,000	2	$20,000
2	**Health and Safety**									
		Health and Safety Officer	hour	$75	4	$300	8	$600	16	$1,200
		Equipment	month	$2,000	0	$0	0	$0	1	$2,000
		PPE	day	$100	2	$200	4	$400	10	$1,000
3	**Site Preparation**									
		Utility Locates	hour	$85	4	$340	8	$680	8	$680
		Site Security	linear foot	$4	100	$400	200	$800	250	$1,000
		Temporary Facilities	month	$3,000	0	$0	0	$0	1	$3,000
		Traffic Control	lump sum	$1,000	0	$0	0	$0	3	$3,000
		Erosion Control	linear foot	$5	100	$500	200	$1,000	250	$1,250
		Storm water Management	day	$500	0	$0	0	$0	4	$2,000
4	**Surveying**									
		Surveying	day	$1,500	1	$1,500	2	$3,000	3	$4,500
5	**Monitoring Wells**									
		Monitoring Well Installation (2" PVC)	linear foot	$75	60	$4,500	60	$4,500	60	$4,500
		Base Price Per Well	each	$500	3	$1,500	3	$1,500	3	$1,500
		Waste Disposal	drum	$150	12	$1,800	12	$1,800	12	$1,800
6	**AS and SVE**									
		Pilot Test	lump sum	$35,000	0	$0	0	$0	1	$35,000
		Air Sparge Well Installation (2" PVC)	linear foot	$75	0	$0	0	$0	80	$6,000
		Soil Vapor Extraction Well Installation (4" PVC)	linear foot	$100	0	$0	0	$0	30	$3,000
		Base Price Per Well	each	$300	0	$0	0	$0	9	$2,700
		Waste Disposal	drum	$150	0	$0	0	$0	25	$3,750
		Compressor	each	$6,000	0	$0	0	$0	1	$6,000
		Knock out pot	each	$2,000	0	$0	0	$0	1	$2,000
		Vacuum Blower	each	$3,500	0	$0	0	$0	1	$3,500
		Granular Activated Carbon	each	$3,000	0	$0	0	$0	1	$3,000
		Permanganate Unit	each	$1,500	0	$0	0	$0	1	$1,500
		Valves	each	$85	0	$0	0	$0	20	$1,700
		Gauges	each	$25	0	$0	0	$0	20	$500
		Treatment Center	lump sum	$12,000	0	$0	0	$0	1	$12,000
		Electrical Service	lump sum	$10,000	0	$0	0	$0	1	$10,000
		Electrical Connections	lump sum	$5,000	0	$0	0	$0	4	$20,000
7	**Trenching**									
		Saw Cut Asphalt (6")	linear foot	$3	0	$0	0	$0	300	$900
		Excavation	cubic yard	$10	0	$0	0	$0	120	$1,200
		Spoils Disposal	ton	$40	0	$0	0	$0	200	$8,000
		Backfill	ton	$10	0	$0	0	$0	200	$2,000
		Piping	linear foot	$25	0	$0	0	$0	200	$5,000
		Asphalt Paving (6")	square foot	$4	0	$0	0	$0	500	$2,000
8	**Enhanced Bioremediation**									
		Injection Wells (4" PVC)	linear foot	$100	0	$0	160	$16,000	0	$0
		Base Price Per Well	each	$500	0	$0	8	$4,000	0	$0
		Waste Disposal	drum	$150	0	$0	30	$4,500	0	$0
		Additive	lbs	$5.00	0	$0	700	$3,500	0	$0
		Application (labor and equipment)	per well	$700	0	$0	8	$5,600	0	$0
Subtotal						**$13,040**		**$52,880**		**$177,180**
Sales Tax (8.8%)						**$1,150**		**$4,650**		**$15,590**
Subtotal						**$14,190**		**$57,530**		**$192,770**
Contingency (30%)						**$4,260**		**$17,260**		**$57,830**
Subtotal, Contractor						**$18,500**		**$74,800**		**$250,600**
PROFESSIONAL TECHNICAL SERVICES										
		Investigation	lump sum	$9,000	0.5	$4,500	0.5	$4,500	2	$18,000
		Permitting	%	5%	$18,500	$930	$74,800	$3,740	$250,600	$12,500
		Engineering design costs	%	20%	$18,500	$3,700	$74,800	$14,960	$250,600	$50,100
		Construction Management	%	15%	$18,500	$2,780	$74,800	$11,220	$250,600	$37,600
		Project Management	%	10%	$18,500	$1,850	$74,800	$7,480	$250,600	$25,100
Subtotal, Professional Services						**$13,800**		**$41,900**		**$143,300**
TOTAL INITIAL COST						**$32,300**		**$116,700**		**$393,900**

Notes:
1. 2007 Dollars.
2. Costs are +50% -30%.
3. 40 hour work week.
4. Level D PPE
5. Waste disposal is non-hazardous solid waste.
6. Soil 1 cubic yard = 1.6 tons
7. Concrete/Asphalt 1 cubic yard = 2 tons
8. Backfill costs assume delivered and placed.
9. Installation of 2 shallow monitoring wells and 1 intermediate monitoring well, all alternatives.
10. 8 injection wells for enhanced bioremediation, Alternative 2.
11. 5 soil vapor extraction wells and 3 air sparging wells, Alternative 3.

TABLE B9-2
IMPLEMENTATION COST ESTIMATE
RECURRING COSTS
AOC-060
Boeing Renton Facility
Renton, Washington

RECURRING COSTS				ALTERNATIVE 1 MNA				ALTERNATIVE 2 Enhanced Biodegradation, Monitored Attenuation				ALTERNATIVE 3 Air Sparge, SVE, Monitored Attenuation			
		Unit	Unit Cost	Annual Quantity	Annual Cost	Lifetime Quantity	Lifetime Cost	Annual Quantity	Annual Cost	Lifetime Quantity	Lifetime Cost	Annual Quantity	Annual Cost	Lifetime Quantity	Lifetime Cost
1	**ENHANCED BIODEGRADATION (Years 1,2,3)**														
	Additive	lbs	$5.00	0	$0	0	$0	700	$3,500	1,400	$7,000	0	$0	0	$0
	Application (labor and equipment)	per well	$700.00	0	$0	0	$0	8	$5,600	16	$11,200	0	$0	0	$0
	Well abandonment (year 3)	linear foot	$25.00	0	$0	0	$0	0	$0	160	$4,000	0	$0	0	$0
	Base price per well abandonment (year 3)	each	$500.00	0	$0	0	$0	0	$0	8	$4,000	0	$0	0	$0
	Waste Disposal	drum	$150	0	$0	0	$0	0	$0	30	$4,500	0	$0	0	$0
Subtotal					**$0**		**$0**		**$9,100**		**$30,700**		**$0**		**$0**
2	**OPERATION AND MAINTENANCE**														
	Monitoring AS/SVE	annual	$15,000	0	$0	0	$0	0	$0	0	$0	1	$15,000	5	$75,000
	Air Sampling AS/SVE	per well	$450	0	$0	0	$0	0	$0	0	$0	9	$4,050	45	$20,250
	Electricity	monthly	$400	0	$0	0	$0	0	$0	0	$0	12	$4,800	60	$24,000
	Carbon Replacement	pound	$2	0	$0	0	$0	0	$0	0	$0	600	$1,200	3000	$6,000
	Permanganate Replacement	pound	$2	0	$0	0	$0	0	$0	0	$0	700	$1,400	3500	$7,000
	Maintenance AS/SVE	lump sum	$5,000	0	$0	0	$0	0	$0	0	$0	1	$5,000	5	$25,000
	Monitoring Well Maintenance	per well	$500	13	$6,500	195	$97,500	13	$6,500	195	$97,500	13	$6,500	195	$97,500
Subtotal					**$6,500**		**$97,500**		**$6,500**		**$97,500**		**$37,950**		**$254,750**
3	**Air Sparge Well Abandonment (Year 5)**														
	Well abandonment	linear foot	$25	0	$0	0	$0	0	$0	0	$0	80	$2,000	80	$2,000
	Base Price per Well abandonment	each	$200	0	$0	0	$0	0	$0	0	$0	4	$800	4	$800
	Waste Disposal	drum	$150	0	$0	0	$0	0	$0	0	$0	15	$2,250	15	$2,250
Subtotal					**$0**		**$0**		**$0**		**$0**	**15**	**$5,050**		**$5,050**
4	**SVE Well Abandonment (Year 5)**														
	Well abandonment	linear foot	$25	0	$0	0	$0	0	$0	0	$0	30	$750	30	$750
	Base Price per Well abandonment	each	$200	0	$0	0	$0	0	$0	0	$0	5	$1,000	5	$1,000
	Waste Disposal	drum	$150	0	$0	0	$0	0	$0	0	$0	10	$1,500	10	$1,500
Subtotal					**$0**		**$0**		**$0**		**$0**		**$3,250**		**$3,250**
7	**QUARTERLY GW MONITORING (Years 1,2)**														
	Sampling	each well	$600	12	$7,200	24	$14,400	12	$7,200	24	$14,400	12	$7,200	24	$14,400
	Analysis	each well	$500	12	$6,000	24	$12,000	12	$6,000	24	$12,000	12	$6,000	24	$12,000
	Reporting	per round	$5,000	4	$20,000	8	$40,000	4	$20,000	8	$40,000	4	$20,000	8	$40,000
Subtotal					**$33,200**		**$66,400**		**$33,200**		**$66,400**		**$33,200**		**$66,400**
8	**SEMIANNUAL GW MONITORING (Years 3-15)**														
	Sampling	each well	$600	26	$15,600	338	$202,800	26	$15,600	338	$202,800	26	$15,600	338	$202,800
	Analysis	each well	$200	26	$5,200	338	$67,600	26	$5,200	338	$67,600	26	$5,200	338	$67,600
	Reporting	per round	$5,000	2	$10,000	26	$130,000	2	$10,000	26	$130,000	2	$10,000	26	$130,000
Subtotal					**$30,800**		**$400,400**		**$30,800**		**$400,400**		**$30,800**		**$400,400**
9	**FIVE YEAR GW MONITORING (Years 5,10,15)**														
	Sampling	each well	$600	13	$7,800	39	$23,400	13	$7,800	39	$23,400	13	$7,800	39	$23,400
	Analysis	each well	$500	13	$6,500	39	$19,500	13	$6,500	39	$19,500	13	$6,500	39	$19,500
	Reporting	per round	$5,000	1	$5,000	3	$15,000	1	$5,000	3	$15,000	1	$5,000	3	$15,000
Subtotal					**$19,300**		**$57,900**		**$19,300**		**$57,900**		**$19,300**		**$57,900**
10	**PROJECT MANAGEMENT**														
	Project Management	year	$12,000	1	$12,000	15	$180,000	1	$12,000	15	$180,000	1	$12,000	15	$180,000
Subtotal					**$12,000**		**$180,000**		**$12,000**		**$180,000**		**$12,000**		**$180,000**

1. 2007 Dollars.
2. Costs are +50% -30%.
3. 40 hour work week.
4. Sales tax of 8.8% included in unit price.
5. Enhanced Biodegradation has three applications (first application is in implementation cost), Alternative 2.

Geomatrix

TABLE B9-3
IMPLEMENTATION COST ESTIMATE
NET PRESENT VALUE
AOC-060

Boeing Renton Facilty
Renton, Washington

Year	ALTERNATIVE 1					ALTERNATIVE 2						ALTERNATIVE 3					
	MNA					Enhanced Biodegradation, Monitored Attenuation						Air Sparge, SVE, Monitored Attenuation					
	Initial Costs	O&M	PM	GW Mon.	Total	Initial Costs	O&M	Enh. Bio.	PM	GW Mon.	Total	Initial Costs	O&M	Air Sparge and SVE Well Abandon.	PM	GW Mon.	Total
0	$32,300				$32,300	$116,700					$116,700	$393,900					$393,900
1		$6,600	$12,200	$33,900	$52,700		$6,600	$9,300	$12,200	$33,900	$62,000		$38,700		$12,200	$33,900	$84,800
2		$6,700	$12,400	$34,600	$53,700		$6,700	$9,500	$12,400	$34,600	$63,200		$39,500		$12,400	$34,600	$86,500
3		$6,800	$12,600	$32,700	$52,100		$6,800	$13,300	$12,600	$32,700	$65,400		$40,300		$12,600	$32,700	$85,600
4		$6,900	$12,900	$33,400	$53,200		$6,900		$12,900	$33,400	$53,200		$41,100		$12,900	$33,400	$87,400
5		$7,000	$13,200	$38,300	$58,500		$7,000		$13,200	$38,300	$58,500		$41,900	$9,200	$13,200	$38,300	$102,600
6		$7,100	$13,500	$34,700	$55,300		$7,100		$13,500	$34,700	$55,300		$7,100		$13,500	$34,700	$55,300
7		$7,200	$13,800	$35,400	$56,400		$7,200		$13,800	$35,400	$56,400		$7,200		$13,800	$35,400	$56,400
8		$7,300	$14,100	$36,100	$57,500		$7,300		$14,100	$36,100	$57,500		$7,300		$14,100	$36,100	$57,500
9		$7,400	$14,400	$36,800	$58,600		$7,400		$14,400	$36,800	$58,600		$7,400		$14,400	$36,800	$58,600
10		$7,500	$14,700	$42,300	$64,500		$7,500		$14,700	$42,300	$64,500		$7,500		$14,700	$42,300	$64,500
11		$7,700	$15,000	$38,300	$61,000		$7,700		$15,000	$38,300	$61,000		$7,700		$15,000	$38,300	$61,000
12		$7,900	$15,300	$39,100	$62,300		$7,900		$15,300	$39,100	$62,300		$7,900		$15,300	$39,100	$62,300
13		$8,100	$15,600	$39,900	$63,600		$8,100		$15,600	$39,900	$63,600		$8,100		$15,600	$39,900	$63,600
14		$8,300	$15,900	$40,700	$64,900		$8,300		$15,900	$40,700	$64,900		$8,300		$15,900	$40,700	$64,900
15		$8,500	$16,200	$46,700	$71,400		$8,500		$16,200	$46,700	$71,400		$8,500		$16,200	$46,700	$71,400
TOTAL	$32,300	$111,000	$211,800	$562,900	$918,000	$116,700	$111,000	$32,100	$211,800	$562,900	$1,034,500	$393,900	$278,500	$9,200	$211,800	$562,900	$1,456,300
				Net Present Value	$521,000					**Net Present Value**	$626,000					**Net Present Value**	$993,000

Notes:
1. Inflated at a rate of 2% annually.
2. Discount rate of 7%.

TABLE B10-1
IMPLEMENTATION COST ESTIMATE
INITIAL COSTS
AOC-090
Boeing Renton Facility
Renton, Washington

INITIAL COSTS					ALTERNATIVE 1 MA		ALTERNATIVE 2 Enhanced Bioremediation, Monitored Attenuation		ALTERNATIVE 3 SVE, Monitored Attenuation	
CONTRACTOR			**Unit**	**Unit Cost**	**Quantity**	**Cost**	**Quantity**	**Cost**	**Quantity**	**Cost**
1	**Mobilization/Demobilization**									
		Mobilization/Demobilization	lump sum	$10,000	0.0	$0	0.5	$5,000	0.75	$7,500
2	**Health and Safety**									
		Health and Safety Officer	hour	$75	0	$0	12	$900	12	$900
		Equipment	month	$2,000	0	$0	1	$2,000	1	$2,000
		PPE	day	$100	0	$0	8	$800	8	$800
3	**Site Preparation**									
		Utility Locates	hour	$85	0	$0	4	$340	0	$0
		Site Security	linear foot	$4	0	$0	100	$400	250	$1,000
		Temporary Facilities	month	$3,000	0	$0	0	$0	1	$3,000
		Traffic Control	lump sum	$1,000	0	$0	1	$1,000	1	$1,000
		Erosion Control	linear foot	$5	0	$0	100	$500	0	$0
		Storm water Management	day	$500	0	$0		$0	0	$0
4	**Surveying**									
		Surveying	day	$1,500	0	$0	0	$0	0	$0
5	**Monitoring Wells**									
		Monitoring Well Installation (2" PVC)	linear foot	$75	0	$0	0	$0	0	$0
		Base Price Per Well	each	$500	0	$0	0	$0	0	$0
		Waste Disposal	drum	$150	0	$0	0	$0	0	$0
6	**SVE**									
		Knock out pot	each	$2,000	0	$0	0	$0	1	$2,000
		Vacuum Blower	each	$3,500	0	$0	0	$0	1	$3,500
		Granular Activated Carbon	each	$3,000	0	$0	0	$0	1	$3,000
		Permanganate Unit	each	$1,500	0	$0	0	$0	1	$1,500
		Valves	each	$85	0	$0	0	$0	10	$850
		Gauges	each	$25	0	$0	0	$0	10	$250
		Treatment Center	lump sum	$12,000	0	$0	0	$0	1	$12,000
		Electrical Service	lump sum	$10,000	0	$0	0	$0	1	$10,000
		Electrical Connections	lump sum	$5,000	0	$0	0	$0	2	$10,000
7	**Enhanced Bioremediation**									
		Additive	lbs	$5.0	0	$0	2,000	$10,000	0	$0
		Application (labor and equipment)	per well	$700	0	$0	7	$4,900	0	$0
Subtotal						**$0**		**$25,840**		**$59,300**
Sales Tax (8.8%)						**$0**		**$2,270**		**$5,220**
Subtotal						**$0**		**$28,110**		**$64,520**
Contingency (30%)						**$0**		**$8,430**		**$19,360**
Subtotal, Contractor						**$0**		**$36,500**		**$83,900**
PROFESSIONAL TECHNICAL SERVICES										
		Investigation	lump sum	$9,000	0.0	$0	1	$9,000	1	$9,000
		Permitting	%	5%	$0	$0	$36,500	$1,830	$83,900	$4,200
		Engineering design costs	%	20%	$0	$0	$36,500	$7,300	$83,900	$16,800
		Construction Management	%	15%	$0	$0	$36,500	$5,480	$83,900	$12,600
		Project Management	%	10%	$0	$0	$36,500	$3,650	$83,900	$8,400
Subtotal, Professional Services						**$0**		**$27,260**		**$51,000**
TOTAL INITIAL COST						**$0**		**$63,760**		**$134,900**

Notes:
1. 2007 Dollars.
2. Costs are +50% -30%.
3. 40 hour work week.
4. Level D PPE
5. Soil 1 cubic yard = 1.6 tons
6. Concrete/Asphalt 1 cubic yard = 2 tons
7. Installation of 2 shallow monitoring wells and 1 intermediate monitoring well, all alternatives.
8. Existing perforated pipe used for enhanced bioremediation application, Alternative 2.
9. Existing perforated pipe used for soil vapor extraction, Alternative 3.

Geomatrix

TABLE B10-2
IMPLEMENTATION COST ESTIMATE
RECURRING COSTS
AOC-090
Boeing Renton Washington
Renton, Washington

	RECURRING COSTS			ALTERNATIVE 1 MA				ALTERNATIVE 2 Enhanced Bioremediation, Monitored Attenuation				ALTERNATIVE 3 SVE, Monitored Attenuation			
		Unit	Unit Cost	Annual Quantity	Annual Cost	Lifetime Quantity	Lifetime Cost	Annual Quantity	Annual Cost	Lifetime Quantity	Lifetime Cost	Annual Quantity	Annual Cost	Lifetime Quantity	Lifetime Cost
1	**ENHANCED BIOREMEDIATION (Years 1,2,3)**														
	Additive	lbs	$5.0	0	$0	0	$0	2000	$10,000	4,000	$20,000	0	$0	0	$0
	Application (labor and equipment)	per well	$700	0	$0	0	$0	7	$4,900	14	$9,800	0	$0	0	$0
	Injection Well Abandonment (year 3)	linear ft	$25	0	$0	0	$0	140	$3,500	140	$3,500	0	$0	0	$0
	Base price per well abandonment (year 3)	each	$300	0	$0	0	$0	7	$2,100	7	$2,100	0	$0	0	$0
	Waste Disposal	drum	$150	0	$0	0	$0	14	$2,100	14	$2,100	0	$0	0	$0
Subtotal					**$0**		**$0**		**$22,600**		**$37,500**		**$0**		**$0**
2	**OPERATION AND MAINTENANCE**														
	Monitoring AS/SVE	annual	$15,000	0	$0	0	$0	0	$0	0	$0	1	$15,000	5	$75,000
	Air Sampling AS/SVE	per well	$450	0	$0	0	$0	0	$0	0	$0	1	$450	5	$2,250
	Electricity	monthly	$400	0	$0	0	$0	0	$0	0	$0	12	$4,800	60	$24,000
	Carbon Replacement	pound	$2	0	$0	0	$0	0	$0	0	$0	600	$1,200	3,000	$6,000
	Permanganate Replacement	pound	$2	0	$0	0	$0	0	$0	0	$0	700	$1,400	3,500	$7,000
	Maintenance AS/SVE	lump sum	$5,000	0	$0	0	$0	0	$0	0	$0	1	$5,000	5	$25,000
	Monitoring Well Maintenance	per well	$500	13	$6,500	180	$90,000	13	$6,500	180	$90,000	13	$6,500	180	$90,000
Subtotal					**$6,500**		**$90,000**		**$6,500**		**$90,000**		**$34,350**		**$229,250**
3	**QUARTERLY GW MONITORING (Years 1,2)**														
	Sampling	each well	$600	52	$31,200	104	$62,400	52	$31,200	104	$62,400	52	$31,200	104	$62,400
	Analysis	each well	$700	52	$36,400	104	$72,800	52	$36,400	104	$72,800	52	$36,400	104	$72,800
	Reporting	per round	$5,000	4	$20,000	8	$40,000	4	$20,000	8	$40,000	4	$20,000	8	$40,000
Subtotal					**$87,600**		**$175,200**		**$87,600**		**$175,200**		**$87,600**		**$175,200**
4	**SEMIANNUAL GW MONITORING (Years 3-15)**														
	Sampling	each well	$600	24	$14,400	312	$187,200	24	$14,400	312	$187,200	24	$14,400	312	$187,200
	Analysis	each well	$200	24	$4,800	312	$62,400	24	$4,800	312	$62,400	24	$4,800	312	$62,400
	Reporting	per round	$5,000	2	$10,000	26	$130,000	2	$10,000	26	$130,000	2	$10,000	26	$130,000
Subtotal					**$29,200**		**$379,600**		**$29,200**		**$379,600**		**$29,200**		**$379,600**
5	**FIVE YEAR GW MONITORING (Years 5,10,15)**														
	Sampling	each well	$600	13	$7,800	39	$23,400	13	$7,800	39	$23,400	13	$7,800	39	$23,400
	Analysis	each well	$700	13	$9,100	39	$27,300	13	$9,100	39	$27,300	13	$9,100	39	$27,300
	Reporting	per round	$5,000	1	$5,000	3	$15,000	1	$5,000	3	$15,000	1	$5,000	3	$15,000
Subtotal					**$21,900**		**$65,700**		**$21,900**		**$65,700**		**$21,900**		**$65,700**
6	**PROJECT MANAGEMENT**														
	Project Management	year	$12,000	1	$12,000	15	$180,000	1	$12,000	15	$180,000	1	$12,000	15	$180,000
Subtotal					**$12,000**		**$180,000**		**$12,000**		**$180,000**		**$12,000**		**$180,000**

Notes:
1. 2007 Dollars.
2. Costs are +50% -30%.
3. 40 hour work week.
4. Sales tax of 8.8% included in unit price.
5. Enhanced Biodegradation has three applications (first application is in implementation cost).
6. Five years of SVE.

Geomatrix

TABLE B10-3
IMPLEMENTATION COST ESTIMATE
NET PRESENT VALUE
AOC-090
Boeing Renton Facility
Renton, Washington

	ALTERNATIVE 1					ALTERNATIVE 2						ALTERNATIVE 3				
	MNA					Enhanced Bioremediation, Monitored Attenuation						SVE, Monitored Attenuation				
Year	Initial Costs	O&M	PM	GW Mon.	Total	Initial Costs	O&M	Enh. Bio.	PM	GW Mon.	Total	Initial Costs	O&M	PM	GW Mon.	Total
0	$0				$0	$63,760					$63,760	$134,900				$134,900
1		$6,600	$12,200	$89,400	$108,200		$6,600	$15,200	$12,200	$89,400	$123,400		$35,000	$12,200	$29,800	$77,000
2		$6,700	$12,400	$91,200	$110,300		$6,700	$15,500	$12,400	$91,200	$125,800		$35,700	$12,400	$30,400	$78,500
3		$6,800	$12,600	$31,000	$50,400		$6,800	$8,200	$12,600	$31,000	$58,600		$36,400	$12,600	$31,000	$80,000
4		$6,900	$12,900	$31,600	$51,400		$6,900		$12,900	$31,600	$51,400		$37,100	$12,900	$31,600	$81,600
5		$7,000	$13,200	$40,300	$60,500		$7,000		$13,200	$40,300	$60,500		$37,800	$13,200	$40,300	$91,300
6		$7,100	$13,500	$32,900	$53,500		$7,100		$13,500	$32,900	$53,500		$7,300	$13,500	$32,900	$53,700
7		$7,200	$13,800	$33,600	$54,600		$7,200		$13,800	$33,600	$54,600		$7,400	$13,800	$33,600	$54,800
8		$7,300	$14,100	$34,300	$55,700		$7,300		$14,100	$34,300	$55,700		$7,500	$14,100	$34,300	$55,900
9		$7,400	$14,400	$35,000	$56,800		$7,400		$14,400	$35,000	$56,800		$7,700	$14,400	$35,000	$57,100
10		$7,500	$14,700	$44,500	$66,700		$7,500		$14,700	$44,500	$66,700		$7,900	$14,700	$44,500	$67,100
11		$7,700	$15,000	$36,300	$59,000		$7,700		$15,000	$36,300	$59,000		$8,100	$15,000	$36,300	$59,400
12		$7,900	$15,300	$37,000	$60,200		$7,900		$15,300	$37,000	$60,200		$8,300	$15,300	$37,000	$60,600
13		$8,100	$15,600	$37,700	$61,400		$8,100		$15,600	$37,700	$61,400		$8,500	$15,600	$37,700	$61,800
14		$8,300	$15,900	$38,500	$62,700		$8,300		$15,900	$38,500	$62,700		$8,700	$15,900	$38,500	$63,100
15		$8,500	$16,200	$49,100	$73,800		$8,500		$16,200	$49,100	$73,800		$8,900	$16,200	$49,100	$74,200
TOTAL	$0	$111,000	$211,800	$662,400	$985,200	$63,800	$111,000	$38,900	$211,800	$662,400	$1,087,900	$134,900	$262,300	$211,800	$542,000	$1,151,000
				Net Present Value	$579,000					Net Present Value	$670,000				Net Present Value	$718,000

1. Inflated at a rate of 2% annually.
2. Discount rate of 7%.

TABLE B11-1
IMPLEMENTATION COST ESTIMATE
INITIAL COSTS
AOC-092

Renton Facility
Renton, Washington

INITIAL COSTS					ALTERNATIVE 1 MNA		ALTERNATIVE 2 Source Area Excavation, Enhanced Bioremediation, Monitored Attenuation	
CONTRACTOR			Unit	Unit Cost	Quantity	Cost	Quantity	Cost
1	**Mobilization/Demobilization**							
		Mobilization/Demobilization	lump sum	$10,000	0.1	$1,000	0.25	$2,500
2	**Health and Safety**							
		Health and Safety Officer	hour	$75	8	$600	4	$300
		Equipment	month	$2,000	0	$0	1	$1,000
		PPE	day	$100	2	$200	4	$400
3	**Site Preparation**							
		Utility Locates	hour	$85	4	$340	4	$340
		Site Security	linear foot	$4	100	$400	100	$400
		Traffic Control	lump sum	$1,000	0	$0	1	$1,000
		Erosion Control	linear foot	$5	100	$500	100	$500
		Storm water Management	day	$500	0	$0	2	$1,000
4	**Surveying**							
		Surveying	day	$1,500	1	$1,500	1	$1,500
5	**Monitoring Wells**							
		Monitoring Well Installation (2" PVC)	linear foot	$75	45	$3,380	45	$3,380
		Base Price Per Well	each	$500	3	$1,500	3	$1,500
		Waste Disposal	drum	$150	11	$1,650	11	$1,650
6	**Source Area Excavation**							
		Saw Cut Asphalt (6")	linear foot	$3	0	$0	40	$120
		Excavation	cubic yard	$12	0	$0	30	$360
		Waste Transportation/Disposal	ton	$40	0	$0	50	$2,000
		Backfill	ton	$12	0	$0	50	$600
		Asphalt Paving (6")	square foot	$4	0	$0	36	$140
7	**Enhanced Bioremediation**							
		Chemical	pound	$15	0	$0	200	$3,000
		Application (labor and equipment)	day	$1,500	0	$0	1	$1,500
Subtotal						**$11,070**		**$23,190**
Sales Tax (8.8%)						**$970**		**$2,040**
Subtotal						**$12,040**		**$25,230**
Contingency (30%)						**$3,610**		**$7,570**
Subtotal, Contractor						**$15,700**		**$32,800**
PROFESSIONAL TECHNICAL SERVICES								
		Investigation	lump sum	$9,000	0.5	$4,500	1	$9,000
		Permitting	%	5%	$15,700	$790	$32,800	$1,640
		Engineering design costs	%	20%	$15,700	$3,140	$32,800	$6,560
		Construction Management	%	15%	$15,700	$2,360	$32,800	$4,920
		Project Management	%	10%	$15,700	$1,570	$32,800	$3,280
Subtotal, Professional Services						**$12,360**		**$25,400**
TOTAL INITIAL COST						**$28,060**		**$58,200**

Notes:
1. 2007 Dollars.
2. Costs are +50% -30%.
3. 40 hour work week.
4. Level D PPE
5. Waste disposal is non-hazardous solid waste.
7. Soil 1 cubic yard = 1.6 tons
8. Concrete/Asphalt 1 cubic yard = 2 tons
9. Backfill costs assume delivered and placed.
10. Installation of 2 shallow monitoring wells, all alternatives.

TABLE B11-2
IMPLEMENTATION COST ESTIMATE
RECURRING COSTS
AOC-092
Boeing Renton Facility
Renton, Washington

				ALTERNATIVE 1				ALTERNATIVE 2			
RECURRING COSTS				MNA				Source Area Excavation, Enhanced Bioremediation, Monitored Attenuation			
		Unit	Unit Cost	Annual Quantity	Annual Cost	Lifetime Quantity	Lifetime Cost	Annual Quantity	Annual Cost	Lifetime Quantity	Lifetime Cost
1	**OPERATION AND MAINTENANCE**										
	Monitoring Well Maintenance	per well	$500	3	$1,500	30	$15,000	3	$1,500	30	$15,000
Subtotal					**$1,500**		**$15,000**		**$1,500**		**$15,000**
2	**QUARTERLY GW MONITORING (Years 1,2)**										
	Sampling	each well	$600	12	$7,200	24	$14,400	12	$7,200	24	$14,400
	Analysis	each well	$500	12	$6,000	24	$12,000	12	$6,000	24	$12,000
	Reporting	per round	$5,000	4	$20,000	8	$40,000	4	$20,000	8	$40,000
Subtotal					**$33,200**		**$66,400**		**$33,200**		**$66,400**
3	**SEMIANNUAL GW MONITORING (Years 3-15)**										
	Sampling	each well	$600	6	$3,600	78	$46,800	6	$3,600	78	$46,800
	Analysis	each well	$200	6	$1,200	78	$15,600	6	$1,200	78	$15,600
	Reporting	per round	$5,000	2	$10,000	26	$130,000	2	$10,000	26	$130,000
Subtotal					**$14,800**		**$192,400**		**$14,800**		**$192,400**
4	**FIVE YEAR GW MONITORING (Years 5,10,15)**										
	Sampling	each well	$600	3	$1,800	9	$5,400	3	$1,800	9	$5,400
	Analysis	each well	$500	3	$1,500	9	$4,500	3	$1,500	9	$4,500
	Reporting	per round	$5,000	1	$5,000	3	$15,000	1	$5,000	3	$15,000
Subtotal					**$8,300**		**$24,900**		**$8,300**		**$24,900**
5	**PROJECT MANAGEMENT**										
	Project Management	year	$12,000	1	$12,000	15	$180,000	1	$12,000	15	$180,000
Subtotal					**$12,000**		**$180,000**		**$12,000**		**$180,000**

Notes:
1. 2007 Dollars.
2. Costs are +50% -30%.
3. 40 hour work week.
4. Sales tax of 8.8% included in unit price.

TABLE B11-3
IMPLEMENTATION COST ESTIMATE
NET PRESENT VALUE
AOC-092
Boeing Renton Facility
Renton, Washington

	ALTERNATIVE 1					ALTERNATIVE 2				
	MNA					Source Area Excavation, Enhanced Bioremediation, Monitored Attenuation				
Year	**Initial Costs**	**O&M**	**PM**	**GW Mon.**	**Total**	**Initial Costs**	**O&M**	**PM**	**GW Mon.**	**Total**
0	$28,060				$28,060	$58,200				$58,200
1		$1,530	$12,200	$33,900	$47,630		$1,530	$12,200	$33,900	$47,630
2		$1,560	$12,400	$34,600	$48,560		$1,560	$12,400	$34,600	$48,560
3		$1,590	$12,600	$15,700	$29,890		$1,590	$12,600	$15,700	$29,890
4		$1,620	$12,900	$16,000	$30,520		$1,620	$12,900	$16,000	$30,520
5		$1,650	$13,200	$17,300	$32,150		$1,650	$13,200	$17,300	$32,150
6		$1,680	$13,500	$16,700	$31,880		$1,680	$13,500	$16,700	$31,880
7		$1,710	$13,800	$17,000	$32,510		$1,710	$13,800	$17,000	$32,510
8		$1,740	$14,100	$17,300	$33,140		$1,740	$14,100	$17,300	$33,140
9		$1,770	$14,400	$17,600	$33,770		$1,770	$14,400	$17,600	$33,770
10		$1,810	$14,700	$19,100	$35,610		$1,810	$14,700	$19,100	$35,610
11		$1,850	$15,000	$18,400	$35,250		$1,850	$15,000	$18,400	$35,250
12		$1,890	$15,300	$18,800	$35,990		$1,890	$15,300	$18,800	$35,990
13		$1,930	$15,600	$19,200	$36,730		$1,930	$15,600	$19,200	$36,730
14		$1,970	$15,900	$19,600	$37,470		$1,970	$15,900	$19,600	$37,470
15		$2,010	$16,200	$21,100	$39,310		$2,010	$16,200	$21,100	$39,310
TOTAL	$28,100	$26,300	$211,800	$302,300	$568,500	$58,200	$26,300	$211,800	$302,300	$598,600
				Net Present Value	$336,000				**Net Present Value**	$364,000

Notes:
1. Inflated at a rate of 2% annually.
2. Discount rate of 7%.

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TABLE B12-1
IMPLEMENTATION COST ESTIMATE
INITIAL COSTS
AOC-093

Boeing Renton Facility
Renton, Washington

INITIAL COSTS					ALTERNATIVE 1 Source Area Excavation and MNA		ALTERNATIVE 2 Source Area Excavation, Enhanced Bioremediation, Monitored Attenuation	
CONTRACTOR			**Unit**	**Unit Cost**	**Quantity**	**Cost**	**Quantity**	**Cost**
1	**Mobilization/Demobilization**							
		Mobilization/Demobilization	lump sum	$10,000	0.1	$1,000	0.25	$2,500
2	**Health and Safety**							
		Health and Safety Officer	hour	$75	4	$300	8	$600
		Equipment	month	$2,000	0	$0	1	$2,000
		PPE	day	$100	2	$200	8	$800
3	**Site Preparation**							
		Utility Locates	hour	$85	4	$340	8	$680
		Site Security	linear foot	$4	100	$400	200	$800
		Temporary Facilities	month	$3,000	0	$0	0.5	$1,500
		Traffic Control	lump sum	$1,000	0	$0	2	$2,000
		Erosion Control	linear foot	$5	100	$500	200	$1,000
		Storm water Management	day	$500	0	$0	2	$1,000
4	**Surveying**							
		Surveying	day	$1,500	0.5	$750	1	$1,500
5	**Monitoring Wells**							
		Concrete Coring	day	$1,500	0.5	$750	0.5	$750
		Monitoring Well Installation (2" PVC)	linear foot	$75	15	$1,130	15	$1,130
		Base Price Per Well	each	$500	1	$500	1	$500
		Waste Disposal	drum	$150	3	$450	3	$450
6	**Source Area Excavation**							
		Saw Cut Concrete (18")	linear foot	$12	60	$720	60	$720
		Excavation	cubic yard	$12	15	$180	15	$180
		Waste Transportation/Disposal	ton	$40	26	$1,040	26	$1,040
		Backfill	ton	$12	26	$310	26	$310
		Groundwater Management	gallon	$3	1,000	$3,000	1,000	$3,000
		Concrete Paving (18")	square foot	$12	200	$2,400	200	$2,400
7	**Enhanced Bioremediation**							
		Chemical (ORC)	pound	$15	0	$0	200	$3,000
		Application (labor and equipment)	day	$1,500	0	$0	1	$1,500
Subtotal						**$13,970**		**$29,360**
Sales Tax (8.8%)						**$1,230**		**$2,580**
Subtotal						**$15,200**		**$31,940**
Contingency (30%)						**$4,560**		**$9,580**
Subtotal, Contractor						**$19,800**		**$41,500**
PROFESSIONAL TECHNICAL SERVICES								
		Permitting	%	5%	$19,800	$990	$41,500	$2,080
		Engineering design costs	%	20%	$19,800	$3,960	$41,500	$8,300
		Construction Management	%	15%	$19,800	$2,970	$41,500	$6,230
		Project Management	%	10%	$19,800	$1,980	$41,500	$4,150
Subtotal, Professional Services						**$9,900**		**$20,760**
TOTAL INITIAL COST						**$29,700**		**$62,260**

Notes:
1. 2007 Dollars.
2. Costs are +50% -30%.
3. 40 hour work week.
4. Level D PPE.
5. Waste disposal is solid waste.
7. Soil 1 cubic yard = 1.6 tons
8. Concrete/Asphalt 1 cubic yard = 2 tons
9. Backfill costs assume delivered and placed.
10. Installation of 1 shallow monitoring well, all alternatives.

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TABLE B12-2
IMPLEMENTATION COST ESTIMATE
RECURRING COSTS
AOC-093
Boeing Renton Facility
Renton, Washington

RECURRING COSTS				ALTERNATIVE 1 MNA				ALTERNATIVE 2 Source Area Excavation, Enhanced Bioremediation, Monitored Attenuation			
		Unit	Unit Cost	Annual Quantity	Annual Cost	Lifetime Quantity	Lifetime Cost	Annual Quantity	Annual Cost	Lifetime Quantity	Lifetime Cost
1	**OPERATION AND MAINTENANCE**										
	Monitoring Well Maintenance	per well	$500	1	$500	15	$7,500	1	$500	15	$7,500
Subtotal					**$500**		**$7,500**		**$500**		**$7,500**
2	**QUARTERLY GW MONITORING (Years 1,2)**										
	Sampling	each well	$600	4	$2,400	8	$4,800	4	$2,400	8	$4,800
	Analysis	each well	$500	4	$2,000	8	$4,000	4	$2,000	8	$4,000
	Reporting	per round	$5,000	4	$20,000	8	$40,000	4	$20,000	8	$40,000
Subtotal					**$24,400**		**$48,800**		**$24,400**		**$48,800**
3	**SEMIANNUAL GW MONITORING (Years 3-15)**										
	Sampling	each well	$600	2	$1,200	26	$15,600	2	$1,200	26	$15,600
	Analysis	each well	$200	2	$400	26	$5,200	2	$400	26	$5,200
	Reporting	per round	$5,000	2	$10,000	26	$130,000	2	$10,000	26	$130,000
Subtotal					**$11,600**		**$150,800**		**$11,600**		**$150,800**
4	**FIVE YEAR GW MONITORING (Years 5,10,15)**										
	Sampling	each well	$600	1	$600	3	$1,800	1	$600	3	$1,800
	Analysis	each well	$500	1	$500	3	$1,500	1	$500	3	$1,500
	Reporting	per round	$5,000	1	$5,000	3	$15,000	1	$5,000	3	$15,000
Subtotal					**$6,100**		**$18,300**		**$6,100**		**$18,300**
5	**PROJECT MANAGEMENT**										
	Project Management	year	$12,000	1	$12,000	15	$180,000	1	$12,000	15	$180,000
Subtotal					**$12,000**		**$180,000**		**$12,000**		**$180,000**

Notes:
1. 2007 Dollars.
2. Costs are +50% -30%.
3. 40 hour work week.
4. Sales tax of 8.8% included in unit price.

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TABLE B12-3
IMPLEMENTATION COST ESTIMATE
NET PRESENT VALUE
AOC-093

Boeing Renton Facility
Renton, Washington

Year	ALTERNATIVE 1 MNA					ALTERNATIVE 2 Source Area Excavation, Enhanced Bioremediation,				
	Initial Costs	O&M	PM	GW Mon.	Total	Initial Costs	O&M	PM	GW Mon.	Total
0	$29,700				$29,700	$62,260				$62,260
1		$500	$12,200	$24,900	$37,600		$500	$12,200	$24,900	$37,600
2		$510	$12,400	$25,400	$38,310		$510	$12,400	$25,400	$38,310
3		$520	$12,600	$12,300	$25,420		$520	$12,600	$12,300	$25,420
4		$530	$12,900	$12,500	$25,930		$530	$12,900	$12,500	$25,930
5		$540	$13,200	$13,100	$26,840		$540	$13,200	$13,100	$26,840
6		$550	$13,500	$13,100	$27,150		$550	$13,500	$13,100	$27,150
7		$560	$13,800	$13,400	$27,760		$560	$13,800	$13,400	$27,760
8		$570	$14,100	$13,700	$28,370		$570	$14,100	$13,700	$28,370
9		$580	$14,400	$14,000	$28,980		$580	$14,400	$14,000	$28,980
10		$590	$14,700	$14,500	$29,790		$590	$14,700	$14,500	$29,790
11		$600	$15,000	$14,400	$30,000		$600	$15,000	$14,400	$30,000
12		$610	$15,300	$14,700	$30,610		$610	$15,300	$14,700	$30,610
13		$620	$15,600	$15,000	$31,220		$620	$15,600	$15,000	$31,220
14		$630	$15,900	$15,300	$31,830		$630	$15,900	$15,300	$31,830
15		$640	$16,200	$16,000	$32,840		$640	$16,200	$16,000	$32,840
TOTAL	$29,700	$8,600	$211,800	$232,300	$482,400	$62,300	$8,600	$211,800	$232,300	$514,900
				Net Present Value	$286,000				**Net Present Value**	$316,000

Notes:
1. Inflated at a rate of 2% annually.
2. Discount rate of 7%.