Installation Restoration Program
Final Feasibility Study

142nd Fighter Wing
Portland Air National Guard Base
Portland International Airport
Portland, Oregon

July 2001

Air National Guard
Andrews AFB, Maryland

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July 2001

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Andrews AFB, Maryland

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ACRONYMS/ABBREVIATIONS

Acronyms/ Abbreviations	Definitions
AGE	Aerospace Ground Equipment
ANGB	Air National Guard Base
ANG/CEVR	Air National Guard/Installation Restoration Program Branch
ANG	Air National Guard
ARAR	Applicable or relevant and appropriate requirement
bgs	Below ground surface
BTEX	Benzene, toluene, ethylbenzene, and xylenes
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
cis-1,2-DCE	cis-1,2-Dichloroethene
COC	Contaminant of concern
CRSA	Columbia River Sand Aquifer
ODEQ	Oregon State Department of Environmental Quality
DNAPL	Dense non-aqueous phase liquid
EE/CA	Engineering Evaluation/Cost Analysis
ERM	Environmental Resources Management
FS	Feasibility Study
GRC	Groundwater Reference Concentration
HI	Hazard index
HMTC	Hazardous Materials Technical Center
IRAC	Interim Remedial Action Construction
IRP	Installation Restoration Program
µg/l	Micrograms per liter
LOF	Locality of the Facility
MASC	Maximum Allowable Soil Concentration
MCL	Maximum Contaminant Level
mg/kg	Milligrams per kilogram
MNA	Monitored natural attenuation
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
OAR	Oregon Administrative Rules

ACRONYMS/ABBREVIATIONS

Acronyms/ Abbreviations	Definitions
ODEQ	Oregon State Department of Environmental Quality
OpTech	Operational Technologies Corporation
ORC	Oxygen Release Compound
O&M	Operation and maintenance
PA	Preliminary Assessment
PAH	Polynuclear aromatic hydrocarbon
PCE	Tetrachloroethylene
pH	Acidity/alkalinity
PIA	Portland International Airport
POL	Petroleum, oil, and lubricants
POTW	Publicly-owned treatment works
PRG	Preliminary remediation goal
PSG	Project screening goal
QC	Quality control
RAO	Remedial action objective
RA	Remedial Action
RCRA	Resource Conservation and Recovery Act
RI	Remedial Investigation
RI/FS	Remedial Investigation/Feasibility Study
RI/DGE	Remedial Investigation/Data Gap Evaluation
RRA	Residual Risk Assessment
SAIC	Science Applications International Corporation
SCL	Soil Cleanup Level
SI	Site Investigation
SVE	Soil vapor extraction
SVOC	Semivolatile organic compound
TCE	Trichloroethene
TGA	Troutdale Gravel Aquifer
TPH	Total petroleum hydrocarbon
TMV	Toxicity, mobility, or volume
UIC	Underground Injection Control
USEPA	United States Environmental Protection Agency

ACRONYMS/ABBREVIATIONS

Acronyms/ Abbreviations	Definitions
UST	Underground storage tank
VC	Vinyl chloride
VOC	Volatile organic compound
WEA	Western Expansion Area
1,2-dichloroethene	1,2-DCA

EXECUTIVE SUMMARY

This Feasibility Study (FS) report has been prepared for the 142nd Fighter Wing, Portland Air National Guard Base (Portland ANGB) in Portland, Oregon as part of the ongoing Remedial Investigation/Feasibility Study process.

The development of an FS represents a critical phase in the environmental investigation and cleanup process and is required when risk to human health or the environment exceeds acceptable levels. The FS report describes the process in which remedial action alternatives are developed, evaluated, and selected.

The remedy selection process ensures that statutory and administrative rule requirements are met, provides the public with a foundation on which to provide comments regarding proposed remedies, and allows regulatory agencies the ability to select or approve the most appropriate remedy for sites at which a release of a hazardous substance(s) has occurred.

The primary objectives of this FS were to:

- Develop, screen, and evaluate remedial alternatives for addressing contaminants in soil and groundwater at the Portland ANGB that may pose a threat to human health or the environment; and
- Recommend the most technically appropriate and cost-effective remedial alternatives that adequately protect human health and welfare and the environment.

The structure for this FS Report has been adapted from several formats recommended by Air National Guard (ANG), United States Environmental Protection Agency (USEPA), and Oregon State Department of Environmental Quality (ODEQ) guidance documents. The ANG includes a recommended FS structure in the document entitled, *Final Air National Guard Installation Restoration Program Investigation Protocol* (ANG 1998). The USEPA document, *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA* (USEPA 1988), is the most widely used and referenced guidance for the production of Remedial Investigation (RI) and FS documents. The State of Oregon document entitled, *Final Guidance for Conducting Feasibility Studies* (ODEQ 1998b), generally follows the process specified in the USEPA Guidance, with certain variations and additional requirements. Additional requirements set by ODEQ include the evaluation of beneficial-use scenarios and hot spots.

The FS was primarily based on the cumulative results of environmental investigations conducted at the Portland ANGB between 1987 and 2000, as fully documented in the RI Report (Environmental Resources Management 2001a). These investigations identified contaminants in soil, sediment, groundwater, and surface water at 10 different Installation Restoration Program (IRP) sites at the Portland ANGB. Based on the investigation results, as well as a baseline risk assessment performed during the RI, three of the 10 IRP sites (IRP Sites 2, 9, and, 11) were determined to require full evaluation in this FS based on volatile organic compounds (VOCs) in groundwater at concentrations that pose unacceptable risk to human health.

Based on the results of the RI and on guidance provided by USEPA and ODEQ, remedial alternatives were identified and developed for each IRP site selected for further evaluation. The alternatives were then compared and evaluated as the basis for recommending the final remediation alternative for the IRP sites.

Development of Remedial Action Objectives (RAOs): RAOs provide specific goals for each affected media (i.e., soil, groundwater, etc.) at the IRP sites requiring additional remediation. These goals are typically based on achievement of a specified cleanup level or specified acceptable risk level. The RAOs for the Portland ANGB are:

- Prevent off-site migration of groundwater containing VOCs above 10^{-6} risk concentrations for individual carcinogens;

- Treat groundwater hot spots of contamination to concentrations below respective significant adverse-effect levels; and

- Prevent on-site exposure to groundwater containing VOCs above 10^{-6} risk concentrations for individual carcinogens.

Development of General Response Actions: General response actions are broadly defined as measures designed to prevent or minimize adverse environmental impacts to satisfy the RAOs. The general response actions developed for remediation of groundwater at IRP Sites 2, 9, and 11 include:

- No action;

- Institutional controls;
- Engineering controls;
- Groundwater collection, treatment, and discharge; and
- In situ groundwater treatment.

Identification and Screening of Technologies: Technologies considered capable of achieving the RAOs were identified and "screened" for further evaluation as feasible remedial alternatives. The technologies selected for further assessment were:

- No action;
- Monitoring;
- Land/Water use restrictions;
- Construction controls;
- Alternative water supplies;
- Groundwater extraction;
- In situ chemical treatment;
- In situ biological treatment;
- In situ physical treatment; and
- Monitored natural attenuation.

Development of Remedial Alternatives: Using the RAOs, general response actions, and technologies selected for further evaluation, six remedial alternatives were developed for evaluation and comparison. These alternatives included:

- *Alternative 1 – No Action.* The FS process requires consideration of the No Action Alternative. Under this alternative, no site modifications or monitoring would be implemented to prevent or eliminate human health and environmental risks.
- *Alternative 2 – Monitored Natural Attenuation.* The use of monitored natural attenuation to achieve remedial objectives relies on biological, physical, and chemical processes occurring in the environment without

artificial stimulus. Monitoring and documenting the intrinsic bioremediation element of natural attenuation is the major focus of this alternative. Under this alternative, active treatment measures would not be taken.

- *Alternative 3 – In Situ Oxidation – Potassium Permanganate/Sodium Persulfate Injection with Monitored Natural Attenuation.* This alternative involves the injection of a solution of either potassium permanganate to treat chlorinated VOCs, or sodium persulfate to treat benzene, into the contaminated zone. These materials are strong oxidants that have been shown to effectively destroy VOCs. This alternative also includes the use of monitored natural attenuation in areas with low levels of VOCs.

- *Alternative 4 – In Situ Oxidation – Ozonation with Monitored Natural Attenuation.* Ozonation involves the injection of a mixture of air and ozone gas at the bottom of the saturated zone to be treated. Ozone is a strong oxidant that has been shown to rapidly destroy VOCs. This alternative also includes the use of monitored natural attenuation in areas with low levels of VOCs.

- *Alternative 5 – Enhanced Bioremediation with Monitored Natural Attenuation.* Enhanced bioremediation involves the injection of a material that stimulates the natural biological activity of the contaminated zone. This alternative also includes the use of monitored natural attenuation in areas with low levels of VOCs.

- *Alternative 6 – In-Well Aeration with Monitored Natural Attenuation.* In-well aeration involves performing stripping of VOCs within a treatment well. Within each aerator well, water is pumped from a lower screen to the upper section of the well where it is sparged with air. The sparged water is then allowed to flow back into the soil through an upper well screen. This alternative also includes the use of monitored natural attenuation in areas with low levels of VOCs.

Each remedial alternative was evaluated for IRP Sites 2, 9, and 11. A conceptual design for each alternative at each IRP site was performed for cost estimating purposes. A detailed analysis of the remedial alternatives for the various IRP sites was performed in accordance with USEPA and ODEQ FS guidance. The criteria used for this evaluation included the overall protectiveness of human health and the environment; compliance with applicable, relevant, and appropriate requirements; long-term effectiveness and permanence; reduction of toxicity, mobility, or volume through treatment; short-term effectiveness; implementability;

reasonableness of cost; and treatment of hot spots. Following an evaluation of each alternative against the above criteria, the alternatives for the individual IRP sites were then compared.

As a result of the evaluation and comparison process, it was determined that Alternative 3, in situ oxidation using potassium permanganate combined with monitored natural attenuation, is the preferred remedial alternative for IRP Site 2. A variation of Alternative 3, using sodium persulfate rather than potassium permanganate, was selected as the preferred remedial alternative for IRP Site 9. Alternative 3 was also selected as the preferred alternative at IRP Site 11. The selection of these alternatives was based on several evaluation criteria, including the level of protectiveness of human health and the environment, effectiveness, cost reasonableness, and implementability. The preferred alternatives for IRP Sites 2, 9, and 11, as described above, best satisfy the FS evaluation criteria.

SECTION 1.0

INTRODUCTION

This Feasibility Study (FS) report has been prepared for the 142nd Fighter Wing, Portland Air National Guard Base (Portland ANGB) in Portland, Oregon as part of the ongoing Remedial Investigation/Feasibility Study (RI/FS) process. The location of the Portland ANGB is shown on Figure 1-1. The FS was conducted as part of the Air National Guard (ANG) Installation Restoration Program (IRP) under contract DAHA-90-94-D-0014 between Environmental Resources Management (ERM) and the National Guard Bureau, Department of the Army and the Air Force. The Air National Guard/Installation Restoration Program Branch (ANG/CEVR) is providing technical and project management oversight for this study on behalf of the ANG.

1.1 Purpose and Objective

The development of an FS represents a critical phase in the environmental investigation and cleanup process. As shown on Figure 1-2, the FS is a critical component of this process and is required when risk to human health or the environment exceeds acceptable levels. The FS report describes the process in which remedial action (RA) alternatives are developed, evaluated, and selected.

The remedy selection process outlined in this FS ensures that statutory and administrative rule requirements are met, provides the public with a foundation on which to provide comments on proposed remedies, and allows regulatory agencies the ability to select or approve the most appropriate remedy for sites at which a release of hazardous substances has occurred.

The primary objectives of the FS are:

- Develop and evaluate remedial alternatives for addressing contaminants in soil and groundwater at the Portland ANGB that may pose a threat to human health or the environment; and

Source: Portland Air National Guard Base Masterplan, May 1997

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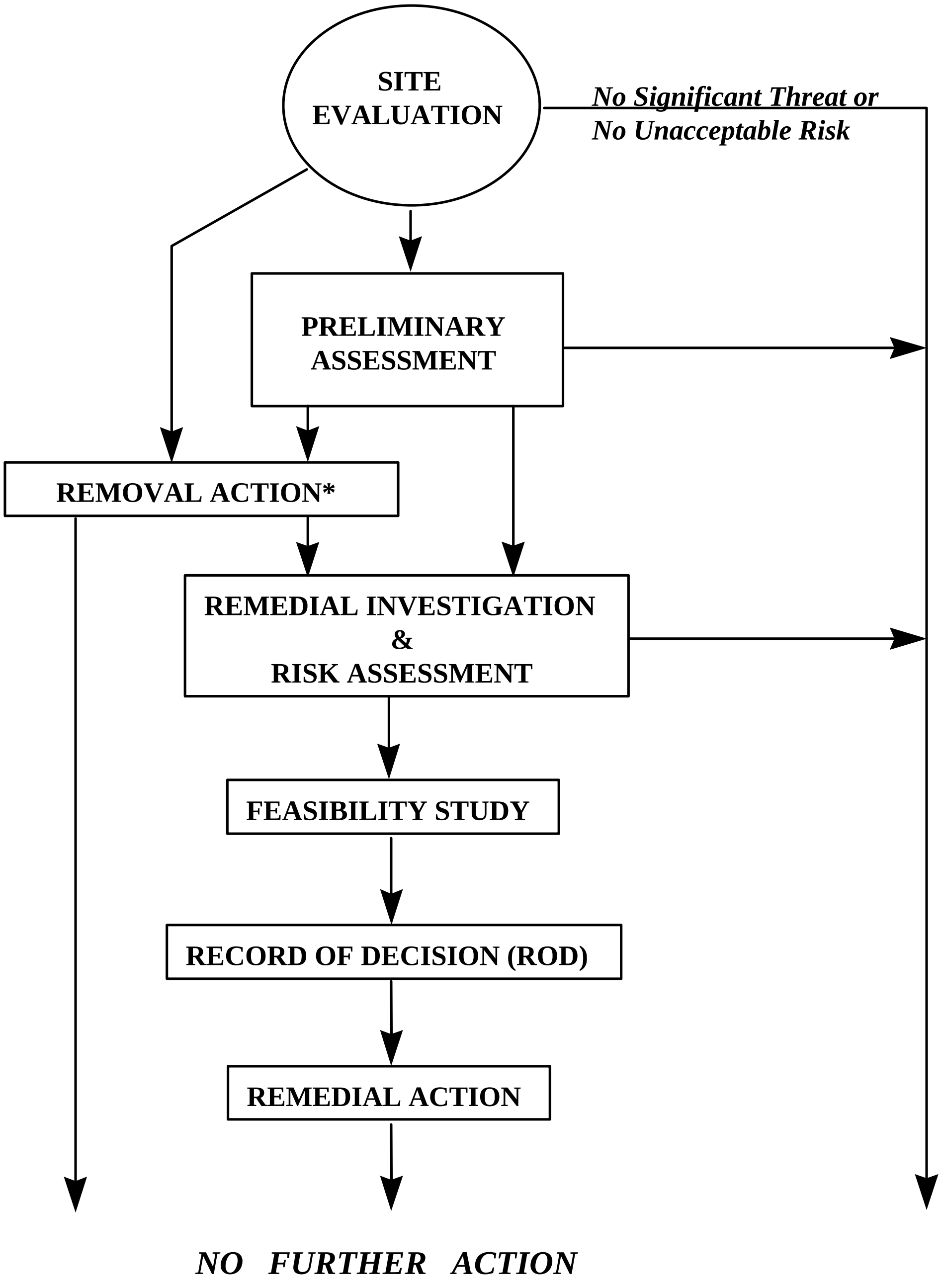
LOCATION OF PORTLAND AIR NATIONAL GUARD BASE PORTLAND, OREGON

142nd FW, PORTLAND ANGB
PORTLAND INTERNATIONAL AIRPORT
PORTLAND, OREGON

FIGURE 1-1



*Removal actions may be taken at any step of the environmental cleanup process prior to issuance of a Record of Decision (ROD).

Adapted from ODEQ Guidance for Conducting Feasibility Studies.

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ENVIRONMENTAL INVESTIGATION AND CLEANUP PROCESS

142nd FW, PORTLAND ANGB
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PORTLAND, OREGON

FIGURE 1-2

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- Recommend the most technically appropriate and cost-effective remedial alternatives that adequately protect human health, welfare, and the environment.

1.2 Feasibility Study Guidance

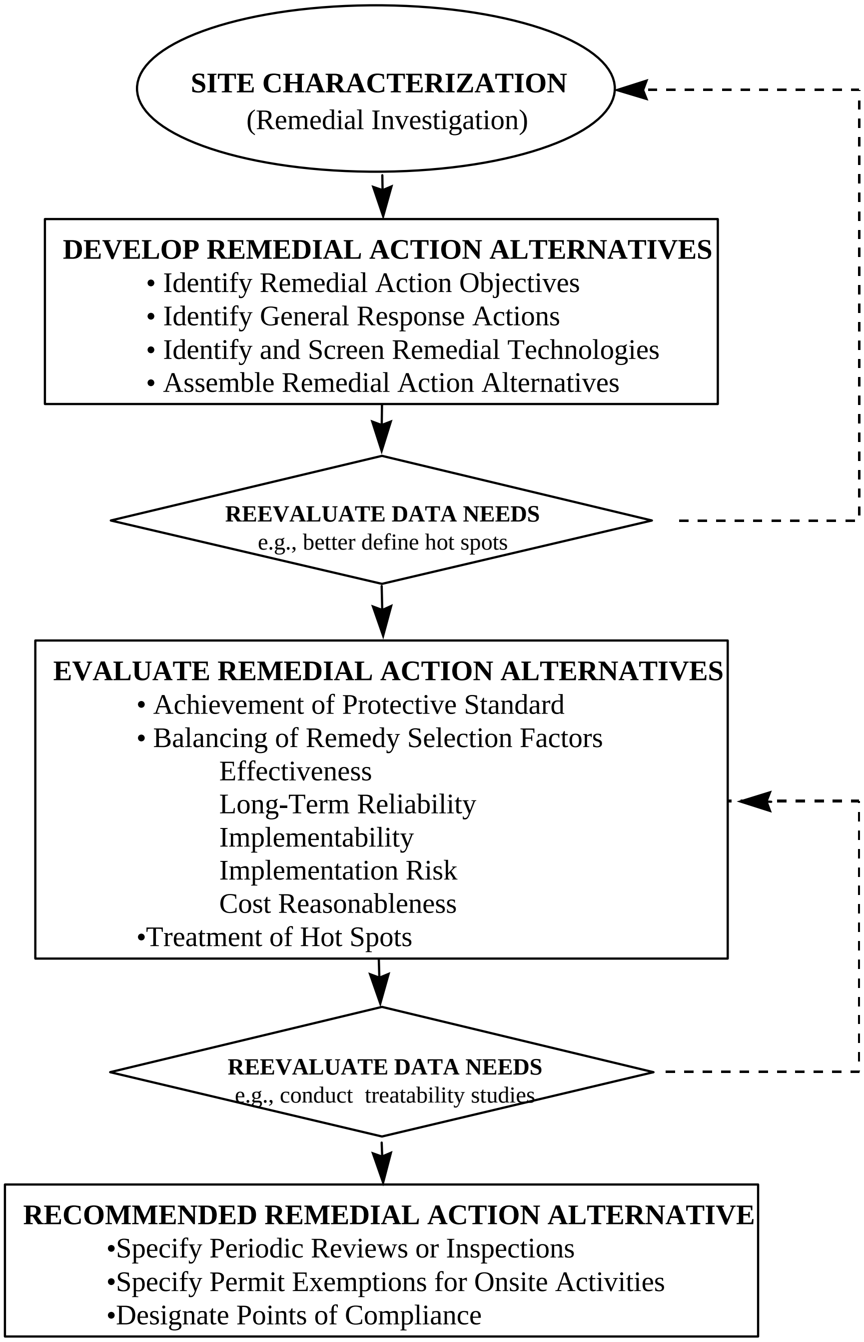
The structure for this FS report is a blend of formats recommended by ANG/CEVR, United States Environmental Protection Agency (USEPA), and Oregon State Department of Environmental Quality (ODEQ) guidance documents. ANG includes a recommended FS structure in the document entitled, *Final Air National Guard Installation Restoration Program Investigation Protocol* (ANG 1998). The USEPA document, *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA* (USEPA 1988), is the most widely used and referenced guidance for the production of Remedial Investigation (RI) and FS documents. The State of Oregon document entitled, *Final Guidance for Conducting Feasibility Studies* (ODEQ 1998b), generally follows the process specified in the USEPA Guidance with certain variations and additional requirements. The additional requirements set by ODEQ include the evaluation of beneficial-use scenarios and hot spots of contamination. Although the ODEQ uses different terminology than the USEPA to identify its criteria for the evaluation of remedial alternatives, both sets of standards are substantively similar.

Adjustments to the formats set by the three guidance documents described above were necessary to accommodate the inclusion of multiple IRP sites in one FS document. Beneficial-use scenarios were evaluated in the RI and summarized in Section 2.10 of this FS and used to delineate the Locality of the Facility (LOF), as required by the *Final Guidance for Conducting Beneficial Water Use Determinations at Environmental Cleanup Sites* (ODEQ 1998a). Based on the beneficial-use scenarios, the potential existence of hot spots of contamination was also evaluated in the RI, based on the ODEQ document, *Final Guidance for Identification of Hot Spots* (ODEQ 1998c), and summarized in Section 2.11 of this FS. The evaluation criteria used to compare remedial alternatives follow the USEPA guidance with the inclusion of substantive additions required by ODEQ. In accordance, the evaluation criteria, Treatment of Hot Spots, required by ODEQ was added to the list of evaluation criteria used.

1.3 Organization of Feasibility Study

The specific elements of the FS, as described in ODEQ Guidance, are diagrammed on Figure 1-3. The organization of this FS follows the main principles of this structure. This organization consists of six sections and six appendices. The contents of these sections are as follows:

- Section 1.0 presents the purpose and objective for the FS. This section also discusses the guidance documents used to select a format for this FS and a description of the elements of that format.
- Section 2.0 presents background information regarding the Portland ANGB, including a brief history and description of the Base, and a brief discussion of land use, topography, climate, sensitive receptors, geology, hydrogeology, previous environmental activity, and current IRP activities.
- Section 3.0 presents a description of each IRP site at the Portland ANGB. This description includes results of the RI that are relevant to the FS process. This information includes history and use of the site, waste disposal history, nature and extent of contamination, risk assessment results, and recommendations. The recommendations made for each IRP site presented in this section discuss the way that the individual IRP sites are treated in the FS. No further action is recommended at some IRP sites, and other IRP sites are recommended for further evaluation in this FS report.
- Section 4.0 describes the process used to develop remedial alternatives for the Portland ANGB. A discussion of the remedial action objectives (RAOs) is provided, along with a list of general response actions that includes categories of technologies expected to meet the RAOs. A series of remedial alternatives are subsequently outlined, which are based on combinations of technologies described under the general response actions.
- Section 5.0 presents a detailed analysis of the remedial alternatives for the various IRP sites. In accordance with the USEPA and ODEQ FS guidance documents, the assessment criteria used to evaluate each remedial alternative is first summarized in this section. Following an evaluation of each alternative, a comparative analysis is presented with a subsequent discussion of the preferred alternative.



Adapted from ODEQ Guidance for Conducting Feasibility Studies.

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ELEMENTS OF THE FEASIBILITY STUDY

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FIGURE 1-3

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- Section 6.0 presents a summary of the recommended RA alternatives for IRP Sites 2, 9, and 11, as well as a summary of the recommendations for the IRP sites not evaluated in Section 5.0. This section also includes a residual risk assessment. This assessment is used to determine the hypothetical risk remaining after completion of the recommended RA alternative at IRP Sites 2, 9, and 11.

- Section 7.0 lists the documents referenced for this FS.

A description of the appendices included as attachments to this document is provided as follows:

- Appendix A presents a description of the IRP process and fundamentals of the RI/FS program presented above and is intended to familiarize the reader with the purpose and structure of FS documents.

- Appendix B includes tables containing cost estimates for the selected remedial alternatives, including the calculations on which these estimates are based.

SECTION 2.0

PORTLAND ANGB DESCRIPTION

The Portland ANGB is immediately south of the Portland International Airport (PIA) in Portland, Oregon, between the Columbia River to the north and the Columbia Slough to the south (Figure 1-1).

The 142nd Fighter Wing is an active unit with a full-time contingency of F-15 fighter planes, crews, and support units, including active-duty ANG personnel. The major support operations at the Portland ANGB that use and dispose of hazardous wastes/materials include aircraft, vehicle, and equipment maintenance; facilities maintenance; and Petroleum, Oil, and Lubricants (POL) management. These activities generate varying quantities of waste oils, recovered fuels, and spent cleaners, solvents, and acids.

2.1 Base History

Site development began in 1936 with the placement of a large quantity of dredge material as fill in various portions of the subject property (Guthrie Slusarenko Associates 1986). The 142nd Fighter Wing began operations in 1941 at the present location of the Portland ANGB, which functioned as an Army Air Base until 1945. The Base was converted to an ANG facility in approximately 1947. Between 1950 and 1964 it was an active Air Force Base; in 1964 the Base was converted back to an ANG facility and has maintained this status to the present time (Science Applications International Corporation [SAIC] 1991).

2.2 Land Use

The Base occupies approximately 245 acres of land leased from the Port of Portland. It is bordered on the west by the Riverside Country Club and the Peninsula Drainage Canal. The areas south and east of the Base are zoned for residential, industrial, and commercial use. A City of Portland municipal well field (Columbia South Shore Well Field) is southeast of the Base (Figure 1-1); the western boundary of the well field is approximately

1 mile from the Base. All of the IRP sites are within the Portland ANGB boundary, with the exception of IRP Site 7 (Burn Pit Area), which straddles the eastern Base boundary. A portion of IRP Site 7 is on Port of Portland property. Figure 2-1 shows the location of the IRP sites at the Portland ANGB. A beneficial land use description is presented in Section 2.10.4.

Land use at the Portland ANGB is industrial. Activities conducted at the Base are consistent with military base or airport usage. ANG leases the land from the Port of Portland, which operates the PIA. The Port of Portland has no plans to change the industrial land use at the Base if ANG vacates the facility (Port of Portland 2000). An expansion of the existing PIA onto the space currently occupied by the Base is the most likely scenario (Port of Portland 2000).

2.3 Topography

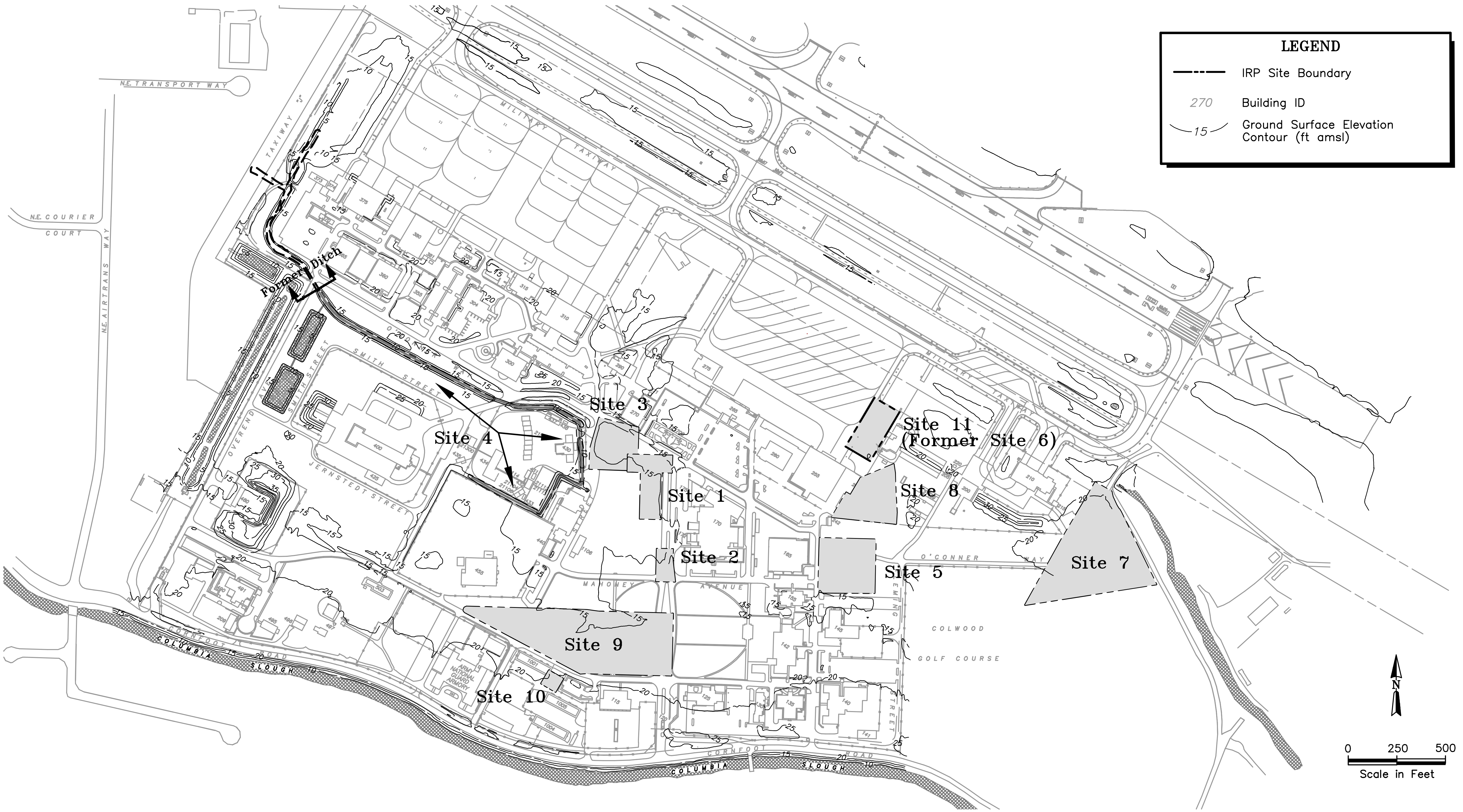
The Portland ANGB is situated on the Columbia River Floodplain. The ground surface across the Base is relatively flat and varies in elevation from approximately 10 to 20 feet above mean sea level. The 100-year floodplain elevation for the area surrounding the Base is 14 feet above mean sea level.

2.4 Climate

The climate in the Portland area is characterized by mild rainy winters and warm-to-hot, dry summers. Approximately 88 percent of the total annual rainfall occurs between October and May. The mean annual temperature is about 53 degrees Fahrenheit (°F), with winters averaging 40 to 50 °F and summers averaging 60 to 70 °F (SAIC 1991). The mean total annual precipitation at the PIA is 37.20 inches. The mean net annual precipitation, calculated by subtracting the mean evapotranspiration from the mean total precipitation, is 13.81 inches (Hazardous Materials Technical Center [HMTC] 1987).

2.5 Ecological Receptors

No endangered or threatened fauna or flora were identified within 1 mile of the Portland ANGB during the Preliminary Assessment (PA)



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IRP SITE LOCATION MAP

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PORTLAND, OREGON

FIGURE 2-1

(HMTC 1987). However, large, open-space, grassland areas associated with the PIA complex provide some habitat for wildlife (Hoffman et al. 1996). The wildlife includes small mammals, songbirds, and raptors. Raptors have been observed along the Main Drainage Ditch and the Columbia Slough (SAIC 1991).

A more recent environmental impact statement completed in the vicinity of the PIA identified no threatened, endangered, or sensitive plants in the area. The only threatened, endangered, or sensitive wildlife observed include the peregrine falcon and the bald eagle (United States Department of Transportation 1998). These two species are transitory near the airport.

A Level I scoping ecological risk assessment of the IRP study area was conducted on 12 and 15 September 2000. This scoping assessment was a qualitative determination of the existence of ecological receptors and/or exposure pathways at each of the ten IRP sites. The full qualitative analysis of potential ecological risks is presented in the Site Ecology Scoping Report (ERM 2001a, Appendix CC).

The results of the Level 1 scoping assessment indicated that eight of the ten IRP sites contain no ecological receptors or exposure pathways. These sites are currently covered by asphalt/concrete pavement, gravel, and/or landscaped grassland, and no aquatic habitats (i.e., storm ditches, wetlands, or streams) occur within the immediate vicinity of the sites. The remaining two sites (Sites 4 and 7) contain potential ecological receptors and exposure pathways; however, ecological risks are not suspected at these sites under current conditions due to the limited contamination and the lack of sensitive ecological receptors (i.e., threatened and endangered species and the respective habitats for either species). To verify the lack of potential impacts to ecological receptors at IRP Site 4, the ANG plans to conduct a Level II (screening) ecological risk assessment in accordance with ODEQ guidance.

2.6 Geology

2.6.1 Regional Geology

The northeastern Portland area is underlain by Tertiary and Quaternary sedimentary and volcanic deposits. The Portland ANGB is in the central portion of the Portland Basin, a northwest-southeast trending structural depression that was formed in the early Tertiary and filled with approximately 1,800 feet of late Tertiary and Quaternary sediments. In ascending order, the basin deposits in the vicinity of the Portland ANGB include Eocene and Miocene rocks, the Sandy River Mudstone, the Troutdale Formation, the Parkrose Formation, the Troutdale Gravel, the Columbia River Sand, and Pleistocene to Recent Alluvium (Hartford and McFarland 1989). The Final RI report (ERM 2001a) describes the geology of the Portland ANGB in detail.

Sediments encountered in borings drilled at the Portland ANGB include Pleistocene to Recent Alluvium and the Columbia River Sand. In the area of the Base and the Portland well field, these sediments have been divided into two distinct hydrogeologic units: the Floodplain Deposits and the Columbia River Sand Aquifer (CRSA). A fence diagram constructed from the cross sections is shown on Figure 2-2.

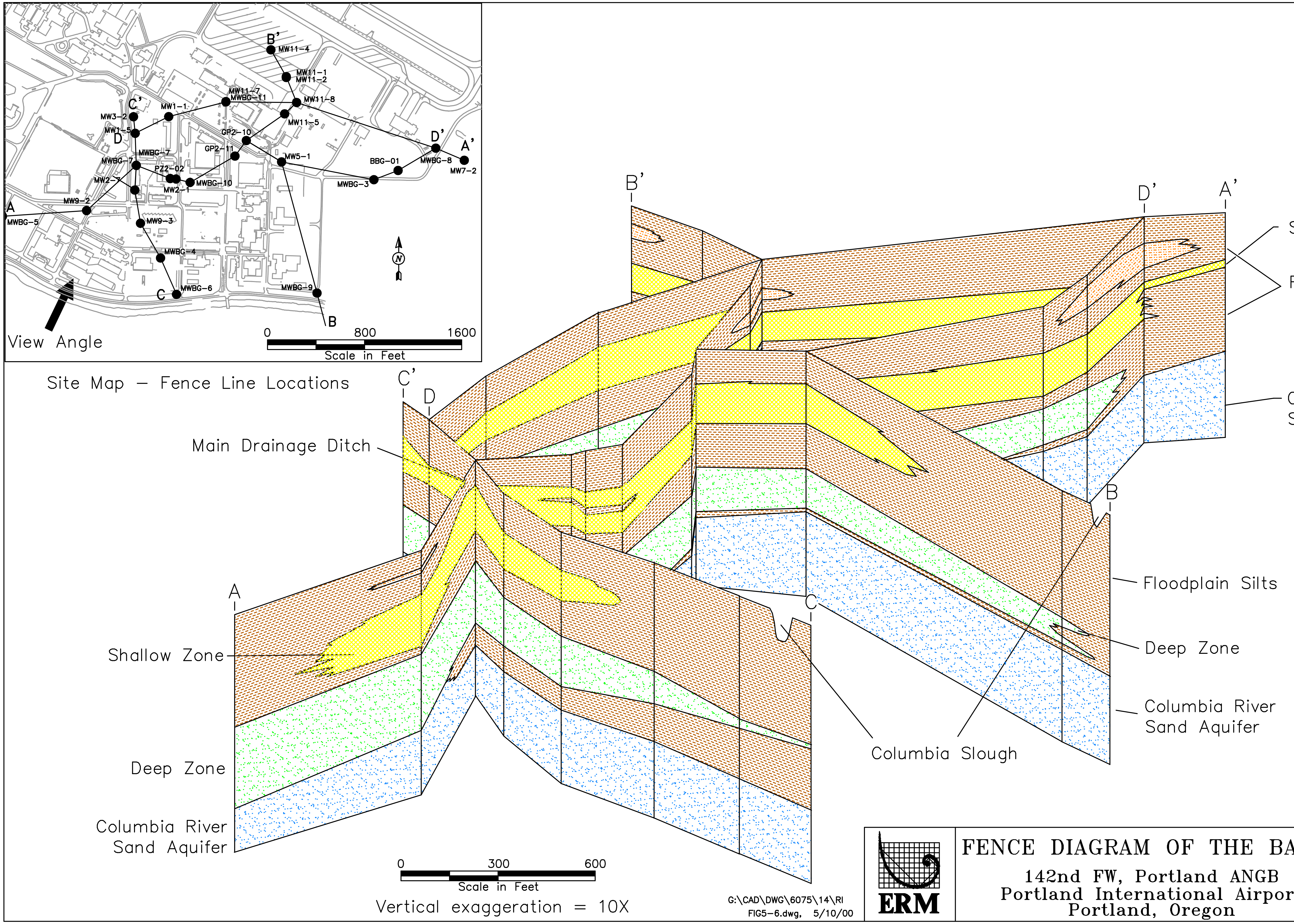
Most of the original surface soils at the Portland ANGB have been altered by regrading or construction activities, or have been covered by fill. Original native soils in the area include Pilchuck and Sauvie-Rafton soils. Pilchuck soils, consisting of dark, grayish-brown to dark brown soil with high permeability, underlie most of the Base. Sauvie-Rafton soils, consisting of poorly drained, silty loam soil, are present in the southeast corner of the Base. The surficial soil at the Base is approximately 15 inches thick and is underlain by a dark brown, silty loam to a depth of about 60 inches. A soils map for the Portland ANGB is included on Figure 2-3.

2.6.2 Hydrogeology

At the Portland ANGB, the Floodplain Deposits extend from the ground surface to depths ranging from approximately 48 to 60 feet below ground surface (bgs). Water-bearing zones within these Floodplain Deposits consist of, in descending order, the Upper Zone, the Shallow Zone, and the Deep Zone. A generalized hydrogeologic cross section for the Portland ANGB is shown on Figure 2-4. A conceptual hydrogeologic model for the Base and the surrounding area is presented on Figure 2-5.

2.6.2.1 Upper Zone

The Upper Zone is a discontinuous, unconfined to semi-confined water-bearing zone that is present at scattered locations in the northern, eastern, and southwestern portions of the Portland ANGB. It consists of brown, well-sorted, fine sand in the eastern portion of the Base, and silty to fine sand in the southwestern and northern portions of the Base. The Upper depths ranging from 5.5 to 9.0 feet bgs, and in thickness ranging from 1 to



Site Map – Fence Line Locations

LEGEND

▨	**Floodplain Silts**
▨	**Sand/Silty Sand**
▨	**Shallow Zone**
▨	**Deep Zone**
▨	**Columbia River Sand Aquifer**

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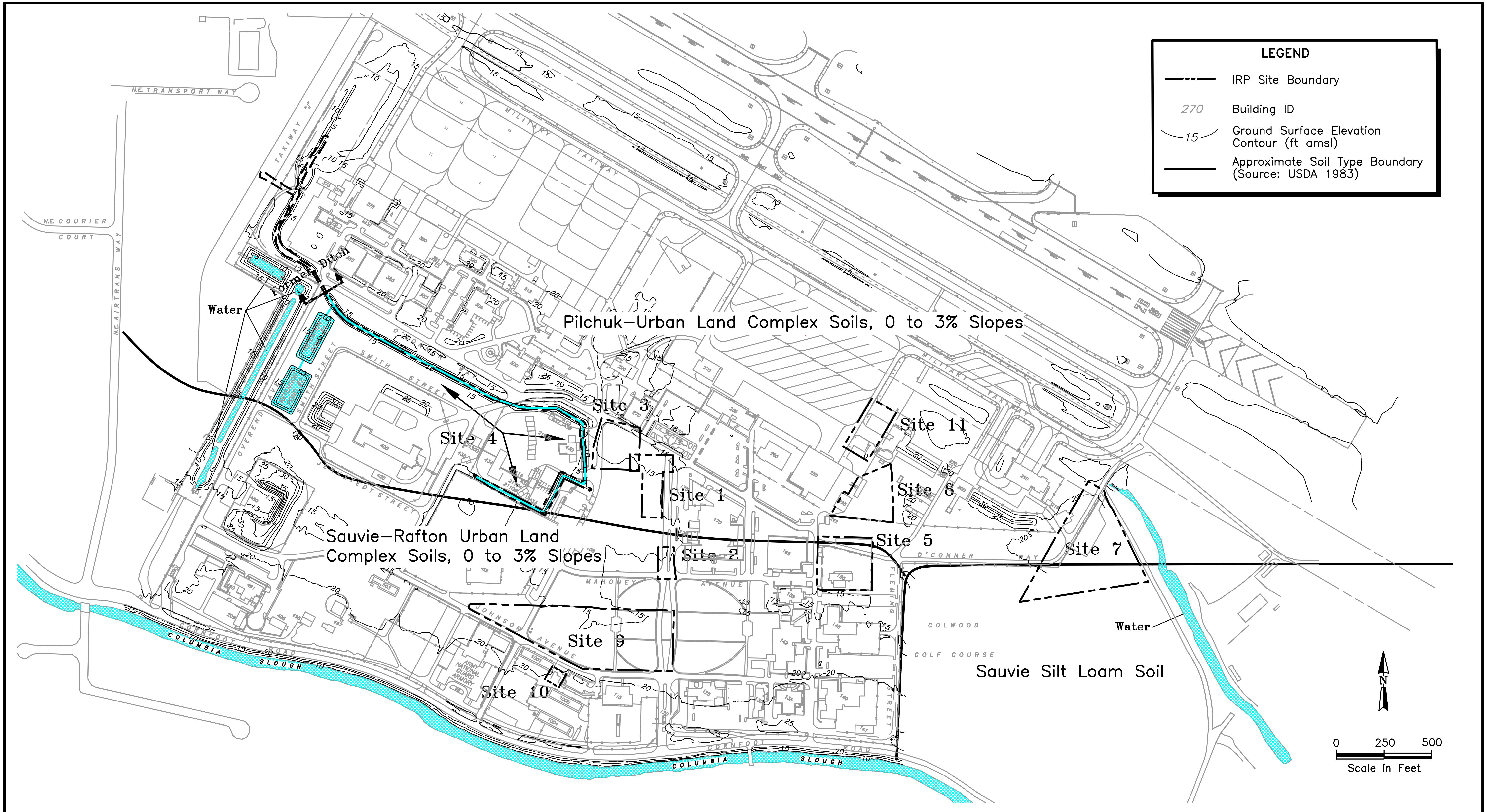
FENCE DIAGRAM OF THE BASE

142nd FW, Portland ANGB
Portland International Airport
Portland, Oregon

FIGURE 2-2



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SOILS MAP

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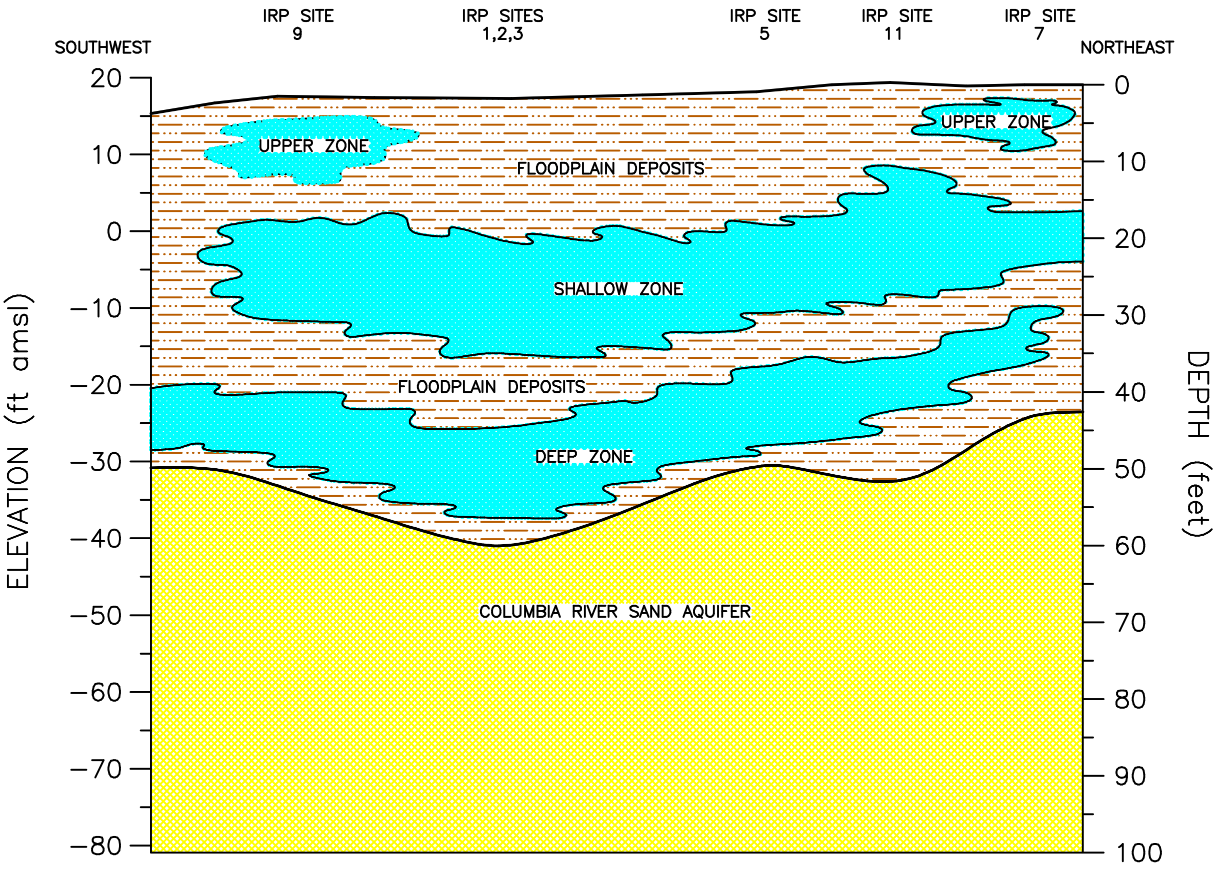
FIGURE 2-3



LEGEND

▨	Water Bearing Zones	Floodplain Deposits
▤	Silt/Clayey Silt/Sandy Silt	
🟨	Columbia River Sand Aquifer	

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GENERALIZED BASE HYDROGEOLOGIC CROSS SECTION

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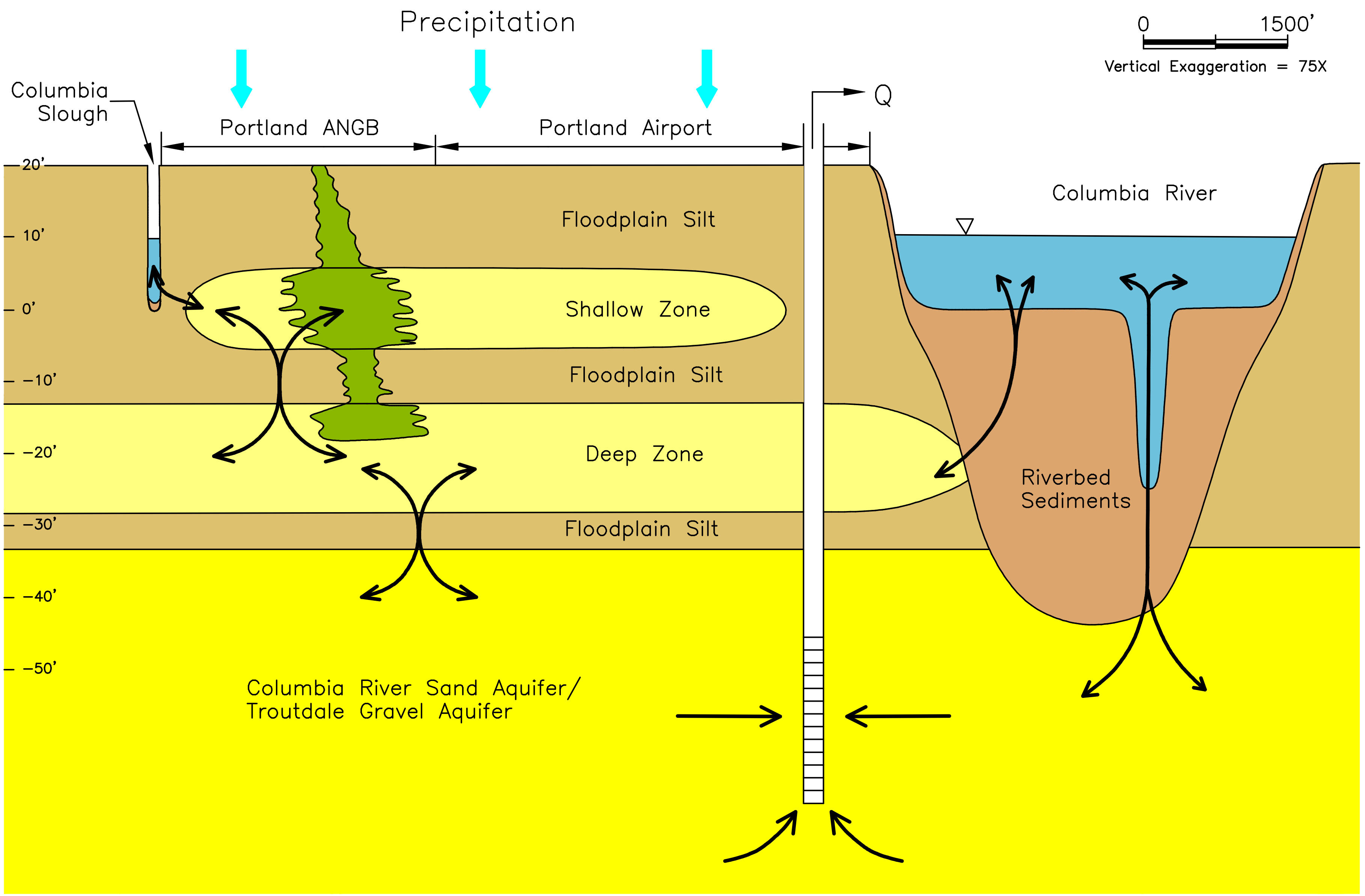
FIGURE 2–4



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Conceptual Hydrogeologic Model

142nd FW, PORTLAND ANGB
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PORTLAND, OREGON

FIGURE 2-5

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Zone was encountered in several borings at IRP Sites 1, 7, 9, and 11 at approximately 18 feet. The Upper Zone is separated from the Shallow Zone by a silty low-permeability zone up to 6 feet thick, and in some areas grades directly into the Shallow Zone.

Hydraulic conductivity values are not available for the Upper Zone; however, hydraulic conductivities from 0.54 to 15 feet per day (ft/day) are estimated based on the similar grain-size distribution of the Upper Zone and Shallow Zone.

2.6.2.2 Shallow Zone

The Shallow Zone is the shallowest extensive and laterally continuous water-bearing zone at the Portland ANGB. It is a semiconfined aquifer consisting of dark gray, well-sorted, fine sand with occasional silt and scattered silty layers. The Shallow Zone was encountered in all but the southern-most borings drilled during the Site Investigation (SI) and the RI. The top of the Shallow Zone was encountered at depths of 7.5 to 21 feet bgs. Where observed, the Shallow Zone generally ranges in thickness from approximately 3 to 19 feet, and is thickest through the central portion of the Base.

The hydraulic conductivity of the Shallow Zone ranges from 0.54 to 15 ft/day based on aquifer pumping and slug tests completed during the RI. A silty low-permeability zone ranging from 2 to 14 feet thick separates the Shallow Zone from the Deep Zone.

The impacted groundwater at the Base primarily occurs within the Shallow Zone unit. The presence of the silty soils between the Shallow Zone and the Deep Zone has limited the downward migration of contaminants from the Shallow Zone, although impacts to the Deep Zone have been confirmed.

2.6.2.3 Deep Zone

The Deep Zone is an extensive, laterally continuous, and semiconfined water-bearing zone that is typically encountered below depths of 28 to 41 feet bgs and consists of gray fine sand with occasional silt and interbedded silty layers. The Deep Zone was encountered in every deep boring across the IRP study area, with the exception of the boring completed for well MWBG-8, near the eastern Base boundary. Where observed, the Deep Zone ranges in thickness from approximately 2 to 19 feet.

The hydraulic conductivity of the Deep Zone ranges from 0.46 to 68 ft/day based on aquifer pumping and slug tests completed during the RI. In most areas of the Portland ANGB, the Deep Zone is separated from the underlying CRSA by an intervening low-permeability zone of gray clayey silt that ranges in thickness from less than 1 foot to 12 feet. In one location at the Portland ANGB (MW9-2), the Deep Zone was observed to be in contact with the CRSA. In general, the aquitard between the Deep Zone and the CRSA is thickest in the northern and northeastern portions of the IRP study area, and thinnest in the central and southwestern portions (Figure 2-2).

2.6.2.4 Columbia River Sand Aquifer

At the Portland ANGB, the CRSA is a semiconfined aquifer consisting of gray, fine-to-medium, micaceous, dense sand. The top of the CRSA was encountered at depths ranging from approximately 48 to 60 feet bgs. Logs of borings that penetrate the CRSA at the PIA note the bottom of the unit at approximately 280 feet bgs. The hydraulic conductivity of the CRSA ranges from 16 to 190 ft/day based on aquifer pumping and slug tests completed during the RI.

The Portland Well Field (Figure 1-1) has wells screened in the CRSA. The Western Expansion Area (WEA) of the Portland Well Field would put CRSA production wells within the LOF for the Portland ANGB. The LOF is discussed further in Section 2.10.1. The vertical migration from the Shallow Zone to the CRSA is a potential migration pathway for groundwater contaminants at the Base to reach human receptors.

2.6.3 Groundwater Elevations

Static groundwater levels in each of the water-bearing zones at the site have been observed ranging from near the ground surface to greater than 12 feet bgs. Seasonal groundwater elevation variations of approximately 4 feet or less have been observed in each of the Shallow Zone and Deep Zone, and variations of up to nearly 6 feet have been observed in the CRSA. Continuous water level data were recorded during the RI indicate that groundwater elevations at the Portland ANGB correlate with both precipitation and Columbia River stage. The groundwater elevation in the Shallow Zone appears to correlate more closely with individual precipitation events; whereas groundwater elevations in the Deep Zone and the CRSA correlate more closely with the Columbia River stage.

2.6.4 Groundwater Flow Directions

A potentiometric surface map for Shallow Zone water levels measured in July 2000 is presented on Figure 2-6. The inferred groundwater flow direction in the Shallow Zone in July 2000 was generally toward the northwest, converging toward the Main Drainage Ditch. However, the inferred groundwater flow direction at the eastern end of the Base (at IRP Site 7) was toward the northeast.

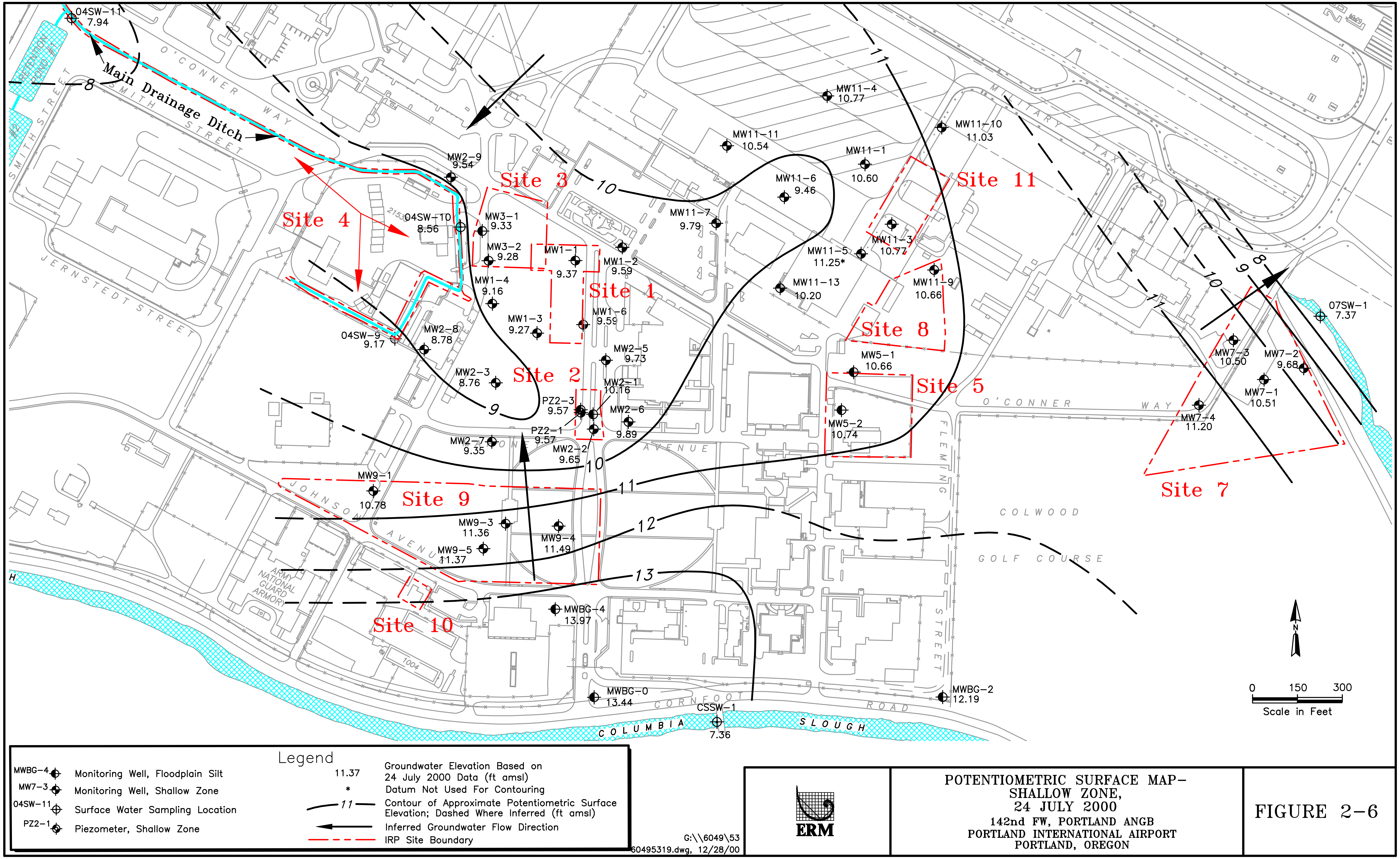
A potentiometric surface map for Deep Zone water levels measured in July 2000 is presented on Figure 2-7. The inferred groundwater flow direction in July 2000 was generally toward the northeast. Previous groundwater flow directions in the Deep Zone have generally been toward the north, although the cumulative water level data indicate occasional temporal and spatial shifts in groundwater flow.

The variable groundwater flow directions in the Deep Zone appear to be related to flow reversals in the CRSA. Significant changes in flow direction in both zones appear to correlate with seasonal fluctuations in the Columbia River stage. When the river stage is low, groundwater generally flows in an easterly direction in the Deep Zone. During moderate-to-high river stages, however, Deep Zone groundwater generally flows west.

The July 2000 potentiometric surface map for the CRSA is presented on Figure 2-8. The inferred groundwater flow direction in the CRSA in July 2000 was toward the northeast. Groundwater flow in the CRSA during previous quarters has fluctuated between northerly and southerly directions. Groundwater flow directions in the CRSA appear to be largely controlled by the Columbia River stage.

2.6.5 Hydraulic Gradients

In July 2000, the horizontal hydraulic gradients in the Shallow Zone and Deep Zone varied across the IRP study area, but averaged approximately 0.004 feet per foot in the Shallow Zone and 0.001 feet per foot in the Deep Zone. The average horizontal hydraulic gradient in the CRSA in July 2000 was approximately 0.0003 feet per foot. Horizontal gradients observed during previous quarters were similar in magnitude to the July 2000 gradients.



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POTENTIOMETRIC SURFACE MAP–
SHALLOW ZONE,
24 JULY 2000
142nd FW, PORTLAND ANGB
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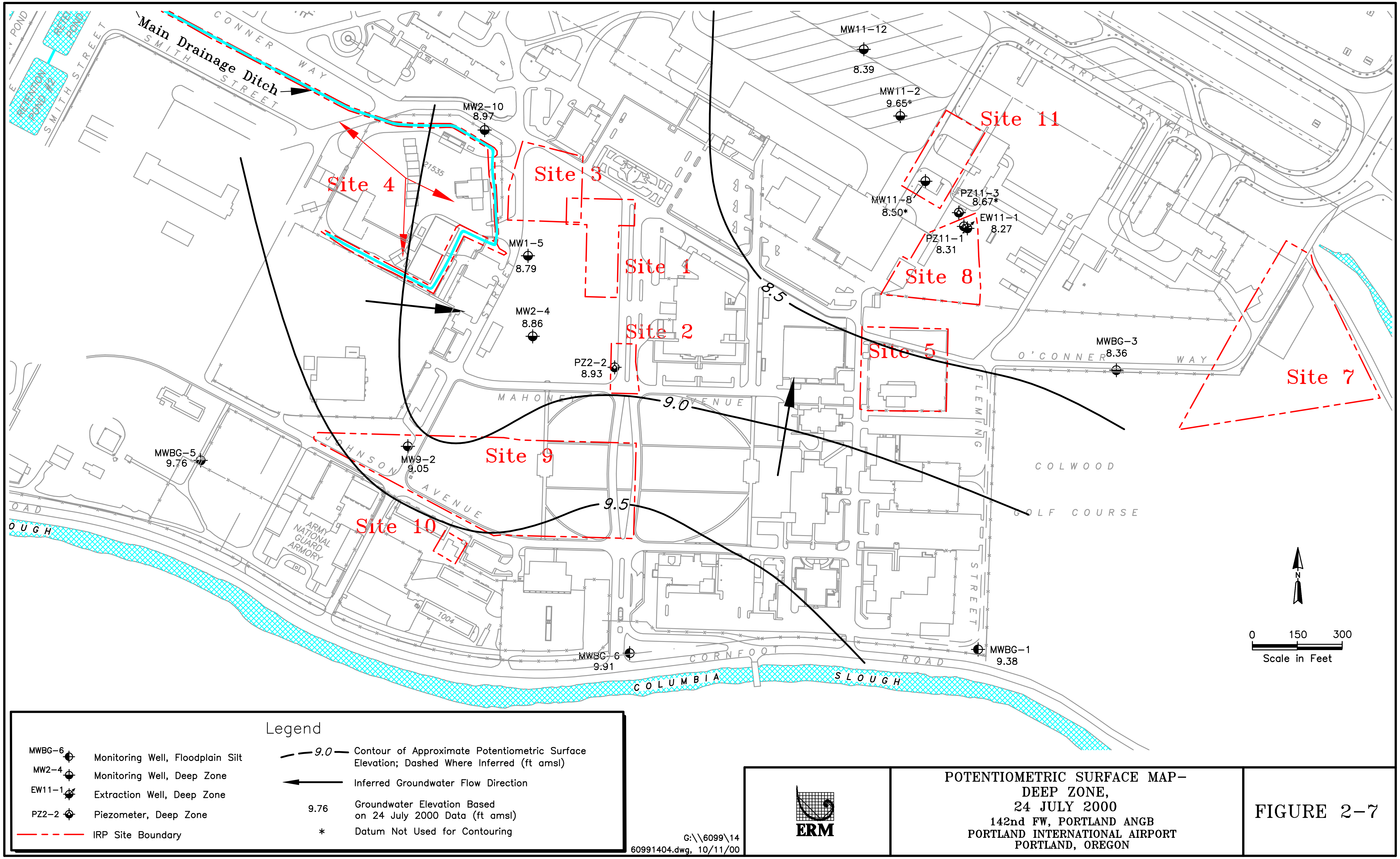
PORTLAND, OREGON

FIGURE 2–6



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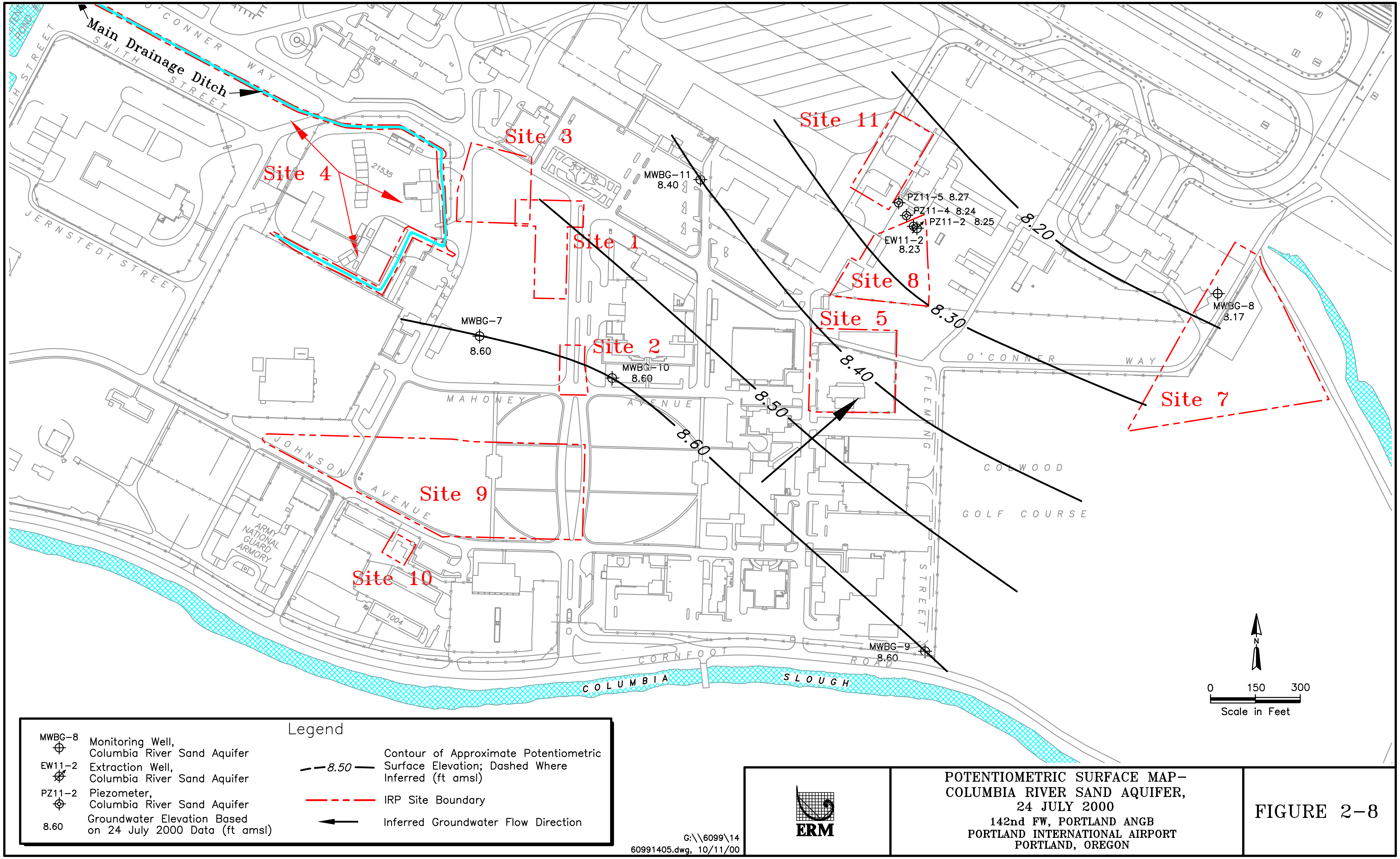
POTENTIOMETRIC SURFACE MAP–
DEEP ZONE,
24 JULY 2000
142nd FW, PORTLAND ANGB
PORTLAND INTERNATIONAL AIRPORT
PORTLAND, OREGON

FIGURE 2–7



Legend

MWBG-8 ⌖	Monitoring Well, Columbia River Sand Aquifer
EW11-2 ⌖	Extraction Well, Columbia River Sand Aquifer
PZ11-2 ⌖	Piezometer, Columbia River Sand Aquifer
8.60	Groundwater Elevation Based on 24 July 2000 Data (ft amsl)
— 8.50 —	Contour of Approximate Potentiometric Surface Elevation; Dashed Where Inferred (ft amsl)
— — —	IRP Site Boundary
←	Inferred Groundwater Flow Direction

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POTENTIOMETRIC SURFACE MAP–
COLUMBIA RIVER SAND AQUIFER,
24 JULY 2000
142nd FW, PORTLAND ANGB
PORTLAND INTERNATIONAL AIRPORT
PORTLAND, OREGON

FIGURE 2-8

In July 2000, the vertical gradient was downward at eight Shallow Zone/Deep Zone well pair locations and upward at one location. The vertical gradient was downward at each of the three Deep Zone/CRSA well pair locations. Gradient magnitudes ranged from 0.002 feet per foot to 0.752 feet per foot. The variable vertical gradients observed in July 2000 and previous months reflect lateral variations in both the horizontal hydraulic gradients within the water-bearing zones and the thickness of the silt layers between the zones.

2.7 Previous Investigations and Remedial Actions

Beginning in 1987, four IRP investigation phases have been completed at the Portland ANGB: the PA, the SI, the RI, and the Engineering Evaluation/Cost Analysis (EE/CA) Investigation. In addition, quarterly groundwater monitoring has been conducted since January 1997. These investigations are summarized in the following subsections.

2.7.1 Preliminary Assessment

In 1987, under the United States Air Force IRP as implemented by the ANG, a Phase I Record Search was completed and recorded as part of the PA (HMTC 1987). The PA investigation included: an on-site visit to interview past and present Portland ANGB employees; the acquisition and analysis of pertinent information and records on the Portland ANGB's hazardous materials use and waste generation and disposal practices; and the analysis of available geological, hydrological, meteorological, and environmental data from Federal, State, and local agencies.

The PA evaluated eight sites on the Portland ANGB (IRP Sites Nos. 1 through 8), and ranked six of these sites in accordance with the United States Air Force Hazardous Assessment Rating Methodology Protocol. The eight sites evaluated during the PA are as follows:

- IRP Site 1 - Central Hazardous Waste Storage Area
- IRP Site 2 - Civil Engineering Hazardous Material Storage Area
- IRP Site 3 - Hush House Area
- IRP Site 4 - Main Drainage Ditch
- IRP Site 5 - Aerospace Ground Equipment (AGE) Maintenance Shop

- IRP Site 6 - Wash Rack West of Building 1355
- IRP Site 7 - Burn Pit Area
- IRP Site 8 - Sanitary Landfill

Following the PA, limited field sampling was conducted at IRP Site 4 by RN Smith Associates in 1987, and at IRP Site 3 by SRH Associates, Inc., in 1988 (SRH 1988).

In December 1988, the Oregon ANG reported an underground storage tank (UST) leak at the POL Facility to the ODEQ. The fuel leak resulted in the identification of an additional IRP site, IRP Site 9 - POL Facility.

2.7.2 Site Investigation

In 1989, an SI of the IRP sites identified in the PA as requiring further investigation (IRP Sites 1 through 5, 7 and 8) was implemented by SAIC. The results of the SI are reported in the *Site Investigation Report* (SAIC 1991).

During the SI phase of work, two additional IRP sites were identified, based on the previous analytical results from samples collected by Portland ANGB personnel:

- IRP Site 10 - Equipment Wash Rack
- IRP Site 11 - Wash Rack West of Building 250 (Formerly IRP Site 6)

2.7.3 Remedial Investigation

Between 1995 and 2000, a multi-phase RI was performed at the Portland ANGB. The RI included the following phases:

- A Phase I RI performed by Operational Technologies Corporation (OpTech 1996);
- A Remedial Investigation/Data Gap Evaluation (RI/DGE) performed by ERM (ERM 1997); and
- An RI performed by ERM (ERM 2001a).

Descriptions of each of the above-referenced phases is provided in the following subsections.

2.7.3.1 Phase I RI

In 1995 and 1996, a Phase I RI was performed by OpTech. The field activities performed during the Phase I RI consisted of installing monitoring wells; collecting soil, sediment, soil gas, and groundwater samples; conducting aquifer tests; and performing geophysical surveys at ten of the IRP sites. The results of the Phase I RI were documented in the *Draft Remedial Investigation Report* (OpTech 1996).

2.7.3.2 Remedial Investigation/Data Gap Evaluation

In 1997, ERM conducted an RI/DGE to fill data gaps in the SI and Phase I RI. RI/DGE activities were performed at IRP Sites 1, 2, 5, 7, and 11. The results of the RI/DGE were presented in the *Final Investigation/Data Gap Evaluation (RI/DGE) Technical Memorandum* (ERM 1997).

2.7.3.3 Phase II RI

Phase II RI field activities were performed by ERM from April 1998 through November 1999 at IRP Sites 1, 2, 3, 4, 5, 7, 9, 10, and 11. The Phase II RI consisted of the following screening and confirmation activities, and additional supporting tasks:

<u>Screening Activities</u>

- Organic vapor (headspace) screening of soil samples; and
- Direct-push groundwater sampling to assess the nature and extent of contamination in groundwater and identify possible source areas.

<u>Confirmation Activities</u>

- Sediment and surface water sampling to determine the nature and extent of contamination in the Main Drainage Ditch;
- Surface and subsurface soil sampling to determine the nature and extent of contamination in soil; identify possible source areas for groundwater contamination; and determine lithology; and
- Installation and sampling of groundwater monitoring wells to determine the nature and extent of contamination in groundwater and monitor potential contaminant migration.

Supporting Tasks

- Measuring groundwater and surface water elevations to characterize hydraulic gradients, groundwater flow patterns, and groundwater/surface water interactions;
- Conducting aquifer testing to determine aquifer hydraulic properties;
- Performing a natural attenuation evaluation to assess the occurrence and rate of dissolved contaminant losses from groundwater due to intrinsic natural processes (for example, biodegradation);
- Conducting groundwater flow modeling to predict the effects of possible, future groundwater withdrawal in the Portland well field WEA;
- Performing an in-well aerator pilot test to assess the efficacy of this remediation technology for reducing chlorinated volatile organic compound (VOC) concentrations in groundwater;
- Conducting location and elevation surveys of the Phase II RI soil borings, groundwater sampling/monitoring points, and surface water measurement benchmarks; and
- Performing a baseline risk assessment to evaluate the potential human health and ecological risks associated with contaminated soil, sediment, groundwater, and surface water.

Soil and/or groundwater samples were collected from direct-push borings, hand-auger borings, hollow-stem auger borings, groundwater monitoring wells, groundwater extraction wells, and piezometers. The results of the Phase II RI are presented in the Final RI Report (ERM 2001a).

2.7.4 EE/CA Investigation and Removal Action

During January through March 1998, ERM performed an EE/CA Investigation at IRP Site 11 to define the lateral and vertical extent of chlorinated- and hydrocarbon-impacted soil at the site. The scope of work of the EE/CA Investigation included the installation of 24 direct-push soil borings, and the collection of a groundwater sample at each location. The results of the EE/CA Investigation were reported in the *Final Engineering Evaluation/Cost Analysis (EE/CA) for IRP Site 11,* (ERM 1998).

A soil removal action was performed at the site in September 1999 as part of the soil EE/CA process. The following scope of work was completed as part of this removal action:

- Sludge and water were removed from the oil/water separator;
- The oil/water separator and washrack were removed and hauled off-site; and
- Approximately 260 cubic yards of impacted soil were removed in the immediate vicinity of the former oil/water separator and hauled off-site to a thermal desorption facility.

The scope results of the 1999 soil removal action are detailed in the *Final Completion Report for Site 11 Interim Remedial Action Construction for Soils Media*, (ERM 2000b).

2.8 Current IRP Activities

Current IRP environmental activity at Portland ANGB includes an EE/CA for a non-time critical, groundwater removal action at IRP Site 11, an IRAC project to evaluate groundwater remediation technologies at IRP Site 2, and ongoing groundwater monitoring. These activities are described in the following subsections.

2.8.1 IRP Site 11 Groundwater EE/CA

A general description of how the EE/CA fits into the FS process is presented in Appendix A. The EE/CA currently being conducted at IRP Site 11 closely parallels this FS, in that many components are similar, such as the establishment of RAOs, the development of remedial alternatives, the detailed analysis of such alternatives, and the selection of a preferred RA alternative. The EE/CA Report follows the recommended ANG/CEVR format and contains the information suggested in the USEPA document *Guidance on Conducting Non-Time-Critical Removal Actions Under CERCLA* (USEPA 1993). The *Final Site 11 Groundwater EE/CA* was submitted in June 2001 (ERM 2001b). In addition, a conceptual design document, representing the first phase of design of the remedial action recommended in the EE/CA, was submitted in April 2001.

2.8.2 IRP Site 2 Interim Remedial Action Construction

The other IRP work currently being conducted at the Portland ANGB is a two-phase, IRAC for the purposes of providing treatability testing support for the FS, and to begin cleanup of groundwater at IRP Site 2. The results of the IRAC will be used to evaluate treatment of VOCs in groundwater across the Base.

The first phase of the IRAC involved a three-month treatability test to evaluate the effectiveness of three in-situ remediation technologies for treatment of VOCs in groundwater at IRP Site 2: enhanced aerobic bioremediation with Oxygen Release Compound (ORC®), ozonation, and potassium permanganate oxidation.

The treatability test phase of the IRAC has been completed. The results indicate that all three technologies were effective in destroying VOCs in groundwater. Certain site-specific factors such as preferential flow paths, high levels of organic carbon in the soil, and low horizontal hydraulic gradient appear to present limitations to treatment at the site. A summary of the IRAC treatability results are presented in the *Interim Remedial Action Construction Phase I Interim Report* submitted in February 2001 (ERM 2001c). A work plan for the second phase of the IRAC has been prepared and the full-scale technology demonstration is expected to be implemented in fall of 2001 (ERM 2001d).

The second phase of the IRP Site 2 IRAC will involve the full-scale demonstration of in situ oxidation by potassium permanganate injection. The purpose of this phase will be to demonstrate that the preferred remediation technology is effective, on a larger scale, at reducing human health and environmental risk to an appropriate level.

2.8.3 Groundwater Monitoring

Basewide groundwater monitoring at the Portland ANGB is expected to continue. Future groundwater monitoring will focus on potential off-site contaminant migration and/or downward migration to the CRSA drinking water aquifer at Sites 2, 9, and 11.

2.9 Contaminant Fate and Transport

This section presents some of the results of the contaminant fate and transport analysis performed during the RI. A more complete discussion of contaminant fate and transport is presented in the Final RI Report (ERM 2001a).

Release mechanisms for contaminants of concern (COCs) in soil include infiltration of precipitation and direct contact of the water table with contaminated soil. The primary pathways for contaminant migration at the Portland ANGB are:

- Leaching of soil contaminants to groundwater; and
- Transport of contaminants away from source areas via advection and dispersion in groundwater.

2.9.1 Leaching of Soil Contaminants

Precipitation has the potential to infiltrate and contact contaminated soil at IRP Sites 1, 3, 5, 7, 9, 10, and 11; however, leaching of the relatively immobile metals detected in surface soil at Sites 5 and 10 is likely insignificant. The rate of contaminant migration for this pathway is controlled by the infiltration rate of precipitation, the contact time between the infiltrating water and the contaminants, the rate of evaporation, the permeability and wetting characteristics of the soil, and the solubility of the COCs. The precipitation infiltration rate in turn depends on seasonal precipitation rates and ground surface conditions (e.g., paved / unpaved, surface vegetation, slope).

2.9.2 Groundwater Transport

Groundwater contamination is present at IRP Sites 1, 2, 3, 9, and 11. Groundwater typically occurs between 2 and 10 feet bgs in monitoring wells at the Portland ANGB. Horizontal groundwater flow occurs primarily through the permeable sand zones. From the surface, infiltrating precipitation contacts the water table within the Floodplain Silt and flows downward to the Shallow Zone. Groundwater then flows horizontally through the Shallow Zone. In areas where the groundwater elevation in the Deep Zone is less than the groundwater elevation in the Shallow Zone, groundwater can potentially flow downward to the Deep

Zone. Likewise, in areas where the groundwater elevation in the CRSA is less than that in the Deep Zone, groundwater can potentially flow downward to the CRSA. Downward vertical hydraulic gradients were observed at various times and locations during the Phase II RI and Basewide groundwater monitoring program.

The results of aquifer testing indicate that vertical groundwater flow through the silt layer separating the Shallow and Deep Zones is relatively slow. The vertical hydraulic conductivity of this silt layer is estimated to be approximately 1.9 gpd/ft^2 (0.25 ft/d) based on pumping test data. Assuming an effective porosity of 30 percent and a vertical hydraulic gradient of 0.001 feet per foot (consistent with observed gradients at IRP Sites 1, 2, and 3) the groundwater seepage velocity through the silt layer is estimated to be on the order of 0.001 ft/d. The seepage velocity through the silt layer separating the Deep Zone from the CRSA is expected to be similar in magnitude.

2.9.3 Groundwater Flow Modeling Results

A groundwater flow model was developed to predict the effects of potential future groundwater withdrawal in the Portland well field WEA on the groundwater flow regime under the Portland ANGB. The WEA is approximately 1.5 miles east of the Base.

The numerical groundwater model was constructed using Visual MODFLOW, a widely used groundwater modeling software package. The basis for the Portland ANGB groundwater model is the City of Portland's Deep Aquifer Yield flow model, which was developed to evaluate groundwater response to pumping in the Portland well field.

The Portland ANGB model was used to conduct predictive simulations of several different pumping scenarios in the Portland well field. In one of the scenarios, the two existing CRSA/Troutdale Gravel Aquifer (TGA) production wells in the WEA and a third CRSA well approximately 3,000 feet east of the WEA were assumed to pump continuously at maximum capacity (3,000 to 6,000 gallons per minute per well). The modeling results for this scenario predict that the pumping wells would not induce groundwater under the Portland ANGB to flow toward the Portland well field.

Another pumping scenario under consideration by the City of Portland involves the installation and operation of two new TGA production wells in the WEA, in addition to the existing TGA well. The modeling results predict that this pumping configuration would cause groundwater under the Base to migrate toward the pumping wells. However, after 3 years of continuous pumping (the maximum anticipated duration of pumping under this scenario), Shallow Zone groundwater would migrate primarily west and then downward into the Deep Zone; lateral migration toward the Portland well field is predicted to be on the order of 100 feet or less. The results for this scenario suggest that the production wells would have to be pumped continuously at full capacity for approximately 26 years before Shallow Zone groundwater under the Base would reach the closest production well.

A third pumping scenario was modeled to evaluate whether any of the new CRSA/TGA production wells currently proposed by the City for the WEA could be installed and operated along with the existing shallow production wells, without significantly affecting groundwater flow under the Portland ANGB. The results for this scenario suggest that up to two additional shallow production wells could be installed at proposed well sites in the WEA. These new wells and the three existing wells could be pumped continuously at capacity with minimal impact on groundwater flow under the Base.

The predictive simulations in the present modeling study are a first-order approximation of the expected groundwater flow response to the pumping scenarios evaluated. A number of simplifying assumptions were made in developing the model, and the inputs to the model were based on limited field data. Additionally, the model simulations assumed steady-state conditions and a static water level in the Columbia River. Water level data for the Portland ANGB and the Columbia River, as well as the observed model behavior during calibration and sensitivity analysis, indicate that the groundwater flow system is very dynamic.

Further discussion regarding groundwater transport and modeling is presented in the Final RI document, including further discussion of uncertainties associated with the groundwater flow monitoring. Also, contaminant transport modeling is currently being performed for the Base and these results will be documented late in 2001.

2.10 Beneficial Use Survey

This section summarizes the results of the beneficial use survey completed for the Portland ANGB.

2.10.1 Locality of the Facility

Oregon regulations require the identification of current and reasonably likely future beneficial water uses in the LOF. LOF is defined in Oregon Administrative Rules (OAR) 340-122-115(34) as any point where a human or an ecological receptor contacts, or is reasonably likely to come into contact with, facility-related hazardous substances. The LOF takes into account the likelihood of the contamination migrating over time, and as such is typically larger than the facility (ODEQ 1998a).

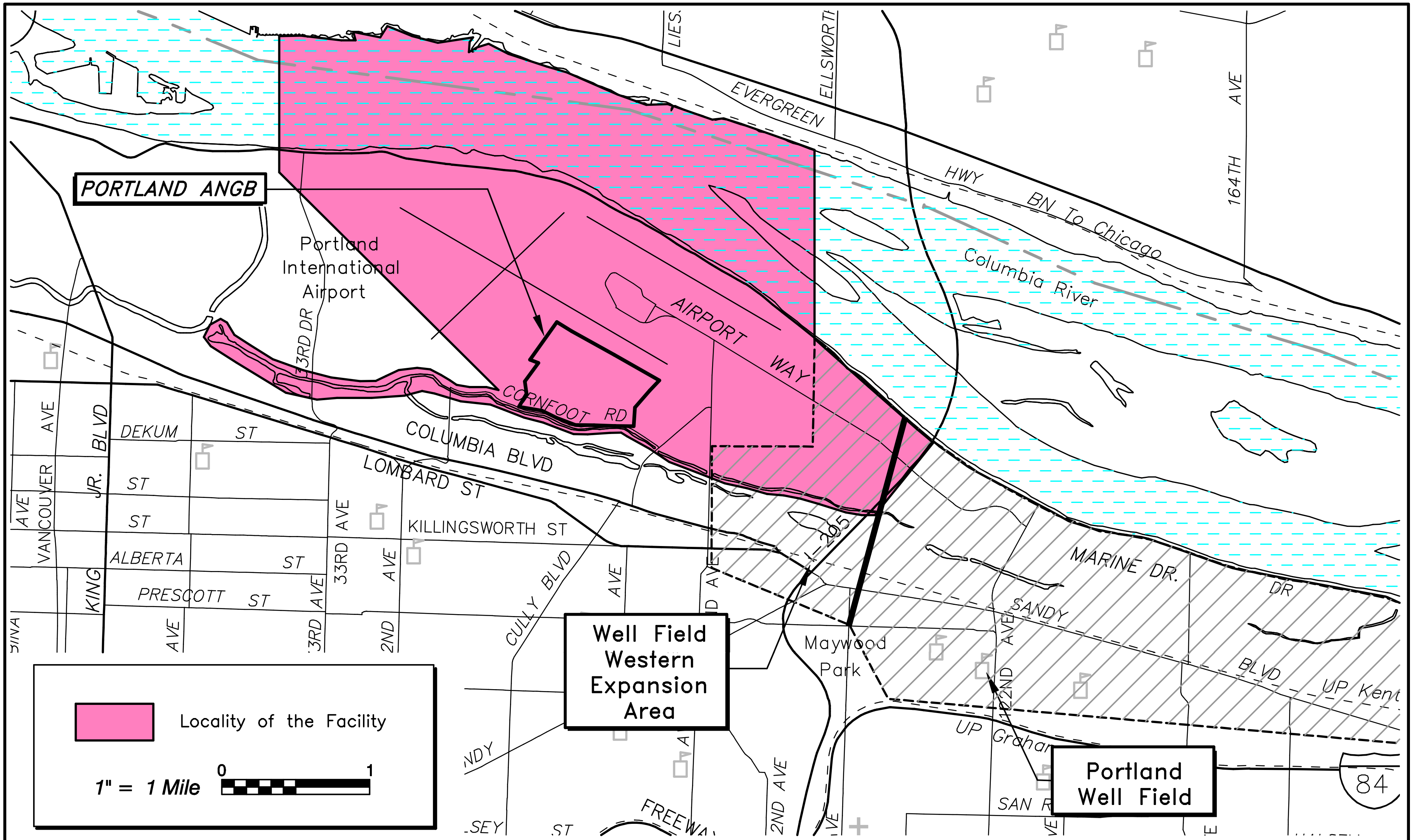
Based on modeling and migration scenarios developed in the Final RI Report (ERM 2001a), the LOF for the Base was determined to extend a significant distance beyond the actual Base footprint. The LOF for the Base, as shown on Figure 2-9, includes off-site areas such as a portion of the Columbia River, the Columbia Slough, and the Portland Well Field. The extent of the LOF for the Base was established based on the slight potential for existing VOCs in groundwater at IRP Sites 2, 9, and 11 to migrate to the above-mentioned areas.

2.10.2 Groundwater

Groundwater within the property boundary of the Portland ANGB is not currently used and there is no plan to use Base groundwater in the future. The industrial nature of the current and planned future use of the Base limits the potential for installing production wells. However, the groundwater resources at the Base, particularly the CRSA, have the capacity to sustain production for uses other than municipal supply, such as use on-site for process water, wash water, or on-site drinking water.

The off-site portion of the LOF includes part of the Portland well field, the Columbia River, and the Columbia Slough. The only current beneficial use of groundwater for this area is recharge of surface water. There are currently no groundwater production wells within the LOF (ERM 2001a). However, the LOF includes the Portland well field WEA, where future pumping of CRSA groundwater could occur.

Possible future beneficial uses of groundwater at the LOF include uses typical of a municipal water supply (drinking, irrigation, industry, etc.) and recharge of surface water. It is possible that planned wells within the Portland well field WEA will be activated. If these wells were activated, there is a potential, under certain pumping scenarios, that groundwater containing VOCs from IRP Sites 2, 9, or 11 could reach the well field.



Source: Portland Air National Guard Base Masterplan, May 1997

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LOCALITY OF THE FACILITY

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FIGURE 2-9

There is also slight potential for groundwater containing VOCs to migrate directly or indirectly to the surface water resources mentioned above. This could effect beneficial uses of these resources, depending on the concentration of VOCs reaching the surface water body. The beneficial use of surface water is discussed in the section below.

2.10.3 Surface Water

As mentioned above, three surface water bodies exist within the LOF for the Portland ANGB; (1) the drainage ditch at IRP Site 4, (2) the Columbia Slough south of the Base, and (3) the Columbia River at the northern boundary of the LOF. Beneficial use of these surface water bodies includes aquatic life habitat, recreation, aesthetic quality, and irrigation. The off-site surface water bodies are included in the LOF due to a potential hydraulic connection to the Shallow Zone at the Base.

Groundwater containing VOCs at IRP Sites 2, 9, and 11 has not impacted off-site surface water. However, if left untreated, VOCs at these sites may migrate to the three above-referenced surface water bodies. The impact to the beneficial uses of the surface water is not expected to be significant due to the time and distance required for VOCs to travel from each IRP site to the nearest off-site surface water body.

2.10.4 Land Use

The Portland ANGB property is leased by the ANG from the Port of Portland. This property is zoned for industrial use (City of Portland Bureau of Planning 2000a). Current operations at the Base are consistent with this land use designation. In order to determine the likely future land use of the property, the Port of Portland planning department was contacted. In addition, the PIA Master Plan and the City of Portland Comprehensive Plan Map were reviewed.

According to the Port of Portland planning department, the Portland ANGB property is expected to be used indefinitely for aviation purposes. There is no likelihood that the Base property would eventually be developed for residential use (Port of Portland 2001). The Portland Airport Master Plan indicates that future development of the airport facilities will most likely include relocation of the Portland ANGB to an area in the northwest part of the airfield. The recommended development alternative calls for construction of a second passenger terminal and a possible third runway in the area currently occupied by the Base (Port of

Portland 2000). The City's Comprehensive Plan Map identifies the area encompassing the Portland ANGB as "Industrial Sanctuary" (City of Portland Bureau of Planning 2000b). Accordingly, the current industrial land use of the Portland ANGB property is not expected to change in the future.

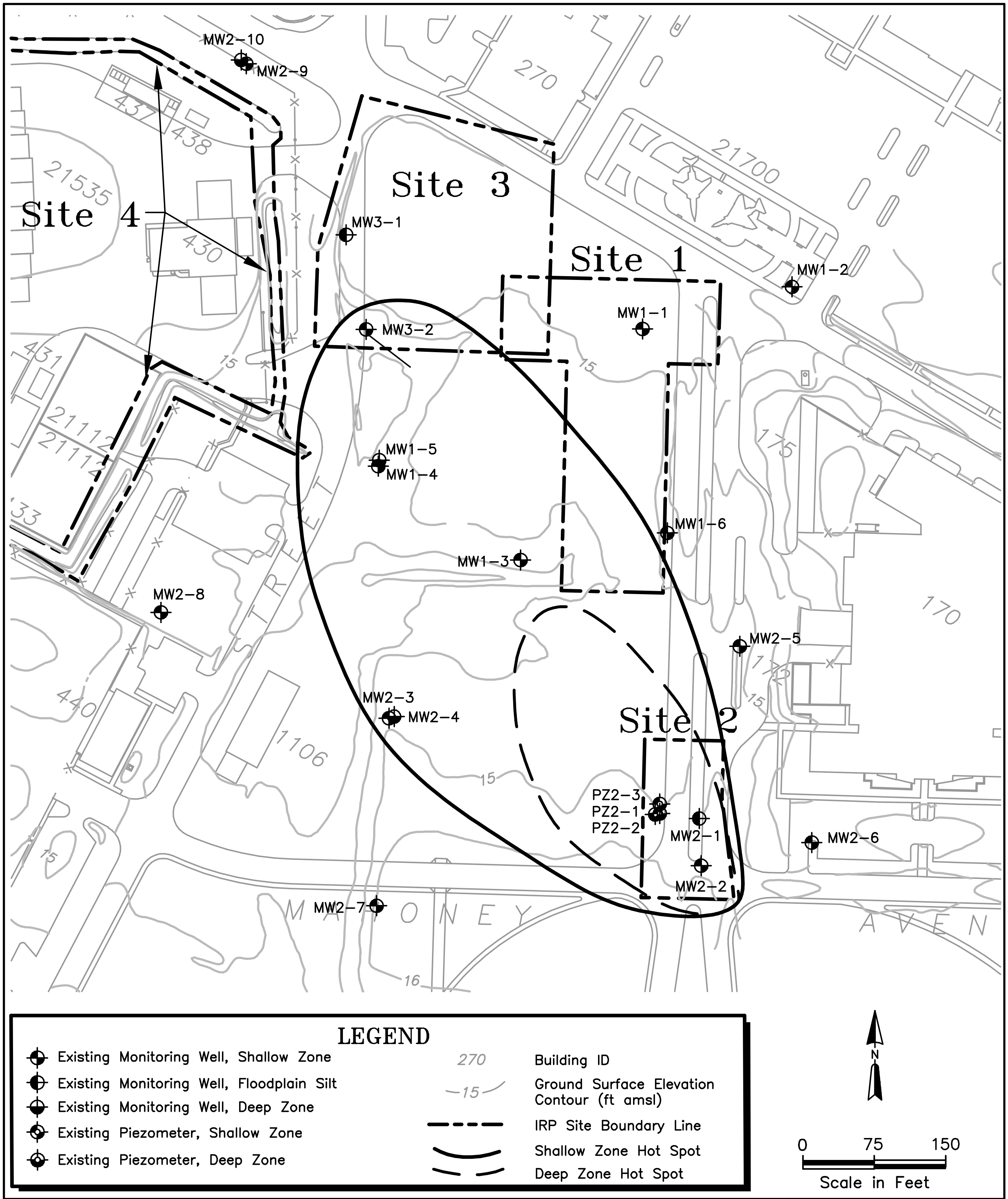
2.11 Hot-Spot Evaluation

ODEQ requires that all remedies considered in an FS address treatment of "hot spots." According to the *Final Guidance for Identification of Hot Spots* (ODEQ 1998c), a hot spot exists if contamination results in a significant adverse effect on the beneficial use of that resource and if restoration or protection of the beneficial use can occur within a reasonable amount of time.

Although unlikely, future pumping scenarios in the Portland well field as described in Section 2.9 above, groundwater at the Portland ANGB has the potential to reach the WEA. The National Primary Drinking Water Standard Maximum Contaminant Level (MCL) is the criteria used to determine if a significant adverse effect exists regarding the use of groundwater at the WEA as drinking water (ODEQ 1998c). Comparing analytical data for several VOCs at IRP Sites 2, 9, and 11 with the respective MCLs indicates that a significant adverse effect would exist if groundwater from these sites were to migrate to the WEA.

The focus of this FS was to determine how to treat groundwater at IRP Sites 2, 9, and 11 to the extent necessary to prevent significant adverse effect on off-site groundwater. Remedial alternatives were developed which are expected to restore the groundwater within a reasonable timeframe.

Certain areas of groundwater at IRP Sites 2, 9, and 11 are considered hot spots based on the two principles described above. The groundwater hot spot at IRP Site 2 consists of the largest area containing an exceedence of either vinyl chloride (VC) at 2 micrograms per liter (µg/l); trichloroethene (TCE) at 5 µg/l; cis-1,2-DCE at 70 µg/l; or trans-1,2-DCE at 100 µg/l. The area of the hot spot at IRP Site 2 is delineated on Figure 2-10. The groundwater hot spot at IRP Site 9 is the area where the benzene concentration exceeds 5 µg/l. The area of the hot spot at IRP Site 9 is delineated on Figure 2-11. The groundwater hot spot at IRP Site 11 is the area where either VC exceeds 2 µg/l; cis-1,2-DCE exceeds 70 µg/l; trans-1,2-DCE exceeds 100 µg/l; or benzene exceeds 5 µg/l. The area of the hot



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IRP SITE 2
HOT SPOT OF CONTAMINATION
IN GROUNDWATER

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FIGURE 2-10

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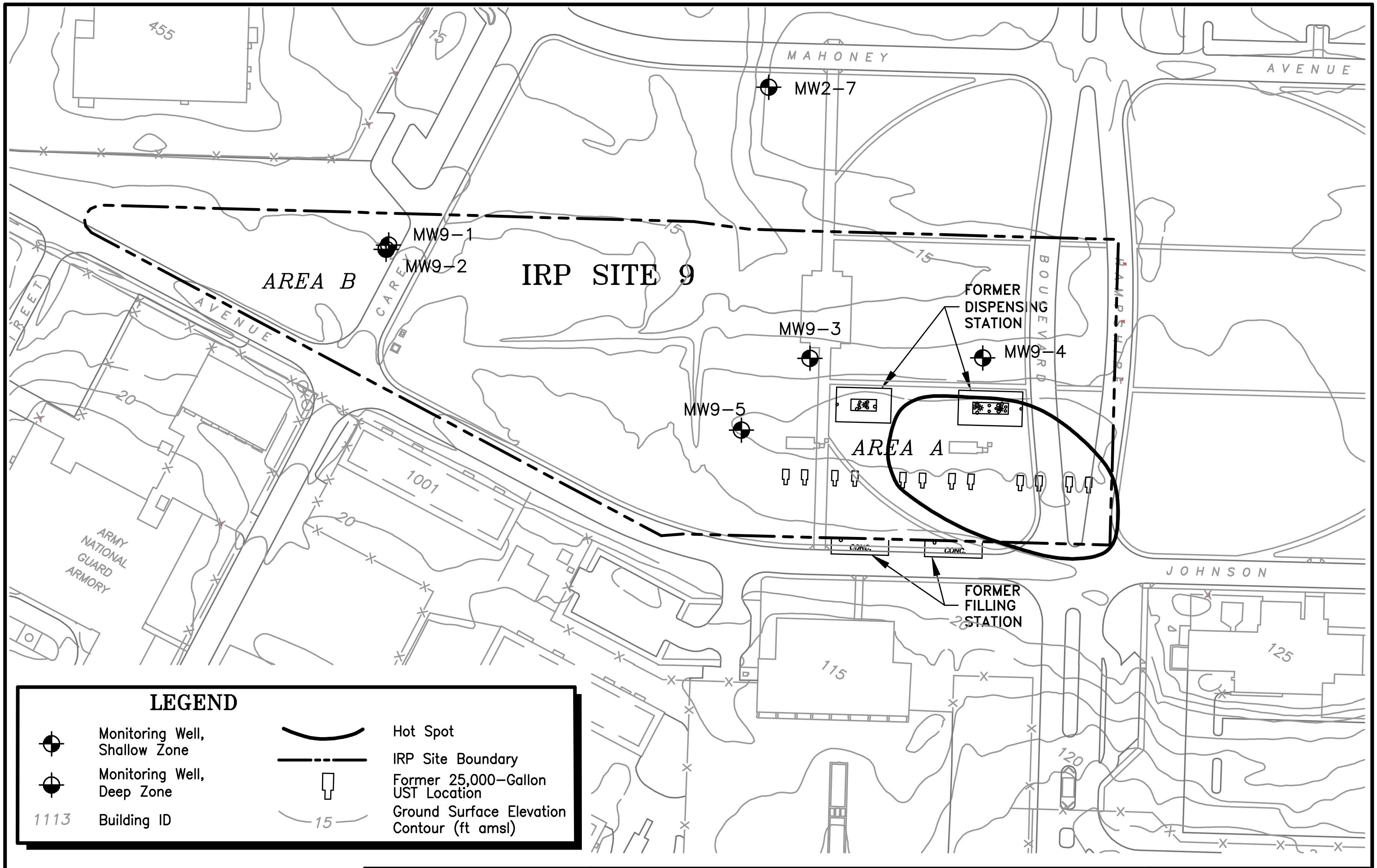

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IRP SITE 9
HOT SPOT OF CONTAMINATION IN GROUNDWATER

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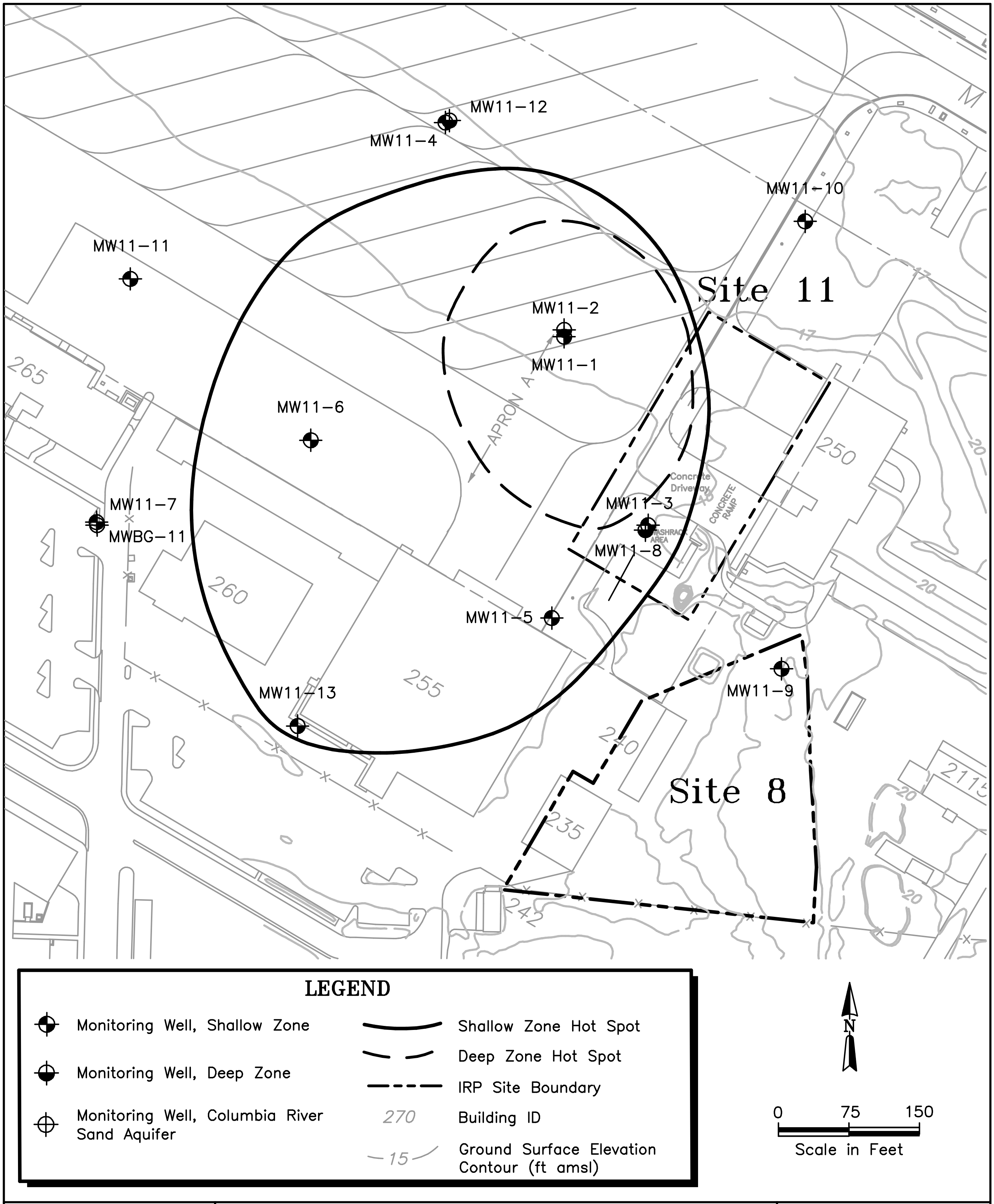
FIGURE 2-11

spot at IRP Site 11 is delineated on Figure 2-12. The hot spots at IRP Sites 2 and 11 include small areas of Deep Zone groundwater due to recent detections of VOCs above respective MCLs. These hot spots will be addressed in the same manner as the hot spots in Shallow Zone groundwater.



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IRP SITE 11
HOT SPOT OF CONTAMINATION IN GROUNDWATER

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FIGURE 2-12

SECTION 3.0

IRP SITE DESCRIPTIONS

This section includes background and historical information regarding each IRP site at the Base, as well as the respective results of the RI. Subsequent to the background and historical summaries provided for each site, the information described below will be presented:

- Waste Storage/Disposal History: A brief history of the waste storage/disposal practices conducted at each IRP site is provided.
- Nature and Extent of Contamination: A summary of the contaminants identified at the site; their concentrations and spatial distribution in soil, groundwater, sediment, and/or surface water; and their exceedances of the project screening goals (PSGs) developed during the RI are presented in Table 3-1.
- Risk Assessment Results: The results of a baseline risk assessment for each IRP site are discussed. These results were the basis for the development of remedial alternatives. The development of remedial alternatives is recommended for sites with risks that exceed ODEQ and/or USEPA acceptable levels.
- Recommendations: A discussion is presented regarding what action should be taken at each IRP site, based on the level of contamination or risk. In cases where a recommendation is made for further analysis of an IRP site, remedial alternatives are fully evaluated in sections 4.0 and 5.0.

A summary of the waste disposal history, nature and extent of contamination, risk assessment results, and recommendations for each IRP site is provided in Table 3-2.

3.1 IRP Site 1 - Central Hazardous Waste Storage Area

The former Central Hazardous Waste Storage Area is on the north side of former Building 1131, as shown on Figure 3-1. The waste storage area did not have a containment structure (SAIC 1991).

TABLE 3-1

Project Screening Goals for Groundwater, Surface Water, and Soil
142nd FW, Portland ANGB, Portland, Oregon

Analyte	Groundwater Project Screening Goal (µg/l)	Surface Water Project Screening Goal (µg/l)	Soil Project Screening Goal (mg/kg)
Acetone	610	610	0.8
Acenaphthene	370	520	29
Acenaphthylene	--	--	--
Anthracene	1800	--	590
Benzene	0.39	0.39	0.002
Benzo(a)anthracene	0.01	0.01	0.08
Benzo(b)fluoranthene	0.01	0.01	0.1
Benzo(k)fluoranthene	0.01	0.01	0.1
Benzo(a)pyrene	0.0092	0.0092	0.1
Benzo(g,h,i)perylene	--	--	--
Benzoic Acid	150000	--	20
Benzyl Alcohol	11000	--	200,000
Bis(2-ethylhexyl)phthalate	4	160	4
Bromodichloromethane	0.18	0.18	0.01
2-Butanone (MEK)	1900	1,900	27,000
Butylbenzylphthalate	7300	3	810
Carbazole	--	--	0.03
Carbon disulfide	21	21	--
Chlorobenzene	39	50	0.07
Chloroform	0.16	1,240	--
Chloromethane	1.5	1.5	--
Chrysene	0.01	--	0.1
Dibenz(a,h)anthracene	--	--	0.08
Dibenzofuran	24	--	2,300
1,4-Dichlorobenzene	0.47	763	0.1
1,3-Dichlorobenzene	180	--	2,000
1,2-Dichlorobenzene	370	763	0.9
1,2-Dichloroethane	0.12	20,000	0.001
1,1-Dichloroethane	810	810	--
1,1-Dichloroethene	0.046	0.046	--
cis-1, 2-Dichloroethene	61	61	0.02
trans-1,2-Dichloroethene	100	100	0.03
total-1,2-Dichloroethene	55	55	--
1,2-Dichloropropane	0.16	5,700	--
Diethylphthalate	29000	3	860,000
2,4-dimethylphenol	730	--	0.4
Dimethylphthalate	370000	3	--
Di-n-butylphthalate	3700	3	270
Di-n-octylphthalate	730	3	10,000
Ethylbenzene	700	700	0.7
Ethylene glycol	73000	73,000	1,400,000
Fluoranthene	1000	--	210
Fluorene	240	240	28
Hexachloroethane	--	--	0.02
2-Hexanone	--	--	--
Indeno(1,2,3-cd)pyrene	--	--	0.1
4-Methyl-2-pentanone (MIBK)	--	--	2,800
Methyl ethyl ketone (MEK)	--	--	27,000
2-Methylnaphthalene	--	--	--
2-Methylphenol	1800	--	0.8
3/4-Methylphenol	180	--	5,300
4-Methylphenol	180	180	--
Methylene chloride (dichloromethane)	4.3	4.3	0.001
Naphthalene	100	620	4
N-Nitrosodiphenylamine	--	--	0.06
Pentachlorophenol	0.56	--	0.003
Phenanthrene	--	--	--
Phenol	22000	--	5
Polychlorinated biphenyls (PCBs)	--	--	0.08
Aroclor-1016	--	--	0.34
Aroclor-1254	--	--	0.34

TABLE 3-1

Project Screening Goals for Groundwater, Surface Water, and Soil
142nd FW, Portland ANGB, Portland, Oregon

Analyte	Groundwater Project Screening Goal (µg/l)	Surface Water Project Screening Goal (µg/l)	Soil Project Screening Goal (mg/kg)
Pyrene	180	180	210
1,1,2,2-Tetrachloroethane (1,1,2,2-PCA)	0.055	--	0.0002
Tetrachloroethene (PCE)	1.1	840	0.003
Toluene	720	720	0.6
TPH-C10 to C24 Aliphatics	--	--	--
TPH-Jet fuel A	--	--	--
TPH-Heavy Oil	--	--	--
TPH-Diesel (5)	--	--	100
TPH-Gasoline (5)	--	--	40
1,1,2-Trichloroethane	0.2	9,400	--
Trichloroethene (TCE)	1.6	21,900	0.003
1,2,4-Trimethylbenzene	12	12	--
1,3,5-Trimethylbenzene	12	12	--
Vinyl chloride	0.02	0.02	0.0007
m,p-Xylenes	--	--	10
o-Xylenes	--	--	9
Total xylenes	1400	1,400	10
Antimony	6	6	0.59
Arsenic	7.83	150	5.81
Barium	--	--	20,000
Beryllium	3.8	5.3	1.24
Cadmium	5	2.2	0.42
Chromium	145	74	39.2
Copper	1,300	9.0	10,000
Lead	15.7	2.5	200
Mercury	2	0.77	80
Nickel	100	52	34.4
Selenium	50	5.0	0.3
Silver	50	50	2
Thallium	2	40	0.67
Zinc	1,100	120	620

Notes:

Project Screening Goals were developed in the RI based on a comparison of regulatory criteria and background concentrations (ERM 2001a)

TPH - Total petroleum hydrocarbons

µg/l - Micrograms per liter

mg/kg - Milligrams per kilogram

-- - Standard not established

TABLE 3-2

IRP Site Description Summary

142nd FW, Portland ANGB, Portland, Oregon

IRP Site	Site Name	Waste Disposal History	Nature and Extent of Contamination	Risk Assessment Results	Recommendation
1	Central Hazardous Waste Storage Area	Waste storage area for misc. wastes incl. waste oil, solvents, fuels, shop wastes, electrical transformers, and capacitors.	Low levels of TCE, PCE, and cis-1,2-DCE in Shallow Zone groundwater. Likely primary source is IRP Site 2.	Unacceptable total carcinogenic risk and noncarcinogenic hazard for hypothetical on-site residential exposure to groundwater (primarily vinyl chloride).	Soil: No further action. Groundwater: Remedial measures to prevent off-site migration and on-site exposure to groundwater with unacceptable concentrations.
2	Civil Engineering Hazardous Material Storage Area	Solvents, paint thinners, and MEK were stored in or near solvent storage shed; paint was stored in Building 1123.	VOCs not detected in soil samples. Chlorinated VOCs detected in both Shallow Zone and Deep Zone groundwater. Dissolved VOC plume extends approx. 750 feet to northwest and is approximately 400 feet wide.	Unacceptable total carcinogenic risk and noncarcinogenic hazard for hypothetical on-site residential exposure to groundwater (primarily vinyl chloride).	Soil: No further action. Groundwater: Remedial measures to prevent off-site migration and on-site exposure to groundwater with unacceptable concentrations.
3	Hush House Area	Waste oil, fuel, and solvents were stored at the Hush House on unpaved surface.	Area B: Benzene, SVOCs, TPH, and metals detected in shallow soil above PSGs near former oil / water separator. Naphthalene, benzene, and vinyl chloride detected in groundwater above PSGs. Area C: TPH detected in shallow soils.	Unacceptable total carcinogenic risk for hypothetical on-site residential exposure to soil (primarily benzo[a]pyrene and dibenz[a,h]anthracene) and groundwater (primarily benzene and vinyl chloride).	Soil: No further action. Groundwater: Remedial measures to prevent off-site migration and on-site exposure to groundwater with unacceptable concentrations.
4	Main Drainage Ditch	Petroleum and oil were reported in the Main Drainage Ditch downstream from the flight apron outfall in 1987. Ditch receives surface water runoff from adjacent facilities. No records of wastes being intentionally disposed of in the ditch.	SVOCs, TPH, and metals detected in sediment in Main Drainage Ditch above PSGs. Bromodichloromethane, antimony, cadmium, copper, lead, zinc, and cis-1,2-DCE detected in surface water above PSGs.	No unacceptable risks.	No further action.
5	Aerospace Ground Equipment Maintenance Shop	Spent battery acid, solvents, lubricants, antifreeze, cleaning solutions, and automobile fluids were generated at Maintenance Shop. Wastes may have been disposed of along the northern and southern fence lines. Former LUST contained heating oil.	Area A: Chloroform, 1,2-dichlorobenzene, TCE, toluene, and xylene detected in groundwater at low concentrations. Area B: 1,2-DCA, TCE, and metals detected above PSGs in surface and subsurface soil.	No unacceptable risks. One soil sample exceeded USEPA screening level for lead for an unrestricted use scenario.	No further action.
7	Burn Pit Area	Flammable liquids incl. waste oil, JP-4 jet fuel, and solvents were reportedly burned in the pit as part of fire training exercises.	BTEX, SVOCs, and TPH detected in soil in the burn pit area above PSGs. Benzene, PCE, and TPH detected in groundwater.	Unacceptable carcinogenic risk for hypothetical on-site residential exposure to soil (benzo[a]pyrene).	Soil: No further action. Groundwater: Collect one round of groundwater samples for PAH analysis using lower detection limits.
8	Sanitary Landfill	Wastes incl. ordinary shop and building refuse, paint cans, oil and paint residue, batteries, and broken equipment and parts were reportedly disposed of in trenches and buried.	Soil not sampled; evidence of landfilling not confirmed. No confirmed detections of PCBs, VOCs, SVOCs, or metals in groundwater above PSGs.	No unacceptable risks.	No further action.
9	Petroleum, Oil, and Lubricants Facility	Site consisted of 12 JP-4 USTS, 2 diesel ASTs, 1 waste oil UST, and filling stations.	Benzene, ethylbenzene, and PAHs in groundwater detected above PSGs.	Unacceptable total carcinogenic risk for hypothetical on-site residential exposure to soil (benzo[a]pyrene) and groundwater (primarily benzene and PAHs). Unacceptable noncarcinogenic hazard for hypothetical on-site residential exposure to groundwater (primarily benzene).	Soil: No further action. Groundwater: Remedial measures to prevent off-site migration and on-site exposure to groundwater with unacceptable concentrations.
10	Equipment Washrack	Liquids from equipment washing operations discharged via drain pipe to a roadside ditch.	Antimony, cadmium, lead, and selenium detected above PSGs in soil.	No unacceptable risks. One soil sample exceeded USEPA screening level for lead for an unrestricted use scenario.	No further action.
11	Washrack West of Building 250	Liquids from aircraft washing operations flowed from washrack area to the catch basin of the oil / water separator. Prior to removal, cracks were noticed in the oil / water separator.	Soil: Chlorinated VOCs, BTEX, TPH, and metals in area of former oil / water separator. Groundwater: VOCs and petroleum hydrocarbons in Shallow Zone; extend to northwest. Benzene, 1,2-DCA, cis-1,2-DCE, and vinyl chloride detected above PSGs in Deep Zone.	Unacceptable total carcinogenic risk and noncarcinogenic hazard for hypothetical on-site residential exposure to groundwater (primarily benzene, 1,2-DCA, and vinyl chloride).	Soil: In-situ treatment. Groundwater: Remedial measures to prevent off-site migration and on-site exposure to groundwater with unacceptable concentrations.

NOTES:

bgs - Below ground surface

ft - Feet

LUST - Leaking underground storage tank

PCB - Polychlorinated biphenyl

MEK - Methyl ethyl ketone

PCB - Polychlorinated Biphenyl

PSG - Project screening goal

UST - Underground storage tank

SVOC - Semivolatile organic compound

TPH - Total petroleum hydrocarbon

USEPA - United States Environmental Protection Agency

1,2-DCA - 1,2-Dichloroethane

AST - Aboveground storage tank

VOC - Volatile organic compound

TCE - Trichloroethylene

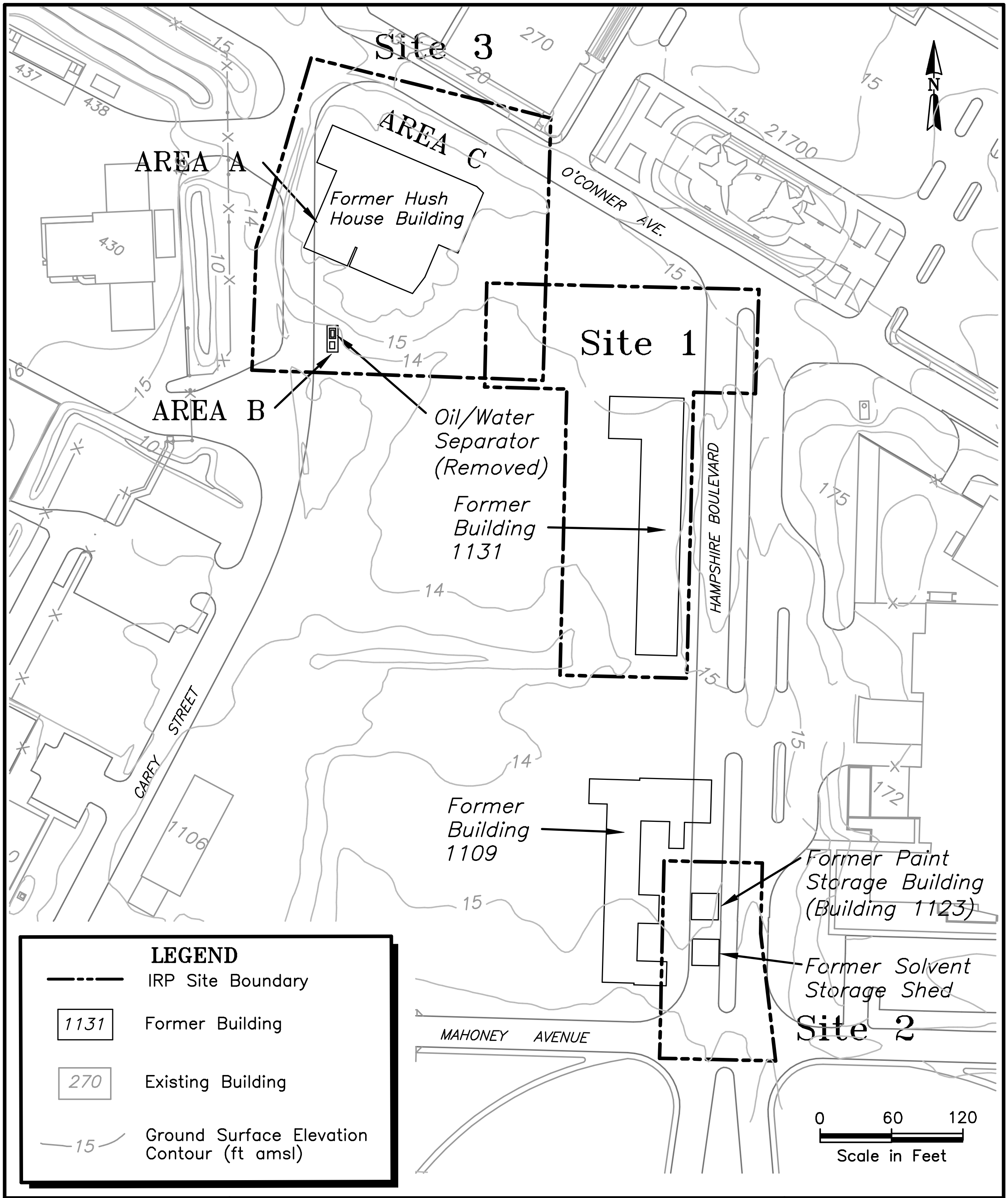
cis-1,2-DCE - cis-1,2-Dichloroethene

PCE - Tetrachloroethylene

PAH - Polynuclear aromatic hydrocarbon

BTEX - Benzene, toluene, ethylbenzene, and xylenes

IRP sites shown in blue are recommended for further evaluation in this Feasibility Study report. Groundwater issues at IRP Sites 1 and 3 are addressed under IRP Site 2



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IRP SITES 1, 2, and 3

142nd FW, PORTLAND ANGB
PORTLAND INTERNATIONAL AIRPORT
PORTLAND, OREGON

FIGURE 3-1

The surrounding area to the north and west of the site is grassy and unpaved. Hampshire Boulevard intersects the eastern part of the site and O'Conner Way borders the site on the north.

Building 1131 was a wooden structure that was used to store lawn maintenance equipment. An asphalt-paved area on the western side of the building was used for temporary storage of electrical transformers and other miscellaneous equipment.

Underground utility lines, including a new storm sewer, run along the eastern portion of the site. Surface water drains off-site through catch basins on the north and west sides of the site, flows into the Main Drainage Ditch along Carey Street, and is eventually pumped into the Columbia Slough from retention ponds at the west end of the Main Drainage Ditch.

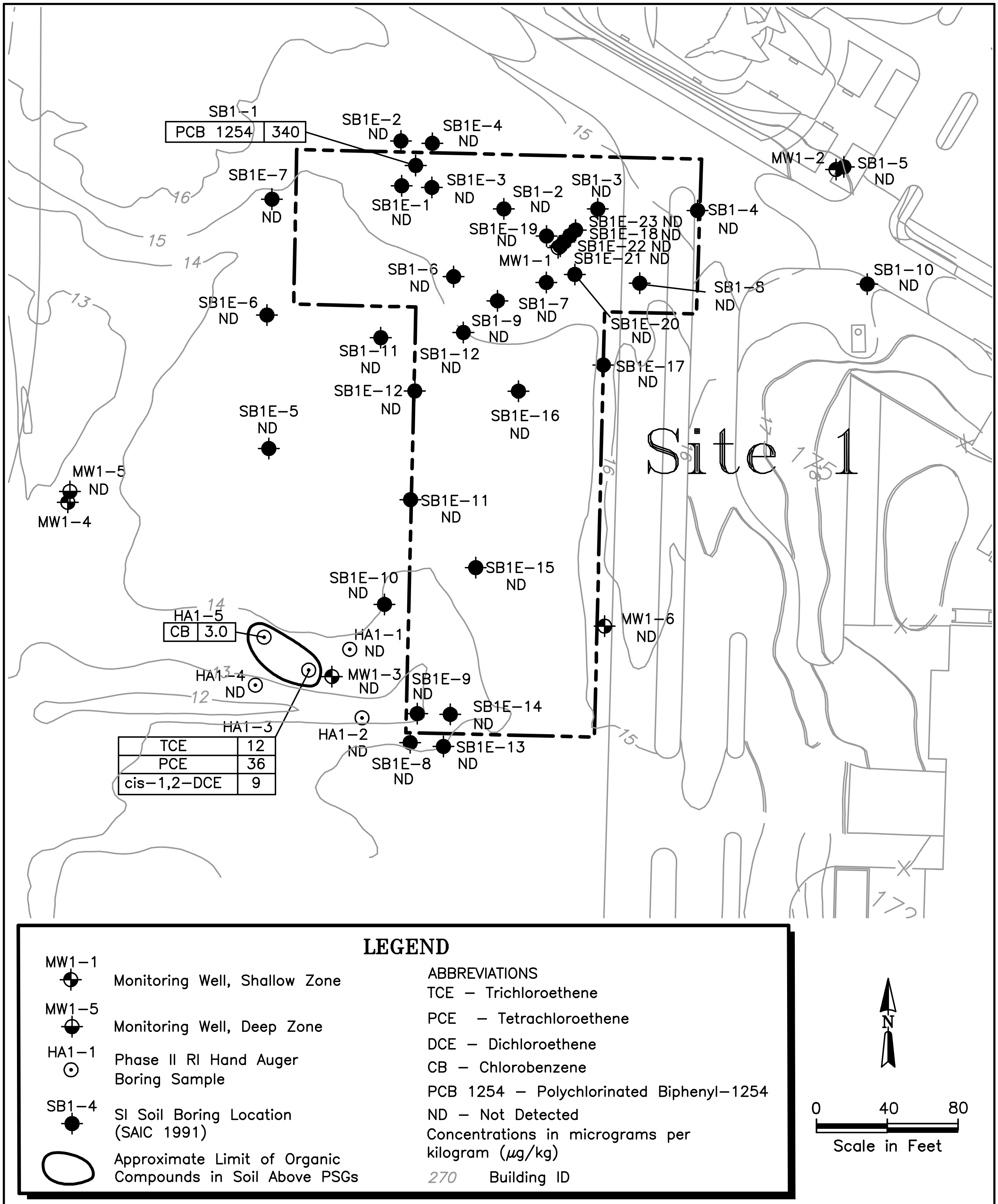
3.1.1 Waste Disposal History

Beginning in 1970, IRP Site 1 was used as a waste storage area for miscellaneous wastes including 55-gallon drums of waste oil, solvents, fuels, shop wastes, electrical transformers, and capacitors. Storage of these materials was suspended in approximately 1990.

3.1.2 Nature and Extent of Contamination

Cis-1,2-DCE and VC were the most prevalent VOCs detected in Shallow Zone groundwater proximal to IRP Site 1. In addition, cis-1,2-DCE was detected below the project screening goal (PSG) in Deep Zone well MW1-5 in July 2000. Based on the observed distribution of chlorinated VOCs in groundwater, IRP Site 2 appears to be the primary source area for the VOCs observed proximal to IRP Site 1. However, a potential secondary source was identified at Site 1 during the Phase II RI: low levels of TCE, tetrachloroethylene (PCE), and cis-1,2-DCE were detected in a soil sample collected within 10 feet of monitoring well MW1-3 (Figure 3-2). Degradation of the TCE detected in soil in this area could act as a source of cis-1,2-DCE and VC in groundwater. Additionally, the single detection of PCE in a sample from monitoring well MW1-3 in 1997 may be related to the PCE detected in soil.

Figure 3-3 shows the extent of VOCs in Shallow Zone groundwater at IRP Sites 1, 2, and 3, observed in April 2000. The VC concentration



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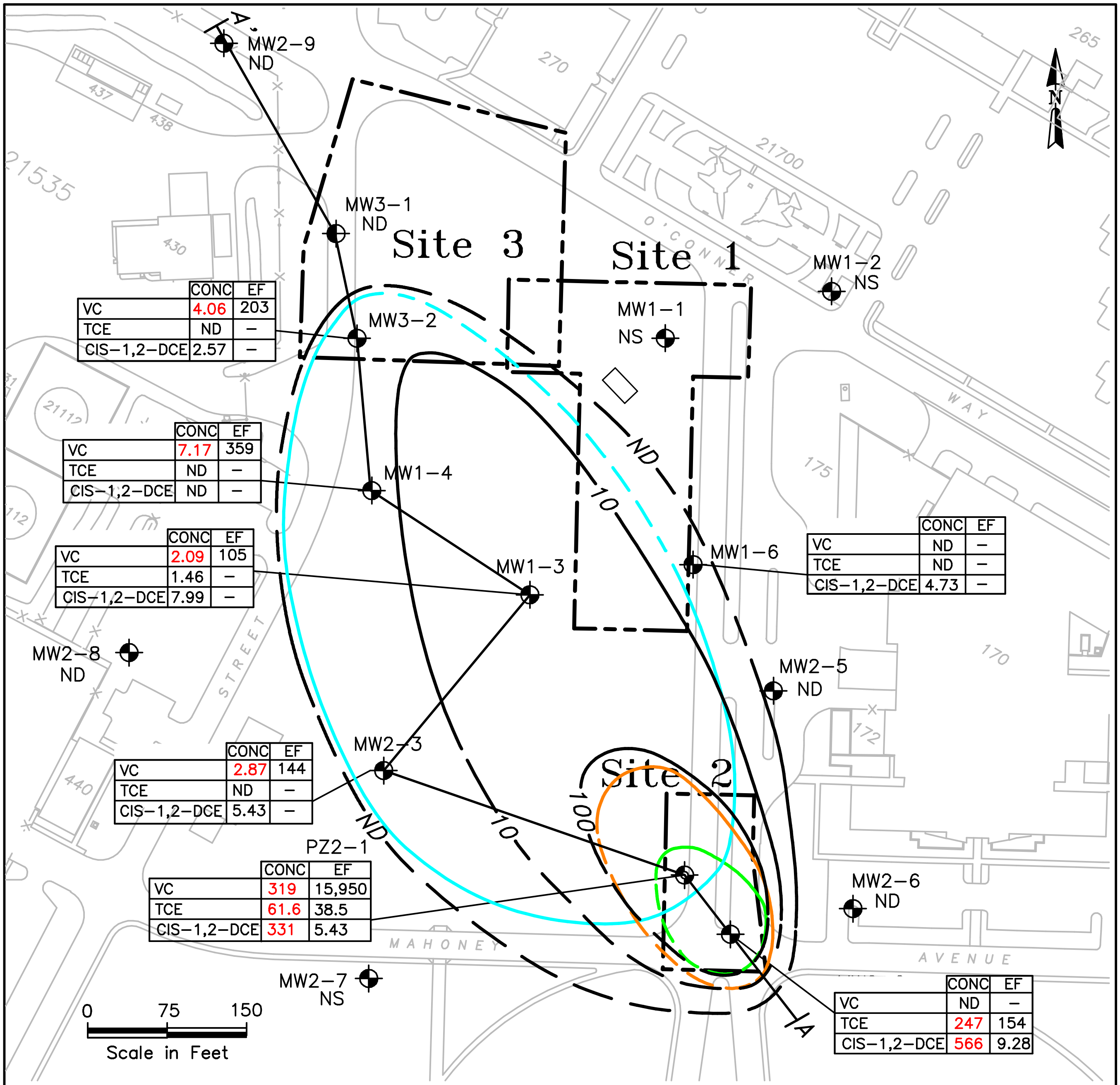
IRP SITE 1
EXTENT OF CONTAMINATION IN SOIL

142nd FW, PORTLAND ANGB
PORTLAND INTERNATIONAL AIRPORT
PORTLAND, OREGON

FIGURE 3-2



MW3−2

	CONC	EF
VC	4.06	203
TCE	ND	–
CIS−1,2−DCE	2.57	–

MW1−4

	CONC	EF
VC	7.17	359
TCE	ND	–
CIS−1,2−DCE	ND	–

MW1−3

	CONC	EF
VC	2.09	105
TCE	1.46	–
CIS−1,2−DCE	7.99	–

MW1−6

	CONC	EF
VC	ND	–
TCE	ND	–
CIS−1,2−DCE	4.73	–

MW2−3

	CONC	EF
VC	2.87	144
TCE	ND	–
CIS−1,2−DCE	5.43	–

PZ2−1

	CONC	EF
VC	319	15,950
TCE	61.6	38.5
CIS−1,2−DCE	331	5.43

	CONC	EF
VC	ND	–
TCE	247	154
CIS−1,2−DCE	566	9.28

LEGEND

⊕ Monitoring Well, Shallow Zone
⊕ Monitoring Well, Floodplain Silt
⊕ Piezometer, Shallow Zone

ND	Not Detected
NS	Not Sampled
–	Not Applicable
J	Estimated Value
PSG	Project Screening Goal
CONC	Concentration in μg/L. Values in Red Exceed PSGs.
EF	PSG Exceedence Factor

Estimated Extent of Cis−1,2−Dichloroethene (CIS−1,2−DCE) > PSG (61 μg/L); Dashed Where Inferred

Estimated Extent of Trichloroethene (TCE) > PSG (1.6 μg/L); Dashed Where Inferred

Estimated Extent of Vinyl Chloride (VC) > PSG (0.02 g/L); Dashed Where Inferred

270 Building ID

IRP Site Boundary Line

A├──┤A' Hydrogeologic Cross−Section Line

─10─ Total Chlorinated Hydro−carbon Concentration Contour (μg/L); Dashed Where Inferred

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IRP SITES 1, 2, & 3
SHALLOW ZONE
APPROXIMATE EXTENT of SELECTED VOCs EXCEEDING PSGs
APRIL 2000
142nd FW, PORTLAND ANGB
PORTLAND INTERNATIONAL AIRPORT
PORTLAND, OREGON

FIGURE 3−3

in well MW1-3 decreased by an order of magnitude following the initial groundwater sampling event in January 1997, and remained relatively stable through July 1999; the concentration detected in January 2000 was 17.6 µg/l; the concentration detected in April 2000 was 2.09 µg/l. Concentrations of TCE and cis-1,2-DCE in well MW1-3 have remained relatively stable throughout the monitoring program.

3.1.3 Risk Assessment Results

The results of the risk characterization for IRP Site 1 indicate the following:

- The estimated carcinogenic risks for Base workers, construction workers, and reservists are within the range of acceptable risk levels established by the USEPA (i.e., 1×10^{-6} to 1×10^{-4}).[1] Thus, the risks associated with the defined exposures are acceptable under USEPA guidelines. The carcinogenic risks for Base workers, construction workers, and reservists are also less than the ODEQ benchmark of 1×10^{-5} for total risk (i.e., exposure to multiple constituents and/or exposure via multiple pathways), indicating that the estimated carcinogenic risks are acceptable under ODEQ regulations.

- The estimated noncarcinogenic hazards for Base workers, construction workers, and reservists are below the USEPA and ODEQ acceptable hazard level (i.e., the calculated hazard indices are less than 1). Consistent with USEPA guidelines, this indicates that no adverse health effects are anticipated to occur under the defined conditions of exposure.

- The potential carcinogenic risk and noncarcinogenic hazard associated with soil exposures under a conservative residential scenario are less than USEPA and ODEQ guidelines for evaluation of acceptable risk. However, the total carcinogenic risk and noncarcinogenic hazard for hypothetical on-site residents exceed both USEPA and ODEQ levels of acceptable risk, as a result of assumed exposures to groundwater under the residential-use scenario. The risk is primarily associated with the presence of VC in groundwater. By extension of the results

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[1] A risk of 1×10^{-6} indicates that there is an upper bound probability of 1 in 1,000,000 (one million) that an individual will develop cancer during his or her lifetime as a result of the defined conditions of exposure. Because of the conservatism of the assumptions used to derive risk estimates, any actual risks associated with a defined exposure are expected to be lower than the estimated risks (USEPA 1989).

for the on-site residential scenario, the potential future risks to off-site residents related to the possible off-site migration and residential use of contaminated groundwater also exceed USEPA and ODEQ criteria.

3.1.4 Recommendation

The risks associated with soil at IRP Site 1 have been determined to be acceptable for all anticipated land-use scenarios. It is therefore recommended that no further action be performed related to soil.

The results of previous investigations at IRP Site 1 have indicated that the VOCs detected in Shallow Zone and Deep Zone groundwater at this site are primarily associated with a VOC plume originating from IRP Site 2. Accordingly, remedial alternatives developed for the VOCs in IRP Site 2 groundwater will include the area of the plume that has migrated onto IRP Site 1.

3.2 IRP Site 2 - Civil Engineering Hazardous Material Storage Area

The former Civil Engineering Hazardous Material Storage Area is east of former Building 1109, as shown on Figure 3-1. The site includes the former locations of the solvent storage shed and the paint storage building (Building 1123). The PA report (HMTC 1987) defined IRP Site 2 as the area between the storage shed and Building 1123; however, during the SI it was determined that the storage shed itself may also have been a source of contamination (SAIC 1991). The solvent storage shed consisted of an open-walled structure with a gravel floor. The storage shed and Building 1123 were removed during non-IRP-related construction activities.

Currently, IRP Site 2 is situated largely in the roadway of Hampshire Boulevard immediately north of the intersection with Mahoney Avenue. The former locations of the solvent storage shed and Building 1123 are in the southbound lanes of Hampshire Boulevard. Underground utilities and storm drains run along the eastern and western sides of Hampshire Boulevard. Site topography is relatively flat.

3.2.1 Waste Disposal History

Drums containing solvents, paint thinners, and methyl ethyl ketone were stored on wooden pallets in the solvent storage shed, and on a rack within the shed (HMTC 1987); paint was stored in Building 1123. There are no reports of waste disposal activities.

3.2.2 Nature and Extent of Contamination

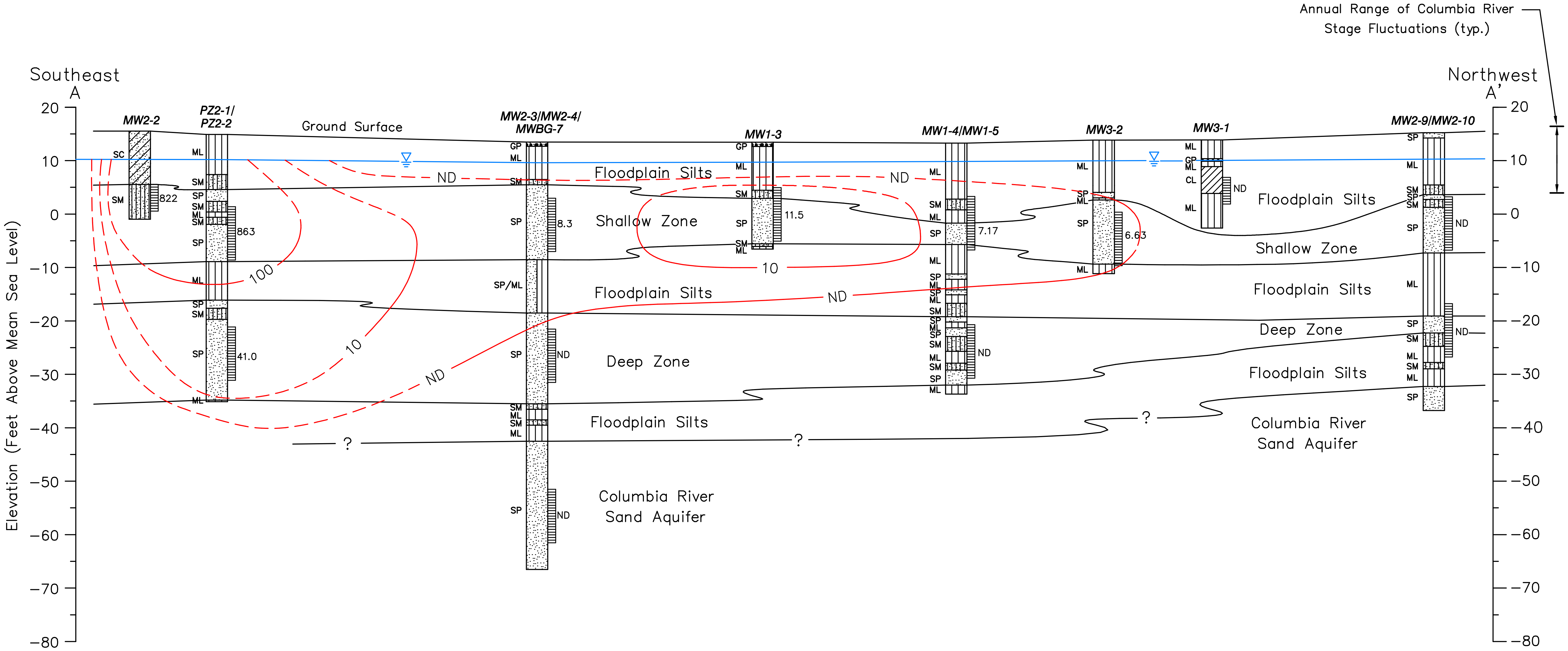
Chlorinated VOCs (primarily TCE; cis-1,2-DCE; and VC) were detected in groundwater in both the Shallow Zone and the Deep Zone at IRP Site 2. The highest concentrations of TCE; cis-1,2-DCE; and VC were detected near the former location of the solvent storage shed. This suggests that the dissolved VOCs originated from past releases in the vicinity of the solvent storage shed. VOCs were not detected in soil samples collected in this area during the Phase II RI, possibly because near-surface soils at Site 2 were removed during road construction activities.

The groundwater data indicate that dissolved VOCs have migrated mainly toward the northwest from the apparent source area at IRP Site 2. This migration pattern is consistent with the local direction of groundwater flow in the Shallow Zone. The dissolved VOC plume extends approximately 750 feet downgradient of IRP Site 2, and is approximately 400 feet wide. Figures 3-3 and 3-4 show the lateral and vertical extent of chlorinated hydrocarbons in groundwater. The absence or relatively low concentrations of VOCs in direct-push groundwater samples collected to the southwest, south, and southeast of Site 2 provides additional evidence that the VOC source area is at Site 2.

Concentrations of TCE and cis-1,2-DCE have varied significantly in source-area Shallow zone wells MW2-1 and MW2-2 over the monitoring period; concentrations of VC in piezometer PZ2-1 have also varied significantly.

Deep Zone wells/piezometers in the vicinity of IRP Site 2 include PZ2-2, MW2-4, MW1-5, and MW2-10. The consistent detections of VC above the PSG in piezometer PZ2-2, and the cis-1,2-DCE detections in wells MW1-5 and MW2-10 in July 2000, indicate that dissolved VOCs have migrated to the Deep Zone directly beneath and northwest of IRP Site 2.

There have been no confirmed detections of contaminants in the CRSA wells in the vicinity of IRP Site 2 (MWBG-7 and MWBG-10).



Note: See Figure 3–5 for Cross Section Orientation

Legend

27.5	Total Chlorinated Hydrocarbon Concentration (TCH) in April 2000 (μg/L)
▤	Screened Interval
▽	April 2000 Water Level in Shallow Zone
10	Line of Equal TCH Concentration (μg/L); Location Approximate; Dashed Where Inferred
ND	Not Detected
NS	Not Sampled
▨	Gravelly Clay/Sandy Clay/Silty Clay/Clay
▥	Silt/Clayey Silt/Sandy Silt
▨	Clayey Sand
▥	Silty Sand
░	Gravelly Sand/Sand
⁘	Gravel/Sandy Gravel

0 100
Feet
Vertical Exaggeration = 5x

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IRP SITES 1, 2, AND 3
VERTICAL DISTRIBUTION OF TOTAL CHLORINATED
HYDROCARBONS IN GROUNDWATER
APRIL 2000
142nd FW, PORTLAND ANGB
PORTLAND INTERNATIONAL AIRPORT
PORTLAND, OREGON

FIGURE 3–4

A source of the total petroleum hydrocarbon (TPH) as diesel detected in groundwater samples from several of the IRP Site 2 monitoring wells was not identified in soil. Soils containing residual hydrocarbons may have been removed during road construction activities. During monitoring events conducted in February 1998 and March 1999, TPH as diesel was detected in samples from monitoring well MW2-7, located immediately north of IRP Site 9. The presence of TPH as diesel at this well may be related to petroleum contamination identified at IRP Site 9.

With the exception of isolated detections of benzene (0.7 to 3 µg/l) in piezometers PZ2-1 and PZ2-2, and a single detection of toluene (0.6 µg/l) in piezometer PZ2-1, petroleum-related VOCs and semivolatile organic compounds (SVOCs) were not detected in the IRP Site 2 monitoring wells.

Buried utilities are present near IRP Site 2, particularly at the intersection of Mahoney Avenue and Hampshire Boulevard. These utilities may provide a preferential pathway for VOC vapors to travel a small distance away from the source of those vapors. If deep enough, the utility channels may allow groundwater to flow a short distance away from the general flow path. However, would need to be buried at the depth required (below approximately 12 feet bgs) to have any effect on groundwater contaminant flow direction. The apparent contaminant distribution from the source area at IRP Site 2 is relatively uniform, indicating that preferential pathways resulting from the presence of buried utilities are not affecting distribution of contaminants. Remedial action at this site will require consideration of the presence of buried utilities.

3.2.3 Risk Assessment Results

The results of the risk characterization for IRP Site 2 indicate the following:

- Both the estimated carcinogenic risks and the noncarcinogenic hazards are acceptable for Base workers, construction workers, and reservists under USEPA and ODEQ guidelines.

- The potential carcinogenic risk and noncarcinogenic hazard associated with soil exposures under a conservative residential scenario are less than USEPA and ODEQ guidelines for evaluation of acceptable risk. However, the total carcinogenic risk and noncarcinogenic hazard for hypothetical on-site residents exceed both USEPA and ODEQ levels of acceptable risk, as a result of assumed exposures to groundwater under the residential-use scenario. The risk is primarily associated with the presence of VC in groundwater. By extension of the results for the on-site residential scenario, the potential future risks to off-site residents related to the possible off-site migration and residential use of contaminated groundwater also exceed USEPA and ODEQ criteria.

- Reported lead concentrations in soil were below the USEPA screening level of 400 milligrams per kilogram (mg/kg) for an unrestricted-use scenario (USEPA Region 9 2000); thus lead in soil is not expected to pose an unacceptable risk.

3.2.4 Recommendation

The risks associated with soil at IRP Site 2 have been determined to be acceptable for all anticipated land-use scenarios. It is therefore recommended that no further action be performed related to soil.

As discussed, previous investigations have indicated that the VOCs in groundwater in the area of IRP Sites 1 and 2 have originated from releases at the former solvent storage shed at IRP Site 2. In addition, previous investigations also indicate a probably correlation between VOCs in groundwater at IRP Site 3 (as discussed in Section 3.3) and releases at the former solvent storage shed. As such, the VOCs in groundwater at IRP Sites 1, 2, and 3 will be addressed in this FS as one plume, and referred to as IRP Site 2 groundwater.

Anticipating the need to conduct an FS for groundwater at IRP Site 2, the IRAC program described in Section 2.8.2 was initiated for the purpose of providing data from which to base decisions made during the FS process. The first phase of the IRAC provided bench- and pilot-scale treatability data indicating that chemical and biological treatment technologies are effective at reducing VOC concentrations in groundwater at IRP Site 2. Using these results, a presumptive approach was taken to select potential remedies for VOCs in groundwater. The second phase of the IRAC program is expected to be conducted during the fall of 2001 and will provide full-scale treatability data to be used to adjust some of the recommendations made during this FS prior to full-scale RA construction.

The second phase of the IRAC program is also intended to significantly reduce the mass of VOCs at IRP Site 2. The full-scale demonstration will focus on a large area of Shallow Zone groundwater containing the highest concentrations of VOCs (ERM 2001d). Implementation of this demonstration is expected to reduce the potential for migration of VOCs to downgradient areas of the Shallow Zone and to the Deep Zone.

Although a significant reduction of VOCs is expected during the second phase of the IRAC program, a conservative position is taken in this FS by not considering this reduction during the development and evaluation of the remedial alternatives presented later in the document.

Due to the extent and concentrations of VOCs in Shallow Zone and Deep Zone groundwater originating from IRP Site 2, remedial alternatives were developed based on technologies known to be effective at treating VOCs in groundwater. Identification and screening of technologies are presented in section 4.0 of this FS. Development and evaluation of remedial alternatives are presented in section 5.0 of this FS.

3.3 IRP Site 3 - Hush House Area

The former Hush House Area is at the southeast corner of the intersection of Carey Street and O'Conner Way, as shown on Figure 3-1. The Hush House building was used to test the performance of jet engines. An oil/water separator existed approximately 75 feet south of the Hush House. An exhaust tower and associated piping from the condensation system drained into the oil/water separator and a holding tank.

During the SI, the former Hush House building was designated as Area A, the oil/water separator was designated as Area B, and an area to the northeast of the former Hush House, where petroleum hydrocarbon contamination was encountered during construction activities, was designated as Area C.

The ground surface across most of IRP Site 3 is approximately 2 to 3 feet higher than the surrounding area, and generally slopes toward the south and east. Site surface water drains into the Main Drainage Ditch through a culvert that passes under Carey Street to the west.

3.3.1 Waste Disposal History

Drums of waste oil, fuel, and solvents were reportedly stored at the southwest corner of the Hush House on an unpaved surface (SAIC 1991). Base personnel interviewed during the PA indicated that the oil/water separator did not function properly. No records were available concerning removal of liquids from the separator or the associated holding tank (HMTC 1987).

3.3.2 Nature and Extent of Contamination

The results of the Phase II RI and previous investigations at IRP Site 3 are discussed below.

3.3.2.1 Area A, Former Hush House Building

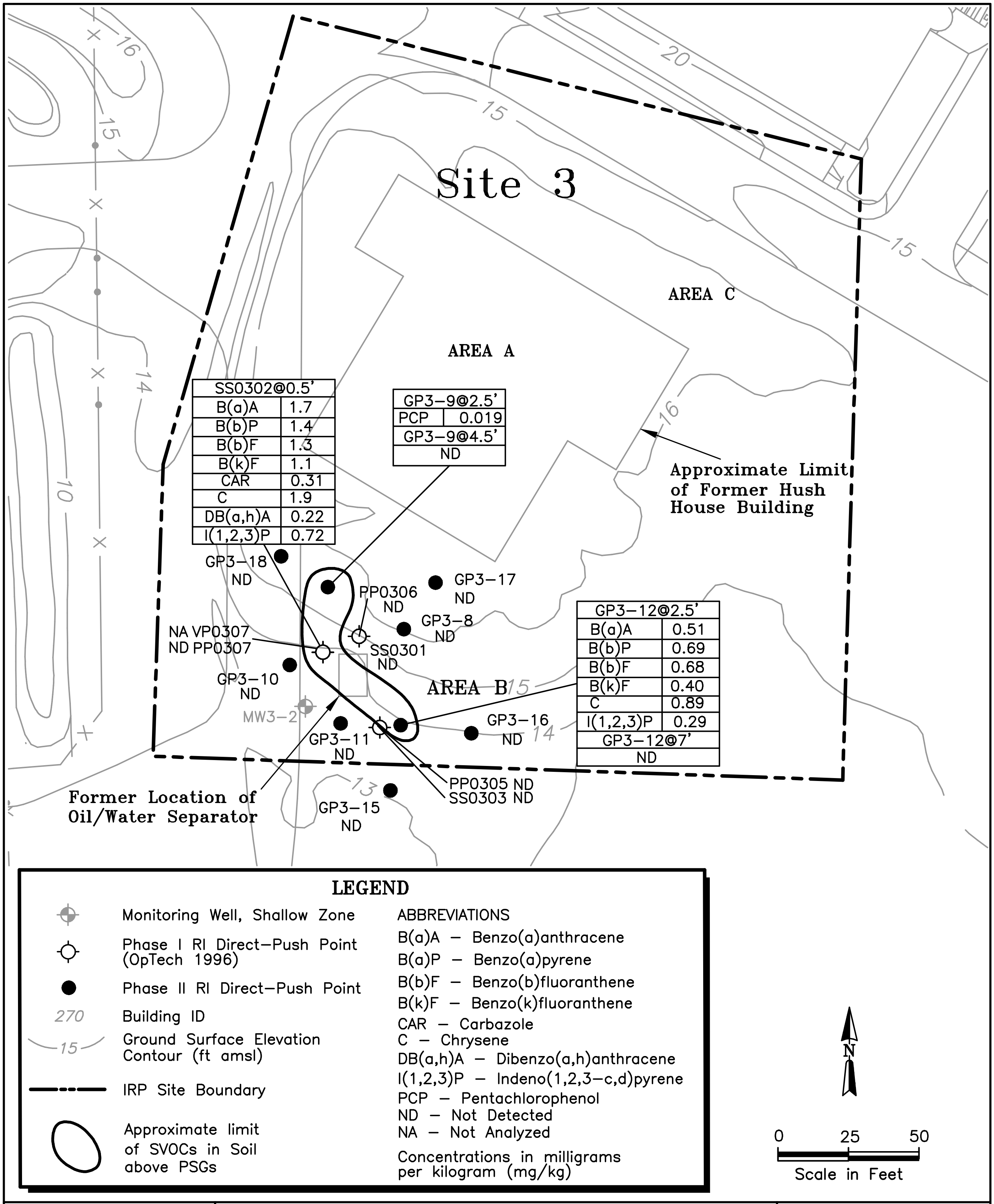
No confirmed contaminants were detected in the soil and groundwater samples collected at Area A during the SI, consequently, no further investigation of this area was performed during the Phase I or II RIs.

3.3.2.2 Area B, Former Oil/Water Separator

Constituents detected above PSGs in soil samples collected at Area B include benzene, petroleum-related SVOCs, TPH as diesel, and metals. SVOC, TPH, and metal concentrations detected in soil samples are shown on Figures 3-5, 3-6, and 3-7 respectively. The RI sampling indicates that the lateral extent of soils impacted by compounds exceeding PSGs is limited to within 30 to 40 feet of the former oil/water separator. Although the lateral extents of TPH and SVOC impacts are almost identical, the data indicate that the maximum TPH concentrations occur at a depth of approximately 8 feet bgs, whereas SVOCs are primarily limited to the upper 2.5 to 3 feet of soil. Metal concentrations exceeding PSGs also are limited to the upper 2.5 to 3 feet of soil.

Petroleum-related SVOCs and TPH as diesel were detected in soils potentially in contact with groundwater. However, only naphthalene and benzene were detected above PSGs in groundwater samples. The naphthalene and benzene were detected close to borings PP0306 and PP0307, in which the highest TPH concentrations in soil were detected close to the water table. TPH-related groundwater impacts are limited to within 10 to 20 feet of the former oil/water separator.

Although VC and other chlorinated VOCs were detected in groundwater at Area B, chlorinated VOCs were not detected in soil. This indicates that the former oil/water separator is not likely a source of the chlorinated VOCs. Further, the presence of chlorinated VOCs in groundwater at IRP Site 3 is likely associated with Site 2 groundwater (Figure 3-3).



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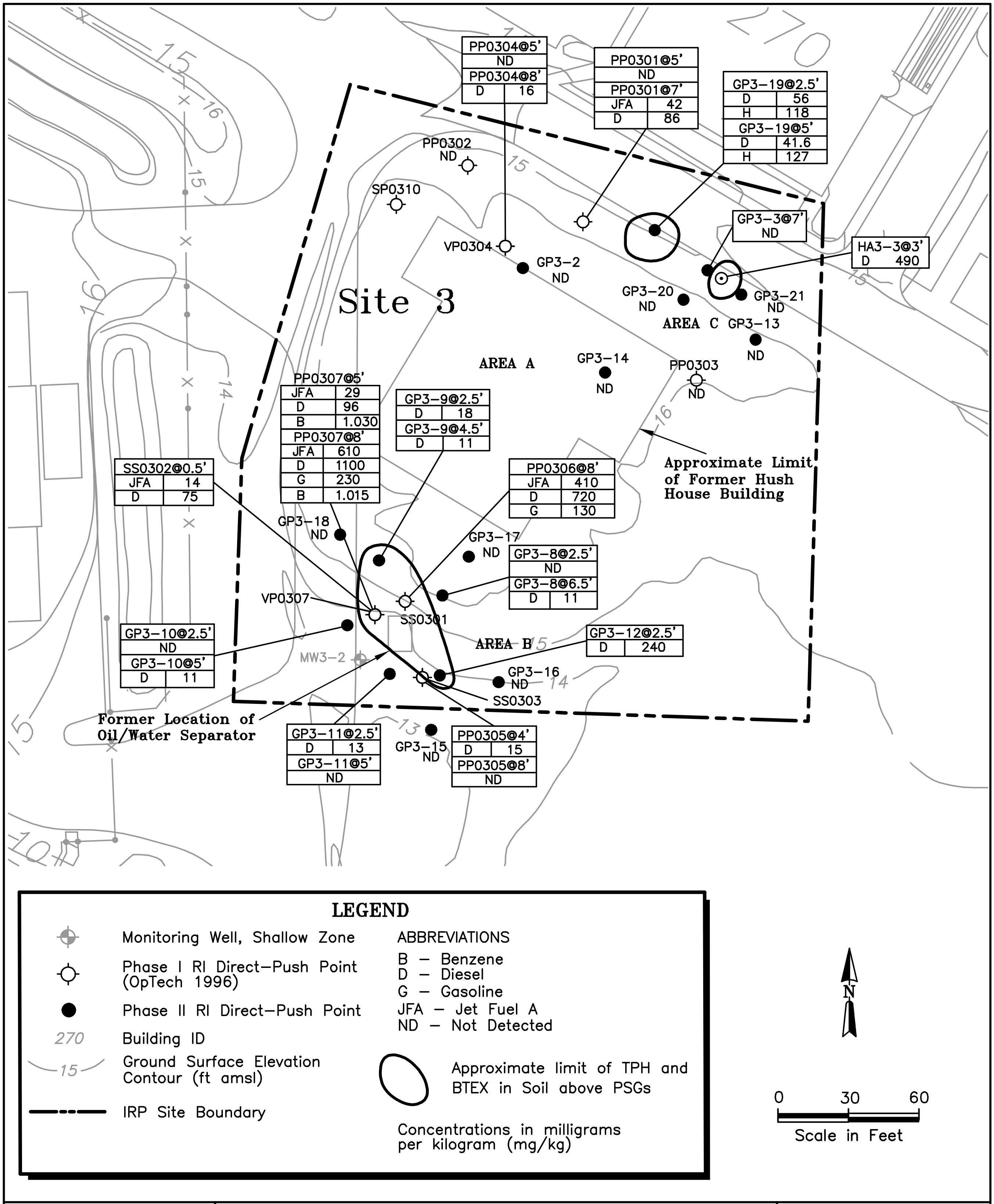
IRP SITE 3
EXTENT OF SEMIVOLATILE ORGANIC COMPOUNDS IN SOIL
142nd FW, PORTLAND ANGB
PORTLAND INTERNATIONAL AIRPORT
PORTLAND, OREGON

FIGURE 3-5



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IRP SITE 3
EXTENT OF TOTAL PETROLEUM HYDROCARBONS IN SOIL
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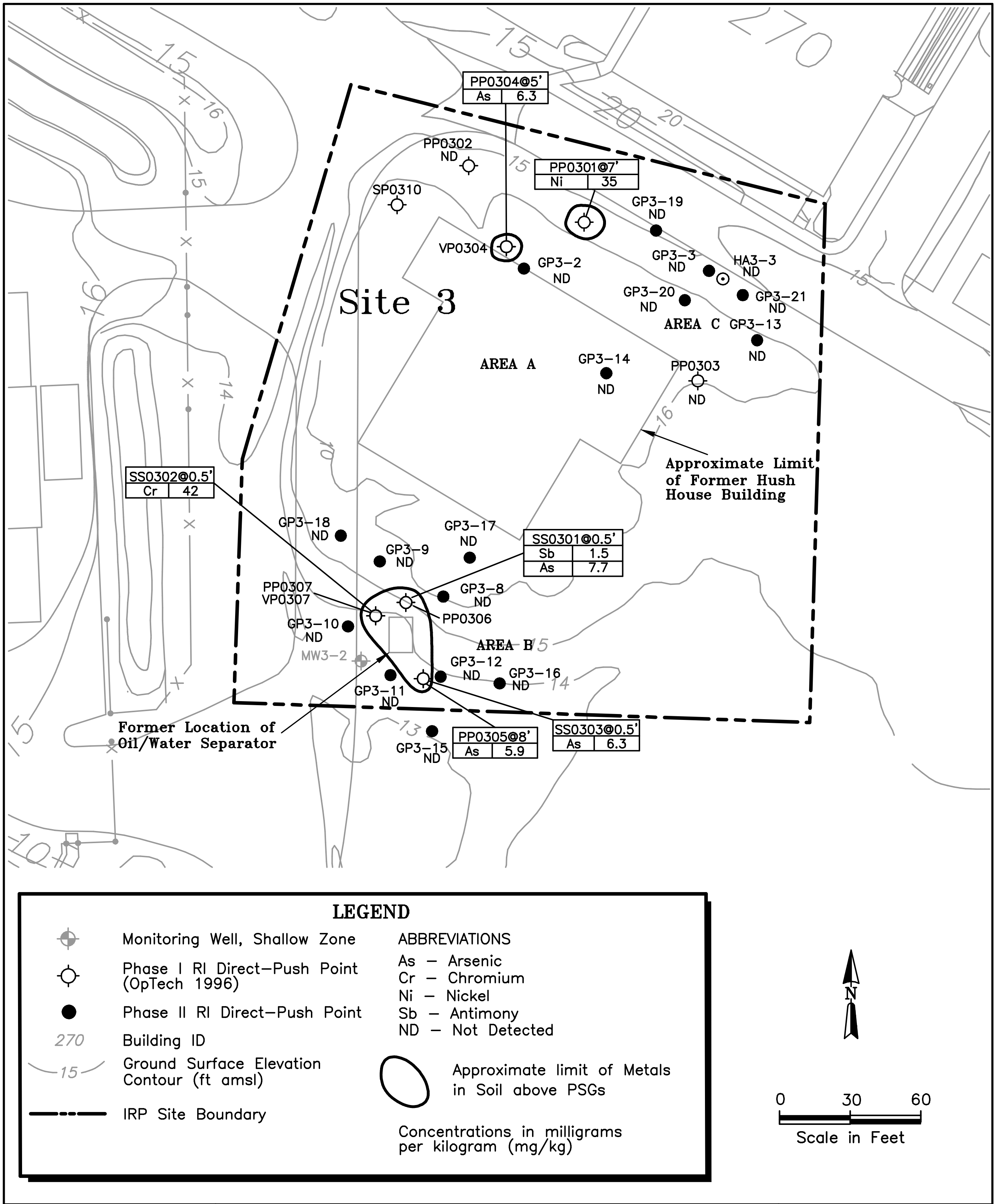
PORTLAND INTERNATIONAL AIRPORT
PORTLAND, OREGON

FIGURE 3-6



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IRP SITE 3
EXTENT OF METALS IN SOIL

142nd FW, PORTLAND ANGB
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PORTLAND, OREGON

FIGURE 3-7

3.3.2.3 Area C, Construction Area

TPH as Jet Fuel A, TPH as diesel, and/or TPH as heavy oil were detected in soil samples collected from borings PP0301, PP0304, and HA3-3. Detections above PSGs include TPH as diesel (490 mg/kg) in the sample collected from 3 feet bgs in boring HA3-3, and TPH as heavy oil in the samples collected from 2.5 feet bgs (118 mg/kg) and 5 feet bgs (127 mg/kg) in boring GP3-19. TPH detections in soil are shown on Figure 3-6. VOCs and SVOCs were not detected in the groundwater sample collected from boring GP3-3.

3.3.3 Risk Assessment Results

The results of the risk characterization for IRP Site 3 indicate the following:

- Both the estimated carcinogenic risks and the noncarcinogenic hazards are acceptable for Base workers, construction workers, and reservists under USEPA and ODEQ guidelines.

- The total estimated carcinogenic risk for hypothetical on-site residents exceeds USEPA and ODEQ acceptable levels, primarily as a result of assumed exposures to benzo(a)pyrene and dibenz(a,h)anthracene in soil and benzene and VC in groundwater under this scenario. By extension of the results for the on-site residential scenario, the potential future carcinogenic risk to off-site residents related to the possible off-site migration and residential use of contaminated groundwater also exceeds USEPA and ODEQ criteria. The total noncarcinogenic hazard is acceptable for both hypothetical on-site residents and off-site residents under USEPA and ODEQ guidelines.

- Reported lead concentrations in soil were below the USEPA screening level for an unrestricted-use scenario; thus lead in soil is not expected to pose an unacceptable risk.

3.3.4 Recommendation

No confirmed contaminants have been detected in soil or groundwater at Area A. It is therefore recommended that no further action be performed at this location.

Soil at Area B in the location of the former oil/water separator contains several contaminants above the PSGs. However, the risk associated with soil in this area is acceptable based on an industrial land-use scenario. It is not expected that the industrial land use of this area will change in the near future (City of Portland 2000).

The results of previous investigations at Area B have indicated that the VOCs detected in groundwater at this site are primarily associated with the VOC plume originating from IRP Site 2, rather than from soil contamination at Area B. As previously mentioned, the area of the plume that has migrated onto IRP Site 3 will be addressed in the remedial alternatives developed for VOCs in IRP Site 2 groundwater.

Area C soil has had detections of petroleum hydrocarbons exceeding the respective PSGs for these constituents. However, because of the small volume of impacted soil and the current and anticipated industrial land use, it is recommended that no further action be performed at this location.

3.4 IRP Site 4 - Main Drainage Ditch

The Main Drainage Ditch in the western-central portion of the Portland ANGB receives surface water runoff from catch basins and drainage ditches across most of the Base. The water in the Main Drainage Ditch flows to two retention ponds near the western Base boundary. Water from the retention ponds is pumped into a ditch west of the Base that discharges into the Columbia Slough.

3.4.1 Waste Disposal History

During initial field surveillance activities and sampling, HMTC (1987) reported the presence of petroleum and oil in the Main Drainage Ditch downstream from the flight apron outfall. Accidental spillage, indirect discharge, and wash water containing residual contaminants from facilities adjacent to the ditch may have impacted storm water and sediments in the ditch (SAIC 1991). There are no records of wastes being intentionally disposed of in the ditch.

3.4.2 Nature and Extent of Contamination

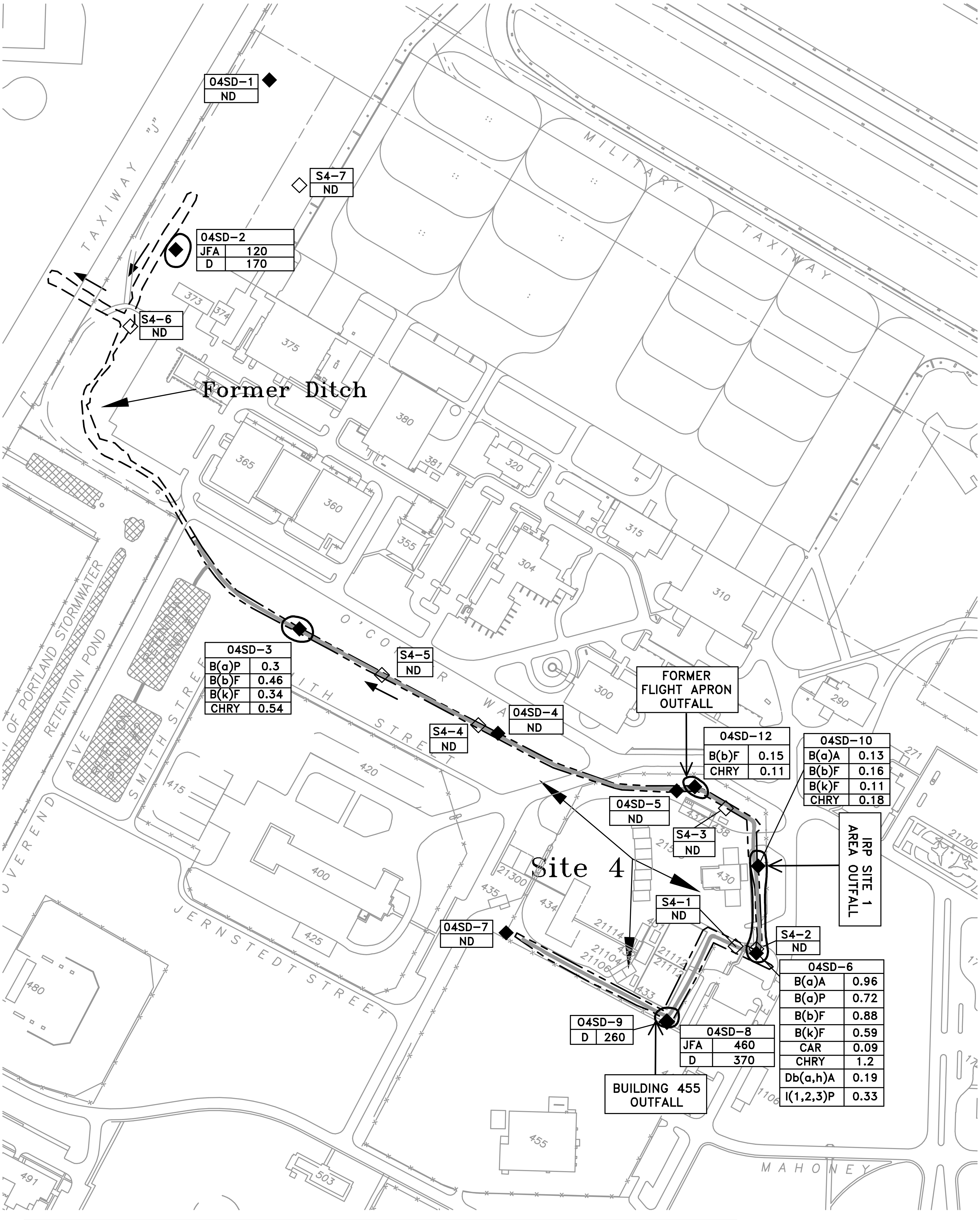
Investigation results at IRP Site 4 indicate that sediment in the Main Drainage Ditch contains SVOCs, TPH, and metals above the respective PSGs. Surface water samples collected at Site 4 during the RI were found to contain bromodichloromethane, cis-1,2-DCE, antimony, cadmium, copper, lead, and/or zinc above the respective PSGs.

The majority and highest concentrations of SVOCs were detected in sediment in the eastern portion of the ditch (samples 04SD-6, 04SD-9, 04SD-10, and 04SD-12). This portion of the ditch receives surface runoff from several storm drain outfalls (Figure 3-8). SVOCs also were detected above respective PSGs in sediment sample 04SD-3 collected near the central portion of the ditch. SVOCs, however, either were not detected or were detected below PSGs in the two sediment samples (04SD-4 and 04SD-5) collected immediately upstream of this location. The source of the SVOCs detected in sample 04SD-3 is unclear.

TPH as diesel was detected above the PSG in three sediment samples (04SD-2, 04SD-8, and 04SD-9) collected from the Main Drainage Ditch (Figure 3-8). Sample 04SD-2 was collected at the former west end of the ditch at the discharge point for surface water runoff originating from the Base parking lots. Samples 04SD-8 and 04SD-9 were collected at the east end of the ditch, below the outfall of a drain line that originates in the area of the Base motor pool (Building 455). The highest concentration of TPH as diesel detected was 370 mg/kg (sample 04SD-8).

Metals were detected above respective PSGs in the majority of the sediment samples collected from the Main Drainage Ditch (Figure 3-9). Cadmium was the metal most frequently detected above PSGs. The highest concentrations of metals were detected in sample 04SD-8, which was collected below the Building 455 outfall.

Bromodichloromethane and dissolved metals (antimony, cadmium, copper, lead, and zinc) were detected above respective PSGs in surface water samples collected during the Phase I RI. Cis-1,2-DCE was detected above the PSG in one surface water sample, and zinc was detected above the PSG in two surface water samples collected during the Phase II RI. The presence of detectable organic compounds and metals in the ditch water likely depends on a variety of factors, including seasonal precipitation patterns and surface water flow rates. Metals detected above PSGs in surface water are shown on Figure 3-10. There is no apparent correlation between the concentrations of metals detected in surface water and those detected in sediment near the same locations.



LEGEND

▨ Retention Pond

◆ 04SD-1 Phase I RI Sediment Sampling Location (OpTech 1996)

◇ S4-1 SI Sediment Sampling Location (SAIC 1991)

○ Approximate Extent of Organic Compounds Above PSGs in Sediment

↖ Direction of Water Flow

↖ Drainline Out-Fall

—·— IRP Site Boundary

ABBREVIATIONS

JFA – Jet Fuel A

D – Diesel

B(a)A – Benzo(a)anthracene

B(a)P – Benzo(a)pyrene

B(b)F – Benzo(b)fluoranthene

B(k)F – Benzo(k)fluoranthene

CAR – Carbazole

CHRY – Chrysene

Db(a,h)A – Dibenzo(a,h)anthracene

I(1,2,3)P – Indeno(1,2,3-CD)pyrene

Concentrations in milligrams per kilogram (mg/kg)

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IRP SITE 4
EXTENT OF ORGANIC COMPOUNDS IN SEDIMENT

142nd FW, PORTLAND ANGB
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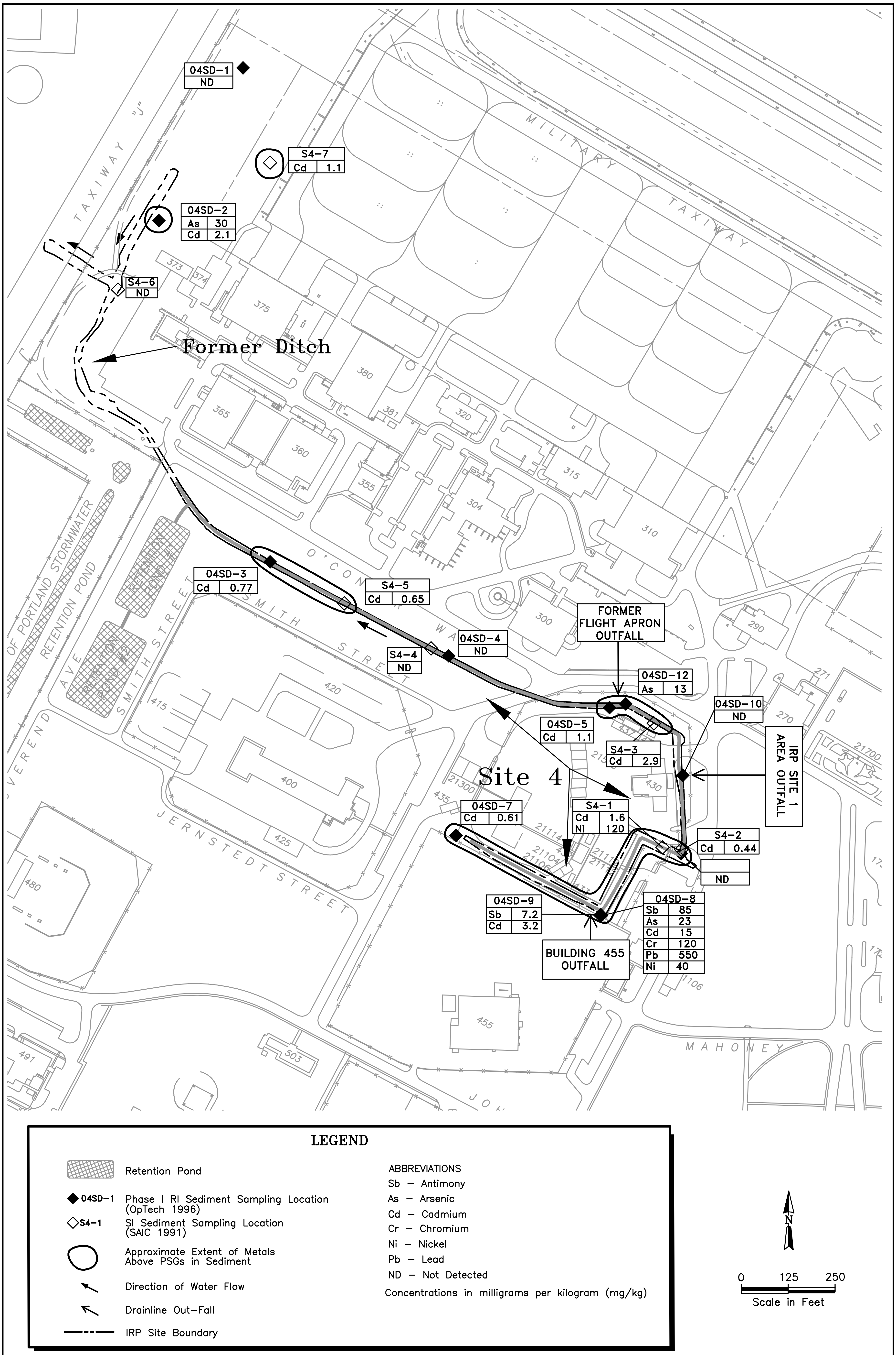
PORTLAND, OREGON

FIGURE 3-8



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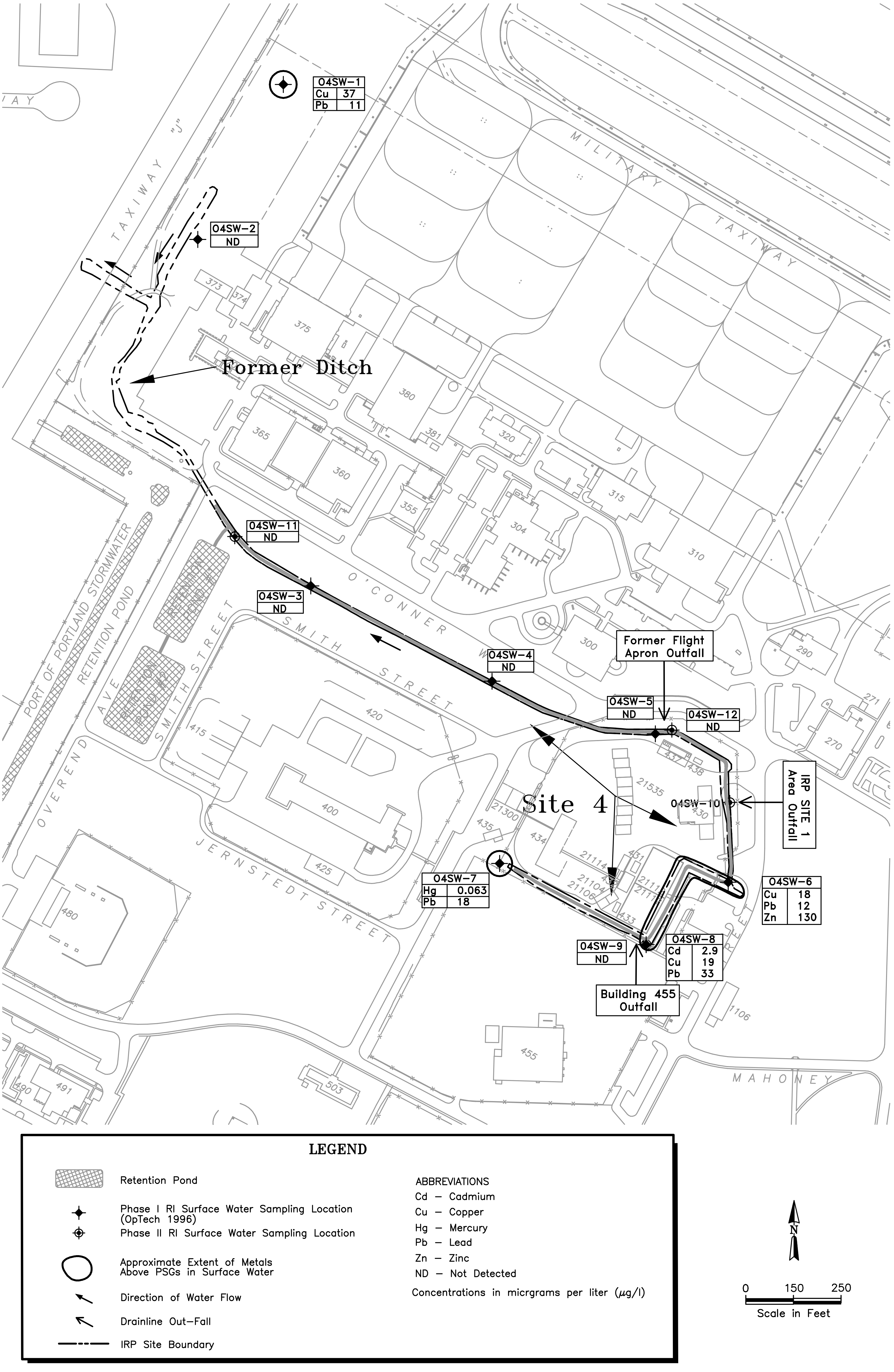
IRP SITE 4
EXTENT OF METALS IN SEDIMENT

142nd FW, PORTLAND ANGB
PORTLAND INTERNATIONAL AIRPORT
PORTLAND, OREGON

FIGURE 3-9



LEGEND

▨	Retention Pond
✦	Phase I RI Surface Water Sampling Location (OpTech 1996)
⊕	Phase II RI Surface Water Sampling Location
○	Approximate Extent of Metals Above PSGs in Surface Water
↖	Direction of Water Flow
↖	Drainline Out-Fall
—·—	IRP Site Boundary

ABBREVIATIONS

Cd – Cadmium
Cu – Copper
Hg – Mercury
Pb – Lead
Zn – Zinc
ND – Not Detected

Concentrations in micrgrams per liter ($\mu g/l$)

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IRP SITE 4
EXTENT OF METALS IN SURFACE WATER

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PORTLAND, OREGON

FIGURE 3-10

3.4.3 Risk Assessment Results

The results of the risk characterization for IRP Site 4 indicate that the estimated carcinogenic risk and the noncarcinogenic hazard are acceptable for construction workers under USEPA and ODEQ guidelines. The results of the screening-level ecological risk assessment indicate that contaminants detected in surface water and sediment in the Main Drainage Ditch do not pose unacceptable risks to on-site ecological receptors. However, because off-site habitats are considered to be of moderate-to-high value to wildlife, further monitoring of the potential for contaminants to migrate from the Main Drainage Ditch to off-site habitats is warranted. In addition, a Level II (screening) ecological risk assessment is planned to further evaluate potential risks to ecological receptors at the Main Drainage Ditch.

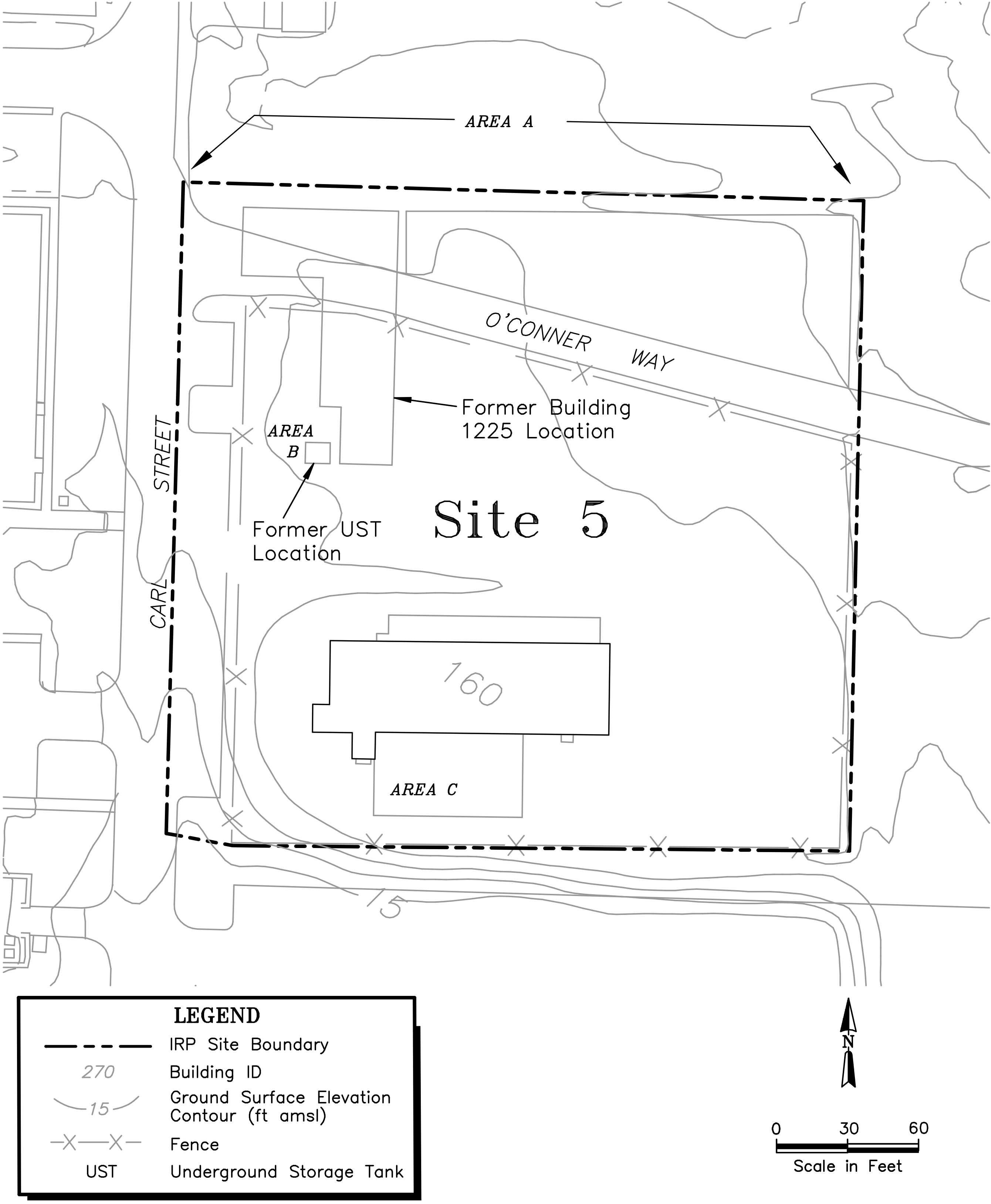
3.4.4 Recommendation

No unacceptable risks were identified at IRP Site 4. However, based on a recommendation made in the RI, monitoring of the potential for contaminants to migrate from the Main Drainage Ditch to off-site habitats will be continued. Based on recommendations from DEQ, the Level II ecological risk assessment mentioned above will be performed to verify the lack of impacts to ecological receptors at the Main Drainage Ditch.

3.5 IRP Site 5 - Aerospace Ground Equipment Maintenance Shop

Liquid wastes were reportedly disposed of to the ground surface at points along two fence lines at the AGE Maintenance Shop. One area (Area A) is north of O’Conner Way, and the second (Area C) is approximately 50 feet south of Building 160 (Figure 3-11). The former location of a leaking UST is designated as Area B. The UST, Building 1225, and the northern fence line were removed in 1988. O’Conner Way separates the remainder of IRP Site 5 from the former northern fence line.

The topography at IRP Site 5 is relatively flat with a slight slope toward the north and the east. Stormwater catch basins exist near the eastern and southern site boundaries. There are storm sewer and water lines along the east side of Carl Street, and buried power lines along O’Conner Way.



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IRP SITE 5

AEROSPACE GROUND EQUIPMENT MAINTENANCE SHOP

142nd FW, PORTLAND ANGB
PORTLAND INTERNATIONAL AIRPORT
PORTLAND, OREGON

FIGURE 3-11

3.5.1 Waste Disposal History

Wastes generated at the AGE Maintenance Shop include spent battery acid, solvents, lubricants, antifreeze, cleaning solutions, and automobile fluids. Some of these wastes may have been disposed of along the northern and southern fence lines as evidenced by soil staining (HMTC 1987). The former leaking UST contained heating oil, and was excavated and removed in late 1988.

3.5.2 Nature and Extent of Contamination

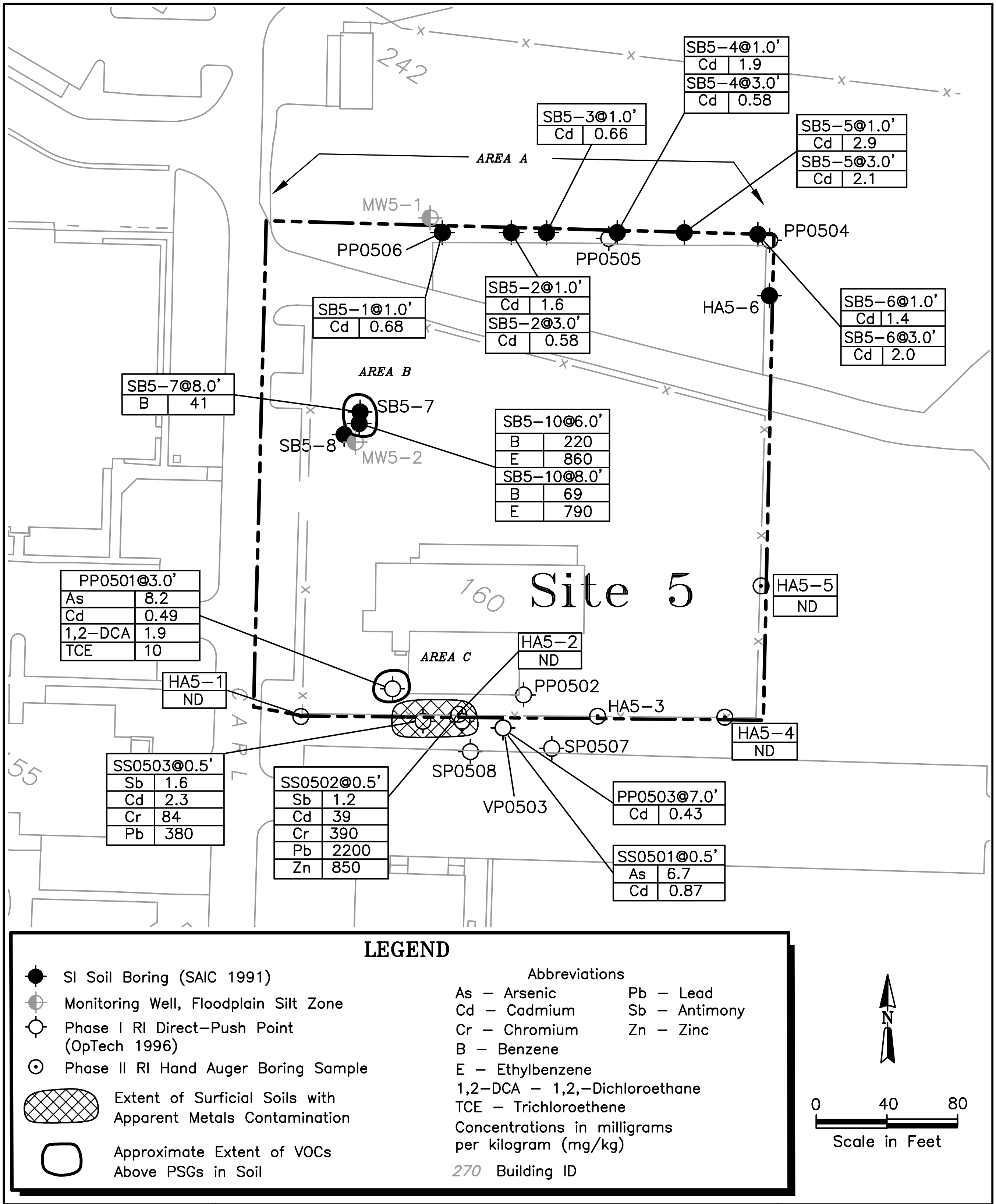
The results of the investigations conducted at Areas A and C are discussed below. Area B was not investigated as part of the IRP; this area is being addressed through the Base’s UST program.

3.5.2.1 Area A, Former Northern Fence Line

The soil investigations conducted at Area A have not found conclusive evidence to indicate that wastes were discharged to the ground surface along the northern fence line. Although cadmium was detected above the PSG in ten of the twelve soil samples collected along the former fence line (Figure 3-12), the frequency of the detections suggests that the elevated cadmium levels may be associated with imported fill material or native soil conditions in the vicinity of IRP Site 5.

TCE was detected above the PSG in groundwater samples collected from monitoring well MW5-1 in December 1988 at a concentrations of 6.2 µg/l, and in April 1996 at a concentration of 2.5 µg/l. In May 1996, TCE also was detected below the PSG in direct-push groundwater sample PP0506 (located within 5 to 10 feet of monitoring well MW5-1) 1 at a concentration of 1.3 µg/l. TCE was not detected in well MW5-1 during the Phase II RI. Concentrations of chloroform; 1,2-dichlorobenzene; toluene; and xylene were each detected in samples collected from well MW5-1, at concentrations of 2.0 µg/l or less. Five reported detections of methylene chloride (0.49 to 8.5 µg/l) in IRP Site 5 groundwater samples are suspected laboratory artifacts.

The source of the VOCs detected in groundwater is uncertain, but the absence of VOCs in soil indicates that Area A is not a likely source. The VOCs and TPH as diesel detected in monitoring well MW5-1 may be related to the former leaking UST at Area B.



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IRP SITE 5
EXTENT OF CONTAMINATION IN SOIL

142nd FW, PORTLAND ANGB
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PORTLAND, OREGON

FIGURE 3-12

3.5.2.2 Area C, Southern Fence Line

The constituents 1,2-dichloroethene (1,2-DCA) and TCE were detected above respective PSGs in the soil sample collected from 3 feet bgs in boring PP0501. VOCs were not detected in the soil sample collected from 7 feet bgs in boring PP0501, nor were VOCs detected in other soil samples collected at Area C.

Antimony, arsenic, cadmium, chromium, lead, and/or zinc were detected above respective PSGs in three surface soil samples and two subsurface soil samples collected at Area C during the Phase I RI. As discussed above, the frequency of cadmium detections above the PSG at IRP Site 5 suggests that the elevated cadmium levels may be associated with imported fill or native soil conditions in the area. Additionally, although arsenic was detected above the PSG in one surface soil sample and one subsurface soil sample, these detections were not associated with elevated concentrations of other metals. This suggests that the elevated arsenic levels may also be naturally-occurring.

The concentrations of antimony, cadmium, chromium, and lead in surface soil samples SS0502 and SS0503, and zinc in sample SS0502, are higher than area background concentrations of these metals, and may be indicative of local surface soil contamination. The lateral extent of the apparent contamination is shown on Figure 3-12. The absence of metals detected above respective PSGs in the soil sample collected from 1.5 feet bgs in boring HA5-2 indicates that the vertical extent of contamination is limited to approximately the upper 1 foot of soil.

3.5.3 Risk Assessment Results

The results of the risk characterization for IRP Site 5 indicate the following:

- Both the estimated carcinogenic risks and the noncarcinogenic hazards are acceptable for Base workers, construction workers, reservists, hypothetical on-site residents, and by extension, off-site residents, under USEPA and ODEQ guidelines.

- With one exception, reported lead concentrations in soil were below the USEPA screening level of 400 mg/kg for an unrestricted-use scenario. An isolated detection of lead at 2,200 mg/kg exceeded this screening level, as well as the 750 mg/kg industrial-use screening level. Analytical results for adjacent soil samples confirm that this is an isolated detection.

3.5.4 Recommendation

Because Area A has had only sporadic detections of VOCs in groundwater, and the frequent detections of cadmium in soil likely are associated with background soil conditions, no further action is recommended for this location.

The risks associated with groundwater at IRP Site 5 have been determined to be acceptable for all anticipated land and water use scenarios. It is therefore recommended that no further action be performed related to groundwater.

3.6 IRP Site 6 – Washrack West of Building 1355

The PA report recommended no further action at IRP Site 6 based on the results of the Phase I Records Search (HMTC 1987). IRP Site 6 was subsequently redesignated as IRP Site 11 during the SI (OpTech 1996) after TPH and metals were detected in soil samples collected by Base personnel during the installation of underground utilities near the washrack. IRP Site 11 is discussed in Section 3.11.

3.7 IRP Site 7 - Burn Pit Area

The former Burn Pit Area is situated southeast of Building 210 and for the most part, is located outside of the Portland ANGB boundary. The majority of IRP Site 7 lies on Port of Portland property.

3.7.1 Waste Disposal History

The burn pit was used for fire training exercises between 1957 and 1979. Several thousand gallons of flammable liquids, including waste oil, JP-4 jet fuel, and solvents, reportedly were burned each year in the pit (HMTC 1987). The former burn pit area has been filled with gravel and compacted.

3.7.2 Nature and Extent of Contamination

The results of soil gas and soil sampling conducted at IRP Site 7 indicate that petroleum-related VOCs including benzene, toluene, ethylbenzene, and xylenes (BTEX) are present above respective PSGs in the area of the former burn pit (Figure 3-13). Acetone was detected at concentrations ranging from 15 to 980 micrograms per kilogram in several Phase II RI soil samples. SVOCs and TPH as gasoline and diesel were also detected above PSGs in the area of the former burn pit (Figure 3-13). The lateral extent of soil contamination above PSGs is limited to the former burn pit area. Constituents detected above PSGs in shallow groundwater include benzene in direct-push samples PP0701 and GP7-10SZ, at concentrations of 1.7 µg/l and 2.97 µg/l, respectively, and PCE in a sample collected from monitoring well MW7-4 at a concentration of 2.0 µg/l in 1997. Additionally, TPH as diesel was detected in monitoring wells MW7-1 and MW7-3, and in three direct-push samples collected at the center and perimeter of the former burn pit. The cumulative analytical testing results for IRP Site 7 show that the constituents detected above PSGs are isolated detections rather than indicators of persistent groundwater contamination.

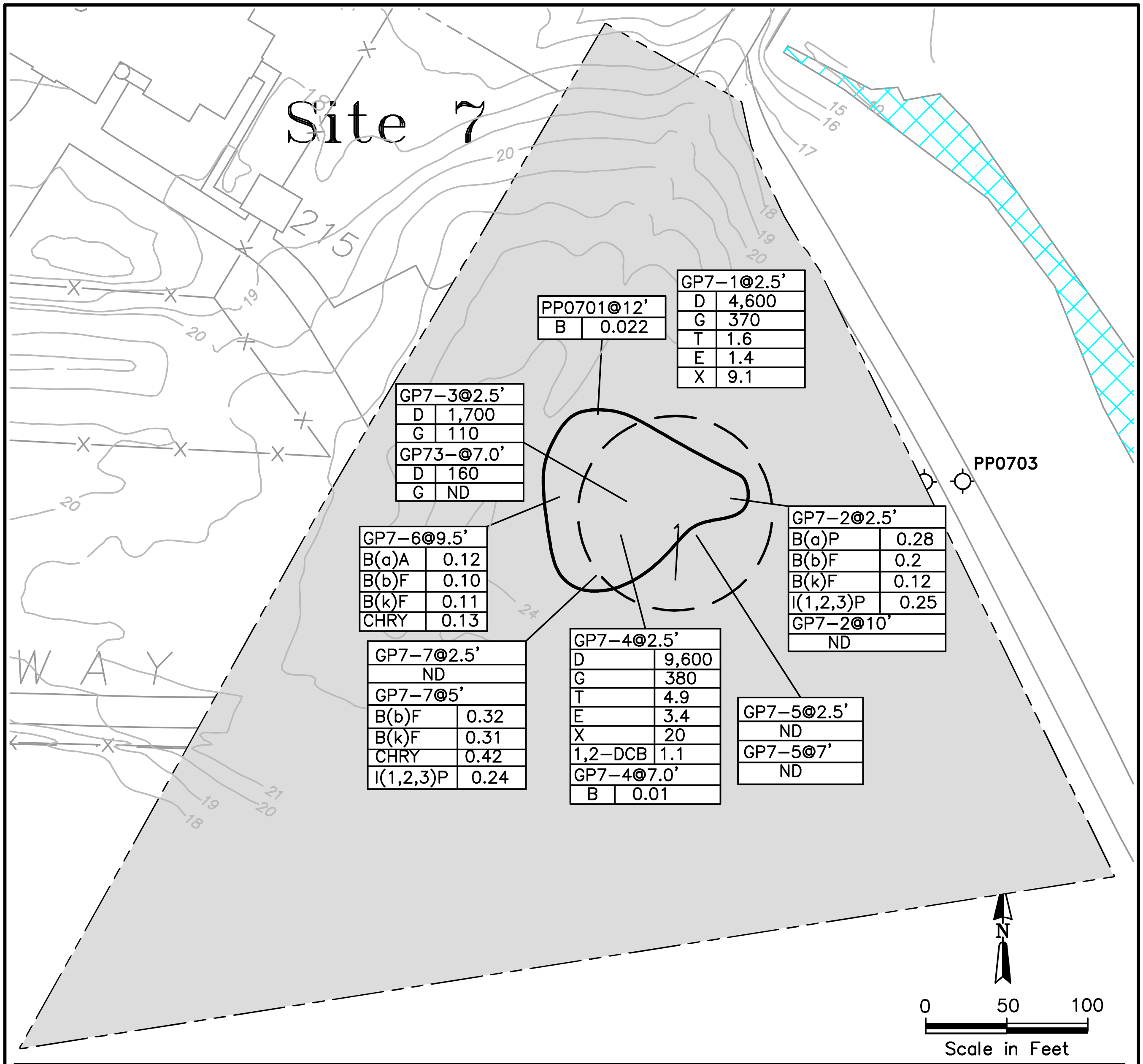
3.7.3 Risk Assessment Results

The results of the risk characterization for IRP Site 7 indicate the following:

- Both the estimated carcinogenic risks and the noncarcinogenic hazards are acceptable for Base workers, construction workers, reservists, hypothetical on-site residents, and by extension, off-site residents, under USEPA and ODEQ guidelines.

- Reported lead concentrations in soil were below the USEPA screening level for an unrestricted use scenario; thus lead in soil is not expected to pose an unacceptable risk.

Several groundwater samples in which PAHs were not detected were analyzed using detection limits greater than risk-based action levels, which may have underestimated associated risk. To verify the lack of risk associated with PAHs in groundwater at IRP Site 7, one round of groundwater samples will be collected and analyzed for PAHs using USEPA Method 8270-Selective Ion Monitoring (SIM) which will provide lower detection limits. This sampling is expected to occur during the second half of year 2001.



LEGEND

⊕ Monitoring Well, Shallow Zone
⊕ Monitoring Well, Floodplain Silt Zone
⊕ Monitoring Well, Columbia River Sand Aquifer
● Phase II RI Direct-Push Point
⊕ Phase I RI Direct-Push Point (OpTech 1996)
-·-·- IRP Site Boundary
270 Building ID
15 Ground Surface Elevation Contour (ft amsl)

D – Diesel
G – Gasoline
B – Benzene
T – Toluene
E – Ethylbenzene
X – Xylenes
ND – Not Detected

ABBREVIATIONS
B(a)A – Benzo(a)Anthracene
B(a)P – Benzo(a)Pyrene
B(b)F – Benzo(b)Fluoranthene
B(k)F – Benzo(k)Fluoranthene
CHRY – Chrysene
I(1,2,3-CD)P – Indeno(1,2,3-CD)Pyrene
DCB – Dichlorobenzene

Concentrations in milligram per kilogram (mg/kg)

◌ Approximate Limit of Former Burn Pit
○ Approximate Extent of Organic Compounds Above PSGs in Soil

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IRP SITE 7
EXTENT OF CONTAMINATION IN SOIL

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PORTLAND, OREGON

FIGURE 3-13

3.7.4 Recommendation

The constituents detected in groundwater at IRP Site 7 are isolated detections and do not indicate persistent groundwater contamination. The risk associated with these groundwater detections is acceptable based on all anticipated land and water use scenarios. It is recommended that no further remedial action be performed related to groundwater. It is also recommended that one round of groundwater samples be collected at IRP Site 7 and analyzed for PAHs using EPA Method 8270-SIM, as described in Section 3.7.3 above.

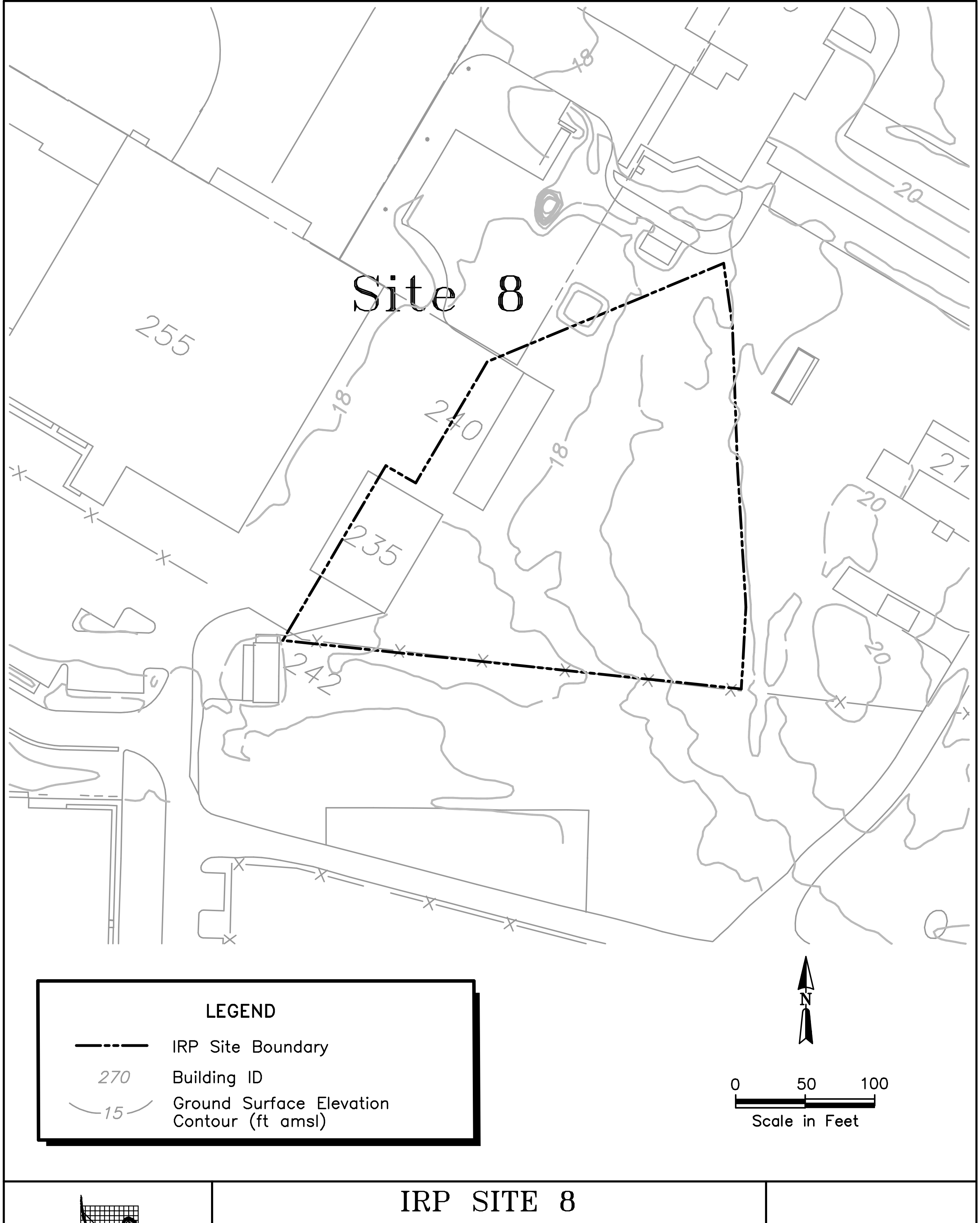
VOCs, SVOCs, and TPH as gasoline and diesel have been detected at concentrations greater than respective PSGs in soil samples collected from the area of the former burn pit. The soil contamination is limited to the area immediately surrounding the burn pit. The risks associated with soil at IRP Site 7 are acceptable based on an industrial land-use scenario. The use of this area is not expected to change in the future (City of Portland Bureau of Planning 2000a, 2000b). It is therefore recommended that no further action be performed related to soil.

3.8 IRP Site 8 - Sanitary Landfill

The former Sanitary Landfill is east of Building 255, and encompasses most of Building 235 and all of Building 240 (Figure 3-14). Reportedly, limited information is available to identify the exact location of past disposal activities at the Sanitary Landfill (HMTC 1987).

3.8.1 Waste Disposal History

The Sanitary Landfill was active between 1949 and 1956 and occupied an area of approximately 1 acre. Wastes were reportedly disposed of in trenches 6 to 8 feet deep, 60 to 70 feet long, 10 feet wide, and spaced 5 to 20 feet apart. Filled trenches were covered with 3 to 4 feet of excavated materials. The Sanitary Landfill received wastes generated by the Portland ANGB and the Army National Guard. The wastes consisted of ordinary shop and building refuse, paint cans, oil and paint residue, batteries, and broken equipment and parts (OpTech 1996).



IRP SITE 8
SANITARY LANDFILL

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FIGURE 3-14

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3.8.2 Nature and Extent of Contamination

Three trenches were excavated through IRP Site 8 for underground utility construction following the SI. No evidence of landfilling was encountered. Evidence of landfilling also was not confirmed by an aerial photograph review performed during the SI.

Three direct-push groundwater samples were collected during the Phase I RI in an area downgradient of the subsurface anomalies identified by a ground-penetrating radar survey. These samples were analyzed for VOCs, SVOCs, PCBs, and metals. PCBs were not detected, and there were no confirmed detections of VOCs, SVOCs, or metals above applicable or relevant and appropriate requirements (ARARs). Reported detections of methylene chloride and bis(2-ethylhexyl)phthalate, both below 10 µg/l in one sample, are suspected laboratory artifacts.

Since landfilling activities were not confirmed and the Phase I RI sampling results indicated no adverse impacts to groundwater, IRP Site 8 was not investigated further.

3.8.3 Risk Assessment Results

The results of the risk characterization for IRP Site 8 indicate the following:

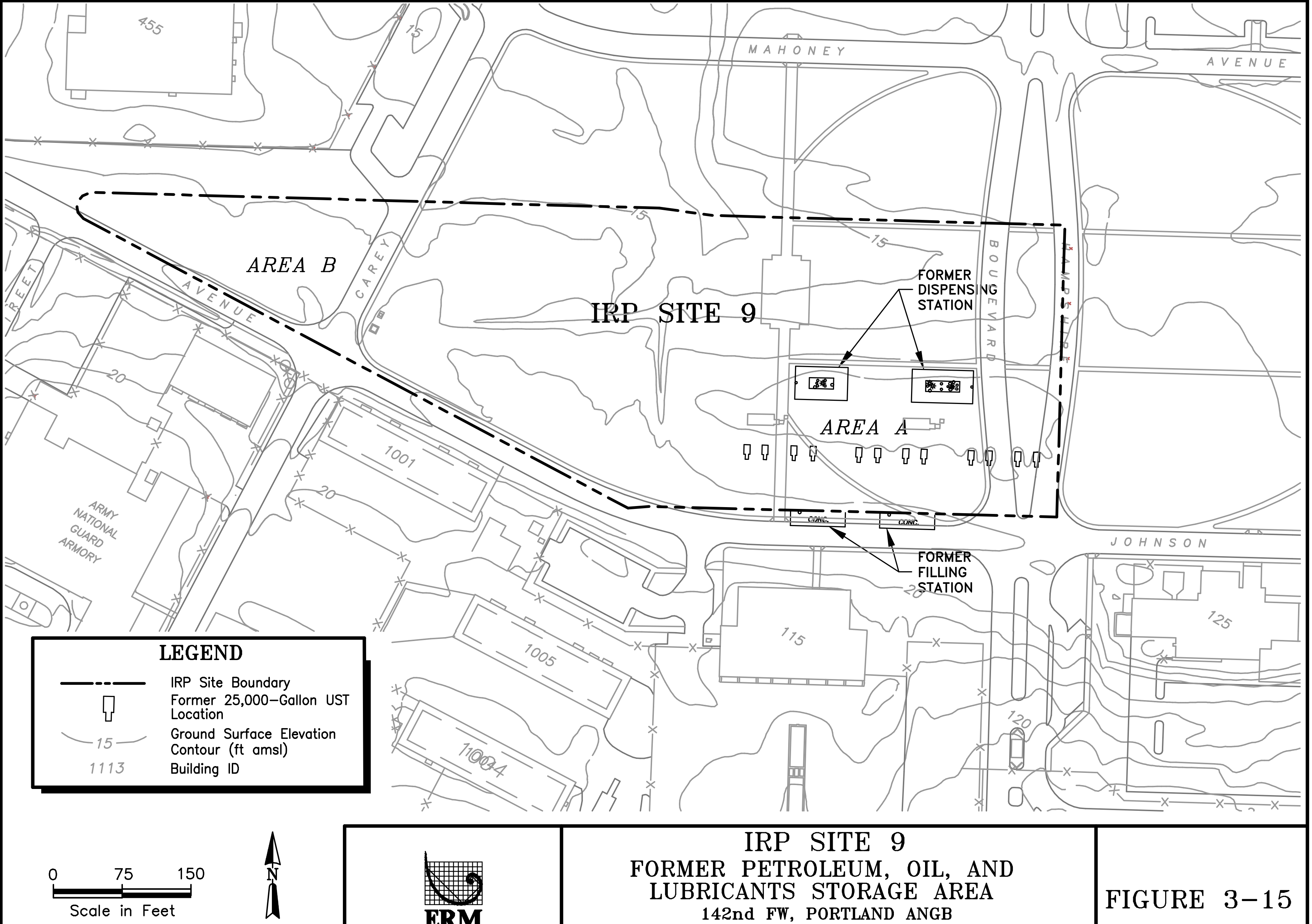
- No carcinogenic COCs were identified. The estimated non-carcinogenic hazards are acceptable for Base workers, construction workers, reservists, hypothetical on-site residents, and by extension, off-site residents, under USEPA and ODEQ guidelines.

3.8.4 Recommendation

No further action is recommended for IRP Site 8 due to the lack of confirmed detections of constituents above PSGs.

3.9 IRP Site 9 - Petroleum, Oil, and Lubricants Facility

The former POL Facility is northwest of the intersection of Hampshire Boulevard and Johnson Avenue (Figure 3-15). Area A comprises the former main POL Facility, and two former fuel dispensing stations. Area B is the former diesel storage and dispensing area. Area A contained twelve 25,000-gallon USTs and one waste oil UST, which were all removed in



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ERM

IRP SITE 9
FORMER PETROLEUM, OIL, AND
LUBRICANTS STORAGE AREA
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FIGURE 3-15

March 1994. The scope and results of the UST removals are not well documented. Two aboveground storage tanks were also located at Area B (HMTC 1987).

The 25,000-gallon USTs at Area A were used to store JP-4 jet fuel. Refueler trucks were used to transfer fuel from IRP Site 9 to the flight apron area. Inventories and tightness test results did not indicate leaks in any of the tanks or associated piping.

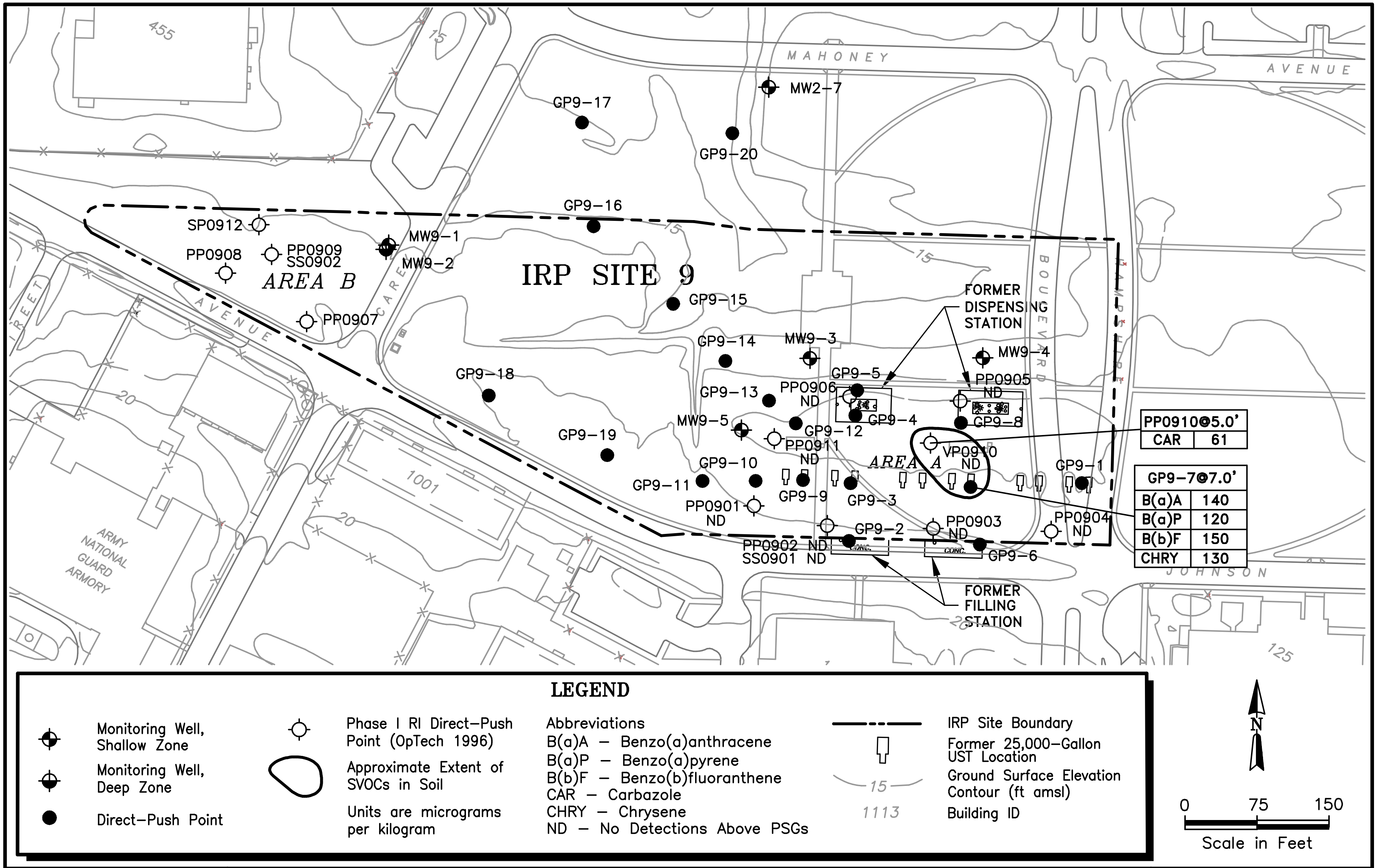
3.9.1 Waste Disposal History

No waste disposal or storage activities are reported for IRP Site 9. During site construction activities in 1991, ANG personnel discovered TPH contamination in soils at Area A.

3.9.2 Nature and Extent of Contamination

TPH as gasoline and diesel were detected below respective PSGs in soil samples collected from Area A, as well as in samples collected from the area between Areas A and B (Figure 3-16). Groundwater samples collected at Area A were found to contain TPH as gasoline, diesel, and heavy oil; benzene, ethylbenzene, and xylenes; and petroleum-related polynuclear aromatic hydrocarbons (PAHs). Scattered detections of chlorinated VOCs also were observed in several direct-push groundwater samples collected at IRP Site 9. The benzene, ethylbenzene, and PAH concentrations in several groundwater samples exceeded respective PSGs. The distribution of TPH and BTEX in groundwater at IRP Site 9 is depicted on Figure 3-17. The extent of dissolved petroleum compounds in groundwater generally corresponds to the area of the highest TPH concentrations detected in soil. This correlation suggests that residual soil contamination in the vicinity of the former USTs may act as a continuing source of groundwater contamination. The PAHs are likely associated with the dissolved TPH, as there are no other known sources of these compounds at IRP Site 9.

Evidence of light non-aqueous phase liquid was not observed during the investigations at IRP Site 9. Although all of the groundwater monitoring wells are screened below the water table, the concentrations of TPH and BTEX detected in soil and groundwater at IRP Site 9 are significantly less than the concentrations typically observed at non-aqueous phase liquid sites.



PP0910@5.0'	
CAR	61

GP9-7@7.0'	
B(a)A	140
B(a)P	120
B(b)F	150
CHRY	130

ERM

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IRP SITE 9

EXTENT OF CONTAMINATION IN SOIL

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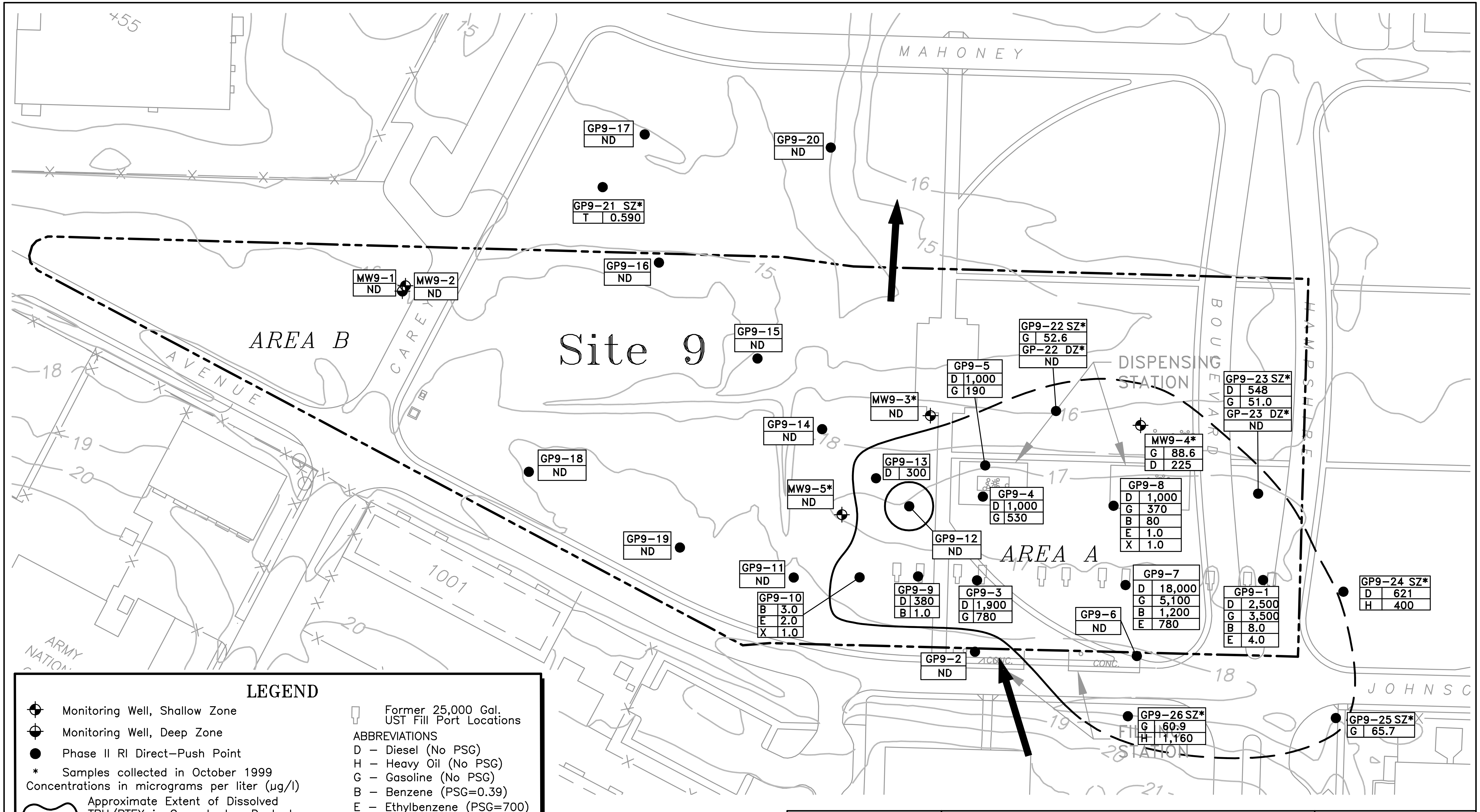
FIGURE 3-16



LEGEND

Monitoring Well, Shallow Zone
Monitoring Well, Deep Zone
● Phase II RI Direct–Push Point
* Samples collected in October 1999
Concentrations in micrograms per liter (µg/l)
Approximate Extent of Dissolved TPH/BTEX in Groundwater; Dashed Where Inferred
Shallow Zone Groundwater Flow Direction – October 1999
IRP Site Boundary
270 Building ID
Former 25,000 Gal. UST Fill Port Locations

ABBREVIATIONS
D – Diesel (No PSG)
H – Heavy Oil (No PSG)
G – Gasoline (No PSG)
B – Benzene (PSG=0.39)
E – Ethylbenzene (PSG=700)
T – Toluene (PSG=720)
X – Xylene (PSG=1,400)
ND – Not Detected
SZ – Shallow Zone
DZ – Deep Zone

ERM

IRP SITE 9
TPH AND BTEX CONCENTRATIONS DETECTED IN GROUNDWATER
FEBRUARY/MARCH 1998 AND OCTOBER 1999
142nd FW, PORTLAND ANGB
PORTLAND INTERNATIONAL AIRPORT
PORTLAND, OREGON

FIGURE 3-17

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Sporadic detections of TCE; cis-1,2-DCE; and VC were observed in several groundwater samples. These compounds were not detected in any of the soil samples, and there are no known sources of chlorinated VOCs at IRP Site 9.

Buried utilities are present at IRP Site 9. These utilities may provide a preferential pathway for VOC vapors to travel a small distance away from the source of those vapors. If deep enough, the utility channels may also allow groundwater to flow a short distance away from the general flow path. However, utilities would need to be buried within the Shallow Zone (below approximately 12 feet bgs) to have any effect on groundwater or contaminant flow direction. Remedial action at this site will require consideration of the presence of buried utilities.

3.9.3 Risk Assessment Results

The results of the risk characterization for IRP Site 9 indicate the following:

- Both the estimated carcinogenic risks and the noncarcinogenic hazards are acceptable for Base workers, construction workers, and reservists under USEPA and ODEQ guidelines.

- The total estimated carcinogenic risk for hypothetical on-site residents exceeds USEPA and ODEQ acceptable levels, primarily as a result of assumed exposures to benzene and PAHs in groundwater under this scenario. Additionally, the carcinogenic risk associated with benzo(a)pyrene in soil under the on-site residential scenario exceeds the ODEQ benchmark for acceptable risk associated with an individual constituent. The noncarcinogenic hazard for hypothetical on-site residents also exceeds both USEPA and ODEQ guidelines, primarily as a result of benzene in groundwater. By extension of the results for the on-site residential scenario, the potential future risks to off-site residents related to the possible off-site migration and residential use of contaminated groundwater also exceed USEPA and ODEQ criteria.

Reported lead concentrations in soil were below the USEPA screening level for an unrestricted-use scenario; thus lead in soil is not expected to pose an unacceptable risk.

3.9.4 Recommendation

SVOCs have been detected at concentrations greater than PSGs in soil samples collected at IRP Site 9. However, the risks associated with soil at IRP Site 9 are acceptable based on an industrial land-use scenario. The industrial land use of this area is not expected to change in the future (City of Portland Bureau of Planning 2000a, 2000b). It is therefore recommended that no further action be performed related to soil.

It is recommended that remedial alternatives be developed that address TPH and BTEX compounds remaining in IRP Site 9 groundwater. The development of these alternatives is discussed in Sections 4.0 and 5.0.

3.10 IRP Site 10 - Equipment Washrack

The Equipment Washrack is at the southeast corner of Building 1001 (Figure 3-18). The washrack consists of an irregularly shaped concrete pad, approximately 45 feet long by 30 feet wide; a catch basin; and a drain pipe.

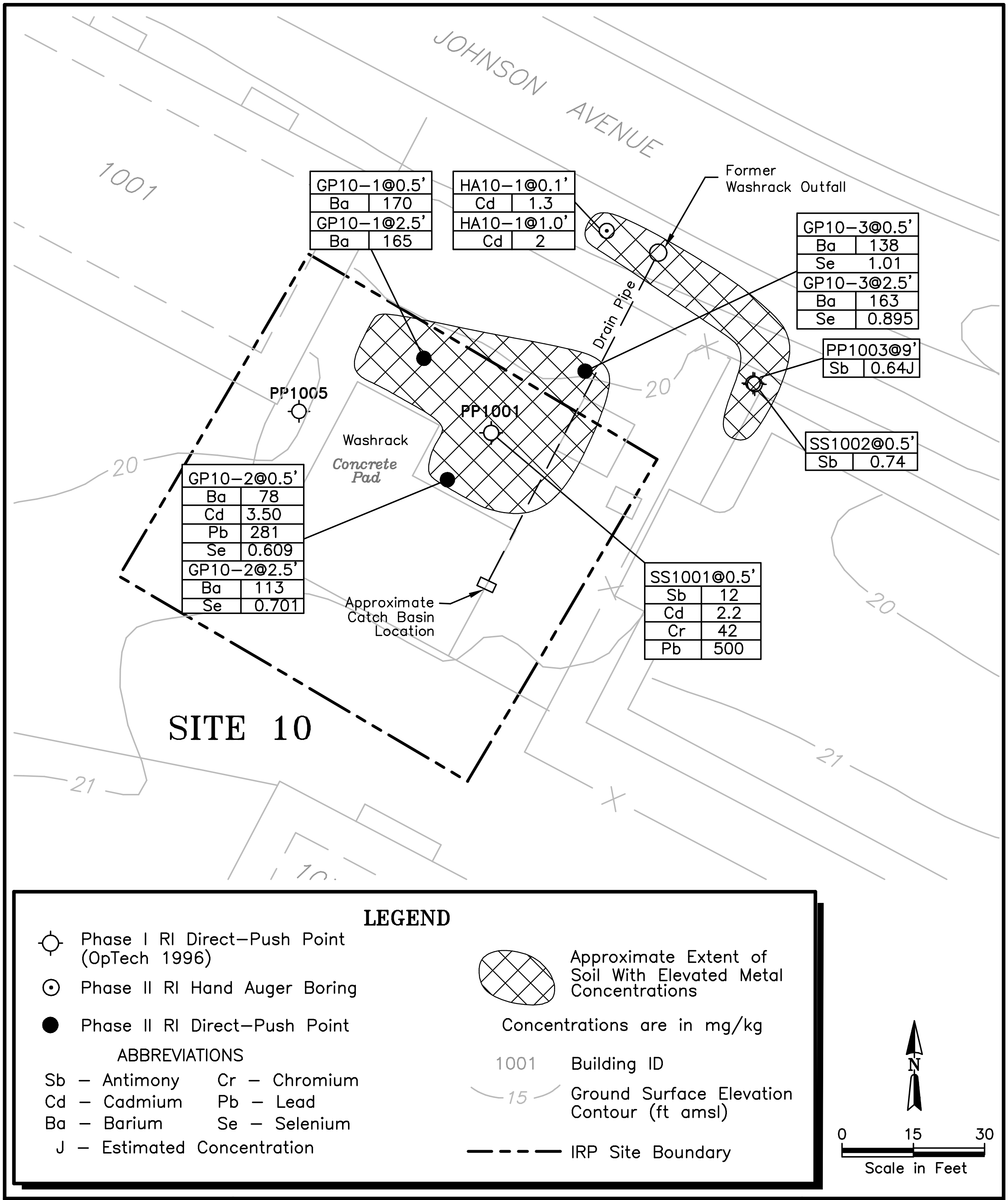
3.10.1 Waste Disposal History

The washrack was installed in 1950 and used until 1993. The concrete pad slopes toward the east to a catch basin that collected wash fluids from equipment and vehicle-cleaning activities. The wash fluids discharged via the drain pipe to a roadside ditch along Johnson Avenue, northeast of the washrack area.

3.10.2 Nature and Extent of Contamination

TPH was detected below PSGs in two surface soil samples collected from the former drainage ditch north of Site 10 during the RI. The presence of petroleum compounds detected above PSGs in soil in 1993 was not confirmed by the RI sampling, suggesting that the elevated concentrations are very limited in extent and/or have attenuated.

As shown on Figure 3-18, antimony, cadmium, lead, and/or selenium were detected above respective PSGs in soil samples collected from five locations. The concentrations of antimony detected in surface soil sample SS1002 and in the subsurface sample collected from boring PP1003 (0.74 and 0.64 mg/kg, respectively) are not significantly higher than the



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IRP SITE 10

EXTENT OF CONTAMINATION IN SOIL

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FIGURE 3-18

Portland ANGB background level of 0.59 mg/kg; these antimony detections likely reflect background conditions.

A site-specific background value for selenium is not available for comparison with the RI soil sampling results. However, the selenium results also appear to reflect background conditions, as indicated by the consistent selenium concentrations in the RI samples, and the absence of cadmium and lead concentrations above respective PSGs in the majority of samples with selenium detections above PSGs.

Concentrations of antimony, cadmium, and lead detected in surface soil sample SS1001 are elevated relative to Portland ANGB background levels.

Similarly, cadmium concentrations in the samples collected from boring HA10-1, and cadmium and lead concentrations detected in the sample collected from 0.5 feet bgs in boring GP10-2, appear to be elevated relative to background. These elevated metal concentrations may be related to past equipment and vehicle washing activities at IRP Site 10. The elevated metal concentrations at these locations are limited to the uppermost 1 to 2.5 feet of soil.

The results of direct-push groundwater sampling indicate that groundwater quality at IRP Site 10 has not been adversely impacted by past site activities.

3.10.3 Risk Assessment Results

The results of the risk characterization for IRP Site 10 indicate the following:

- Both the estimated carcinogenic risks and the noncarcinogenic hazards are acceptable for Base workers, construction workers, reservists, hypothetical on-site residents, and by extension, off-site residents, under USEPA and ODEQ guidelines.

- With one exception, reported lead concentrations in soil were below the USEPA screening level of 400 mg/kg for an unrestricted-use scenario. Lead was detected in one sample at a concentration of 500 mg/kg, which is below the USEPA screening level of 750 mg/kg for an industrial-use scenario.

3.10.4 Recommendation

The results of the RI indicate that groundwater quality at IRP Site 10 has not been adversely impacted by past site activities. Therefore, it is recommended that no further action be performed related to groundwater.

Metals have been detected at concentrations greater than respective PSGs in soil samples collected at IRP Site 10. However, the risks associated with soil are acceptable based on an industrial land-use scenario. It is not expected that the use of this area will change in the future. It is therefore recommended that no further action be performed related to soil.

3.11 IRP Site 11 - Washrack West of Building 250

The former Washrack West of Building 250 is at the southeast corner of Apron A, adjacent to Building 250 (Figure 3-19), and was used to wash aircraft. The washrack facility consisted of a 60-foot by 80-foot pad, and an oil/water separator. The concrete pad sloped toward the east, where surface runoff from the pad drained to the oil/water separator. Solvents and degreasers were sometimes applied to the aircraft before washing them with a soap and water mixture. The washrack and oil/water separator were removed in September 1999 as part of a soil removal action (ERM 2000b). Contaminated soil was hauled off-site and treated by thermal desorption.

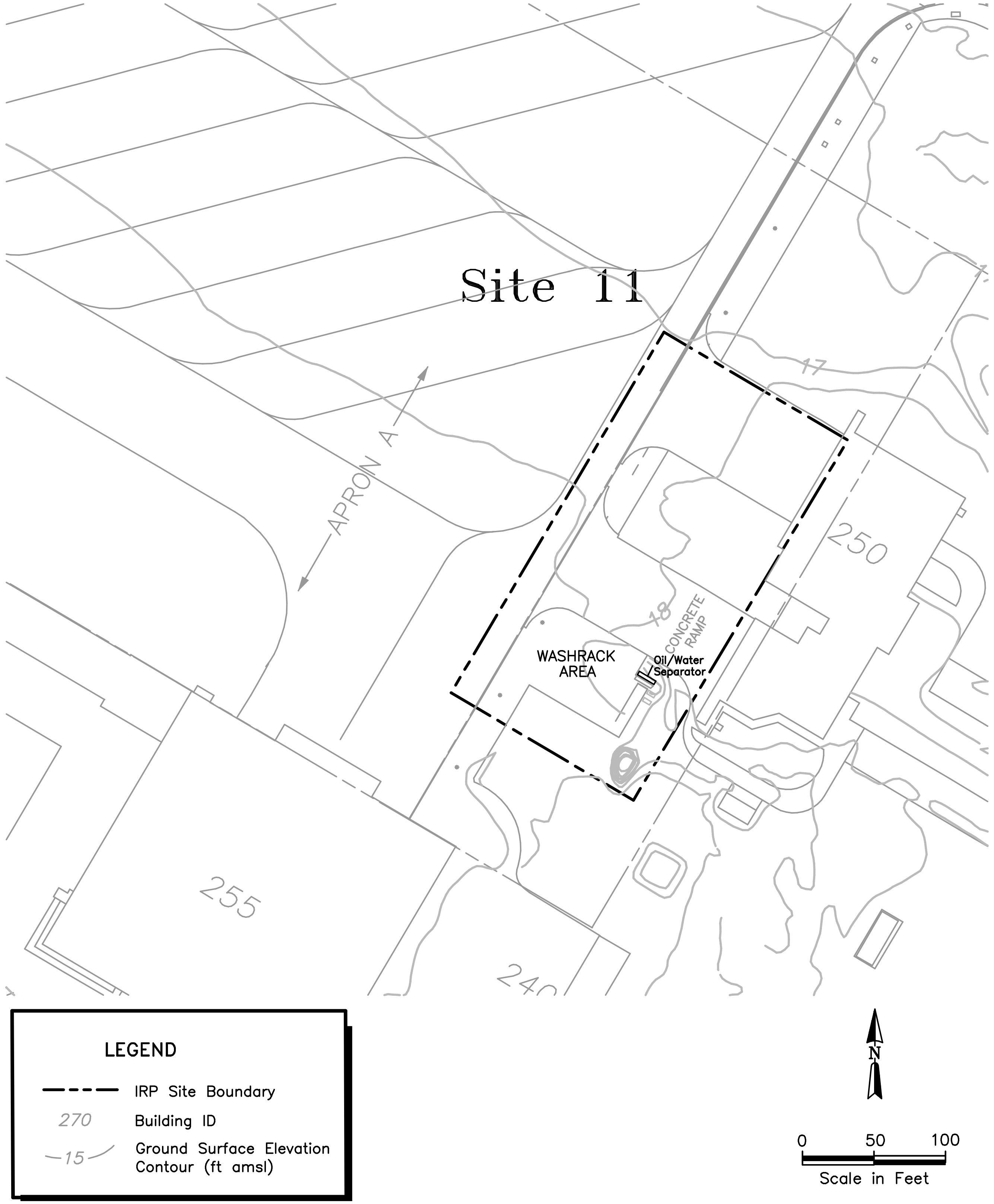
3.11.1 Waste Disposal History

Liquids from aircraft washing operations flowed from the washrack area to the catch basin of the oil/water separator. The oil/water separator discharged into the storm sewer prior to 1984, and into the sanitary sewer after 1984.

The oil/water separator was a three-stage, concrete, gravity-type separator, which was removed from service in 1989 after cracks were discovered in the center stage.

3.11.2 Nature and Extent of Contamination

Contaminants detected in soil and groundwater at IRP Site 11 include chlorinated VOCs, BTEX, TPH, and metals. The lateral extent of VOCs and TPH in soil prior to the 1999 removal action was generally limited to



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IRP SITE 11
WASHRACK WEST OF BUILDING 250

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FIGURE 3-19

within 25 feet of the oil/water separator. Figure 3-20 shows the extent of organic contaminants remaining in soil after the 1999 removal action; VOCs and TPH are still present above respective PSGs in soil near the water table.

VOCs and petroleum hydrocarbons have impacted groundwater in the Shallow Zone and Deep Zone at IRP Site 11. The extent of chlorinated VOCs in groundwater is shown on Figure 3-21. VOCs have migrated primarily toward the northwest from the area of the former separator, and have also dispersed radially. The concentrations of chlorinated VOCs have fluctuated since regular groundwater monitoring began in 1997. The fluctuating concentrations most likely reflect seasonal changes in groundwater levels and flow directions.

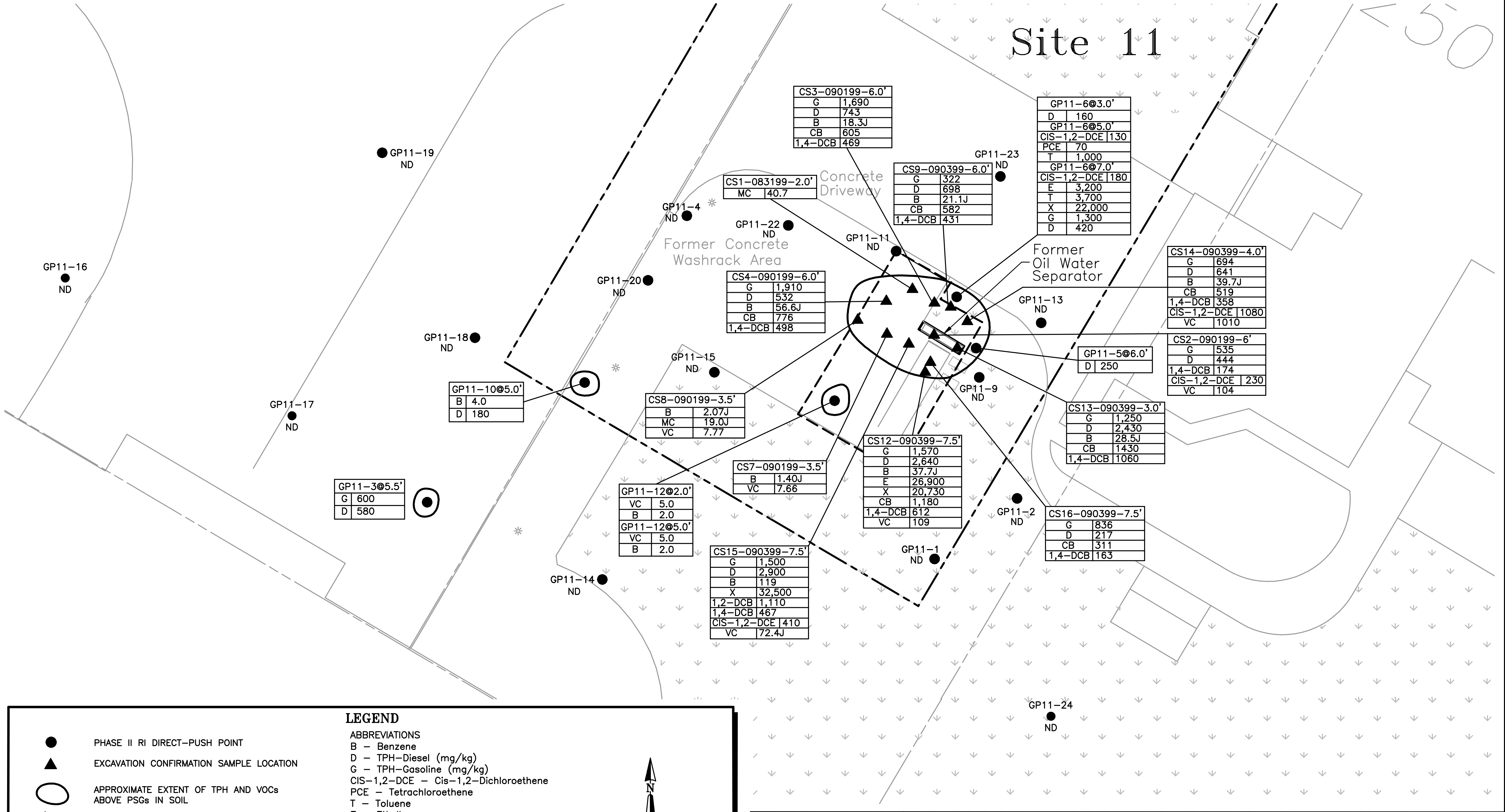
Deep Zone wells/piezometers in the vicinity of Site 11 include EW11-1, PZ11-1, PZ11-3, MW11-2, MW11-8, and MW11-12. Benzene; toluene; 1,2-DCA; cis-1,2-DCE; and VC were detected above respective PSGs in groundwater samples collected from well MW11-2. Additionally, VC was detected above the PSG in piezometer PZ11-3, and cis-1,2-DCE was detected below the PSG in well MW11-12. These detections indicate that dissolved VOCs have migrated to the Deep Zone northwest and southeast of the former oil/water separator. Figure 3-22 shows the vertical distribution of total chlorinated hydrocarbons at IRP Site 11.

CRSA wells/piezometers in the vicinity of IRP Site 11 include EW11-2, PZ11-2, PZ11-4, PZ11-5, and MWBG-11. There have been no confirmed detections of contaminants in these wells/piezometers.

During the Phase II RI, two direct-push groundwater samples (GP11-5 and GP11-6) were collected from the bottom of the Shallow Zone to assess the potential presence of dense non-aqueous phase liquid (DNAPL) in the immediate vicinity of the oil/water separator. Although dissolved VOCs were detected in these groundwater samples, the concentrations were not indicative of DNAPL; the maximum VOC concentration detected was 63 µg/l (VC). Concentrations on the order of 10,000 µg/l indicate the possible presence of DNAPL (Pankow and Cherry 1996).

3.11.3 Risk Assessment Results

The results of the risk characterization for IRP Site 11 indicate the



CS3-090199-6.0'	
G	1,690
D	743
B	18.3J
CB	605
1,4-DCB	469

CS1-083199-2.0'	
MC	40.7

CS9-090399-6.0'	
G	322
D	698
B	21.1J
CB	582
1,4-DCB	431

GP11-6@3.0'	
D	160
GP11-6@5.0'	
CIS-1,2-DCE	130
PCE	70
T	1,000
GP11-6@7.0'	
CIS-1,2-DCE	180
E	3,200
T	3,700
X	22,000
G	1,300
D	420

CS4-090199-6.0'	
G	1,910
D	532
B	56.6J
CB	776
1,4-DCB	498

CS14-090399-4.0'	
G	694
D	641
B	39.7J
CB	519
1,4-DCB	358
CIS-1,2-DCE	1080
VC	1010

CS2-090199-6'	
G	535
D	444
1,4-DCB	174
CIS-1,2-DCE	230
VC	104

GP11-5@6.0'	
D	250

GP11-10@5.0'	
B	4.0
D	180

CS8-090199-3.5'	
B	2.07J
MC	19.0J
VC	7.77

CS13-090399-3.0'	
G	1,250
D	2,430
B	28.5J
CB	1430
1,4-DCB	1060

CS12-090399-7.5'	
G	1,570
D	2,640
B	37.7J
E	26,900
X	20,730
CB	1,180
1,4-DCB	612
VC	109

CS7-090199-3.5'	
B	1.40J
VC	7.66

GP11-3@5.5'	
G	600
D	580

GP11-12@2.0'	
VC	5.0
B	2.0
GP11-12@5.0'	
VC	5.0
B	2.0

CS16-090399-7.5'	
G	836
D	217
CB	311
1,4-DCB	163

CS15-090399-7.5'	
G	1,500
D	2,900
B	119
X	32,500
1,2-DCB	1,110
1,4-DCB	467
CIS-1,2-DCE	410
VC	72.4J

LEGEND

●	PHASE II RI DIRECT-PUSH POINT
▲	EXCAVATION CONFIRMATION SAMPLE LOCATION
○	APPROXIMATE EXTENT OF TPH AND VOCs ABOVE PSGs IN SOIL
▱	EXCAVATION LIMITS, SEPTEMBER 1999
▨	GRASS
— - —	SITE 11 BOUNDARY

ABBREVIATIONS
B – Benzene
D – TPH-Diesel (mg/kg)
G – TPH-Gasoline (mg/kg)
CIS-1,2-DCE – Cis-1,2-Dichloroethene
PCE – Tetrachloroethene
T – Toluene
E – Ethylbenzene
X – Xylene
VC – Vinyl Chloride
CB – Chlorobenzene
1,2-DCB – 1,2-Dichlorobenzene
1,4-DCB – 1,4-Dichlorobenzene
MC – Methylene Chloride
All units are μg/kg unless otherwise noted

0 15 30
Scale in Feet

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IRP SITE 11
EXTENT OF CONTAMINATION
IN SOIL

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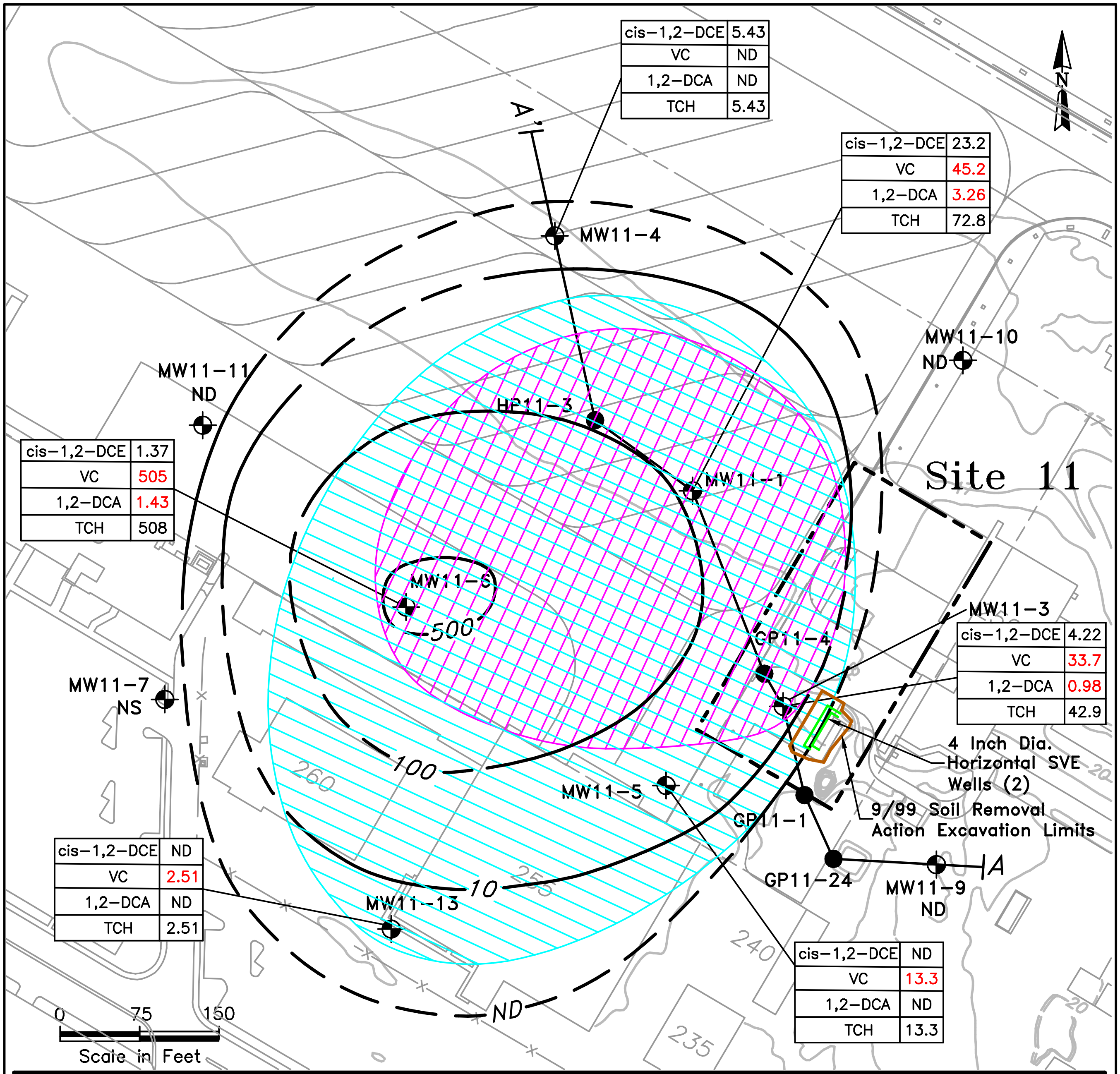
FIGURE 3-20



cis-1,2-DCE	5.43
VC	ND
1,2-DCA	ND
TCH	5.43

cis-1,2-DCE	23.2
VC	45.2
1,2-DCA	3.26
TCH	72.8

cis-1,2-DCE	1.37
VC	505
1,2-DCA	1.43
TCH	508

cis-1,2-DCE	4.22
VC	33.7
1,2-DCA	0.98
TCH	42.9

cis-1,2-DCE	ND
VC	2.51
1,2-DCA	ND
TCH	2.51

cis-1,2-DCE	ND
VC	13.3
1,2-DCA	ND
TCH	13.3

Legend

⊕ Monitoring Well, Shallow Zone

● Geoprobe/Hydropunch Location (Sampled 1/97 or 1/98)

ND Not Detected
NS Not Sampled
PSG Project Screening Goal
SVE Soil Vapor Extraction

Note: Units are μg/L.
Values in Red Exceed PSGs.

Total Chlorinated Hydrocarbon (TCH) Contour; Dashed Where Inferred

▨ Estimated Extent of 1,2-Dichloroethane (1,2-DCA) > PSG (0.12 μg/L)

▨ Estimated Extent of Vinyl Chloride (VC) > PSG (0.02 μg/L);

The PSG for cis-1,2-Dichloroethene (cis-1,2-DCE) = 61μg/L

A├──┤A' Hydrogeologic Cross-Section Line

270 Building ID

IRP Site Boundary Line

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IRP SITE 11
SHALLOW ZONE
EXTENT OF CHLORINATED HYDROCARBONS IN GROUNDWATER
JANUARY 2000
142nd FW, PORTLAND ANGB
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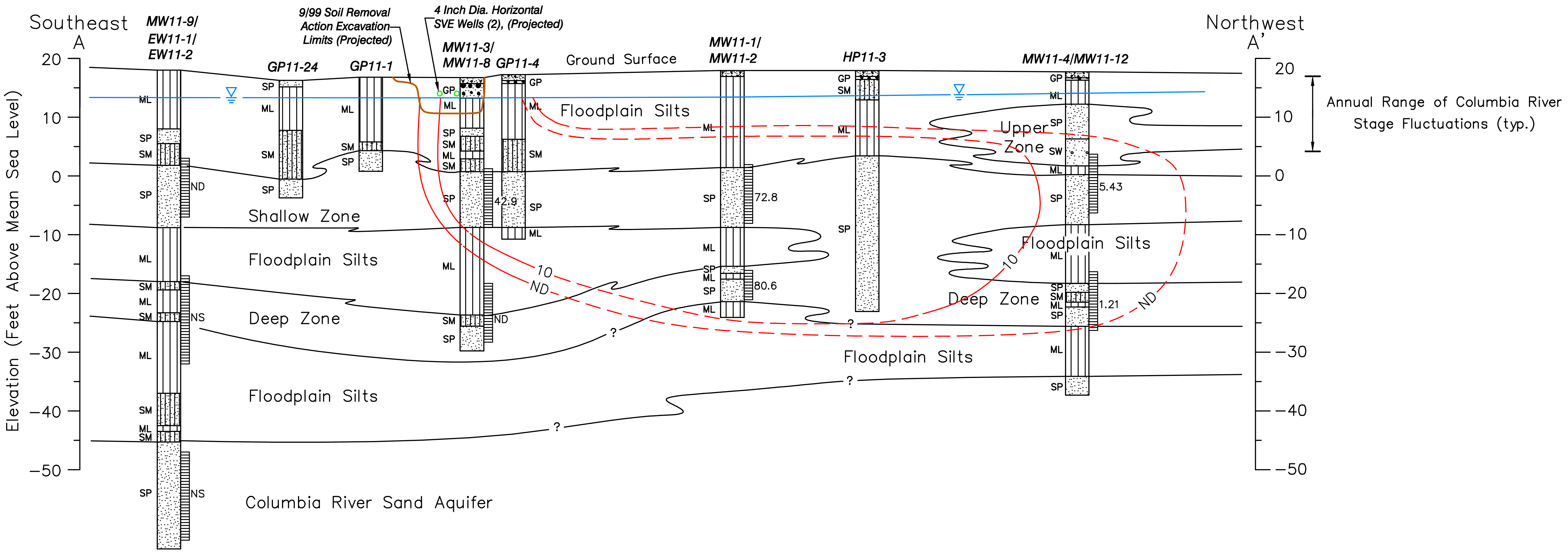
PORTLAND, OREGON

FIGURE 3-21



Notes: 1. See Figure 3–7 for Cross Section Orientation

Legend

10.8 Total Chlorinated Hydrocarbon Concentration (TCH) in January 2000 (µg/L)

▤ Screened Interval

▽ January 2000 Water Level in Shallow Zone

–10– Line of Equal TCH Concentration (µg/L); Location Approximate: Dashed Where Inferred

ND Not Detected

NS Not Sampled

SVE Soil Vapor Extraction

▨ Concrete

▥ Silt/Clayey Silt/Sandy Silt

▨ Clayey Sand

▦ Silty Sand

▨ Poorly Graded Gravelly Sand/Sand

▨ Well Graded Gravelly Sand/Sand

▨ Gravel/Sandy Gravel

0 100
Feet
Vertical Exaggeration = 5x

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IRP SITE 11
VERTICAL DISTRIBUTION OF TOTAL CHLORINATED
HYDROCARBONS IN GROUNDWATER
JANUARY 2000
142nd FW, PORTLAND ANGB
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PORTLAND, OREGON

FIGURE 3–22

following:

- Both the estimated carcinogenic risks and the noncarcinogenic hazards are acceptable for Base workers, construction workers, and reservists under USEPA and ODEQ guidelines.

- The potential carcinogenic risk and noncarcinogenic hazard associated with soil exposures under the on-site residential land-use scenario are less than USEPA and ODEQ guidelines for evaluation of acceptable risk. However, the total carcinogenic risk and noncarcinogenic hazard for hypothetical on-site residents exceed both USEPA and ODEQ levels of acceptable risk, as a result of assumed exposures to groundwater under this scenario. The unacceptable risks are associated with the presence of benzene; 1,2-DCA; and VC in groundwater. In addition, the presence of cis-1,2-DCE in both soil and groundwater results in a cumulative hazard index (HI) for this contaminant that exceeds USEPA and ODEQ guidelines. By extension of the results for the on-site residential scenario, the potential future risks to off-site residents related to the possible off-site migration and residential use of contaminated groundwater also exceed USEPA and ODEQ criteria.

- Reported lead concentrations in soil were below the USEPA screening level for an unrestricted-use scenario, thus lead in soil is not expected to pose an unacceptable risk.

3.11.4 Recommendation

Due to the extent and concentrations of VOCs in groundwater at IRP Site 11, remediation is necessary to prevent possible off-site migration and residential use of the contaminated groundwater. Remedial alternatives have been developed and are presented later in this FS for the treatment of groundwater contaminated with VOCs.

Contaminated soil remaining at the excavation limits of the 1999 soil removal action should also be remediated, to prevent potential leaching of contaminants to groundwater. During the 1999 soil removal action, soil vapor extraction (SVE) piping was installed in the imported excavation backfill material. SVE removes VOCs and TPH through volatilization and enhanced aerobic bioremediation. The SVE system at Site 11 should be completed and placed in operation to treat the contaminated soil.

In order to begin a non-time critical removal action of VOCs in groundwater, the groundwater EE/CA described in Section 2.8.1 was initiated at IRP Site 11 (ERM 2001b). The groundwater EE/CA is currently being designed and is expected to be constructed during the year 2002. The purpose of the EE/CA is to remove a large amount of VOC mass from Shallow Zone groundwater in order to stop or slow migration of VOCs to downgradient areas of Shallow Zone groundwater and to Deep Zone groundwater. The design focuses on the central area of the Shallow Zone VOC plume, where concentrations of VC and cis-1,2-DCE, the primary contaminants of concern at IRP Site 11, are above approximately 100 μg/l. In addition to treatment of Shallow Zone groundwater at IRP Site 11, the EE/CA also presents a plan to remediate the area of contaminated soil remaining following the 1999 soil removal action described above. This remedial action will consist of completing and activating the SVE system, as mentioned, as well as injecting an oxygen releasing material into the vadose zone soil that becomes saturated during the wetter months. Although a significant reduction of VOCs is expected during the groundwater EE/CA implementation, a conservative position is taken in this FS by not considering this reduction during the development and evaluation of the remedial alternatives presented later in the document.

SECTION 4.0

DEVELOPMENT OF REMEDIAL ALTERNATIVES

In the preceding section (Section 3.0, Description of IRP sites), each of the IRP sites at the Portland ANGB was described with respect to the site history, nature and extent of contamination, the environmental and human health risk, and a recommendation for RA. As described in Section 3.0, IRP Sites 2, 9, and 11 are recommended for further evaluation of RA.

In this section, the proposed remedial alternatives are identified and the process by which the proposed remedies were developed and evaluated, based on USEPA (USEPA 1988) and ODEQ (ODEQ 1998b) guidance, is presented. The remedial alternatives will be compared and evaluated further in Section 5.0, which presents the preferred remedial alternatives proposed for the IRP sites.

The process of identifying RA alternatives for IRP Sites 2, 9, and 11 involves the following primary steps:

- **Identification of ARARs**: "Applicable" requirements are substantive environmental protection requirements specifically addressing a hazardous substance, pollutant, contaminant, activity, location, or other circumstance at a site. "Relevant and appropriate" requirements are those that, while not applicable, are sufficiently similar to circumstances encountered at a site that their use is well suited.

- **Development of RAOs**: RAOs provide specific goals for each of the affected media (i.e., soil, groundwater, etc.) at the IRP sites requiring remediation. These goals are typically based on achievement of a specified clean-up level, or specified acceptable risk level.

- **Development of General Response Actions**: General response actions are broadly defined as measures designed to prevent or minimize the adverse environmental impacts to satisfy the RAOs.

- **Identification and Screening of Technologies**: Once general response actions are identified, technologies that are capable of achieving the RAOs are identified, and subsequently "screened" to provide a short list of technologies appropriate for further consideration.

- **Development of Remedial Alternatives**: Using the RAOs, general response actions, and technologies known to be applicable to the COCs, remedial alternatives are then developed for comparison and further evaluation relative to the USEPA and ODEQ criteria.

4.1 ARARs

Section 121 of Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) requires RAs to comply with all ARARs formally promulgated under Federal and State environmental laws. “Applicable” requirements are substantive environmental protection requirements specifically addressing a hazardous substance, pollutant, contaminant, RA, location, or other circumstance at a site. “Relevant and appropriate” requirements are those that, while not applicable, are sufficiently similar to circumstances encountered at a site that their use is well suited. Administrative requirements, such as Federal, State, or local permitting, for RAs completed entirely on-site are waived under CERCLA Section 121(e)(1).

There are three types of ARARs:

- Location-specific ARARs are restrictions imposed on activities or concentrations of hazardous substances solely because they occur in special locations.

- Chemical-specific ARARs are health- or risk-based criteria that establish the acceptable amount or concentration of a chemical that may be found in or discharged to the ambient environment.

- Action-specific ARARs set controls or restrictions on design and performance aspects of activities at the site.

ARARs are progressively identified on a site-specific basis as the RI/FS proceeds. During the RI, confirmation of contamination at a site, identification of the specific contaminant(s), and subsequent laboratory analysis and quantification allow for the determination of chemical-specific ARARs. These chemical-specific ARARs, along with chemical-specific guidance “to be considered,” are identified in this section, along with action- and location-specific ARARs identified as part of the FS process.

4.1.1 Federal Applicable or Relevant and Appropriate Requirements

4.1.1.1 Safe Drinking Water Act

Federal regulations pursuant to the Safe Drinking Water Act govern the quality of groundwater that is or could be used for drinking water purposes. Safe Drinking Water Act MCLs specified in Title 40, Part 141, Sections 11 to 16 of the Code of Federal Regulations are chemical-specific ARARs for groundwater at the Portland ANGB. MCLs for the constituents identified at the Portland ANGB are listed in Tables 4-1 and 4-2.

4.1.1.2 Clean Water Act

The Federal Clean Water Act and pursuant regulations provide potential location-, chemical-, and action-specific ARARs, such as water quality standards and wastewater discharge requirements. RAs that involve discharge to surface water will require compliance with the substantive requirements of the Clean Water Act.

4.1.1.3 Clean Air Act

The Federal Clean Air Act provides potential action- and chemical-specific ARARs for IRP activities that may release contaminants to the atmosphere. RAs that involve discharge of contaminants, particularly VOCs, to the atmosphere will require compliance with the substantive requirements of the Clean Air Act.

4.1.1.4 Resource Conservation and Recovery Act

Federal Resource Conservation and Recovery Act (RCRA) regulations contain requirements that apply to the generation, management, and disposal of hazardous waste. Based on the *Listed Hazardous Waste Evaluation* (ERM 1999c) prepared by ERM, contaminated media containing TCE and degradation product chlorinated VOCs at IRP Sites 1, 2, 3, 4, and 5 meet the criteria for hazardous waste under RCRA. Soil, sediment, surface water, and groundwater waste containing TCE and generated from these sites should be managed as hazardous waste. Hazardous waste generation, storage, and transport requirements under RCRA are applicable to these materials.

TABLE 4-1

Federal and Oregon Numeric Criteria for VOCs and SVOCs in Groundwater
142nd FW, Portland ANGB, Portland, Oregon

Analyte	Federal Primary MCL (µg/l)	Oregon GRC (1) (µg/l)	USEPA Region 9 Carcinogenic Tap Water PRG (µg/l)	USEPA Region 9 Non-Carcinogenic Tap Water PRG (µg/l)	Project Screening Goal (µg/l)
Acenaphthene	--	2,000	--	370	370
Acetone	--	--	--	610	610
Anthracene	--	10,000	--	1,800	1,800
Benzene	5	3	0.39	10	0.39
Benzo(a)anthracene	--	0.01	0.092	--	0.01
Benzo(a)pyrene	0.2	0.01	0.0092	--	0.0092
Benzo(b)fluoranthene	--	0.01	0.092	--	0.01
Benzo(k)fluoranthene	--	0.01	0.92	--	0.01
Benzoic Acid	--	--	--	150,000	150,000
Benzyl Alcohol	--	--	--	11,000	11,000
Bis(2-ethylhexyl)phthalate	6	4	4.8	730	4
Bromochloromethane	--	--	--	--	--
Bromodichloromethane	100*	0.7	0.18	120	0.18
2-Butanone	--	--	--	--	--
Butylbenzylphthalate	--	--	--	7,300	7,300
Carbon disulfide	--	--	--	21	21
4-Chloro-3-Methylphenol	--	--	--	--	--
Chlorobenzene	100	700	--	39	39
Chloroform	100*	10	0.16	61	0.16
Chloromethane	--	--	1.5	--	1.5
Chrysene	--	0.01	9.2	--	0.01
Dibenzofuran	--	--	--	24	24
1,2-Dichlorobenzene	600	--	--	370	370
1,3-Dichlorobenzene	--	--	--	180	180
1,4-Dichlorobenzene	75	--	0.47	1,400	0.47
1,1-Dichloroethane	--	--	--	810	810
1,2-Dichloroethane	5	--	0.12	370	0.12
1,1-Dichloroethene	7	0.1	0.046	55	0.046
cis-1,2-Dichloroethene	70	70	--	61	61
trans-1,2-Dichloroethene	100	100	--	120	100
total-1,2-Dichloroethene	--	--	--	55	55
1,2-Dichloropropane	5	--	0.16	6.9	0.16
Diethylphthalate	--	--	--	29,000	29,000
2,4-Dimethylphenol	--	--	--	730	730
Dimethylphthalate	--	--	--	370,000	370,000
Di-n-butylphthalate	--	--	--	3,700	3,700
Di-n-octylphthalate	--	--	--	730	730
Ethylbenzene	700	700	--	1,300	700
Ethylene glycol	--	--	- -	73,000	73,000
Fluoranthene	--	1,000	--	1,500	1,000
Fluorene	--	1,000	--	240	240
Methylene chloride (dichloromethane)	5	5	4.3	1,600	4.3
Methyl ethyl ketone	--	--	--	1,900	1,900
2-Methylnaphthalene	--	--	--	--	--
2-Methylphenol	--	--	--	1,800	1,800
3/4-Methylphenol	--	--	--	180	180
4-Methylphenol	--	--	--	180	180
Naphthalene	--	100	--	240	100

TABLE 4-1

Federal and Oregon Numeric Criteria for VOCs and SVOCs in Groundwater
142nd FW, Portland ANGB, Portland, Oregon

Analyte	Federal Primary MCL (µg/l)	Oregon GRC (1) (µg/l)	USEPA Region 9 Carcinogenic Tap Water PRG (µg/l)	USEPA Region 9 Non-Carcinogenic Tap Water PRG (µg/l)	Project Screening Goal (µg/l)
Pentachlorophenol	1	0.7	0.56	1,100	0.56
Phenanthrene	--	--	--	--	--
Phenol	--	--	--	22,000	22,000
Pyrene	--	1,000	--	180	180
1,1,2,2-Tetrachloroethane	--	--	0.055	--	0.055
Tetrachloroethene	5	2	1.1	61	1.1
Toluene	1,000	1,000	--	720	720
1,1,2-Trichloroethane	5	5	0.2	24	0.2
Trichloroethene	5	5	1.6	37	1.6
1,2,4-Trimethylbenzene	--	--	--	12	12
1,3,5-Trimethylbenzene	--	--	--	12	12
Vinyl chloride	2	0.04	0.02	--	0.02
Xylenes	10,000	7,000	--	1,400	1,400

Notes:
-- - Standard not established
* - MCL for total trihalomethanes
µg/l - Micrograms per liter
GRC - Oregon Groundwater Reference Concentration OAR 340-122-045(6)(b)
MCL - Maximum Contaminant Level (Enforceable Level) (USEPA, February, 1996, Drinking Water and Health Advisories)
PRG - Preliminary Remediation Goal
SVOC - Semivolatile organic compound
USEPA - United States Environmental Protection Agency
VOC - Volatile organic compound
(1) Oregon rules state that GRCs are not to be used as an ARAR for site cleanups conducted under CERCLA. They are included here for comparison purposes only.

Note: There are no total petroleum hydrocarbons (TPH) standards for groundwater in Oregon. Soil TPH detections require follow-up analysis of VOCs, SVOCs, and/or metals in groundwater.

TABLE 4-2

Federal and Oregon Numeric Criteria for Metals in Groundwater
142nd FW, Portland ANGB, Portland, Oregon

Analyte	Federal Primary MCL (µg/l)	Oregon GRC (1) (µg/l)	USEPA Region 9 Carcinogenic Tap Water PRG (µg/l)	USEPA Region 9 Non-Carcinogenic Tap Water PRG (µg/l)	Background Concentration* (µg/l)	Project Screening Goal (µg/l)
Antimony	6	--	--	15	--	6
Arsenic	50	0.04	0.045	11	7.83	7.83
Beryllium	4	0.02	0.016	180	3.8	3.8
Cadmium	5	5	--	18	--	5
Chromium	100	100	--	180 (2)	145	145
Copper	--	1,300	--	1,400	44.7	1,300
Lead	--	15	--	--	15.7	15.7
Mercury	2	2	--	3.7 (3)	0.121	2
Nickel	--	100	--	730	78	100
Selenium	50	--	--	180	--	50
Silver	--	50	--	180	--	50
Thallium	2	--	--	2.9 (4)	--	2
Zinc	--	--	--	1,100	142	1,100

Notes:
MCL - Maximum Contaminant Level (Enforceable Level) (USEPA, February, 1996, Drinking Water and Health Advisories)
GRC - Groundwater Reference Concentration, OAR 340-122-045(6)(b)
USEPA - United States Environmental Protection Agency
PRG - Preliminary Remediation Goal
µg/l - Micrograms per liter
-- - Standard not established
(1) Oregon rules state that GRCs are not to be used as an ARAR for site cleanups conducted under CERCLA.
They are included here for comparison purposes only.
(2) PRG listed is for Chromium VI; no tap water PRG exists for total chromium.
(3) PRG listed is for methyl mercury; no tap water PRG exists for elemental mercury.
(4) PRG listed is for thallium chloride; no tap water PRG exists for total thallium.

4.1.2 Federal Guidance to be Considered

In addition to Federal and State requirements that may be ARARs for IRP activities, Federal nonregulatory criteria must be considered. Chemical-specific Federal nonregulatory criteria that may be used to help characterize risks and to set cleanup goals include the USEPA Region 9 preliminary remediation goals (PRGs).

USEPA Region 9 PRGs (USEPA Region 9 2000) are risk-based preliminary screening levels that are used to assess potential concerns related to chemical occurrence defined during previous and ongoing investigations. The PRGs are generally used to eliminate sites of interest that are not of concern with regard to human health risk. The PRGs developed by the USEPA Region 9 for carcinogenic substances correspond to an excess lifetime cancer risk of 1×10^{-6}; the PRGs for noncarcinogenic substances correspond to a HI of 1.

4.1.3 State Applicable or Relevant and Appropriate Requirements

The State of Oregon laws governing cleanup of contaminated sites are outlined in Oregon Revised Statute 465. Environmental Cleanup Rules developed in support of the Oregon Revised Statute laws are included in the OAR 340-122. OAR 340-122 outlines cleanup requirements to ensure the protection of human health and the environment while allowing flexibility in site-specific application of these requirements. OAR 340-122 defines a three-step approach for establishing cleanup requirements for individual sites: (1) determining human and ecological exposure pathways of concern for contaminants, (2) establishing appropriate cleanup standards, and (3) selecting cleanup actions that would best achieve the cleanup standards.

OAR 340-122 provides a number of options for establishing site-specific cleanup levels. Each of these options uses human health risk as the main determinant in setting cleanup levels. The options outlined in OAR 340-122 are described in the sections below. In addition, ODEQ requires that PRGs established by the USEPA Region 9 be reviewed as potential screening-level concentrations. Potential State of Oregon ARARs for soil and groundwater at the Portland ANGB, and the soil screening levels from the USEPA Region 9 PRG tables, are presented in Tables 4-1 through 4-5.

TABLE 4-3

Federal Numeric Criteria for Organic Compounds and Metals in Surface Water
142nd FW, Portland ANGB, Portland, Oregon

Analyte	USEPA Ambient Water Quality Criteria* (1) (µg/l)	Project Screening Goal (µg/l)
Organic compounds:		
Acenaphthene	520 a,b	520
Acetone	--	610
Benzene	--	0.39
Benzo(a)anthracene	--	0.01
Benzo(a)pyrene	--	0.0092
Benzo(b)fluoranthene	--	0.01
Benzo(k)fluoranthene	--	0.01
Bis(2-ethylhexyl)phthalate	160 a	160
Bromochloromethane	--	--
Bromodichloromethane	--	0.18
Butylbenzylphthalate	3 a	3
Carbon disulfide	--	21
4-Chloro-3-Methylphenol	--	--
Chlorobenzene	50 a,b	50
Chloroform	1,240 a	1,240
Chloromethane	--	1.5
1,2-Dichlorobenzene	763 a	763
1,4-Dichlorobenzene	763 a	763
1,1-Dichloroethane	--	810
1,2-Dichloroethane	20,000 a	20,000
1,1-Dichloroethene	--	0.046
cis-1, 2-Dichloroethene	--	61
trans-1,2-Dichloroethene	--	100
total-1,2-Dichloroethene	--	55
1,2-Dichloropropane	5,700 a	5,700
Diethylphthalate	3 a	3
Dimethylphthalate	3 a	3
Di-n-butylphthalate	3 a	3
Di-n-octylphthalate	3 a	3
Ethylbenzene	--	700
Ethylene glycol	--	73,000
Fluorene	--	240
Methylene chloride (dichloromethane)	--	4.3
Methyl ethyl ketone	--	1,900
2-Methylnaphthalene	--	--
4-Methylphenol	--	180
Naphpthalene	620 a	620
Pyrene	--	180
Tetrachloroethene	840 a	840
Toluene	--	720
1,1,2-Trichloroethane	9,400 a	9,400
Trichloroethene	21,900 a,b	21,900
1,2,4-Trimethylbenzene	--	12
1,3,5-Trimethylbenzene	--	12
Vinyl chloride	--	0.02
Xylenes	--	1,400

TABLE 4-3

Federal Numeric Criteria for Organic Compounds and Metals in Surface Water
142nd FW, Portland ANGB, Portland, Oregon

Analyte	USEPA Ambient Water Quality Criteria* (1) (µg/l)	Project Screening Goal (µg/l)
Metals:		
Antimony	--	6
Arsenic	150	150
Beryllium	5.3 a	5.3
Cadmium	2.2	2.2
Chromium	74	74
Copper	9.0	9.0
Lead	2.5	2.5
Mercury	0.77	0.77
Nickel	52	52
Selenium	5.0	5.0
Silver	--	50
Thallium	40 a	40
Zinc	120	120

Notes:

PSG - Project Screening Goal

USEPA - United States Environmental Protection Agency

µg/l - Micrograms per liter

-- - Criterion not established

*Numbers presented correspond to freshwater values for protection of aquatic life, and are for chronic exposu unless otherwise noted. Hardness-dependent values were calculated using an assumed hardness of 100 milligrams per liter.

(1) Source: USEPA 1999, except as noted.

a - Lowest Observed Effect Level; CARWQCB 1998.

b - Exposure duration (i.e., acute/chronic) not specified

For constituents with no Ambient Water Quality Criteria, the PSG derived for groundwater is used as the surface water PSG.

FINAL

TABLE 4-4

Federal and Oregon Numeric Criteria for VOCs, SVOCs, and TPH in Soil

142nd FW, Portland ANGB, Portland, Oregon

Analyte	Oregon Maximum Residential (1,2) (mg/kg)	Oregon Maximum Industrial (1,2) (mg/kg)	USEPA Region 9 Carcinogenic Industrial Soil PRG (mg/kg)	USEPA Region 9 Non-Carcinogenic Industrial Soil PRG (mg/kg)	USEPA Region 9 Soil Screening Level, DAF=1 (3) (mg/kg)	Oregon SCL (4) (mg/kg)	Project Screening Goal (mg/kg)
Acetone	--	--	--	8,800	0.8	--	0.8
Acenaphthene	20,000	100,000	--	11,000	29	2,000	29
Acenaphthylene	--	--	--	--	--	--	--
Anthracene	80,000	600,000	--	160,000	590	20,000	590
Benzene	1	2	1.4	2.4	0.002	0.1	0.002
Benzo(a)anthracene	0.1	1	2.6	--	0.08	0.1	0.08
Benzo(b)fluoranthene	0.1	1	2.6	--	0.2	0.1	0.1
Benzo(k)fluoranthene	0.1	1	26	--	2	0.1	0.1
Benzo(a)pyrene	0.1	1	0.26	--	0.4	0.1	0.1
Benzo(g,h,i)perylene	--	--	--	--	--	--	--
Benzoic Acid	--	--	--	2,700,000	20	--	20
Benzyl Alcohol	--	--	--	200,000	--	--	200,000
Bis(2-ethylhexyl)phthalate	50	400	140	14,000	--	4	4
Bromodichloromethane	5	40	1.4	620	0.03	0.01	0.01
2-Butanone (MEK)	--	--	--	27,000	--	--	27,000
Butylbenzylphthalate	--	--	--	140,000	810	--	810
Carbazole	--	--	95	--	0.03	--	0.03
Chlorobenzene	5,000	40,000	--	220	0.07	--	0.07
Chrysene	0.1	1	260	--	8	--	0.1
Dibenz(a,h)anthracene	0.1	1	0.26	--	0.08	--	0.08
Dibenzofuran	--	--	--	2,300	--	--	2,300
1,4-Dichlorobenzene	--	--	8.5	17,000	0.1	--	0.1
1,3-Dichlorobenzene	--	--	--	2,000	--	--	2,000
1,2-Dichlorobenzene	--	--	--	3,900	0.9	--	0.9
1,2-Dichloroethane	7	60	0.55	51	0.001	--	0.001
cis-1, 2-Dichloroethene	3,000	20,000	--	100	0.02	--	0.02
trans-1,2-Dichloroethene	5,000	40,000	--	270	0.03	--	0.03
Diethylphthalate	--	--	--	860,000	--	--	860,000
2,4-dimethylphenol	--	--	--	21,000	0.4	--	0.4
Di-n-butylphthalate	--	--	--	68,000	270	--	270
Di-n-octylphthalate	--	--	--	14,000	10,000	--	10,000
Ethylbenzene	15,000	20,000	--	5,800	0.7	--	0.7
Ethylene glycol	--	--	--	1,400,000	- -	- -	1,400,000
Fluoranthene	10,000	80,000	--	27,000	210	--	210
Fluorene	10,000	80,000	--	18,000	28	--	28
Hexachloroethane	300	2,000	140	680	0.02	--	0.02
2-Hexanone	--	--	--	--	--	--	--
Indeno(1,2,3-cd)pyrene	0.1	1	2.6	--	0.7	--	0.1
4-Methyl-2-pentanone (MIBK)	--	--	--	2,800	--	--	2,800
Methyl ethyl ketone (MEK)	--	--	--	27,000	--	--	27,000
2-Methylnaphthalene	--	--	--	--	--	--	--
2-Methylphenol	--	--	--	34,000	0.8	--	0.8
3/4-Methylphenol	--	--	--	5,300	--	--	5,300
Methylene chloride (dichloromethane)	--	--	18	7,800	0.001	--	0.001
Naphthalene	--	--	--	4,400	4	--	4
N-Nitrosodiphenylamine	--	--	390	--	0.06	--	0.06
Pentachlorophenol	5	50	7.9	10,000	0.003	5	0.003
Phenanthrene	--	--	--	--	--	--	--
Phenol	--	--	--	100,000	5	--	5
Polychlorinated biphenyls (PCBs)	0.08	0.7	0.34	--	--	0.08	0.08
Aroclor-1016	--	--	0.34	65	--	--	0.34
Aroclor-1254	--	--	0.34	19	--	--	0.34
Pyrene	8,000	60,000	--	20,000	210	6,000	210
1,1,2,2-Tetrachloroethane (1,1,2,2-PCA)	--	--	0.87	--	0.0002	--	0.0002
Tetrachloroethene (PCE)	9	10	16	160	0.003	0.3	0.003
Toluene	5,000	6,000	--	2,700	0.6	80	0.6
TPH-C10 to C24 Aliphatics	--	--	--	--	--	--	--
TPH-Jet fuel A	--	--	--	--	--	--	--
TPH-Heavy Oil	--	--	--	--	--	--	--
TPH-Diesel (5)	--	--	--	--	--	100	100
TPH-Gasoline (5)	--	--	--	--	--	40	40

TABLE 4-4

Federal and Oregon Numeric Criteria for VOCs, SVOCs, and TPH in Soil

142nd FW, Portland ANGB, Portland, Oregon

Analyte	Oregon Maximum Residential (1,2) (mg/kg)	Oregon Maximum Industrial (1,2) (mg/kg)	USEPA Region 9 Carcinogenic Industrial Soil PRG (mg/kg)	USEPA Region 9 Non-Carcinogenic Industrial Soil PRG (mg/kg)	USEPA Region 9 Soil Screening Level, DAF=1 (3) (mg/kg)	Oregon SCL (4) (mg/kg)	Project Screening Goal (mg/kg)
Trichloroethene (TCE)	20	20	6.1	79	0.003	0.4	0.003
Vinyl chloride	0.03	0.05	0.048	--	0.0007	0.008	0.0007
m,p-Xylenes	--	--	--	16,000	10	--	10
o-Xylenes	--	--	--	22,000	9	--	9
Total xylenes	2,000	2,500	--	18,000	10	800	10

Notes:
USEPA - United States Environmental Protection Agency
PRG - Preliminary Remediation Goal
DAF - Dilution and attenuation factor
VOC - Volatile organic compound
SVOC - Semivolatile organic compound
TPH - Total petroleum hydrocarbons
SCL - Soil cleanup level
mg/kg - Milligrams per kilogram
-- - Standard not established
(1) Oregon Department of Environmental Quality Hazardous Substance Remedial Action Rules, Appendix 1
(2) Maximum Allowable Soil Concentration
(3) Dilution and attenuation factor of 1 used; assumes no dilution or attenuation between source and receptor.
(4) Oregon Soil Cleanup Levels (OAR 340-122-045)
(5) Level 1 cleanup values in OAR 340-122-335 are quoted for Oregon SCLs for TPH.

TABLE 4-5

Federal and Oregon Numeric Criteria for Metals in Soil
142nd FW, Portland ANGB, Portland, Oregon

Analyte	Oregon Maximum Residential (1,2) (mg/kg)	Oregon Maximum Industrial (1,2) (mg/kg)	USEPA Region 9 Carcinogenic Industrial Soil PRG (mg/kg)	USEPA Region 9 Non-Carcinogenic Industrial Soil PRG (mg/kg)	USEPA Region 9 Soil Screening Level, DAF=1 (3) (mg/kg)	Background Concentration* (mg/kg)	Project Screening Goal (mg/kg)
Antimony	--	--	--	680	0.3	0.59	0.59
Arsenic	0.4	3	2.4	380	1	5.81	5.81
Barium	20,000	140,000	--	--	--	--	20,000
Beryllium	0.1	1	1.1	8,500	3	1.24	1.24
Cadmium	100	1,000	3,000	850	0.4	0.42	0.42
Chromium	1,000	1,500	450	--	2	39.2	39.2
Copper	10,000	80,000	--	63,000	--	33.5	10,000
Lead	200	2,000	--	1,000	--	27.8	200
Mercury	80	600	--	68 (4)	--	0.09	80
Nickel	5,000	40,000	--	34,000	7	34.4	34.4
Selenium	--	--	--	8,500	0.3	--	0.3
Silver	1,500	10,000	--	8,500	2	0.51	2
Thallium	--	--	--	140 (5)	0.4 (5)	0.67	0.67
Zinc	--	--	--	100,000	620	87.9	620

Notes:
USEPA - United States Environmental Protection Agency
DAF - Dilution and attenuation factor
PRG - Preliminary Remediation Goal
mg/kg - Milligrams per kilogram
-- - Standard not established
(1) Oregon Department of Environmental Quality Hazardous Substance Remedial Action Rules, Appendix 1
(2) Maximum Allowable Soil Concentration
(3) Dilution and attenuation factor of 1 used; assumes no dilution or attenuation between source and receptor.
(4) No PRGs are available for elemental mercury; values given are for methyl mercury.
(5) USEPA PRG and Soil Screening Level values are for thallium chloride.
* Background calculated by 90% Upper Confidence Limit (UCL).

4.1.3.1 Oregon Soil Matrix Cleanup Levels

Oregon Soil Matrix Cleanup Levels (OAR 340-122-315 through 335) apply to soil remediation of petroleum releases from UST systems at relatively simple sites. Individual sites are evaluated by assigning a numerical score for each of the following parameters: (1) depth to groundwater, (2) mean annual precipitation, (3) native soil or rock type, (4) sensitivity of uppermost aquifer, and (5) potential receptors (water supply wells). Total scores for each site determine which of three cleanup levels for gasoline-range hydrocarbons (40, 80, or 130 mg/kg) and diesel-range hydrocarbons (100, 500, or 1,000 mg/kg) apply.

4.1.3.2 Oregon Soil Cleanup Levels

Oregon rules specifically indicate that the Oregon Soil Cleanup Levels (SCLs) are not to be used as an ARAR for site cleanups conducted under CERCLA. However, they are discussed here for completeness and comparison to other chemical-specific ARARs and screening levels.

Oregon SCLs (OAR 340-122-045) comprise Maximum Allowable Soil Concentrations (MASCs) for remediation of 64 common organic compounds for sites where contaminant leaching to groundwater is a concern. SCLs for compounds identified at the Portland ANGB are included in Table 4-4. Oregon SCL concentrations were developed based on human health risk; OAR 340-122-045(3)(a) states that at sites with multiple contaminants, these cleanup levels may be prorated downward to keep health risks below targeted levels.

4.1.3.3 Groundwater Reference Concentrations

Oregon rules indicate that the Groundwater Reference Concentrations (GRCs) are not to be used as an ARAR for site cleanups conducted under CERCLA. However, they are discussed for completeness and comparison to other chemical-specific ARARs and screening levels.

GRCs are presented in the OARs for the purpose of establishing alternative soil cleanup levels under OAR 340-122-045. They were developed as maximum allowable groundwater concentrations for 64 organic compounds, 11 metals, and cyanide. GRCs for constituents identified at the Portland ANGB are included in Tables 4-1 and 4-2. If an Oregon GRC is not available for a particular contaminant, the ODEQ generally accepts the Federal MCL or Secondary Maximum Contaminant Level for the contaminant. If an MCL or Secondary Maximum Contaminant Level is not available for the contaminant, ODEQ generally accepts concentrations that are protective of human health to an excess cancer risk level of 1 x 10^{-6}.

4.1.3.4 Maximum Allowable Soil Concentrations

MASCs (OAR 340-122-045) were developed for sites where groundwater impacts are not a concern. Oregon has developed residential and industrial MASCs. MASCs for constituents identified at the Portland ANGB are listed in Tables 4-4 and 4-5.

4.1.3.5 Oregon Air Pollution Control Requirements

Air emissions from site RAs are regulated under two State requirements: *Notice of Construction and Approval Plans* (OAR 340-028-800 to 820), and *Rules Applicable to Sources Required to Have Air Contaminant Discharge Permits* (OAR 340-028-0600). Of these regulations, the only potentially substantive air pollution control requirement that could be considered an ARAR for the possible RAs at the Portland ANGB is contained in OAR 340-028-0600(1) which states that degradation of existing air quality by new contamination sources shall be minimized to the greatest extent possible.

Compliance with OAR 340-028-0600(1) is defined as compliance with emission requirements in the ODEQ's Hazardous Air Pollutant regulations (OAR 340-032-0105 through 0130). Rates of VOC emissions from the anticipated RAs would be far lower than *de minimis* rates specified in OAR 340-032-0130. Therefore, anticipated RAs are expected to be in compliance with the anti-degradation provision in OAR 340-028-0600(1).

4.1.3.6 Underground Injection Well Requirements

A well or boring used for the purpose of injecting a remediation fluid is classified as a Class V Injection Well by ODEQ. The ODEQ requires submittal of an Underground Injection Control (UIC) Registration for Aquifer Remediation Systems for RAs where fluids will be injected into the subsurface (e.g., in situ chemical oxidation). In addition to registering injection wells, ODEQ has emphasized several requirements that must be met during remediation using underground injection. The primary components of these requirements are:

- The Air National Guard (ANG) must provide public notice (published in local newspaper and mailers sent to interested parties) and a 30-day opportunity to comment on any proposed injection activities. A public meeting must be held to receive comments if requested by 10 or more persons or by a group with a membership of 10 or more.
- No activities shall be conducted that exacerbate existing groundwater contamination or that could cause an adverse impact on existing or potential beneficial uses of groundwater.
- Activities must include an adequate monitoring and reporting program that will allow the public to confirm that the activities are not having an adverse impact.

4.1.4 Wastewater Discharge Requirements

Non-hazardous wastewater generated during RAs will require testing to ensure compliance with the limits set by the City of Portland Bureau of Environmental Services, the operator of the publicly-owned treatment works (POTW) to which the wastewater will be discharged. Wastewater in compliance with these limits may be discharged to the POTW under the existing Portland ANGB discharge permit. If necessary, the water will be treated prior to discharge so that it complied with the POTW limits.

4.2 Remedial Action Objectives

This section presents the development of RAOs for IRP Sites 2, 9, and 11. The RAOs provide media and contaminant-specific (i.e., specific to soil, groundwater, etc.) goals for protecting human health and the environment. The RAOs specify:

- The media and COCs;
- Exposure routes and receptors; and
- Clean-up levels (i.e. acceptable contaminant levels) and applicable criteria.

These criteria are discussed in more detail below:

Media and Contaminants of Concern. The medium of concern for evaluation in the FS is groundwater at IRP Sites 2, 9, and 11. Shallow Zone groundwater is a medium of concern at all three mentioned sites. Deep Zone groundwater is also a media of concern at IRP Sites 2 and 11.

The COCs in groundwater at the Portland ANGB are VOCs. For the purpose of simplifying the discussion of several COCs, the COCs used for this FS were limited to the four most commonly detected compounds: benzene, TCE, cis-1,2-DCE, and VC. These compounds were chosen based on their frequency and distribution of detections above respective PSGs relative to other VOCs detected at the Base. Several other VOCs have been detected at the Base above their PSGs but these detections have either been sporadic and less predictable or have consistently occurred along with detections of the more common VOCs mentioned above.

Specifically, TCE; cis-1,2-DCE; and VC are the COCs at IRP Site 2. Benzene is the COC for IRP Site 9, and cis-1,2-DCE and VC will be used at IRP Site 11.

VC is the primary contaminant of concern in Deep Zone groundwater at IRP Sites 2 and 11. Other VOCs have been detected in samples from Deep Zone monitoring wells at these sites, but not at concentrations significantly higher than the PSGs, as is the case with VC.

Exposure Routes and Receptors. There are several potential exposure pathways for groundwater at the Portland ANGB. As discussed in the beneficial-use survey presented in Section 2.0, some potential pathways correspond with direct exposure to groundwater contaminants, such as ingestion of drinking water or aquatic life exposure via groundwater discharge to surface water. Other pathways involve indirect exposure to groundwater or contaminants in groundwater, such as exposure by indoor air inhalation.

The indoor air inhalation pathway was explored due to the presence of buildings near areas with chemically impacted groundwater. Based on the industrial use of such buildings and on methods developed by the American Society for Testing and Materials (ASTM), risk-based groundwater screening concentrations that result in acceptable indoor air concentrations were calculated for the various contaminants of concern at the Base. The calculations utilized a simple box model (ASTM 1995, Standard Guide for Risk-Based Corrective Action Applied at Petroleum Release Sites, E1739-95) to conservatively represent the transfer of volatile constituents to buildings. The groundwater screening concentrations are presented in Table 4-6. Detected groundwater concentrations less than or

TABLE 4-6

Indoor Air Inhalation Risk Calculation

142nd FW, Portland ANGB, Portland, Oregon

Constituent	Inhalation Slope Factor $(mg/kg/d)^{-1}$	Acceptable Air Concentration (Carcinogenic Effects) (ug/m^3)	Inhalation Reference Dose (mg/kg/d)	Acceptable Air Concentration (Noncarcinogenic Effects) (ug/m^3)	SSSL air (µg/m^3)	H' (dimensionless)	Da (cm^2/sec)	Dw (cm^2/sec)	Deff(cap) (cm^2/sec)	Deff(soil) (cm^2/sec)	Deff(ws) (cm^2/sec)	Deff(crack) (cm^2/sec)	Vfwesp $(mg/m^3_{air}/(mg/l_{water})$	SSSLwater (µg/l)
Benzene	2.7E-02	8.7E-01	1.7E-03	1.1E+01	8.7E-01	2.3E-01	8.8E-02	9.8E-06	1.96E-05	6.87E-03	5.52E-04	6.87E-03	2.54E-03	3.4E+02
cis-1,2-DCE			1.0E-02	6.7E+01	6.7E+01	1.7E-01	7.4E-02	1.1E-05	2.21E-05	5.78E-03	6.06E-04	5.78E-03	1.82E-03	3.7E+04
trans-1,2-DCE			2.0E-02	1.3E+02	1.3E+02	3.8E-01	7.1E-02	1.2E-05	1.53E-05	5.54E-03	4.31E-04	5.54E-03	3.33E-03	4.0E+04
TCE	6.0E-03	3.9E+00	6.0E-03	4.0E+01	3.9E+00	4.2E-01	7.9E-02	9.1E-06	1.44E-05	6.16E-03	4.11E-04	6.16E-03	3.74E-03	1.0E+03
Vinyl chloride	1.6E-02	1.5E+00	2.9E-02	1.9E+02	1.5E+00	1.1E+00	1.1E-01	1.2E-06	1.44E-05	8.58E-03	4.19E-04	8.58E-03	1.12E-02	1.3E+02

Notes:

1. 1E-02 = 0.01
2. SSSLair = Site Specific Screening Level for air, the minimum of the acceptable air concentration based on carcinogenic effects and the acceptable air concentration based on noncarcinogenic effects.
3. The toxicity information is based on the most current information available from IRIS (USEPA, December 1, 2000) and on other information compiled by USEPA Region 09 (2000).
4. Calculation of acceptable air concentrations followed methods developed by USEPA (1996) and USEPA Region 09 (2000).

Model Parameters

Inhalation Rate (adult)		1.9	m^3/hour	(ODEQ, 2000)
Exposure Time		8	hours/day	(ODEQ, 2000; based on an 8-hour work day)
Exposure Frequency		250	days/year	(ODEQ, 2000; USEPA, 1991, USEPA Region 09, 2000)
Exposure Duration (adult)		20	years	(site-specific, based on a 20 year enlistment in the Armed Services)
Body Weight (adult)		70	kilograms	(ODEQ, 2000; USEPA, 1991, USEPA Region 09, 2000)
Averaging Time (carcinogens)		25550	days	(ODEQ, 2000; USEPA, 1991, USEPA Region 09, 2000)
Averaging Time (noncarcinogens)		7300	days	(ODEQ, 2000; USEPA, 1991, USEPA Region 09, 2000)
volumetic air content (capillary fringe)	øacap =	3.80E-02	(dimensionless)	(ASTM, 1996)
volumetic air content (foundation cracks)	øacrack =	2.60E-01	(dimensionless)	(ASTM, 1996)
volumetic air content (vadose zone)	øas =	2.60E-01	(dimensionless)	(ASTM, 1996)
total soil porosity	øtotal =	3.80E-01	(dimensionless)	(ASTM, 1996)
volumetric water content (capillary fringe)	øwcap =	3.42E-01	(dimensionless)	(ASTM, 1996)
volumetic water content (foundation cracks)	øwcrack =	1.20E-01	(dimensionless)	(ASTM, 1996)
volumetic water content (vadose zone)	øws =	1.20E-01	(dimensionless)	(ASTM, 1996)
thickness of capillary fringe	hcap =	5.00E+00	cm	(ASTM, 1996)
thickness of vadose zone	hvadose =	1.47E+02	cm	(Site-specific assumption, based on a depth of 5 feet to groundwater)
air exchange rate	ER =	3.00E-04	sec^-1	(Site-specific assumption, based on 1 unit volume air exchange per hour)
enclosed space volume/infiltration area ratio	Lb =	6.10E+02	cm	(Site-specific assumption, based on buildings that are approximately 20 feet tall)
depth to ground water (= hcap + hvadose)	Lgw =	1.52E+02	cm	(based on a depth of 5 feet to groundwater)
foundation thickness	Lcrack =	1.50E+01	cm	(ASTM, 1996)
areal fraction of foundation cracks	n =	1.00E-02	(dimensionless)	(ASTM, 1996)
Henry's Law Constant (dimensionless form)	H' =	chemical specific		(USEPA Region 09, 2000)
Diffusion coefficient (air)	Da =	chemical specific		(USEPA Region 09, 2000)
Diffusion coefficient (water)	Dw =	chemical specific		(USEPA Region 09, 2000)

Deff(cap) = [Da x (øacap^3.33)/(øtotal^2)] + [Dw x (1/H') x (øwcap^3.33)/(øtotal^2)]	(ASTM, 1996)
Deff(soil) = (Da x (øas^3.33)/(øtotal^2)) + [Dw x (1/H') x (øws^3.33)/(øtotal^2)]	(ASTM, 1996)
Deff(ws) = (hcap + hv)/[(hcap/Deff(cap)) + (hv/Deff(soil))]	(ASTM, 1996)
Deff(crack) = (Da x (øacrack^3.33)/(øtotal^2)) + [Dw x (1/H') x (øwcrack^3.33)/(øtotal^2)]	(ASTM, 1996)
VFwesp = {1000 l/m^3 x H' x [(Deff(ws)/Lgw)/(ER x Lb)]}/{1 + [(Deff(ws)/Lgw)/(ER x Lb)] + [(Deff(ws)/Lgw)/(n x Deff(crack)/Lcrack)]}	(ASTM, 1996)
SSSL (water) = SSSL(air)/VFwesp	(ASTM, 1996)

equal to these screening levels will not pose an unacceptable risk (as defined by ODEQ regulations) to workers who may be present in these buildings.

VOCs in groundwater at some locations at the Base currently exceed the screening concentrations of some of the compounds listed in Table 4-6. However, the only occupied buildings near impacted groundwater are Buildings 255 and 260 in the vicinity of IRP Site 11. Chlorinated VOCs, primarily VC and cis-1,2-DCE, have been detected in groundwater monitoring wells near these buildings, but recent monitoring has shown that these compounds are at concentrations much less than those calculated in Table 4-6. Because of this, potential indoor air exposures for site personnel currently working in these buildings are acceptable under ODEQ regulations. Furthermore, groundwater concentrations are expected to decrease to concentrations below the indoor air screening levels as a result of interim remedial actions for groundwater. Thus, in the event that a new building is constructed on the Base, indoor air exposures are not expected to pose an unacceptable risk under future conditions. For these reasons, the indoor air inhalation exposure pathway was not retained for further evaluation in this FS.

The exposure pathways retained for the FS include ingestion of CRSA groundwater pumped from municipal wells that would be installed in the Portland well field WEA and ingestion of CRSA groundwater pumped at the Base by Base workers. Neither pathway currently exists, and the pathway involving extraction of CRSA groundwater at the Base is not likely. However, because the CRSA has the capacity to support these scenarios, they must be considered.

Clean-Up Levels and Applicable Criteria. Future RA taken at the Portland ANGB must comply with Federal, State, and local laws and regulations, as discussed in the ARARs section above. In accordance with USEPA guidance, chemical-, action-, and location-specific ARARs have been identified for the COCs at the Portland ANGB.

The RAOs for the Portland ANGB correspond with the exposure pathways and Federal and State requirements. The RAOs are as follows:

- Prevent off-site migration of groundwater containing VOCs above 10^{-6} risk concentrations for individual carcinogens;

- Treat groundwater hot spots of contamination (as defined by ODEQ guidance) to concentrations below significant adverse effect levels which correspond with the Federal MCLs;

- Treat the small area of VOC and TPH impacted soil remaining from the 1999 soil removal action; and

- Prevent on-site exposure to groundwater containing VOCs above 10^{-6} risk concentrations for individual carcinogens.

4.3 General Response Actions

General response actions are broadly defined as measures designed to prevent or minimize the adverse environmental impacts of chemicals, and satisfy the RAOs. Appropriate general response actions for IRP Sites 2, 9, and 11 have been identified based on data collected during the RI and pilot tests performed at the Base. The general response actions developed for remediation of groundwater include:

- No action;

- Institutional controls;

- Engineering controls;

- Groundwater collection, treatment, and discharge; and

- In situ groundwater treatment.

4.3.1 No Action

No Action is a general response action required for consideration in the FS by the National Contingency Plan as a baseline condition. The No Action option is retained for further evaluation. There are no costs associated with this option.

4.3.2 Institutional Controls

Institutional controls are designed to limit exposure to hazardous materials through the use of legal or administrative measures or actions. The technologies and process options developed under the institutional control general response action are briefly described in Table 4-7. Three

TABLE 4-7

Remedial Technology Screening - IRP Sites 2, 9, & 11
142nd FW, Portland ANGB, Portland, Oregon

Risk Drivers	Remedial Action Objectives	General Response Action	Remedial Technologies	Process Options	Description	Effectiveness[1]	Implementability[1]	Cost Effectiveness[1]	Retain?	Reason
Trichloroethene, cis-1,2-Dichloroethene, trans-1,2-Dichloroethene, and Vinyl Chloride in Groundwater	Prevent the off-base migration of groundwater containing VOCs above concentrations corresponding to a Hazard Index greater than 1 or a lifetime excess cancer risk greater than 1x10-6 for individual carcinogens.	**No Action**	No Action	No Action	No institutional controls or treatment.	1	3	3	Yes	Retaining No Action is required for comparison.
		In Situ Treatment - Source area will be treated to reduce VOC concentrations sufficiently to prevent off-base migration of groundwater with unacceptable risk. Preliminary target cleanup levels are MCLs, which will also be protective of human health on site based on an industrial land use scenario	Chemical treatment	Permanganate oxidation	Injection of potassium permanganate into saturated zone. Contaminants are destroyed through oxidation.	3	3	2	Yes	Pilot-scale treatability testing at Base indicates potential for full-scale effectiveness.
				Persulfate oxidation	Injection of sodium persulfate into saturated zone. Contaminants are destroyed through oxidation.	3	3	2	Yes	Persulfate's anticipated effectiveness at treating benzene serves as a substitute or amendment for permanganate when treating benzene is the objective.
				Fenton's Reagent oxidation	Injection of a mixture of hydrogen peroxide and an iron-based catalist. The breakdown of hydrogen peroxide produces hydroxyl radical, which destroys contaminants through oxidation.	3	2	2	No	Safety concerns associated with the use of concentrated hydrogen peroxide are too great. This technology does not provide a significant residual treatment capacity, relative to potassium permanganate.
				Ozone Sparging	Sparging of ozonated air into saturated zone. Contaminants are destroyed through oxidation.	3	2	2	Yes	Pilot-scale treatability testing at Base indicates potential for full-scale effectiveness.
				Zero Valent Iron Oxidation	Construction of a reactive barrier wall using zero valent iron. VOCs in groundwater flowing through wall are oxidized.	1	2	1	No	The slowness and variability of groundwater flow at the Base are not compatible with this type of technology.
			Biological Treatment	Enhanced aerobic bioremediation	Injection of oxygen releasing substance into saturated zone stimulates activity of aerobic microbes. Applicable to contaminants capable of aerobic degradation.	3	3	2	Yes	Treatability testing at Base indicates potential for full-scale effectiveness.
				Enhanced anaerobic bioremediation	Injection of hydrogen releasing substance into saturated zone stimulates activity of anaerobic microbes. Applicable to contaminants capable of anaerobic degradation.	3	3	2	Yes	Testing at sites with similar conditions indicate potential effectiveness at treating TCE in groundwater.
			Physical Treatment	In-well Aeration	In-well aerators perform air stripping of groundwater within the well. Groundwater is not removed from the well, but is circulated through the aquifer.	3	2	2	Yes	Pilot-scale treatability testing at Base indicates potential for full-scale effectiveness.
				Air Sparging	Sparging of air into saturated zone volatilizes contaminants. Contaminants are transferred to vapor phase. This technology is usually combined with soil vapor extraction and off-gas treatment to control release of volatilized contaminants.	2	2	2	No	Requirement for soil vapor extraction wells and the expected duration of this technology results in reduced cost-effectiveness.
			Monitored Natural Attenuation	Intrinsic Bioremediation	Involves monitoring parameters used to quantify natural biodegradation of contaminants.	2	3	3	Yes	Natural attenuation has been shown to be slow, but active at the Base. Use of natural attenuation should be used only at lower concentration areas of contaminant plumes, or as a polishing method following active treatment.
		Groundwater Collection / Treatment / Discharge	Groundwater extraction	Groundwater extraction wells	Use of groundwater extraction wells to pump groundwater out of the aquifer for treatment and disposal.	2	2	1	No	Pump and treat technologies are not expected to be cost-effective relative to in situ treatment technologies.
			Physical Treatment	Air stripping	Countercurrent flow of air and water transfers VOCs from aqueous phase to vapor phase.	2	2	2	No	Pump and treat technologies are not expected to be cost-effective relative to in situ treatment technologies.

TABLE 4-7

Remedial Technology Screening - IRP Sites 2, 9, & 11
142nd FW, Portland ANGB, Portland, Oregon

Risk Drivers	**Remedial Action Objectives**	**General Response Action**	**Remedial Technologies**	**Process Options**	**Description**	**Effectiveness**[1]	**Implementability**[1]	**Cost Effectiveness**[1]	**Retain?**	**Reason**
			Off-site discharge	Discharge to POTW	Discharge of extracted and treated groundwater to the sanitary sewer for conveyance to the local POTW.	2	2	3	No	Pump and treat technologies are not expected to be cost-effective relative to in situ treatment technologies.
Trichloroethene, cis-1,2-Dichloroethene, trans-1,2-Dichloroethene, and Vinyl Chloride in Groundwater (continued...)	Prevent the off-base migration of groundwater containing VOCs above concentrations corresponding to a Hazard Index greater than 1 or a lifetime excess cancer risk greater than 1x10-6 for individual carcinogens. (continued…)	**Institutional Controls**	Monitoring	Groundwater monitoring	Regular monitoring of groundwater to evaluate effectiveness in meeting remedial action objectives.	1	3	3	Yes	Groundwater monitoring will be required to evaluate an alternative's effectiveness at meeting remedial action objectives.
			Land / Water use restrictions	Deed Restrictions	Deed restrictions create legal restrictions on specific activities or uses of land or water by current and future land owners.	3	3	3	Yes	Deed restrictions are necessary to prevent unrestricted use of the Base.
				Zoning restrictions	Zoning restrictions prevent the alteration of the zoning classification of the Base.	3	3	3	Yes	Zoning restrictions are necessary to prevent alteration of the zoning classification of the Base.
				Access restrictions	Access restrictions prevent use of a facility by unauthorized personnel and for unauthorized purposes.	3	3	3	Yes	Access restrictions are necessary at the Base to prevent unrestricted access to potentially contaminated sites.
			Construction Controls	Health and safety training, equipment, and monitoring	Construction activities performed in areas containing potentially elevated levels of contaminants must be accompanied by appropriate health and safety monitoring. Construction workers must be appropriately trained and properly equipped.	3	3	3	Yes	Construction activities, excavation below the water table in particular, must be performed in a manner protective of worker health.
		Engineering Controls	Alternative water supplies	Public water system	This option specifies that the Base must tap into the public water system for future water supplies, rather than drilling supply wells on the Base.	3	3	3	Yes	Future water supplies for drinking or process use must not be obtained from Base groundwater.

NOTES:

VOC - Volatile organic compound

MCL - Maximum Contaminant Level

POTW - Publicly Owned Treatment Works

TCE - Trichloroethylene

1 - Effectiveness, implementability and cost effectiveness evaluated on a relative 1 to 3 scale, where 1 is low and 3 is high.

institutional control technologies were screened: monitoring, land- or water-use restrictions, and construction controls. Process options for monitoring consist solely of groundwater monitoring. Process options for land and water use restrictions include deed and zoning restrictions. Process options for construction controls consist of implementing health and safety procedures including training, equipment, and monitoring.

4.3.3 Engineering Controls

Engineering controls are designed to limit exposure to hazardous materials through the use of physical measures. The technologies and process options developed under the engineering control general response action are briefly described in Table 4-7. The engineering control technology that was screened involved alternative water supplies. Process options for alternative water supplies are limited to obtaining new water supplies from the public water system.

4.3.4 Groundwater Collection, Treatment, and Discharge

This general response action involves collection, treatment, and discharge of site groundwater. This action would be performed to reduce concentrations of contaminants in site groundwater to levels required to meet RAOs. Technologies screened under this general response included groundwater extraction, physical treatment, and off-site discharge. The process options for these technologies are groundwater extraction wells, air stripping, and discharge to a POTW. These process options are described briefly in Table 4-7.

4.3.5 In Situ Groundwater Treatment

This general response action involves in situ treatment of site groundwater to meet RAOs. Technologies screened for in situ treatment include chemical treatment, biological treatment, physical treatment, and action monitored natural attenuation (MNA). The process options screened for the chemical treatment technology included zero-valent iron oxidation, Fenton’s reagent oxidation, permanganate oxidation, persulfate oxidation, and ozone sparging. The biological treatment process options include enhanced aerobic and anaerobic bioremediation. The physical treatment process options include in-well aeration and air sparging. The sole process option for MNA involves monitoring the intrinsic bioremediation element of natural attenuation. Table 4-7 provides a brief description and evaluation of these process options.

4.4 Identification and Screening of Remedial Technologies

Following the development of general response actions (Section 4.3), potentially suitable remedial technologies have been identified and screened (i.e., retained or discarded from further consideration). In this process, a set of potentially applicable remedial technologies and process options are identified and generally evaluated with respect to implementability and effectiveness at the site considering the RAOs, the COCs, and the physical/chemical site characteristics.

Based on readily available information for technologies applicable to the types of contaminants and site characteristics at the Portland ANGB, assumptions can be made regarding the initial set of technologies and process options. While it is possible to list dozens of technologies and systematically eliminate a large majority of those due to an obvious lack of applicability, this FS is based on a reasonable subset of technologies specifically applicable to the RAOs, COCs, and site characteristics for the Portland ANGB.

This subset of treatment technologies described below represents: 1) a list of technologies that have been tested at the Base; 2) are proven technologies for the particular application; or 3) are innovative technologies expected to successfully meet remediation objectives. Technologies that are not expected to be implementable or effective at the base were not evaluated in this FS. Examples include technologies such as thermal processes, capping, hydraulic barriers, and numerous ex-situ treatment technologies. It is acknowledged that these technologies have been used as remediation options at sites impacted with similar contaminants. However, due to site restrictions, hydrogeologic constraints, or other factors at the Portland ANGB, these technologies are not expected to be applicable to groundwater treatment at the Portland ANGB.

The remedial technologies and process options identified for each general response action category are shown in Table 4-7. For each technology, at least one process option was selected. These process options are briefly described in Table 4-7. A relative screening is also presented in this table, which served as the basis for a recommendation to either retain or exclude a particular process option from further consideration. Comments also provide a basis for the screening decision. The technologies identified for remediation of groundwater include:

- No action;
- Monitoring;
- Land / water use restrictions;
- Construction controls;
- Alternative water supplies;
- Groundwater extraction and treatment;
- In situ chemical treatment;
- In situ biological treatment;
- In situ physical treatment; and
- MNA.

These remedial technologies are described below under the appropriate general response actions.

4.4.1 No Action

Under the No Action general response action, No Action was the only technology / process option proposed. Under the No Action option, site modifications or groundwater monitoring would not be implemented to prevent or eliminate human health and environmental risks associated with VOCs in groundwater.

This alternative does not reduce or control potential future risk posed by groundwater contaminants at IRP Sites 2, 9, or 11. Because the alternative excludes remedial, institutional, and monitoring activities, it is considered easily implemented. There is no cost associated with this alternative.

Consideration of No Action as a technology is required in the FS process for comparison purposes; therefore this option is retained for further evaluation.

4.4.2 Institutional Controls

The Institutional Controls general response action includes consideration of three remedial technologies or processes: monitoring, land/water use restrictions, and construction controls. These technologies and the relative process options are described below.

4.4.2.1 Monitoring

Monitoring is an institutional control used to evaluate the presence of COCs at specific locations. This technology is used to evaluate the migration of VOCs at the Base to ensure compliance with the RAOs. The single monitoring process option used for this FS is groundwater monitoring. Specific existing and proposed monitoring wells screened in the various water-bearing zones underlying the Base will be monitored at regular intervals.

4.4.2.2 Land-/Water-Use Restrictions

The use of land- and water-use restrictions as a remedial technology/process involves placing restrictions on the current and future uses of the land and groundwater within the Base boundary. Several process options are available for this purpose, including deed restrictions, zoning restrictions, and access restrictions. Implementing these restrictions protects Base workers and future residents of the Base property, should a property transfer occur.

Deed restrictions create legal restrictions on specific activities or uses of land or water by current and future landowners. These restrictions are intended to prevent unauthorized development of the land and water.

Zoning restrictions are similar to deed restrictions, but prevent the future alteration of land use classification. This would prevent the Base from later being designated mixed use or residential use.

Access restrictions prevent unauthorized access or use of the Base. This would prevent unauthorized access to areas containing unacceptable levels of contaminants.

4.4.2.3 Construction Controls

The use of construction controls involves control and monitoring of construction crews at the Base to prevent unhealthy exposure to contaminants by construction personnel. During excavation activities, construction workers may be exposed to shallow groundwater containing VOCs. The one process option for this technology involves implementing a site-specific health and safety program consisting of training construction workers, providing appropriate equipment, and monitoring work areas to prevent contaminant exposure during construction.

4.4.3 Engineering Controls

The engineering controls general response action includes consideration of one technology: alternative water supplies. This technology is described below.

4.4.3.1 Alternative Water Supplies

As an engineering control, alternative water supplies provide an option for obtaining additional water at the Base. To prevent the need to drill production wells on the Base, alternative water supplies must be available to supply additional water needs. Process options for alternative water supplies are limited to obtaining new water supplies from the public water system.

4.4.4 Groundwater Extraction and Treatment

Groundwater extraction and treatment is a general response action category that involves a number of traditional technologies and process options for groundwater remediation through contaminant migration control and contaminant mass removal methods. Based on the site characteristics and the nature and extent of contamination, only one technology is presented here for discussion. While several process options are available to extract groundwater from the subsurface (trenches, horizontal piping, vacuum systems, etc.) the process option identified and screened for the Portland IRP sites involves the use of groundwater pumping wells placed at specified intervals in the Shallow and Deep Zones. Dissolved contaminants in groundwater would be captured via pumping processes, extracted to the surface, physically or chemically treated, and disposed through one of several potential process options (e.g. disposal to an off-site POTW, re-infiltration, etc.).

While the dissolved contaminants present at IRP Sites 2, 9, and 11 are susceptible to capture and removal by pumping processes, the success of groundwater extraction technologies is highly dependant on the ability to efficiently pump contaminated water from the water bearing zone. Often this success is measured in terms of the efficiency, or the mass of contaminant removed per unit cost to operate the system.

Lithologic data from the RI indicate that the thickness of the Shallow and Deep Zones vary significantly over short distances, and that significant silty intervals are present in both zones. Also, the silty intervals bracketing the zones are saturated. These conditions are problematic for successful remediation by groundwater extraction, as VOCs have a moderately strong affinity for sorption to fine-grained soil particles and because preferential flow pathways can be expected to develop in coarser-grained intervals within the Shallow and Deep Zones.

The low storativity values estimated from groundwater pumping test data also indicate that even relatively low groundwater pumping rates (i.e., 5 gallons per minute) would significantly lower the groundwater level in the overlying silt and, likely, the upper Shallow Zone. Much of the residual VOCs sorbed to soils would be stranded above the zone in which flushing would be achieved by groundwater flow toward the extraction wells. For these reasons, it is unlikely that groundwater extraction would cost-effectively remediate VOCs in groundwater.

This technology was not retained for evaluation in this FS because Shallow Zone hydrogeologic characteristics are not favorable for effective contaminant reduction through groundwater extraction. Since groundwater extraction technology has not been retained as a feasible remedial option, no further discussion of physical treatment or off-site discharge with regard to the groundwater extraction and treatment general response action is necessary.

4.4.5 In Situ Groundwater Treatment

Several remedial technologies were screened for the in situ groundwater treatment general response action. These technologies included chemical, biological, and physical treatment, as well as MNA. Descriptions are provided below.

4.4.5.1 Chemical Treatment

In situ chemical treatment of groundwater contaminants involves the chemical alteration or destruction of the contaminants through processes carried out in the saturated zone, without the need to extract groundwater. Generally, this technology involves the injection of a reactive chemical or mixture of chemicals that reacts with the particular COCs.

The most common mechanism for the in situ chemical treatment of VOCs is oxidation. In situ oxidation is a relatively new technology that involves the placement of an oxidant into the subsurface to react with the COCs. In situ oxidation is applicable for various organic contaminants, including fuel-related hydrocarbons and VOCs, chlorinated VOCs, and PAHs. Because of the wide availability and observed success of oxidation technologies, other in situ chemical treatment mechanisms were not evaluated in this FS.

The potential benefits from in situ oxidation include in situ contaminant destruction, relatively low cost, reliability, simplicity, and rapid treatment. However, site-specific constraints must be considered. Efficient oxidation is dependent on the contact between oxidant and contaminant. Subsurface heterogeneities, preferential flow paths, and poor mixing in the subsurface may result in inefficient treatment. In addition, high levels of other oxidizable substances in the treated zone, such as other organic material and reduced-state metals, can significantly reduce the treatment efficiency and effectiveness.

The primary delivery mechanism for in situ chemical oxidation involves the placement, through fluid injection, gaseous sparging, or bulk soil replacement, of the oxidizing material in the zone of contaminated groundwater being treated. ODEQ is likely to consider all of these mechanisms to be regulated under their UIC program, thus requiring that injection locations be registered and the requirements described in Section 4.1.3.6 be met. The primary concern with in situ oxidation is the long-term degradation of water quality beyond the zone of treatment. All of the technologies described below have the potential to cause unacceptable water quality degradation under certain conditions.

Some potential water quality degradation mechanisms are common to all oxidation processes. For example, the altered oxidation state of the subsurface resulting from in situ oxidation can cause the migration of metals such as chromium that are more soluble and potentially more toxic in their oxidized state. However, dissolved chromium has not been regularly detected in groundwater during the RI at areas being considered for in situ oxidation and chromium concentrations detected in soil have been well below regulatory limits. Due to an induced oxidative state and slightly increased pH, some chromium may oxidize to the hexavalent form and become mobile. However, this transformation is highly dependent on the pH and redox potential of the groundwater (Zumdahl

1989). As groundwater flows away from the area immediately surrounding the treatment location, or as the oxidant is utilized, pH and redox values will decrease until they reach initial conditions. As pH and redox values equilibrate, the equilibrium concentration of hexavalent chromium will decrease significantly.

Other hazards or potential mechanisms for degradation of water quality specific to a particular oxidation technology will be addressed below.

The five chemical treatment process options that have been retained for evaluation in this FS are zero-valent iron oxidation, Fenton's Reagent oxidation, potassium permanganate oxidation, sodium persulfate oxidation, and ozone sparging, all of which rely on the oxidation of contaminants.

Zero-Valent Iron Oxidation

Metallic iron has been used successfully to oxidize subsurface contaminants, including VOCs. This technology is generally applied as a funnel and gate or standard reactive-barrier wall and relies on the horizontal flow of groundwater past a wall of iron in the form of granules or filings. The wall of iron is constructed by excavating the soil from the top of the water-bearing zone down to the confining layer and replacing the soil with iron and other wall components.

The advantage of an iron reactive barrier wall is that the treatment is performed passively, as groundwater flows past the wall. The only maintenance required would be replacement of the iron as its oxidation capacity reduces. The main disadvantage of this technology is that it relies on the horizontal flow of groundwater past the reactive wall.

The introduction of solid zero-valent iron has the potential to cause a degradation of water quality. As described previously, the oxidative state induced by the iron has the potential to cause dissolution of heavy metals such as hexavalent chromium. The potential for this to occur is based on the reactive life span of the iron. If the iron is allowed to remain in place and the oxidative effects are long lived, the original conditions of the water-bearing zone being treated may not readily equilibrate, allowing oxidized metals to migrate further than some other technologies. Also, small quantities of other metals such as chromium, arsenic, and cadmium may be present in the granular iron used for this technology. The contaminants introduced by this technology may impact water quality if present at high levels.

Because horizontal groundwater flow at the Portland ANGB is relatively slow and directionally variable, and the primary exposure scenario relies on the downward flow of groundwater and contaminants, this technology would not be expected to meet the RAOs. Therefore, zero-valent iron oxidation is not retained for further evaluation in this FS.

Fenton's Reagent Oxidation

The chemistry of Fenton's reagent involves the production of hydroxyl radicals through the catalysis of hydrogen peroxide. Ferrous iron (Fe^{2+}), either in native soil or delivered in the form of iron salts such as ferrous sulfate, catalyses the breakdown of hydrogen peroxide and the production of the hydroxyl radical.

The use of Fenton's reagent chemistry as an in situ remediation technology has been developed in several proprietary, commercially available forms. The hydrogen peroxide is mixed with iron salts and other proprietary components and delivered to the groundwater treatment zone in the same manner as other in situ fluid delivery technologies. This technology is applicable for a wide range of organic contaminants, including free phase contamination. The reactivity of the hydroxyl radical is very high and rapid.

There is a limit to the effectiveness of Fenton's Reagent by virtue of it's relative environmental instability . Hydroxyl radicals are relatively short lived. The hydroxyl radical will react with free radical scavengers/sinks and eventually be destroyed. Free radical sinks include metals, natural organics, or hydrogen peroxide itself. When the hydroxyl radicals react with hydrogen peroxide, heat and gas are produced. Because of the threat of rapid decomposition, 5-10 percent hydrogen peroxide solution is considered as a relatively safe range for the application of hydroxyl radicals. Above this concentration the decomposition of peroxide is sufficiently exothermic to produce steam, which if not captured in an engineered fashion can create safety hazard, as encountered in a few field-applications. The floodplain silts confining the Shallow Zone and Deep Zone water bearing units at the Base would prevent the gradual release of any steam or VOC vapors produced from this reaction. This could produce a buildup of high pressure, resulting in a dangerous sudden release through a preferential pathway, such as a monitoring well or utility vault. This potential scenario would be unacceptable at the Base, particularly at IRP Site 11 where aircraft and aircraft fuel are stored.

Because of the instability and potential heat and steam production due to the reaction of hydrogen peroxide, this technology was not retained for further evaluation in this FS.

Potassium Permanganate Oxidation

One of the most common oxidants available for use in the chemical treatment of organic contaminant is potassium permanganate. Potassium permanganate is delivered into the water-bearing zone as a water-based solution of approximately 1 to 5 percent potassium permanganate, by weight. Upon dissolution, permanganate ion causes the solution to turn purple, which provides an indicator mechanism. When the permanganate is reduced upon reaction with organic matter, it forms manganese dioxide, which is an insoluble brown precipitate under most conditions. In some cases, the manganese dioxide can cause a slight reduction of hydraulic conductivity in the treatment area (Environmental Security Technology Certification Program 1999). Permanganate is very effective at oxidizing most VOCs, and is capable of oxidizing petroleum hydrocarbons and related compounds. Permanganate has not been proven to be as effective at treating benzene as some other compounds.

Potassium permanganate has been proven to provide effective treatment of the chlorinated VOCs impacting groundwater at IRP Sites 2 and 11. Potassium permanganate is the least expensive oxidant available. A remediation system consisting of injecting potassium permanganate using direct-push injection points or permanent injection wells can be significantly less expensive than constructing a continuously operating remediation system. Permanganate injection can also be performed using horizontal wells. This will allow use of this technology when disturbing the ground surface above the treatment area is not feasible.

The COCs at IRP Site 9 require different considerations when choosing an appropriate oxidant. In particular, benzene has been shown to react slowly when treated with potassium permanganate.

A pilot test using injection of potassium permanganate was conducted at IRP Site 2. The purpose of the test was to evaluate the effectiveness of potassium permanganate at treating chlorinated VOCs in Shallow Zone groundwater and to determine a radius of influence for the injection. Significant reduction of chlorinated VOC concentrations in groundwater was observed. Over a 3-month monitoring period, VC was reduced by between 80 percent and greater than 90 percent at downgradient monitoring wells. Significant removal of cis-1,2-DCE and trans-1,2-DCE was also observed (up to 90 percent). Significant reduction of VC (greater than 80 percent) and trans-1,2-DCE (approximately 75 percent) were observed at the furthest monitoring well, 12-feet downgradient of the injection location. Further details regarding the results of this pilot test are provided in the *Interim Remedial Action Construction Phase I Interim Report* (ERM 2001c).

Potassium permanganate reacts rapidly with the double bonds in chlorinated ethenes. Permanganate oxidizes the chlorinated ethenes to carbon dioxide and chloride ion. The end products of the reaction of potassium permanganate with CVOCs are carbon dioxide, water, hydroxide ion, potassium ion, manganese dioxide, and chloride ion. For example, the reaction of potassium permanganate with VC is represented in the following balanced stoichiometric equation:

$10KMnO_4 + 3C_2H_3Cl \text{ ---> } 6CO_2 + 10MnO_2 + 10K^+ + 3Cl^- + 7OH^- + H_2O$

The end products are not expected to cause a detrimental impact to groundwater quality. Unreacted permanganate can discolor groundwater (purple color). However, unreacted permanganate is not expected to reach a receptor, because the natural oxidant demand of native materials in the soil and groundwater will cause the permanganate to react with these materials before the permanganate can migrate a significant distance. This behavior was confirmed during the Phase I IRAC (ERM 2001c), where purple colored groundwater was not observed at a significant distance downgradient.

When the permanganate is reduced upon reaction with organic matter, it forms manganese dioxide, which is an insoluble brown precipitate under most conditions. However, precipitated manganese dioxide is not expected to inhibit groundwater flow at the low concentration of potassium permanganate that will be injected.

The raw material used for this technology is technical grade solid potassium permanganate. This is the same material used in drinking water and wastewater treatment, and its composition is regulated by the American Water Works Association. It is possible that the material used could contain trace amounts of impurities from the manufacturing process. These impurities could include toxic heavy metals such as chromium and mercury at very low concentrations. One manufacturer of potassium permanganate lists typical values of the three regulated impurities as less than 5 mg/kg cadmium, less than 20 mg/kg chromium, and less than 0.5 mg/kg mercury. At the concentration of potassium permanganate to be injected into the groundwater at IRP Site 11, the resulting concentrations of these three metals will be less than their respective MCLs. As the injectate disperses and mixes with groundwater immediately surrounding the injection location, the resulting concentrations will decrease further. For verification, a sample of the raw material will be analyzed for impurities.

The long-term effects of potassium permanganate injection are expected to be favorable for subsequent natural attenuation of low concentrations of the remaining chlorinated VOCs in groundwater. Although the oxidative environment caused by the injected potassium permanganate may temporarily inhibit intrinsic biodegradation in the treatment area, intrinsic biological activity is expected to resume at pre-treatment levels soon after this oxidative environment attenuates.

The United States Department of Energy (DOE) evaluated the use of potassium permanganate in an Innovative Technology Summary Report titled *In Situ Chemical Oxidation using Potassium Permanganate* (DOE 1999). The DOE made several conclusions regarding the use of potassium permanganate and associated community and regulatory issues. Among the conclusions of the DOE evaluation were the following:

- The materials injected ($KMnO_4$) pose no hazard to the community or environment due to their low concentration after dispersal into the soil or groundwater;

- The community is not exposed to harmful by-products and there is no significant environmental impact as the overall reaction results in generation of carbon dioxide, MnO_2 solids, cations (e.g., potassium), and halides (when chlorinated solvents are present);

- In situ chemical oxidation using $KMnO_4$ does not produce VOCs (due to cleavage of the organic compound); and

- No unusual or significant safety concerns are associated with transport of equipment or other materials associated with this technology.

Persulfate Oxidation

Persulfates are strong but slow reacting oxidants. They exist as salts and are commonly available as the sodium, potassium or ammonium forms. Persulfates require activation in order to react, due to their high activation energy. They are typically thermally activated in industrial use.

Activation through the use of metal catalysis such as iron catalysis is also possible. The application of persulfates in groundwater remediation has not been tested extensively, but is expected to be effective based on chemical reaction data (Brown 1999). The application of persulfate is similar to that for potassium permanganate. A water-based solution is injected through injection wells or direct-push injection points.

Persulfate is expected to be effective primarily for benzene and is not expected to effectively treat chlorinated VOCs. This option would be useful at IRP Site 9, for treating benzene.

Water quality issues for persulfates are similar to that of permanganate since the reaction mechanism is essentially the same. Persulfate is similarly a strong oxidant and will induce oxidative conditions in the water-bearing zone. However, as with the application of potassium permanganate, the persulfate is injected in low concentrations and the effects of this injection will not be seen at a great distance from the treatment zone. The use of persulfate oxidation is only proposed at IRP Site 9, where chlorinated hydrocarbons are not present. Because of this, production of more toxic VOCs is not a concern.

The composition of sodium persulfate and appropriate catalysts must be analyzed to prevent introduction of contaminants that may degrade water quality.

Ozone Sparging

The chemical process of in situ oxidation using ozonation is very similar to permanganate oxidation. Ozone is a strong oxidizer that readily breaks down organic compounds. Chemical oxidation by ozone is applicable for various organic contaminants including fuel-related hydrocarbons and VOCs, chlorinated VOCs, and PAHs.

Ozone sparging significantly differs from the other oxidation technologies, in that the implementation of ozone sparging is significantly more complex than that required for liquid injection. Ozone is delivered to the contaminated zone in the gas phase. Ozone is sparged using a typical air-sparging system, with the addition of between 1 and 5 percent ozone gas, by weight, to the air to be sparged. The gas mixture flows upward, oxidizing organic material in the process. Ozone can also be delivered through horizontal wells. Horizontal sparge wells installed near the bottom of the treatment zone can provide effective distribution of sparged gasses.

Ozone is the strongest oxidant available for remediation and is very effective at oxidizing most organic contaminants. However, because ozone is so reactive in nature, it does not provide the stable, residual treatment capacity of some other oxidants, including permanganate. Also, ozone sparging is very susceptible to preferential flow, which can lead to pockets of untreated contaminants in heterogeneous soil.

Ozone sparging has been proven to provide efficient treatment of contaminants under the correct conditions. The COCs at IRP Sites 2, 9, and 11, chlorinated VOCs and benzene can all be treated effectively by ozone sparging.

The only water quality issues related to this technology is that related to the induced oxidative state of the groundwater as previously described. However, because ozone is so short-lived, the oxidative effects do not remain as long as other technologies. This is why an ozone system must be continuously operated. Oxidative effects of the ozone will not travel very far outside of the treatment zone. Native material in soil will quickly utilize any available ozone. There are no other byproducts of the oxidation reactions that would be expected to cause degradation of water quality at the Portland ANGB. However, there are safety concerns associated with ozone sparging. Ozone leaking from a system prior to being injected into the subsurface can pose a health and explosion hazard if in significant concentrations. Also, since this technology relies on the continuous injection of a gas into the subsurface, the use of pressure relief points in the subsurface must be considered, particularly in a confined water-bearing zone.

A pilot test using ozonation was conducted at IRP Site 2. The purpose of the test was to evaluate the effectiveness of ozone at treating chlorinated VOCs in Shallow Zone groundwater and to determine a radius of influence for the sparging system. Reduction of chlorinated VOC concentrations in groundwater was observed in nearby wells. Following 24-hours of ozone sparging, concentrations of cis-1,2-DCE and trans-1,2-DCE were reduced by approximately 75 percent. Contaminant removal was not observed in the furthest downgradient monitoring well at a distance of 12-feet. However, a significant change in wellhead VOC concentration was observed in this well during air sparging and ozone sparging, indicating some influence at this distance. Since contaminant reduction was not observed at this well, it must be concluded that the true radius of influence of the system is less than 12-feet.

The radius of influence for this system was estimated to be 8 to approximately 9-feet (ERM 2001c).

4.4.5.2 Biological Treatment

In situ biological treatment involves the injection of a material that stimulates the natural biological activity of the contaminated zone. The natural biological activity of a contaminated zone can become depressed after an extended period of contaminant degradation. Some sites are capable of extensive contaminant removal if depleted growth factors are replenished. Biological activity in a contaminated zone is frequently limited by the availability of a single growth factor, such as an electron acceptor or donor. Supplying this growth factor can often stimulate bacterial growth and biodegradation rates, and is generally used to treat saturated zone contamination.

The COCs at IRP Sites 2, 9, and 11 are expected to be treatable through biodegradation. A natural attenuation evaluation performed at these sites has shown that the contaminants appear to be degrading at a slow rate (ERM 2001a). This is an indication that the contaminant zone may be depleted of a growth factor as a result of past degradation of the contaminants.

Performing enhanced bioremediation involves injecting the material used to stimulate biological activity into the contaminated zone. Depending on the material used and the concentration of contaminants being treated, the material may require multiple injections to maintain optimal conditions. The two process options for this technology are enhanced aerobic bioremediation and enhanced anaerobic bioremediation.

Enhanced Aerobic Bioremediation

In scenarios where aerobic respiration is the preferred biological pathway for contaminant degradation, oxygen acts as the electron acceptor and is frequently depleted. Contaminants at IRP Sites 2, 9, and 11 that are capable of degradation by aerobic bioremediation include benzene, VC, cis-1,2-DCE, and trans-1,2-DCE. A lack of oxygen results in the use of other electron acceptors and biological pathways, which are much slower than aerobic respiration. Increasing the dissolved oxygen content in the contaminated zone ensures that aerobic respiration is the dominant biological pathway. This can be accomplished by injecting a substance that slowly releases oxygen.

One material that has been shown to be effective at treating a variety of contaminants is ORC®, produced by Regenesis. ORC® is a magnesium peroxide material that slowly releases elemental oxygen when hydrated.

A pilot test using ORC® was conducted at IRP Site 2. The purpose of the test was to evaluate the effectiveness of ORC® at reducing chlorinated VOCs in Shallow Zone groundwater and to determine a radius of influence for the injected ORC®. Significant reduction of chlorinated VOC concentrations in groundwater was observed, particularly cis-1,2-DCE and VC. Over the 3-month test duration, VC, cis-1,2-DCE, and trans-1,2-DCE were reduced by 70 to 75 percent at the furthest monitoring well, 12 feet downgradient of the injection location. Because the biological treatment of VOCs is slower than other methods, it can be assumed that the radius of influence for this test is at least 12 feet (ERM 2001c).

Enhanced Anaerobic Bioremediation

The correct oxidation-reduction state and the presence of electron donors are important factors in scenarios where reductive dechlorination is the preferred pathway for degradation of chlorinated hydrocarbons. TCE is the contaminant present at the Base that is most conducive to reductive dechlorination. Dissolved hydrogen added to source area groundwater can act as the required electron donor when others have been depleted, as well as serve to lower the redox potential to the appropriate range.

Several hydrogen sources exist that can be injected into the contaminated zone. Sodium lactate has been used successfully to enhance the biodegradation of chlorinated hydrocarbons, particularly tetrachloroethene and TCE. Sodium lactate is consumed quickly by subsurface bacteria, and as such repeated applications are required. Soybean oil has also been used as a hydrogen source for the treatment of chlorinated hydrocarbons. Soybean oil is expected to be an economical, long-lasting hydrogen source, but has not been extensively tested beyond the microcosm level. One widely used hydrogen source is a product called Hydrogen Release Compound, also produced by Regenesis. This product is a slow-releasing lactate product that has been proven effective at accelerating the biodegradation of some chlorinated hydrocarbons.

4.4.5.3 Physical Treatment

In situ physical treatment takes advantage of the physical properties of the COCs, such as volatility, and applies a technology based on this property. These technologies use processes that have traditionally been applied to extracted groundwater, such as counter-current air stripping. In-well aeration was the physical treatment process option retained for evaluation in this FS and is described below.

In-Well Aeration

In-well aeration, also known as in-well vapor stripping, is a technology for the in situ remediation of groundwater contaminated by VOCs (Ground-Water Remediation Technologies Analysis Center 1997). The in-well aeration process involves the creation of a groundwater circulation cell surrounding a well through which contaminated groundwater is cycled. The typical aeration well has hydraulically separated upper- and lower-screened intervals within the same water-bearing zone. The lower screen, through which groundwater enters, is placed at or near the bottom of the contaminated aquifer and the upper screen, through which groundwater is discharged, is installed across or above the water table.

The mechanism for aerating the groundwater varies with each particular technology. One mechanism involves sparging groundwater at the lower screen, volatilizing VOCs and causing the water to rise up an inner well casing. The water exits the top of the inner casing and flows out the upper screen in an outer well casing. Another method involves pumping the groundwater from the lower screen, air stripping the water in a small stripping tower built into the top of the well, and allowing the water to flow out the upper well screen. In both methods the discharged groundwater flows downward, eventually reaching the lower portion of the aquifer, where it is cycled back through the well into the lower screened interval.

Contaminated vapors can be drawn off above ground, or injected into the vadose zone for treatment by natural biodegradation. Vapors extracted from the well exhibiting sufficiently low VOC concentration can be discharged directly to the atmosphere. Those extracted vapor exhibiting elevated VOC concentrations, would be discharged through a catalytic oxidizer, or through activated carbon beds.

Discharging vapors through a catalytic oxidizer involves heating the vapor stream using a natural gas burner, and passing the heated vapor stream across a platinum-based catalyst, which oxidizes the VOCs into carbon dioxide, water, and in the case of chlorinated VOCs, hydrochloric acid. A scrubber can be used to remove the hydrochloric acid from the air stream if required. The air stream is then discharged to the atmosphere through a stack.

Discharging vapors through an activated carbon vessel also removes VOCs from the air stream. This is accomplished through an adsorption process. The activated carbon eventually becomes saturated and must be transported off-site for regeneration or disposal.

The effectiveness of in-well aeration is based on the ability of the contaminants to be volatilized, and the flow characteristics of the aquifer. This option is best suited for VOCs in environments that allow significant horizontal and vertical groundwater flow. The VOCs at IRP Sites 2, 9, and 11 are all readily volatilized. The Shallow Zone at these sites and the Deep Zone at IRP Sites 2 and 11 are fairly homogenous fine sand, and should be conducive to groundwater flow to the aeration well. However, this process relies on the flow of groundwater out of the upper screen at the top of the water-bearing zone being treated. Aeration wells installed in the Deep Zone would have the lower screen set just above the bottom of the Deep Zone and the upper screen set just below the floodplain silts separating the Deep Zone from the Shallow Zone. However, wells installed to treat the Shallow Zone would require that the upper screen be set in the floodplain silts above the Shallow Zone due to the shallow nature of groundwater in the Shallow Zone. The restriction of flow out of the upper screen in Shallow Zone aeration wells may limit the overall effectiveness of this alternative.

During the RI for the Portland ANGB (ERM 2001a), a treatability test was performed using in-well aeration at IRP Site 2. At the completion of this test a full 100 percent removal of all VOCs (including VC; cis- and trans-1,2-dichloroethene; and TCE) from treated groundwater was achieved at a moderate air flow. This system differed from most in-well aeration systems in that the groundwater was aerated within the well, and was pumped out for disposal rather than circulated back into the aquifer. Although this system required disposal of treated groundwater, the contaminant levels resulting from the treatment were suitable for discharge to the sanitary sewer. No indication of a radius of influence of the aeration system was observed.

4.4.5.4 Monitored Natural Attenuation

The use of MNA to achieve RAOs relies on biological, physical, and chemical processes that are naturally occurring in the environment. These processes may include biodegradation, dispersion and dilution, sorption, and volatilization. Monitoring and documenting the intrinsic bioremediation element of natural attenuation is the major focus of this alternative. MNA involves no active measures to contain or treat groundwater contaminated with VOCs.

Strategically located new monitoring wells are combined with current monitoring wells to accurately monitor the extent of each VOC plume. The groundwater would also be monitored for intrinsic bioremediation parameters such as nitrate, sulfate, dissolved iron, methane, ethene, carbon dioxide, alkalinity, dissolved oxygen, and redox potential. These parameters measured with VOC concentrations will allow calculation of removal rates.

MNA is considered a treatment technology, as described in *Use of Monitored Natural Attenuation at Superfund, RCRA Corrective Action, and Underground Storage Tank Sites*, USEPA, OSWER Directive 9200.4-17, November 1997 (USEPA 1997).

The MNA alternative is most appropriate at sites where the following conditions exist:

1. The source of contamination to the groundwater has been removed.

2. The quantity of contaminants remaining in the environment is minor, limited in extent, and not migrating.

3. The risk to human health, safety, and the environment is insignificant.

The VOCs that make up the COCs at IRP Sites 2, 9, and 11 are all capable of natural biodegradation. However, the most widespread VOC, VC, degrades naturally at a very slow rate, and has a tendency to accumulate since it is a degradation product of the higher-order chlorinated VOCs, primarily TCE and cis-1,2-DCE, which tend to naturally degrade more quickly.

4.5 Development of Remedial Alternatives

Several of the remedial technology process options described above have been tested at the Portland ANGB, and are known to be effective at treating VOCs in groundwater. The selected process options were developed into remedial alternatives, which address the RAOs developed for the Portland ANGB. Six alternatives were developed using an appropriate combination of process options.

4.5.1 Remedial Alternative 1: No Action

This remedial alternative implements the no action process option. As discussed, the FS process requires consideration of the No Action Alternative. Under this alternative, no site modifications or groundwater monitoring would be implemented, and the engineering and institutional controls previously described would not be used.

4.5.2 Process Options Common to Alternatives 2, 3, 4, 5, and 6

Process options described under the institutional or engineering controls general response actions are included in the remaining alternatives. These process options provide protection from existing or future remaining risks at the Base. These components will be the same for each alternative, and are therefore described separately, rather than repeatedly for each alternative. The costs associated with these common tasks are not included in the cost estimates for each remedial alternative because they are common to all the alternatives (except Alternative 1) and are not specific to each IRP site. The No Action remedial alternative is the only alternative that does not include these additional components. The common tasks for each of the remaining remedial alternatives include:

- Monitoring VOCs in Shallow Zone, Deep Zone, and CRSA beyond each of the boundaries of IRP Sites 2, 9, and 11. Monitoring would be conducted annually for approximately 30 years.
- Implement Base-wide deed restrictions that limit the development of Base groundwater as a water supply.
- Implement zoning restrictions encompassing the current Base footprint that restricts rezoning of the property for uses other than industrial.
- Implement Base-wide access restrictions that prevent use of the facility by unauthorized personnel and/or for unauthorized purposes.
- Implement a Base-wide health and safety program requiring appropriate training, equipment, and monitoring during activities that put Base workers in contact with groundwater.
- Utilize alternative water supplies, such as the existing public water supply, when additional water capacity is required, rather than obtaining this capacity through extraction of groundwater at the Base.

4.5.3 Remedial Alternative 2: Monitored Natural Attenuation

Alternative 2 involves the implementation of MNA as the primary treatment method. MNA would be implemented across the full extent of each site. The duration of this alternative is expected to be approximately 30 years. This alternative also involves the implementation of the common elements described in Section 4.5.2.

Implementation of Alternative 2 at IRP Site 2 would involve:

- Performing a brief direct-push investigation to delineate the lateral extent of VOCs in Deep Zone groundwater. The concentrations of VOCs in the Deep Zone are expected to fluctuate significantly prior to the future implementation of a Deep Zone remedial action. This investigation would consist of collecting approximately 30 direct-push groundwater samples immediately prior to implementation of the remedial action.

- Installing four Shallow Zone monitoring wells, two Deep Zone monitoring wells, and two CRSA monitoring wells within, and surrounding, the hot spot of contamination.

- Monitoring the new and existing monitoring wells quarterly for 1 year and annually for 30 years. Twenty-six wells will be monitored for VOC concentrations. Additionally, 10 of these wells will be monitored for MNA parameters.

Implementation of Alternative 2 at IRP Site 9 would involve:

- Installing seven Shallow Zone monitoring wells within, and surrounding, the hot spot of contamination.

- Monitoring the new and existing monitoring wells quarterly for 1 year and annually for 30 years. Ten wells will be monitored for VOC concentrations. Additionally, three of these wells will be monitored for MNA parameters.

Implementation of Alternative 2 at IRP Site 11 would involve:

- Performing a direct-push investigation immediately prior to remedial action implementation to determine the current extent of VOCs in Deep Zone groundwater similar to that described above for IRP Site 2.

- Installing four Shallow Zone monitoring wells, two Deep Zone monitoring wells, and three CRSA monitoring wells within, and surrounding, the hot spot of contamination.

- Monitoring the new and existing monitoring wells quarterly for 1 year and annually for 30 years. Twenty-three wells will be monitored for VOC concentrations. Additionally, 10 of these wells will be monitored for MNA parameters.

4.5.4 Remedial Alternative 3: In Situ Oxidation-Potassium Permanganate/ Persulfate Injection with Monitored Natural Attenuation

Alternative 3 utilizes a combination of the treatment process options discussed in Section 4.4. The primary contaminant treatment within the hot spot will be performed through in situ oxidation. Because of the similarity in application technique, potassium permanganate and persulfate are interchanged in this alternative. Potassium permanganate will be used to treat chlorinated VOCs and persulfate will be used to treat benzene. MNA will be used to measure the natural degradation of low concentration contaminants immediately outside of the hot spot. The active treatment duration for this alternative is expected to be 2 years, followed by 5 years of monitoring. This treatment duration is an approximation of the expected duration required to meet the RAOs and is based on similar cases. Injection spacing used for this alternative is based on the results of the permanganate injection pilot test conducted at IRP Site 2 (ERM 2001c). This alternative also includes implementation of the common elements discussed in Section 4.5.2.

Implementation of Alternative 3 at IRP Site 2 would involve:

- Performing a direct-push investigation immediately prior to remedial action implementation to determine the current extent of VOCs in Deep Zone groundwater.
- Installing four Shallow Zone monitoring wells, two Deep Zone monitoring wells, and two CRSA monitoring wells within, and surrounding, the hot spot of contamination;
- Injecting 35 pounds of potassium permanganate as a 2 percent water-based solution in each of numerous direct-push injection locations performed at a specific frequency. This is the expected limit of injection at a single location, per event. The locations and frequency consist of:
  - Approximately 250 injections at a 25-foot spacing within the primary treatment area injected from the bottom of the Shallow Zone up to the water table. These injections will be performed every 6 months for 2 years, resulting in four applications total. The locations will be adjusted for each application, resulting in a net spacing of approximately 12 feet.
  - Approximately 60 injections at a 25-foot spacing in the area outside of the primary treatment area but within the hot spot, injected from

  the bottom of the Shallow Zone up to the water table. These injections will be performed every year for 2 years, or two injections total. The locations will be adjusted for each application, resulting in a net spacing of approximately 18 feet.

  - Approximately 80 injections at a 25-foot spacing within the southeast portion of the hot spot, near the source area, injected from the bottom of the Deep Zone up to the top of the Deep Zone. These injections will be performed every 6 months for 2 years, resulting in four applications total. The locations will be adjusted for each application, resulting in a net spacing of approximately 12 feet.

- Monitoring the new and existing monitoring wells quarterly for 2 years and annually for 5 years. Twenty-six wells will be monitored for VOC concentrations. Additionally, 10 of these wells will be monitored for MNA parameters and potential byproducts such as chromium, cadmium, and mercury.

Implementation of Alternative 3 at IRP Site 9 would involve:

- Installing seven Shallow Zone monitoring wells within, and surrounding, the hot spot of contamination;

- Injecting iron-catalyzed sodium persulfate at approximately 50 locations on a 25-foot spacing. Approximately 95 pounds of persulfate as a 3 to 5 percent water-based solution will be injected from the bottom of the Shallow Zone up to the water table. These injections will be performed every 6 months for 2 years, resulting in four applications total. The locations will be adjusted for each application, resulting in a net spacing of approximately 12 feet.

- Monitoring the new and existing monitoring wells quarterly for 2 years and annually for 5 years. Ten wells will be monitored for VOC concentrations. Additionally, three of these wells will be monitored for MNA parameters and potential byproducts such as chromium, cadmium, and mercury.

Implementation of Alternative 3 at IRP Site 11 would involve:

- Performing a direct-push investigation immediately prior to remedial action implementation to determine the current extent of VOCs in Deep Zone groundwater.

- Installing four Shallow Zone monitoring wells, two Deep Zone monitoring wells, and three CRSA monitoring wells within, and surrounding, the hot spot of contamination;

- Installing eight Shallow Zone horizontal injection wells and four Deep Zone horizontal injection wells within the hot spot of contamination. These wells will be placed at the approximate vertical mid-points of the Shallow Zone and Deep Zone. Horizontal injection wells were selected over vertical wells or direct-push drilling methods to prevent disturbance of flight operations or the concrete flight apron.

- Injecting potassium permanganate as a 2 percent water-based solution in each of the injection wells. Approximately 12 gallons of permanganate solution will be injected for each foot of screen length at each well. This volume meets the oxidant stoichiometric demand for the contaminants. These injections will be performed every 6 months for 2 years, resulting in a total of four applications.

- Monitoring the new and existing monitoring wells quarterly for 2 years and annually for 5 years. Twenty-three wells will be monitored for VOC concentrations. Additionally, 10 of these wells will be monitored for MNA parameters and potential byproducts such as chromium, cadmium, and mercury.

4.5.5 Remedial Alternative 4: In Situ Oxidation-Ozonation with Monitored Natural Attenuation

Alternative 4 also utilizes a combination of the treatment process options discussed in Section 4.4. The primary contaminant treatment within the hot spot will be performed through in situ oxidation. Ozone sparging will be used as the method of oxidation. Groundwater in the Shallow Zone and Deep Zone at IRP Sites 2 and 11 and in the Shallow Zone only at IRP Site 9 will be treated by ozone sparging. SVE will be used to collect excess ozone and any volatilized VOCs in the vadose zone and the top of the Deep Zone. MNA will be used to measure the natural degradation of low concentration contaminants immediately outside on the fringe of the hot spot. The active treatment duration for this alternative is expected to be 3 years, followed by 5 years of monitoring. This treatment duration is an approximation of the expected duration required to meet the RAOs and is based on similar cases and information from system vendors. Injection spacing used for this alternative is also based on similar cases and information from system vendors. This alternative also includes implementation of the common elements discussed in Section 4.5.2.

Implementation of Alternative 4 at IRP Site 2 would involve:

- Performing a direct-push investigation immediately prior to remedial action implementation to determine the current extent of VOCs in Deep Zone groundwater.
- Installing four Shallow Zone monitoring wells, two Deep Zone monitoring wells, and two CRSA monitoring wells within, and surrounding, the hot spot of contamination;
- Installing 32 Shallow Zone sparging wells and 12 Deep Zone sparging wells within the hot spot of contamination;
- Installing SVE equipment and piping;
- Installing below-grade piping from each well to a common system location. Piping installation will involve trenching, laying pipe, and backfilling;
- Operating the ozone sparging system for 3 years;
- Monitoring the new and existing monitoring wells quarterly for 3 years and annually for 5 years. Twenty-six wells will be monitored for VOC concentrations. Additionally, 10 of these wells will be monitored for MNA parameters; and
- Quarterly air sampling of each SVE system’s air effluent to assess the system performance.

Implementation of Alternative 4 at IRP Site 9 would involve:

- Installing seven Shallow Zone monitoring wells within, and surrounding, the hot spot of contamination;
- Installing 16 Shallow Zone sparging wells within the hot spot of contamination;
- Installing SVE equipment and piping;
- Installing below-grade piping from each well to a common system location. Piping installation will involve trenching, laying pipe, and backfilling;
- Operating the ozone sparging system for 3 years;

- Monitoring the new and existing monitoring wells quarterly for 3 years and annually for 5 years. Ten wells will be monitored for VOC concentrations. Additionally, three of these wells will be monitored for MNA parameters; and

- Quarterly air sampling of each SVE system's air effluent to assess the system performance.

Implementation of Alternative 4 at IRP Site 11 would involve:

- Performing a direct-push investigation immediately prior to remedial action implementation to determine the current extent of VOCs in Deep Zone groundwater.

- Installing four Shallow Zone monitoring wells, two Deep Zone monitoring wells, and three CRSA monitoring wells within, and surrounding, the hot spot of contamination;

- Installing eight Shallow Zone horizontal ozone sparge wells and four Deep Zone horizontal ozone sparge wells within the hot spot of contamination. These wells will be placed at approximately the bottom of the Shallow Zone and Deep Zone. Horizontal injection wells were selected over vertical wells or direct-push drilling methods to prevent disturbance of flight operations or the concrete flight apron.

- Installing eight horizontal vapor extraction wells above the Shallow Zone and four horizontal vapor extraction wells at the top of the Deep Zone directly above the respective ozone sparging wells. The Deep Zone vapor extraction wells would be under saturated conditions and would serve to relieve built up gasses resulting from sparging rather than as traditional SVE wells.

- Installing SVE equipment and piping.

- Installing below-grade piping from each well to a common system location. Piping installation will involve concrete removal, trenching, laying pipe, backfilling, and resurfacing.

- Operating the ozone sparging system for 3 years;

- Monitoring the new and existing monitoring wells quarterly for 3 years and annually for 5 years. Twenty-three wells will be monitored for VOC concentrations. Additionally, 10 of these wells will be monitored for MNA parameters; and

- Quarterly air sampling of each system's air effluent to assess the system performance.

4.5.6 Remedial Alternative 5: Enhanced Bioremediation with Monitored Natural Attenuation

This alternative combines the use of enhanced aerobic and anaerobic bioremediation and MNA to treat the COCs. Areas impacted by TCE, such as the source area of IRP Site 2, will be treated using a hydrogen releasing material. All other areas will be treated using an oxygen releasing material.

MNA will be used to measure the natural degradation of low concentration contaminants immediately outside on the fringe of the hot spot. The active treatment duration for this alternative is expected to be 2 years, followed by 5 years of monitoring. This treatment duration is an approximation of the expected duration required to meet the RAOs and is based on similar cases and vendor information. Injection spacing used for this alternative is based on the results of the enhanced aerobic bioremediation pilot test conducted at IRP Site 2 (ERM 2001c). This alternative also includes implementation of the common elements discussed in Section 4.5.2.

Implementation of Alternative 5 at IRP Site 2 would involve:

- Performing a direct-push investigation immediately prior to remedial action implementation to determine the current extent of VOCs in Deep Zone groundwater.

- Installing four Shallow Zone monitoring wells, two Deep Zone monitoring wells, and two CRSA monitoring wells within, and surrounding, the hot spot of contamination;

- Injecting 30 pounds of a hydrogen releasing material in approximately 10 Shallow Zone direct-push injection locations at an initial spacing of 25 feet. The injection amount may vary, based on the conductivity of the Shallow Zone soils. The material will be injected from the bottom of the Shallow Zone up to the water table. The material will be injected every 6 months for approximately 2 years, resulting in four applications total. The locations will be adjusted for each application, resulting in a net spacing of approximately 12 feet;

- Injecting 30 pounds of oxygen releasing material in each of numerous direct-push injection locations performed at a specific frequency. The locations and frequency consist of:
    - Approximately 250 injections at a 25-foot spacing within the primary treatment area injected from the bottom of the Shallow Zone up to the water table. These injections will be performed every 6 months for 2 years, resulting in four applications total. The locations will be adjusted for each application, resulting in a net spacing of approximately 12 feet.
    - Approximately 60 injections at a 25-foot spacing in the area outside of the primary treatment area but within the hot spot, injected from the bottom of the Shallow Zone up to the water table. These injections will be performed every year for 2 years, or two injections total. The locations will be adjusted for each application, resulting in a net spacing of approximately 18 feet.
    - Approximately 80 injections at a 25-foot spacing within the southeast portion of the hot spot, near the source area, injected from the bottom of the Deep Zone up to the top of the Deep Zone. These injections will be performed every 6 months for 2 years, resulting in four applications total. The locations will be adjusted for each application, resulting in a net spacing of approximately 12 feet.
- Monitoring the new and existing monitoring wells quarterly for 2 years and annually for 5 years. Twenty-six wells will be monitored for VOC concentrations. Additionally, 10 of these wells will be monitored for MNA parameters.

Implementation of Alternative 5 at IRP Site 9 would involve:

- Installing seven Shallow Zone monitoring wells within, and surrounding, the hot spot of contamination;
- Injecting 30 pounds of an oxygen releasing material in approximately 50 Shallow Zone direct-push injection locations at an initial spacing of 25 feet. The material will be injected from the bottom of the Shallow Zone up to the water table. The material will be injected every 6 months for approximately 2 years, resulting in four applications total. The locations will be adjusted for each application, resulting in a net spacing of approximately 12 feet; and

- Monitoring the new and existing monitoring wells quarterly for 2 years and annually for 5 years. Ten wells will be monitored for VOC concentrations. Additionally, three of these wells will be monitored for MNA parameters.

Implementation of Alternative 5 at IRP Site 11 would involve:

- Performing a direct-push investigation immediately prior to remedial action implementation to determine the current extent of VOCs in Deep Zone groundwater.

- Installing four Shallow Zone monitoring wells, two Deep Zone monitoring wells, and three CRSA monitoring wells within, and surrounding, the hot spot of contamination.

- Injecting 30 pounds of oxygen releasing material in each of numerous direct-push injection locations performed at a specific frequency. The locations and frequency consist of:

  - Approximately 270 injections at a 25-foot spacing within the primary treatment area injected from the bottom of the Shallow Zone up to the water table. These injections will be performed every 6 months for 2 years, resulting in four applications total. The locations will be adjusted for each application, resulting in a net spacing of approximately 12 feet.

  - Approximately 70 injections at a 25-foot spacing in the area outside of the primary treatment area but within the hot spot, injected from the bottom of the Shallow Zone up to the water table. These injections will be performed every year for 2 years, or two injections total. The locations will be adjusted for each application, resulting in a net spacing of approximately 18 feet.

  - Approximately 90 injections at a 25-foot spacing within the southeast portion of the hot spot, near the source area, injected from the bottom of the Deep Zone up to the top of the Deep Zone. These injections will be performed every 6 months for 2 years, resulting in four applications total. The locations will be adjusted for each application, resulting in a net spacing of approximately 12 feet.

- Coring and repair of the flight apron concrete in accordance with ANG specifications will be required at approximately 75 percent of the direct-push injection locations.

- Monitoring the new and existing monitoring wells quarterly for 2 years and annually for 5 years. Twenty-three wells will be monitored for VOC concentrations. Additionally, 10 of these wells will be monitored for MNA parameters.

4.5.7 Remedial Alternative 6: In-Well Aeration with Monitored Natural Attenuation

Alternative 6 also utilizes a combination of the treatment process options discussed in Section 4.4. The primary contaminant treatment within the hot spot will be performed through in-well aeration. Groundwater in the Shallow Zone and Deep Zone at IRP Sites 2 and 11 and in the Shallow Zone only at IRP Site 9 will be treated. Effluent air will be treated using granular activated carbon. MNA will be used to measure the natural degradation of low concentration contaminants immediately outside of the hot spot. The active treatment duration for this alternative is expected to be 3 years, followed by 5 years of monitoring. This treatment duration is an approximation of the expected duration required to meet the RAOs and is based on information from vendors. Injection spacing used for this alternative is also based on vendor information. This alternative also includes implementation of the common elements discussed in Section 4.5.2.

Implementation of Alternative 6 at IRP Site 2 would involve:

- Performing a direct-push investigation immediately prior to remedial action implementation to determine the current extent of VOCs in Deep Zone groundwater.

- Installing four Shallow Zone monitoring wells, two Deep Zone monitoring wells, and two CRSA monitoring wells within, and surrounding, the hot spot of contamination;

- Installing 21 Shallow Zone aeration wells and 5 Deep Zone aeration wells within the hot spot of contamination;

- Installing below-grade piping from each aeration well to a common system location. Piping installation will involve trenching, laying pipe, and backfilling;

- Operating the system for 3 years;

- Monitoring the new and existing monitoring wells quarterly for 3 years and annually for 5 years. Twenty-six wells will be monitored for VOC concentrations. Additionally, 10 of these wells will be monitored for MNA parameters; and

- Quarterly air sampling of each system's air effluent to assess the system performance.

Implementation of Alternative 6 at IRP Site 9 would involve:

- Installing seven Shallow Zone monitoring wells within, and surrounding, the hot spot of contamination;
- Installing four Shallow Zone aeration wells within the hot spot of contamination;
- Installing below-grade piping from each well to a common system location. Piping installation will involve trenching, laying pipe, and backfilling;
- Operating the system for 3 years;
- Monitoring the new and existing monitoring wells quarterly for 3 years and annually for 5 years. Ten wells will be monitored for VOC concentrations. Additionally, three of these wells will be monitored for MNA parameters; and
- Quarterly air sampling of each system's air effluent to assess the system performance.

Implementation of Alternative 6 at IRP Site 11 would involve:

- Performing a direct-push investigation immediately prior to remedial action implementation to determine the current extent of VOCs in Deep Zone groundwater.
- Installing four Shallow Zone monitoring wells, two Deep Zone monitoring wells, and three CRSA monitoring wells within, and surrounding, the hot spot of contamination;
- Installing 26 Shallow Zone aeration wells and seven Deep Zone aeration wells within the hot spot of contamination. For cost estimating purposes, it is assumed that 75 percent of the wells will be installed within the flight apron concrete at IRP Site 11, and will require concrete coring and completion in accordance with ANG specifications;

- Installing below-grade piping from each well to a common system location. Piping installation will involve concrete removal, trenching, laying pipe, backfilling, and resurfacing;

- Operating the system for 3 years;

- Monitoring the new and existing monitoring wells quarterly for 3 years and annually for 5 years. Twenty-three wells will be monitored for VOC concentrations. Additionally, 10 of these wells will be monitored for MNA parameters; and

- Quarterly air sampling of each system's air effluent to assess the system performance.

SECTION 5.0

DETAILED ANALYSIS OF ALTERNATIVES

This section presents a detailed evaluation of RA alternatives. First, the evaluation criteria set forth in *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA* (USEPA 1988) are described. Subsequently, as outlined in the Oregon Guidance for Conducting Feasibility Studies (ODEQ 1998b), elements used to compare RA alternatives are presented. Next, the remedial alternatives described in Section 4.0 for IRP Sites 2, 9, and 11 are evaluated with respect to the criteria. Finally, the alternatives for each of the sites are collectively evaluated through a comparative analysis based on the criteria. Table 5-1 summarizes the results of this evaluation and the comparative analysis of the remedial alternatives for IRP Sites 2, 9, and 11.

5.1 Assessment Criteria

The following sections describe the elements of the nine criteria used for detailed analysis of remedial alternatives.

5.1.1 Overall Protection of Human Health and the Environment

This evaluation criterion provides a final check to assess whether each alternative provides adequate protection of human health and the environment. The overall assessment of protection considers the assessments conducted under other evaluation criteria, particularly long-term effectiveness and permanence, short-term effectiveness, and compliance with ARARs. This evaluation also allows for consideration of whether an alternative poses any unacceptable short-term or crossmedia impacts.

Oregon’s Environmental Cleanup Law uses a Residual Risk Assessment (RRA) to demonstrate protectiveness. For RAs consisting solely of treatment, the RRA provides only the quantitative assessment of the risk from treatment residuals or untreated wastes remaining at the site.

TABLE 5-1

Alternatives Evaluation Summary Table
142nd FW, Portland ANGB, Portland, Oregon

IRP Site	Remedial Alternative	Evaluation Criteria									Comparative Ranking
		Overall Protection of Human Health and Environment	Compliance with ARARs	Long-Term Effectiveness and Permanence	Reduction of TMV Through Treatment	Short-Term Effectiveness	Implementability	Cost	Cost Reasonableness	Treatment of Hot Spots	
2	1. No Action	Low	Low	Low	Low	Low	High	$0	Low	Low	6
	2. Monitored Natural Attenuation (MNA)	Low	Low	Low	Low	Low	High	$717,000	Low	Low	5
	3. In-situ Oxidation-Potassium Permanganate Injection w/ MNA	High	High	High	High	Medium	High	$2,301,000	High	High	1
	4. In-Situ Oxidation – Ozonation w/ MNA	High	High	High	High	Medium	Medium	$3,501,000	Medium	High	2
	5. Enhanced Bioremediation w/ MNA	Medium	Medium	Medium	Medium	Medium	High	$2,780,000	Medium	Medium	4
	6. In-Well Aeration w/ MNA	Medium	High	High	High	Medium	Medium	$3,721,000	Medium	High	3
9	1. No Action	Low	Low	Low	Low	Low	High	$0	Low	Low	6
	2. Monitored Natural Attenuation (MNA)	Low	Low	Low	Low	Low	High	$292,000	Low	Low	5
	3. In-situ Oxidation-Sodium Persulfate Injection w/ MNA	High	High	High	High	Medium	High	$573,000	High	High	1
	4. In-Situ Oxidation – Ozonation w/ MNA	High	High	High	High	Medium	Medium	$1,198,000	Medium	High	3
	5. Enhanced Bioremediation w/ MNA	High	High	High	High	Medium	High	$596,000	High	High	2
	6. In-Well Aeration w/ MNA	High	High	High	High	Medium	Medium	$1,075,000	Medium	High	4
11	1. No Action	Low	Low	Low	Low	Low	High	$0	Low	Low	6
	2. Monitored Natural Attenuation (MNA)	Low	Low	Low	Low	Low	High	$763,000	Low	Low	5
	3. In-situ Oxidation-Potassium Permanganate Injection w/ MNA	High	High	High	High	Medium	Medium	$2,607,000	High	High	1
	4. In-Situ Oxidation – Ozonation w/ MNA	High	High	High	High	Medium	Medium	$4,409,000	Medium	High	2
	5. Enhanced Bioremediation w/ MNA	Medium	Medium	Medium	Medium	Medium	Low	$4,309,000	Medium	Medium	4
	6. In-Well Aeration w/ MNA	Medium	High	High	High	Medium	Low	$5,554,000	Medium	High	3

NOTES:

The assessment of the degree to which an alternative meets the requirements of the individual balancing factors is presented as low, medium, or high.

The six remedial alternatives for each site are then ranked from 1 (highest) to 6 (lowest) based on the overall results of this assessment.

5.1.2 Compliance with ARARs

This evaluation criterion is used to determine whether each alternative will meet all of its identified federal and state ARARs.

5.1.3 Long-Term Effectiveness and Permanence

The evaluation of a remedial alternative relative to its long-term effectiveness and permanence is made considering the risks remaining at the site after the remedial goals have been met. The assessment of long-term effectiveness is made considering the following four major factors:

- Magnitude of residual risk to human and environmental receptors remaining from untreated waste or treatment residues at the completion of remedial activities;
- Assessment of the type, degree, and adequacy of long-term management required for untreated waste or treatment residues remaining at the site;
- Assessment of the long-term reliability of engineering and/or institutional controls to provide continued protection from untreated waste or treatment residues; and
- Potential need for replacement of the remedy, and the continuing need for repairs to maintain the performance of the remedy.

Some of the criteria of Oregon's Environmental Cleanup Law Effectiveness Balancing Factor, and all of the criteria developed for the Long-Term Reliability Balancing Factor, correspond to the criteria described above.

5.1.4 Reduction of Toxicity, Mobility, or Volume through Treatment

This evaluation criterion addresses the degree to which RAs employ treatment technologies that permanently and significantly reduce the toxicity, mobility, or volume (TMV) of the hazardous substance(s). The evaluation considers the following factors:

- Treatment processes;
- Amount of hazardous materials that will be treated;

- Degree of expected reduction in TMV, including how the principal threat is addressed through treatment;

- Degree to which the treatment will be irreversible; and

- Type and quantity of treatment residuals that will remain following treatment.

Some of the criteria of the Effectiveness Balancing Factor developed in Oregon's Environmental Cleanup Law correspond to the above USEPA criteria.

5.1.5 Short-Term Effectiveness

The short-term effectiveness of a remedial alternative is evaluated relative to its effect on human health and the environment during implementation of the RA. The short-term effectiveness is assessed based on the following factors:

- Short-term risks that might be posed to the community during implementation of an alternative;

- Potential impacts on workers during RA, and the effectiveness and reliability of protective measures;

- Potential environmental impacts of the RA, and the effectiveness and reliability of mitigative measures during implementation; and

- Length of time required to achieve RAOs.

The criteria listed above correspond with the criteria used to assess the Implementation Risk Balancing Factor developed in Oregon's Environmental Cleanup Law.

5.1.6 Implementability

The remedial alternatives must be evaluated to estimate the degree to which each can satisfy implementability criteria. Implementability refers to the technical, administrative, and environmental feasibility of implementing an alternative, and the availability of various materials and services required during its implementation.

The USEPA Implementability definition generally corresponds to that specified by Oregon's Environmental Cleanup Law. However, as summarized below, Oregon defines criteria by which Implementability is measured:

- Practical, technical, and legal difficulties and unknowns associated with the construction and implementation of a technology, engineering control, or institutional control, including potential scheduling delays;
- The ability to monitor the effectiveness of the remedy;
- Consistency with federal, state and local requirements; activities needed to coordinate with other agencies; and the ability and time required to obtain any necessary authorization from other governmental bodies;
- Availability of necessary services, materials, equipment, and specialists, including the availability of adequate off-site treatment, storage, and disposal capacity and services, and availability of prospective technologies; and
- Any other information relevant to implementability.

5.1.7 Cost

A detailed cost estimate was developed for each remedial alternative in accordance with the Remedial Action Costing Procedures Manual (USEPA 1985). These cost estimates are presented in Appendix B. Costs are based on conceptual design, and are expressed in terms of year 2000 dollars.

The Reasonableness of Cost Balancing Factor specified by Oregon's Environmental Cleanup Law provides additional requirements that must be evaluated. These criteria are:

- Cost of the RA including:
  - Capital costs, including both direct and indirect costs;
  - Annual operation and maintenance (O&M) costs;
  - Costs of any periodic review requirements; and
  - Net present value of all of the above.

- Degree to which the costs of the RA are proportionate to the benefits to human health and the environment created through risk reduction or risk management;

- With respect to hot spots of contamination in water, the degree to which the costs of the RA are proportionate to the benefits created through restoration or protection of existing and reasonably likely future beneficial uses of water;

- The degree of sensitivity and uncertainty of the costs; and

- Any other information relevant to cost-reasonableness.

5.1.8 State Acceptance

This criterion evaluates the technical and administrative issues and concerns the ODEQ may have regarding each of the alternatives.

5.1.9 Community Acceptance

This criterion evaluates technical and administrative issues and concerns the public may have regarding each of the alternatives.

5.1.10 Treatment of Hot Spots

For hot spots in groundwater, the FS must evaluate the feasibility of treatment to levels that will no longer produce significant adverse effects on the beneficial uses of the water. This criterion evaluates the ability of an alternative to meet the requirement to treat contaminated groundwater to below significant, adverse-effect levels.

5.2 IRP Site 2

5.2.1 IRP Site 2 - Individual Analysis of Alternatives

The following presents an evaluation of the RA alternatives for IRP Site 2 against the evaluation criteria. The remedial alternatives evaluated for IRP Site 2 include:

- Alternative 1: No Action

- Alternative 2: MNA
- Alternative 3: In Situ Oxidation – Potassium Permanganate Injection with MNA
- Alternative 4: In Situ Oxidation – Ozone Sparging with MNA
- Alternative 5: Enhanced Bioremediation with MNA
- Alternative 6: In-Well Aeration with MNA

5.2.1.1 IRP Site 2 - Alternative 1: No Action

The following is an evaluation of the application of Alternative 1 at IRP Site 2 with respect to the criteria described in Section 5.1.

Overall Protection of Human Health and Environment. The No Action Alternative would not be protective of human health and the environment in the short-term, because the risks associated with site groundwater would not immediately be reduced, either by treatment or by implementing restrictions that would prevent exposure site groundwater, such as institutional controls. Because contaminated Shallow Zone and Deep Zone groundwater has the potential to migrate off-site, the No Action Alternative would not provide long-term protection of human health and the environment.

Compliance with ARARs. The No Action Alternative does not meet chemical-specific ARARs because several chlorinated VOCs in Shallow Zone groundwater and VC in Deep Zone groundwater currently exceed ARARs. The No Action Alternative would potentially reduce VOC concentrations to below respective ARARs in downgradient areas of IRP Site 2 due to natural processes. However, the higher concentration VOCs in the upgradient area of IRP Site 2 are not expected to naturally degrade to below ARARs within a reasonable timeframe.

Long-Term Effectiveness and Permanence. The No Action Alternative will not provide long-term effectiveness and permanence because a residual risk to human and environmental receptors remaining from untreated chlorinated VOCs in Shallow Zone and Deep Zone groundwater exists.

Reduction of TMV through Treatment. The No Action Alternative does not include any treatment to reduce TMV. As a result, it is possible that chlorinated VOCs would continue to migrate laterally and vertically and eventually reach off-site receptors. Biodegradation of TCE in Shallow Zone groundwater may continue to occur as observed in the past, but the natural degradation of lower-order chlorinated ethenes (cis- and trans-1,2-DCE and VC) in the Shallow Zone and Deep Zone is not expected to be significant. The degradation is expected to be slower than migration, thereby increasing the volume of contaminated groundwater.

Short-Term Effectiveness. The No Action Alternative would present short-term human health risks associated with chlorinated VOCs in groundwater at IRP Site 2. However, these risks are no greater than the existing risks at the site.

Implementability. The No Action Alternative would not incur implementation obstacles. In addition, there are no operations and maintenance requirements for the alternative.

Cost. No costs would be associated with implementing the No Action Alternative. Because this alternative is not effective in meeting the RAOs for the site, and is therefore not protective, it has a low degree of cost reasonableness.

Treatment of Hot Spots. The No Action Alternative does not meet Oregon’s requirement that hot spots in water be treated to below the significant adverse-effect level.

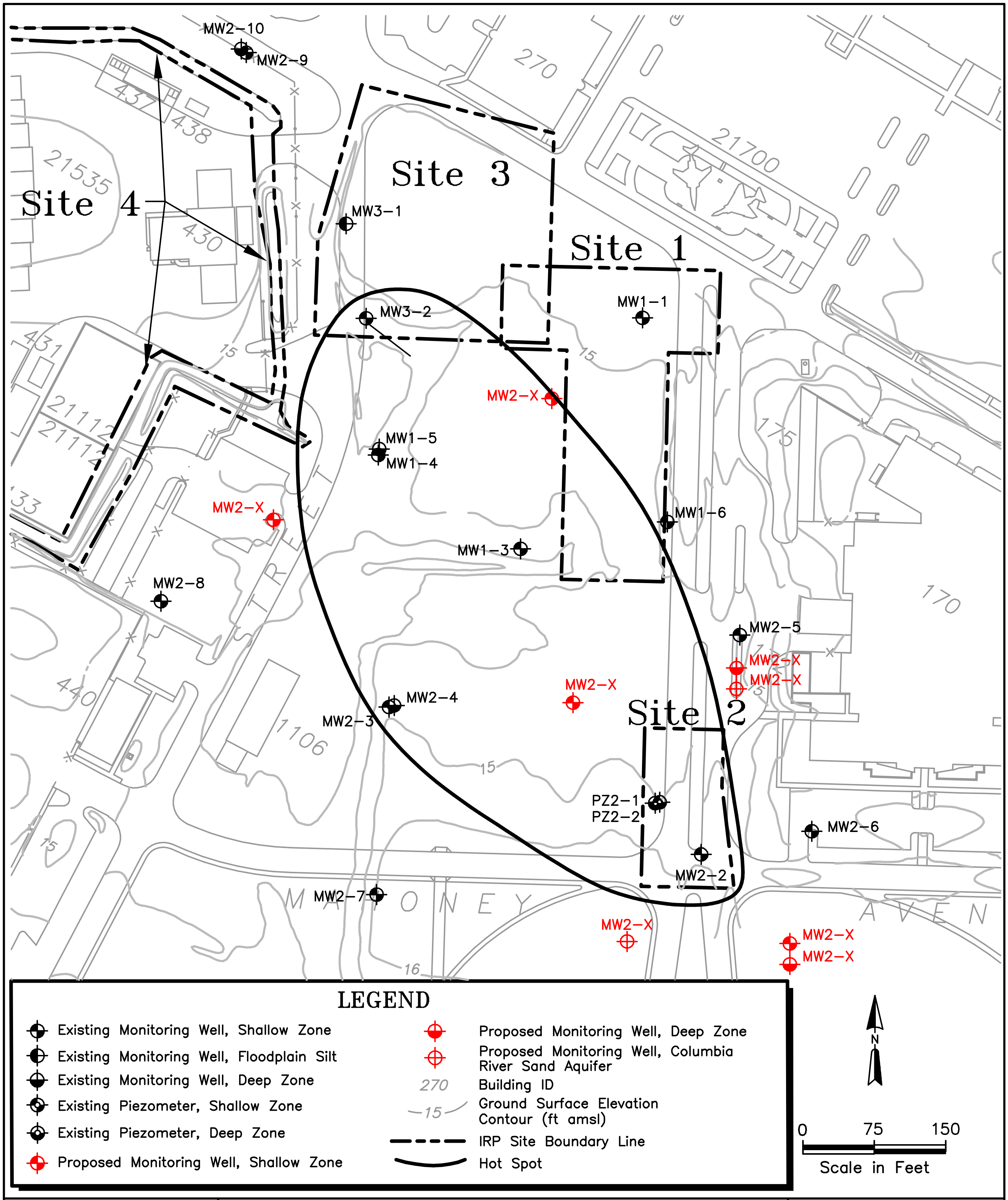
State Acceptance. The No Action Alternative would not be acceptable to ODEQ. Oregon requires that hot spots such as that present in groundwater at IRP Site 2 be treated to below the significant adverse-effect level.

Community Acceptance. The No Action Alternative is not expected to be acceptable to the community. The community is active at the Base in the form of a Restoration Advisory Board (RAB), and would not be accepting of leaving an area of groundwater impacted at the level of IRP Site 2 untreated.

5.2.1.2 IRP Site 2 - Alternative 2: Monitored Natural Attenuation

The following is an evaluation of the application of Alternative 2 at IRP Site 2 with respect to the criteria described in Section 5.1. Figure 5-1 depicts the layout of the primary components of this alternative.

Overall Protection of Human Health and Environment. The MNA Alternative would be protective of human health and the environment in



ERM

IRP SITE 2

ALTERNATIVE 2
MONITORED NATURAL ATTENUATION
LOCATION OF MONITORING WELLS

142nd FW, PORTLAND ANGB
PORTLAND INTERNATIONAL AIRPORT
PORTLAND, OREGON

FIGURE 5–1

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the short term. Near-future exposure to groundwater with unacceptable risk is prevented through institutional and engineering controls implemented at the Base. Groundwater with VOC concentrations above unacceptable risk levels has not migrated to any off-site receptors, and is not expected to do so in the near future. However, there is long-term risk associated with off-site migration of groundwater containing VOCs. During the Natural Attenuation Evaluation conducted as part of the RI (ERM 2001a), it was concluded that the degradation rate of VC is very slow. Because of this, it is possible that Shallow Zone and Deep Zone groundwater containing levels of VC above the RAOs has the potential to migrate off-site. The MNA Alternative, therefore, would not provide long-term protection of human health and the environment.

<u>Compliance with ARARs.</u> The MNA Alternative does not meet chemical-specific ARARs. Several chlorinated VOCs in Shallow Zone and Deep Zone groundwater currently exceed ARARs, and are not expected to naturally degrade to below levels determined by the chemical-specific ARARs within a reasonable timeframe compared to the time frames offered by other methods.

<u>Long-Term Effectiveness and Permanence.</u> The MNA Alternative may provide long-term effectiveness and permanence due to eventual natural degradation of VOCs below RAOs. However, this is unlikely to occur within a reasonable time period. It is uncertain if this alternative will treat groundwater to appropriate levels prior to migrating off-site, thereby violating the first RAO.

The institutional and engineering controls implemented as part of this alternative should be reliable in the long term, based on the current and future land-use scenarios. However, care must be taken to ensure that the controls remain in effect with each future tenant, if the ownership or leaseholder of the Base property changes.

<u>Reduction of TMV through Treatment.</u> The MNA Alternative is not expected to significantly reduce the TMV of VOCs at IRP Site 2 within a reasonable timeframe. Biodegradation of TCE in Shallow Zone groundwater may continue to occur as observed in the past, but the natural degradation of lower-order chlorinated ethenes such as cis-1,2-DCE and VC in Shallow Zone and Deep Zone groundwater is not expected to occur rapidly. As such, the toxicity of groundwater may be slowly reduced. As VC is produced through reductive dechlorination of TCE and dichloroethene, the mobility will actually increase due to the increased solubility and decreased sorption tendency of VC in relation to

its parent compounds. The volume of contaminated groundwater may actually increase due to potential further downgradient and vertical migration of slowly degrading VOCs, particularly VC.

Short-Term Effectiveness. The MNA Alternative would present short-term human health risks associated with chlorinated VOCs in groundwater at IRP Site 2. The short-term risks associated with this alternative are a result of the expected duration required to meet treatment objectives. The required duration of MNA could exceed 30 years. Within that period, groundwater containing unacceptable concentrations of VOCs may migrate off-site, violating the first RAO and presenting risk to off-site receptors.

The institutional and engineering controls implemented under this alternative are expected to prevent unacceptable risk to on-site receptors, including Base workers and other workers implementing this RA.

Implementability. The MNA Alternative would not present implementation obstacles. The additional proposed wells will ensure the ability to monitor the effectiveness of this alternative, and the required technologies used for this alternative are readily available and implementable.

Cost. Capital and O&M costs associated with Alternative 2 are summarized in Table B-2, and detailed in Table B-3. Direct and indirect capital costs for this alternative are estimated to be $116,100, and include all equipment, materials, contractor services, labor, project administration, and project management required for implementation. The O&M cost for the first year is estimated to be $110,000, which assumes quarterly groundwater sampling. The O&M cost for the following 30 years is estimated to be $27,500 per year, which assumes annual groundwater sampling. The net present value of 31 years of O&M costs is $434,800, which assumes a discount rate of 7.5 percent. This discount rate was selected based on ODEQ guidance. The total estimated cost for Alternative 2, including a 30 percent contingency, is $717,000. In accordance with USEPA and ODEQ Guidance, these estimates are expected to be accurate to +50 to –30 percent.

Because Alternative 2 does not meet the RAOs for the site within a reasonable time period, this alternative is not protective, and therefore has a low degree of cost reasonableness.

Treatment of Hot Spots. Although MNA is considered a treatment technology by the State of Oregon, the hot spot at IRP Site 2 is not expected to be treated to concentrations below the significant adverse-effect level in a timely manner under this alternative. The hot spot, defined by the extent of contaminants above respective significant adverse-effect levels, could potentially expand due to migration of the source area.

State Acceptance. The Natural Attenuation Alternative would not be expected to be acceptable to ODEQ. Oregon requires that hot spots such as that present in groundwater at IRP Site 2 be treated within a reasonable timeframe and this is not expected to occur using the Natural Attenuation alternative.

Community Acceptance. The Natural Attenuation Alternative is not expected to be acceptable to the community due to the expected duration required to meet treatment goals.

5.2.1.3 IRP Site 2 - Alternative 3: In Situ Oxidation - Potassium Permanganate Injection with Monitored Natural Attenuation

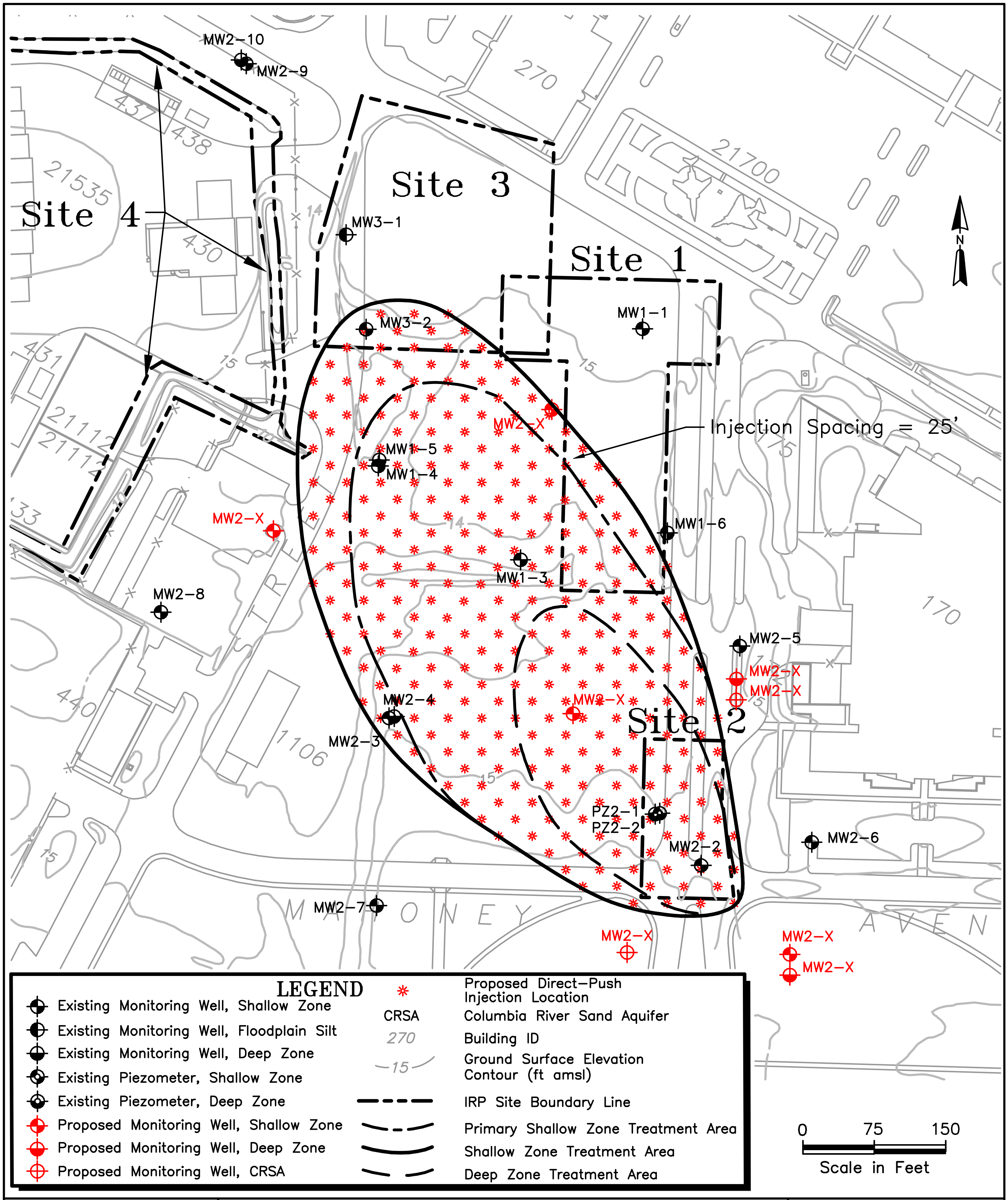
The following is an evaluation of the application of Alternative 3 at IRP Site 2 with respect to the criteria described in Section 5.1. Figure 5-2 depicts the layout of the primary components of this alternative.

Overall Protection of Human Health and Environment. This alternative is expected to effectively remove or significantly reduce the concentrations of VOCs from Shallow Zone and Deep Zone groundwater at IRP Site 2. The risks associated with exposure to these compounds would be reduced to an acceptable level based on the current and future land use.

Compliance with ARARs. This alternative is expected to effectively reduce the concentrations of VOCs in groundwater to below the levels set by chemical-specific ARARs. Any injection activities must be coordinated through the Oregon UIC program described in Section 4.1.3.6. Compliance with this program is expected to be achievable through registration, monitoring, and reporting.

Long-Term Effectiveness and Permanence. The residual risk posed by groundwater at IRP Site 2 would be reduced by this alternative because the contaminants associated with the risks are destroyed. Groundwater monitoring would be required for an extended period after the completion of this alternative in order to verify attainment of the RAOs.

The contaminants in the downgradient areas of the site treated by MNA are expected to be destroyed within a reasonable time frame, due to



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IRP SITE 2
ALTERNATIVE 3
IN SITU OXIDATION–POTASSIUM PERMANGANATE INJECTION WITH MONITORED NATURAL ATTENTUATION PLAN VIEW OF TREATMENT SYSTEM LAYOUT

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FIGURE 5–2

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enhanced conditions from upgradient permanganate injection. However, if long-term monitoring indicates that VOCs in this area are not degrading at an acceptable rate, potassium permanganate will be injected in this area.

The institutional and engineering controls implemented as part of this alternative should be reliable in the long term, based on the current and future land use scenarios. However, care must be taken to ensure that the controls remain in effect with each future tenant if the ownership or leaseholder of the Base property changes.

Reduction of TMV through Treatment. The use of potassium permanganate oxidation and MNA to treat VOCs in Shallow Zone and Deep Zone groundwater will result in reduced toxicity, mobility, and volume of hazardous materials in IRP Site 2 groundwater. This reduction is performed through chemical and biological destruction rather than transfer of contaminants from one media to another. The treatment process is irreversible and will result in the production of only harmless byproducts.

Short-Term Effectiveness. Workers performing the injection will be in contact with potassium permanganate in solid or dissolved form. Worker exposure would be minimized by the use of appropriate health and safety personal protective equipment.

Adverse effects on groundwater that is used for drinking or irrigation is not expected. The oxidative effects of the potassium permanganate will diminish with time as it reacts with organic material in the subsurface. As described in Section 4.4.5.1, other water quality effects are not expected to be significant enough to reach nearby receptors. Groundwater in the treatment area will be impacted by dilute potassium permanganate, requiring consideration if Base workers expect to come into contact with groundwater within the treatment area.

Risks associated with VOCs in groundwater are quickly reduced due to the rapid treatment resulting from permanganate oxidation. Destruction of VOCs in areas treated by potassium permanganate is expected to be complete within 1 to 2 years.

Implementability. The implementability of this alternative may be inhibited by the geology at the site. Preferential flow paths and areas of low conductivity will dictate where the injected potassium permanganate will flow. This may result in small regions of an aquifer not receiving injected material. This can be overcome by reducing the grid spacing for the direct-push injection and staggering the locations of later injections.

The injection of potassium permanganate will require coordination with the ODEQ UIC program. This will create scheduling delays due to ODEQ review and public participation requirements.

The technical aspects of the actual direct-push injection of potassium permanganate are simple and should not be constrained.

Cost. Capital and O&M costs associated with Alternative 3 are summarized in Table B-2 and detailed in Table B-4. Direct and indirect capital costs for this alternative are estimated to be $1,438,550, and include all equipment, materials, contractor services, labor, project administration, and project management required for implementation. The O&M cost for the first 2 years is estimated to be $220,000, which assumes quarterly groundwater sampling. The O&M cost for the following 5 years is estimated to be $27,500 per year, which assumes annual groundwater sampling. The net present value of 7 years of O&M costs is $331,300, which assumes a discount rate of 7.5 percent. This discount rate was selected based on ODEQ guidance. The total estimated cost for Alternative 3, including a 30 percent contingency, is $2,301,000. In accordance with USEPA and ODEQ Guidance, these estimates are expected to be accurate to +50 to –30 percent.

Alternative 3 is the least expensive of the alternatives that employ active remedial measures. Additionally, this alternative is expected to meet the RAOs for the site within a reasonable time period and is thus protective. As a result, this alternative has a high degree of cost reasonableness.

Treatment of Hot Spots. This alternative is expected to treat the VOCs in Shallow Zone and Deep Zone groundwater at IRP Site 2 to below significant adverse effect levels within a reasonable timeframe.

State Acceptance. The use of potassium permanganate to treat groundwater at the Base has been accepted by ODEQ for relatively small-scale implementation and is expected to be acceptable for full-scale application. However, ODEQ approval of larger scale use of potassium permanganate injection is likely to be contingent on an appropriate monitoring and reporting plan to ensure compliance with the UIC program.

Community Acceptance. The use of potassium permanganate is expected to have some community resistance since it relies on the injection of a foreign material into the groundwater and the perception that it will cause groundwater flowing away from the site to remain purple. An appropriate monitoring and reporting system is an important component of this alternative to allow the public the opportunity to monitor water quality during the remedial action.

5.2.1.4 IRP Site 2 - Alternative 4: In Situ Oxidation - Ozonation with Monitored Natural Attenuation

The following is an evaluation of the application of Alternative 4 at IRP Site 2 with respect to the criteria described in Section 5.1. Figure 5-3 depicts the layout of the primary components of this alternative.

Overall Protection of Human Health and Environment. This alternative is expected to effectively remove or significantly reduce the concentrations of VOCs from Shallow Zone and Deep Zone groundwater at IRP Site 2. The risks associated with exposure to these compounds would be reduced to an acceptable level based on the current and future land use.

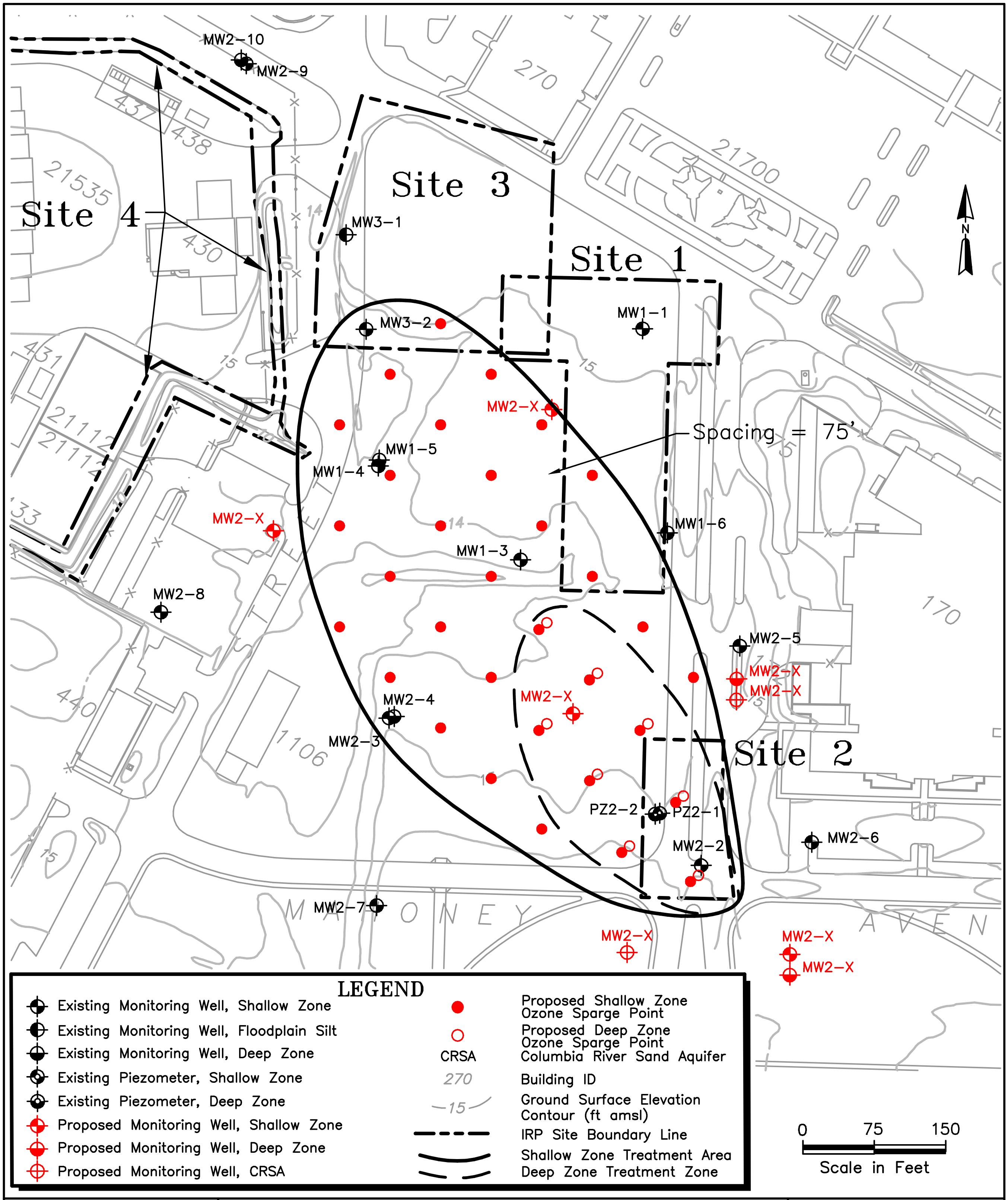
Compliance with ARARs. This alternative is expected to effectively reduce the concentrations of VOCs in Shallow Zone and Deep Zone groundwater to below the levels set by chemical-specific ARARs. Any injection activities must be coordinated through the Oregon UIC program described in Section 4.1.3.6. Compliance with this program is expected to be achievable through registration, monitoring, and reporting.

Long-Term Effectiveness and Permanence. The residual risk posed by groundwater at IRP Site 2 would be reduced by this alternative because the contaminants associated with the risks are destroyed. Groundwater monitoring would be required for an extended period after the completion of this alternative in order to verify attainment of the RAOs.

The contaminants in the downgradient areas of the site treated by MNA are expected to be destroyed within a reasonable time frame, due to enhanced conditions from upgradient ozonation.

The institutional and engineering controls implemented as part of this alternative should be reliable in the long term, based on the current and future land-use scenarios. However, care must be taken to ensure that the controls remain in effect with each future tenant if the ownership or leaseholder of the Base property changes.

Reduction of TMV Through Treatment. The use of ozonation and MNA to treat VOCs in groundwater will result in reduced toxicity, mobility, and



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IRP SITE 2
ALTERNATIVE 4
IN SITU OXIDATION-OZONATION WITH MONITORED NATURAL ATTENTUATION
PLAN VIEW OF TREATMENT SYSTEM LAYOUT

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FIGURE 5-3

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volume of hazardous materials in IRP Site 2 Shallow Zone and Deep Zone groundwater. This reduction is performed through chemical and biological destruction rather than transfer of contaminants from one media to another. The treatment process is irreversible and will result in the production of only harmless byproducts.

Short-Term Effectiveness. Ozone is a strong oxidant and care must be taken to prevent worker or base employee exposure to ozone generated for injection. This would include periodic monitoring of ozone in workspace air and enclosing and locking the ozone generator and sparge wellheads to prevent tampering.

Adverse effects on groundwater that is used for drinking or irrigation is not expected. The oxidative effects of ozone are short lived in groundwater. As described in Section 4.4.5.1, other water quality effects are not expected to be significant enough to reach nearby receptors.

Risks associated with VOCs in groundwater are quickly reduced due to the rapid treatment resulting from ozonation. Destruction of VOCs in areas treated by ozonation is expected to be complete within 3 years.

Implementability. Implementability issues identified for the installation of this alternative include installation of sub-grade piping across base roads, if necessary, avoidance of underground utilities, and connection to base utilities.

The implementability of this alternative may be inhibited by the geology at the site. Preferential flow paths and areas of low conductivity will dictate where sparged air will flow. This can usually be overcome by utilizing a pulsed sparging technique consisting of alternating periods of sparging and rest.

The injection of ozone will require coordination with the ODEQ UIC program. This will create scheduling delays due to ODEQ review and public participation requirements.

Cost. Capital and O&M costs associated with Alternative 4 are summarized in Table B-2 and detailed in Table B-5. Direct and indirect capital costs for this alternative are estimated to be $1,940,750, and include all equipment, materials, contractor services, labor, project administration, and project management required for implementation. The O&M cost for the first 3 years is estimated to be $639,300, which assumes quarterly groundwater sampling and 3 years of treatment system operation. The O&M cost for the following 5 years is estimated to be $27,500 per year, which assumes annual groundwater sampling. The net present value of 8 years of O&M costs is $752,100, which assumes a discount rate of 7.5 percent. This discount rate was selected based on ODEQ guidance. The total estimated cost for Alternative 4, including a 30 percent contingency, is $3,501,000. In accordance with USEPA and ODEQ Guidance, these estimates are expected to be accurate to +50 to -30 percent.

Alternative 4 is expected to meet the RAOs for the site within a reasonable timeframe, and is thus protective. However, Alternative 4 is one of the most expensive of all the alternatives, therefore, it has a mid-range degree of cost reasonableness.

Treatment of Hot Spots. This alternative is expected to treat the VOCs in Shallow Zone and Deep Zone groundwater at IRP Site 2 to below significant adverse-effect levels within a reasonable timeframe.

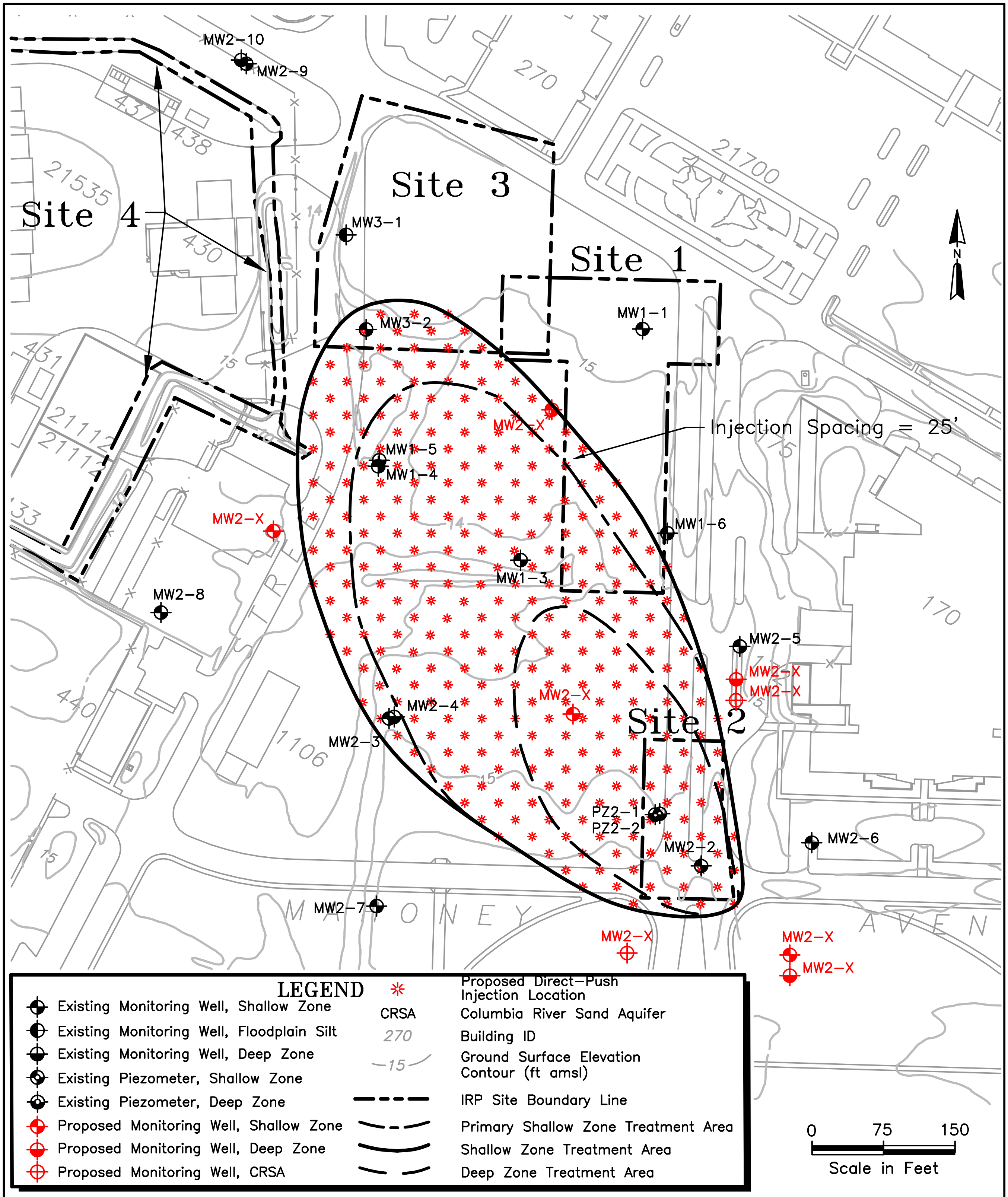
State Acceptance. The use of ozonation to treat groundwater at the Base has been accepted by ODEQ for relatively small-scale implementation and is expected to be acceptable for full-scale application. However, ODEQ approval of larger scale use of an injection technology is likely to be contingent on an appropriate monitoring and reporting plan to ensure compliance with the UIC program.

Community Acceptance. The use of ozonation is expected to have less community resistance than other injection technologies since it relies on the injection of a short-lived gas rather than a liquid. However, an appropriate monitoring and reporting system is still an important component of this alternative to allow the public the opportunity to monitor water quality during the remedial action.

5.2.1.5 IRP Site 2 - Alternative 5: Enhanced Bioremediation with Monitored Natural Attenuation

The following is an evaluation of the application of Alternative 5 at IRP Site 2 with respect to the criteria described in Section 5.1. Figure 5-4 depicts the layout of the primary components of this alternative.

Overall Protection of Human Health and Environment. This alternative is expected to effectively reduce VOCs in Shallow Zone and Deep Zone groundwater at IRP Site 2, as well as the risks associated with exposure to this contamination. However, the effectiveness of this alternative is uncertain, primarily because the use of oxygen releasing materials to treat groundwater containing VC has not been performed extensively. Approximately 75 percent removal of VC was observed during a pilot test



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IRP SITE 2
ALTERNATIVE 5
ENHANCED BIOREMEDIATION WITH MONITORED NATURAL ATTENTUATION PLAN VIEW OF TREATMENT SYSTEM LAYOUT

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FIGURE 5-4

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performed using ORC® at IRP Site 2. It is expected that VC and cis-1,2-DCE will degrade following the creation of enhanced aerobic conditions, but it is uncertain whether the treatment will reduce concentrations to those below RAOs.

This alternative is expected to take longer to begin significant reduction of VOCs than other alternatives, because native microbes must acclimate to the enhanced environment following injection.

Compliance with ARARs. The ability of this alternative to reach ARARs through treatment is uncertain. The use of a hydrogen releasing material is expected to effectively reduce concentrations of TCE to below ARARs. The effectiveness of enhanced aerobic bioremediation at reducing VC to the very low concentrations specified by chemical-specific ARARs is uncertain. Any injection activities must be coordinated through the Oregon UIC program described in Section 4.1.3.6. Compliance with this program is expected to be achievable through registration, monitoring, and reporting.

Long-Term Effectiveness and Permanence. The residual risk posed by Shallow Zone and Deep Zone groundwater at IRP Site 2 would be reduced by this alternative because the contaminants associated with the risks are degraded to harmless byproducts. Although it is uncertain if this alternative will reduce VC to below the significant adverse-effect level at the site, the reduction resulting from treatment should be sufficient to prevent off-site migration, thereby likely meeting the first RAO. Groundwater monitoring would be required for an extended period to verify attainment of this RAO.

The institutional and engineering controls implemented as part of this alternative should be reliable in the long term, based on the current and future land-use scenarios. However, care must be taken to ensure that the controls remain in effect with each future tenant, if the ownership or leaseholder of the Base property changes.

Reduction of TMV through Treatment. Enhancing bioremediation in IRP Site 2 groundwater will reduce the toxicity, mobility, and volume of VOCs. This is performed through irreversible biological destruction, rather than transfer of contaminants from one media to another. The amount of VOCs that will be degraded by enhanced bioremediation at this site is unknown. A significant reduction of VOC concentration is expected, though, which will result in significant reduction of toxicity.

Mobility and volume of contaminated groundwater are also expected to decrease.

Short-Term Effectiveness. This alternative is expected to take a short period to begin effective removal, thus delaying the reduction of risk. Natural biological activity at IRP Site 2 has been shown to be stagnant, and will require acclimation following injection of an enhancing product.

Groundwater containing unacceptable VOC concentrations has not migrated off Base, and is not expected to reach Base boundaries in the immediate future. Also, the institutional and engineering controls used as part of this alternative will prevent exposure to VOCs at the site. These factors limit the added risks related to the delayed effectiveness of this alternative.

Implementability. No issues have been identified for the installation of this alternative. The materials will be injected using a direct-push method.

The treatment of groundwater with oxygen releasing material relies on the flow of groundwater past the injection locations more than the flow of injected material into surrounding groundwater. The shallow gradient of groundwater at IRP Site 2 will limit the rate of transfer of oxygen created by injected material to the surrounding groundwater.

The injection of any material will require coordination with the ODEQ UIC program. This will create scheduling delays due to ODEQ review and public participation requirements.

Cost. Capital and O&M costs associated with Alternative 5 are summarized in Table B-2 and detailed in Table B-6. Direct and indirect capital costs for this alternative are estimated to be $1,806,850, and include all equipment, materials, contractor services, labor, project administration, and project management required for implementation. The O&M cost for the first 2 years is estimated to be $220,000, which assumes quarterly groundwater sampling. The O&M cost for the following 5 years is estimated to be $27,500 per year, which assumes annual groundwater sampling. The net present value of 7 years of O&M costs is $331,300, which assumes a discount rate of 7.5 percent. This discount rate was selected based on ODEQ guidance. The total estimated cost for Alternative 5, including a 30 percent contingency, is $2,780,000. In accordance with USEPA and ODEQ Guidance, these estimates are expected to be accurate to +50 to –30 percent.

Alternative 5 is one of the least expensive of all the alternatives. However, this alternative is not expected to meet the RAOs for the site in a reasonable time period, and is therefore not protective. As a result, this alternative has a mid-range degree of cost reasonableness.

Treatment of Hot Spots. This alternative is expected to treat most VOCs at IRP Site 2 to below respective, significant adverse-effect levels within a reasonable timeframe. It is unknown if VC is capable of being treated to its significant adverse effect level of 2 μg/l (ODEQ 1998c) within a reasonable timeframe by this method.

State Acceptance. The use of enhanced bioremediation to treat groundwater at the Base has been accepted by ODEQ for relatively small-scale implementation and is expected to be acceptable for full-scale application.

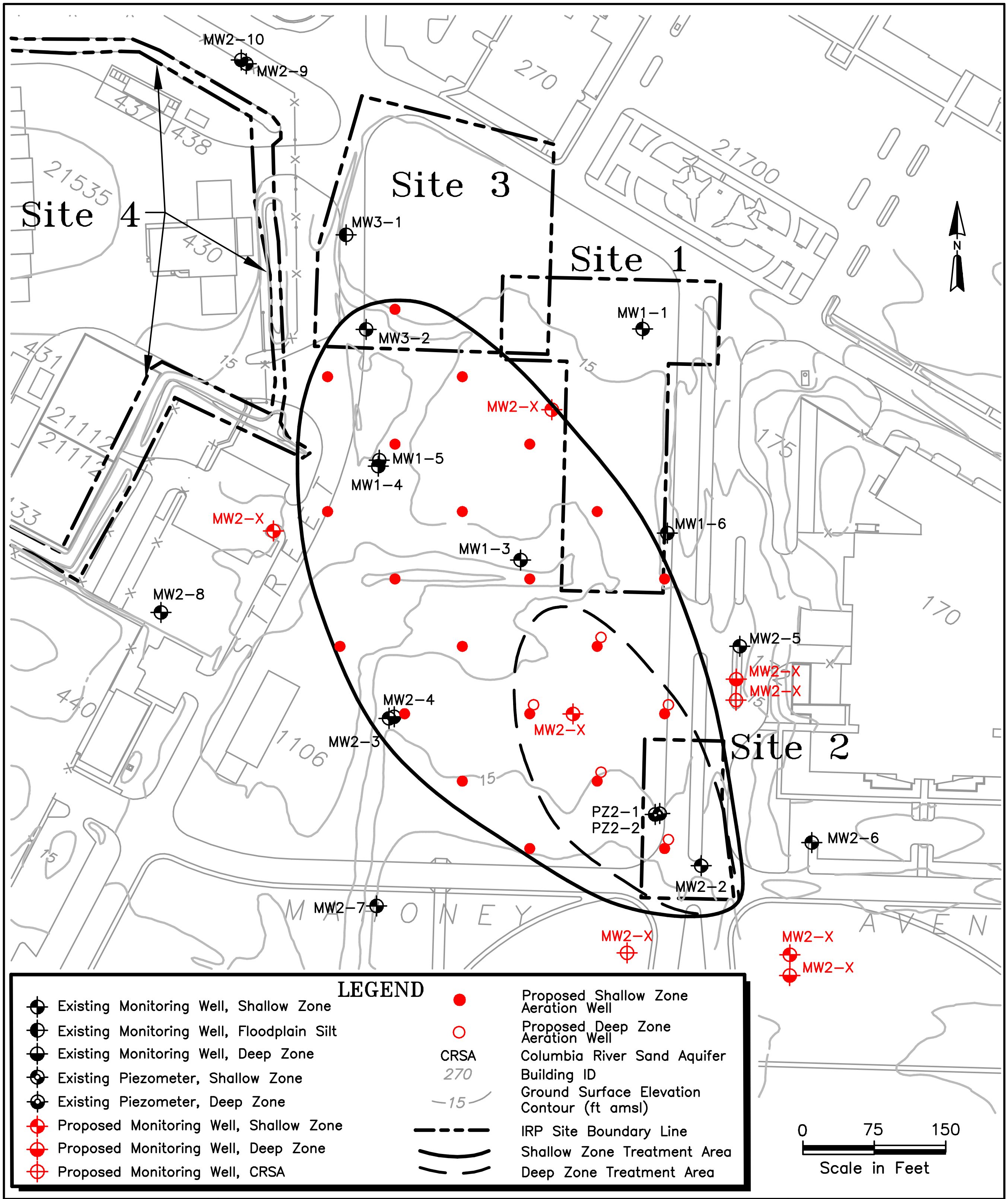
Community Acceptance. The use of enhanced bioremediation is not expected to have community resistance. However, since this technology is less established for treatment of chlorinated hydrocarbons, the community may be skeptical that it would effectively achieve cleanup goals.

5.2.1.6 IRP Site 2 - Alternative 6: In-Well Aeration with Monitored Natural Attenuation

The following is an evaluation of the application of Alternative 6 at IRP Site 2 with respect to the criteria described in Section 5.1. Figure 5-5 depicts the layout of the primary components of this alternative.

Overall Protection of Human Health and Environment. This alternative would reduce the risk posed by IRP Site 2 by reducing the concentration of VOCs in Shallow Zone and Deep Zone groundwater, and the potential for contaminated groundwater to migrate to off-site receptors. The risks associated with exposure to these compounds would be reduced to an acceptable level, based on the current and future land use.

Compliance with ARARs. This alternative is expected to reduce VOCs in IRP Site 2 groundwater to below chemical-specific ARARs. Groundwater within the zone of active treatment by in-well aeration is expected to be treated to concentrations below ARARs within a reasonable time-frame. MNA is expected to degrade VOCs in downgradient groundwater outside of the radius of influence of the in-well aeration system to below ARARs, although at a slower rate than within the active treatment zone.



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IRP SITE 2
ALTERNATIVE 6
IN-WELL AERATION
WITH MONITORED NATURAL ATTENTUATION
PLAN VIEW OF TREATMENT SYSTEM LAYOUT

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FIGURE 5-5

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Long-Term Effectiveness and Permanence. The residual risk posed by IRP Site 2 would be reduced by this alternative because the risk posed by the VOCs in Shallow Zone and Deep Zone groundwater would be significantly reduced. Groundwater monitoring will be required beyond the operation of the in-well aeration system to verify attainment of the clean-up goals.

The contaminants in the downgradient areas of the site treated by MNA are expected to be destroyed within a reasonable timeframe, due to enhanced aerobic conditions from upgradient aeration. However, if long-term monitoring indicates that VOCs in this area are not degrading at an acceptable rate, expansion of the aeration system will be considered to actively treat this area.

The institutional and engineering controls implemented as part of this alternative should be reliable in the long term, based on the current and future land-use scenarios. However, care must be taken to ensure that the controls remain in effect with each future tenant, if the ownership or leaseholder of the Base property changes.

Reduction of TMV Through Treatment. Unlike other treatment technologies discussed in this FS, this technology is based on the transfer of contaminant from one media to another, rather than destruction. Transferring the VOCs from the groundwater to the activated carbon reduces the mobility and volume of the contaminants. The reduction of toxicity of the contaminants would depend on the final disposition of the spent carbon. If the spent carbon is to be disposed of at a landfill, the toxicity is not reduced. This process is irreversible if the activated carbon is handled properly.

Short-Term Effectiveness. It is difficult to estimate with accuracy the time required to achieve the remediation goal. Based on similar scenarios, the in-well aeration system should reduce VOC concentrations in groundwater to below treatment goals within 3 years. The area to be treated by MNA will not experience reductions at the same rate as the in-well aeration area. However, the risks associated with this area are lower.

Implementability. Implementability issues identified for the implementation of this alternative include installation of sub-grade piping across base roads (if necessary), avoidance of underground utilities, and connection to base utilities.

This technology has been shown to effectively remove VOCs from groundwater in locations with adequate subsurface flow characteristics. However, it is still considered an innovative technology, and has not been tested as extensively as some other technologies.

Cost. Capital and O&M costs associated with Alternative 6 are summarized in Table B-2 and detailed in Table B-7. Direct and indirect capital costs for this alternative are estimated to be $1,971,250, and include all equipment, materials, contractor services, labor, project administration, and project management required for implementation. The O&M cost for the first 3 years is estimated to be $777,900, which assumes quarterly groundwater sampling and 3 years of treatment system operation. The O&M cost for the following 5 years is estimated to be $27,500 per year, which assumes annual groundwater sampling. The net present value of 8 years of O&M costs is $891,000, which assumes a discount rate of 7.5 percent. This discount rate was selected based on ODEQ guidance. The total estimated cost for Alternative 6, including a 30 percent contingency, is $3,721,000. In accordance with USEPA and ODEQ Guidance, these estimates are expected to be accurate to +50 to -30 percent.

Alternative 6 is expected to meet the RAOs for the site within a reasonable time period, and is therefore protective. However, this alternative is the most expensive alternative, and therefore has a mid-range degree of cost reasonableness.

Treatment of Hot Spots. This alternative is expected to treat the VOCs in Shallow Zone and Deep Zone groundwater at IRP Site 2 to below significant adverse effect levels within a reasonable timeframe.

State Acceptance. The use of in-well aeration to treat groundwater at the Base would be expected to be acceptable by ODEQ for full-scale implementation. There are no significant water quality issues related to implementation of this technology, which is a major issue with ODEQ.

Community Acceptance. The use of in-well aeration to treat groundwater at the Base would be expected to be acceptable by community residents.

5.2.2 Comparative Analysis of Alternatives – IRP Site 2

The above-detailed evaluation consisted of an individual analysis of each of the six RA alternatives for IRP Site 2 with respect to: protectiveness, compliance with ARARs, long-term effectiveness and permanence, reduction of TMV through treatment, short-term effectiveness, implementability, cost, and treatment of hot spots. Below, the alternatives are compared to each other, and rated based on how well each satisfies the evaluation criteria. Because all of the action alternatives involve the completion of a set of common tasks, the following comparative analysis will focus only on those actions that are in addition to the common tasks for a specific alternative.

5.2.2.1 IRP Site 2 - Overall Protection of Human Health and the Environment

Chemically impacted groundwater at IRP Site 2 does not pose immediate risk to human health and the environment because the impacted groundwater is not currently used. Therefore, all of the alternatives are equally protective in the immediate timeframe. However, since the exposure pathway used for this FS considers migration of impacted groundwater to other water bodies, such as deeper aquifers or surface water, the most protective alternative would be that which would most reliably, completely, and quickly remove those chemicals impacting groundwater at IRP Site 2.

Alternatives 1 (No Action) and 2 (MNA) are not expected to reliably, completely, or quickly remove the chlorinated VOCs impacting groundwater at IRP Site 2.

The reliability of Alternative 6 (In-Well Aeration with MNA) is uncertain. A technology similar to Alternative 6 has been shown to remove VOCs from groundwater extracted from the Shallow Zone at IRP Site 2. However, the recirculation-well form of this technology proposed for this FS has not been tested at the Base.

Alternative 5 (Enhanced Bioremediation with MNA) is expected to reliably and quickly remove risks associated with chlorinated VOCs impacting groundwater at IRP Site 2. It was proven during the IRAC treatability test that the site contaminants can be reduced by an oxygen releasing material. However, Alternative 5 is not expected to reduce VOC concentrations enough to meet the RAOs. It is expected that the effectiveness of a bioremediation enhancing material will diminish as the amount of VOCs and other organic material decreases.

Alternative 4 is expected to reliably and quickly reduce concentrations of VOCs. However, since this technology relies on a recirculation principle similar to that in Alternative 6, its reliability is uncertain.

The alternative that is the most protective of human health and the environment is Alternative 3. Like alternatives based on other technologies, this alternative has been proven to quickly destroy chlorinated VOCs in groundwater at the Base. This alternative is much more reliable and thorough than others because potassium permanganate provides residual treatment capacity and the effectiveness of this technology is more easily monitored. Incomplete removal under this alternative is easily remedied by repeated injections of potassium permanganate.

5.2.2.2 IRP Site 2 - Compliance with ARARs

The ARAR that governs this FS is the federal MCL for each of the chlorinated VOCs impacting groundwater. The alternatives that are not expected to comply with this ARAR include Alternatives 1, 2, and 5, as these options are not expected to reduce the concentration of VC to below the MCL of 2 μg/l for this compound.

Alternatives 4 and 6 do have the potential to reduce concentrations of VOCs to below the respective ARARs. However, as described above, the ability of these technologies to meet this goal across a plume of groundwater is uncertain.

Alternative 3 will most reliably treat VOCs in groundwater at IRP Site 2 to below ARARs. Because of the complete destruction of VOCs that occurs upon contact with potassium permanganate solution, and the simplicity of delivery, this alternative can be tailored in the field to provide complete destruction of VOCs impacting groundwater.

5.2.2.3 IRP Site 2 - Long-Term Effectiveness and Permanence

Alternatives 1 and 2 do not provide long-term effectiveness. These alternatives are not expected to reduce concentrations of VOCs in groundwater at IRP Site 2 to below the respective significant adverse effect levels.

Alternatives 3, 4, and 5 will provide equal long-term effectiveness, provided that these options uniformly meet RAOs as well. These alternatives utilize technologies that provide in situ destruction of contaminants. These technologies are not reversible and do not pose additional risks after meeting treatment goals.

Alternative 6 will provide similar long-term effectiveness to that of Alternatives 3, 4, and 5. However, rather than destroying the contaminants in situ, this alternative uses a technology that strips VOCs from groundwater, and moves them above ground through sparged air. The VOCs are then destroyed. This technology is also non-reversible and poses no additional risks after meeting treatment goals.

Alternative 3 is the most effective alternative in the long term because of the greater residual ability of potassium permanganate to destroy VOCs.

5.2.2.4 IRP Site 2 - Reduction of Toxicity, Mobility, or Volume through Treatment

Alternatives 1 and 2 will not significantly reduce TMV of groundwater impacted by VOCs at IRP Site 2. Some reduction of toxicity may occur through reduction of VOC concentration at localized areas; however, the mobility and volume will remain unchanged, or may possibly increase.

Alternatives 3, 4, and 6 are expected to effectively reduce the toxicity, mobility, and/or volume of VOC-impacted groundwater at IRP Site 2. Alternative 3 is expected to provide the greatest reduction for all three.

Alternative 5 is expected to significantly reduce the toxicity of groundwater impacted by VOCs. However, since this technology is not expected to provide effective treatment at lower concentrations, the reduction of the volume of impacted groundwater may not be as significant as that of Alternatives 3, 4, and 6.

5.2.2.5 IRP Site 2 - Short-Term Effectiveness

The short-term effectiveness of Alternatives 1 and 2 is unacceptably low, based on the time required to reduce VOC concentrations in groundwater at IRP Site 2. VOCs could possibly migrate off-site or down to the CRSA within the time required to reach cleanup goals under these alternatives.

Alternatives 3, 4, 5, and 6 all provide sufficient short-term effectiveness. These alternatives will significantly reduce VOC concentrations in groundwater in a relatively brief time. Alternatives 3 and 4 pose threats to workers in the form of exposure to the oxidizers potassium permanganate and ozone. These threats can be controlled by the use of health and safety measures. The materials used in Alternative 5 exhibits a slight inhalation danger to workers implementing this alternative. No threats to workers are expected during implementation of Alternative 6 beyond the typical mechanical hazards potentially associated with well drilling and machinery installation.

5.2.2.6 IRP Site 2 - Implementability

Alternatives 1 and 2 are the easiest alternatives to implement as the former requires no action and the latter requires only installation of additional monitoring wells and periodic monitoring of VOCs and natural attenuation parameters. However, the reliability of these alternatives is questionable, and it is expected that these alternatives would require future replacement.

The next easiest alternatives to implement are Alternatives 3 and 5. These alternatives involve the direct-push injection of a treatment material and progress monitoring. Alternative 3 is expected to reduce VOCs more fully in IRP Site 2 groundwater. Alternative 5 may require replacement if it should fail to provide complete reduction.

The implementation of Alternatives 4 and 6 involve the construction of numerous, complex sparge wells, as well as a system of piping, compressors, and controls. These systems would require periodic monitoring, trouble shooting, and maintenance.

5.2.2.7 IRP Site 2 - Cost

Alternative 1 and 2 are the least expensive alternatives; however, these alternatives fail to satisfy the protectiveness criterion because they are not expected to meet the site RAOs within a reasonable time period. These alternatives are therefore not cost reasonable. Alternative 5 is also not expected to meet the RAOs within a reasonable time period, although it is one of the least expensive of the alternatives that employ active remedial measures. As a result, Alternative 5 is not the most cost reasonable option. Alternatives 4 and 6 are expected to meet the site RAOs within a reasonable time period, although, these are the two most expensive alternatives. Alternative 3 meets the same level of protectiveness as Alternatives 4 and 6, but is less expensive. Therefore, Alternative 3 is the most cost reasonable alternative.

5.2.2.8 IRP Site 2 - Treatment of Hot Spots

Alternatives 1 and 2 are not expected to effectively treat hot spots of contamination in groundwater at IRP Site 2. The implementation of either of these alternatives could potentially allow the extent of these hot spots to increase.

All of the remaining alternatives would likely reduce the size of the hot spots at IRP Site 2 through treatment. It is uncertain whether Alternative 5 would be effective at treating VOCs, particularly VC, to below the significant adverse-effect level.

Alternatives 3, 4, and 6 are potentially capable of treating VOCs to below the significant adverse-effect levels; however, the expected reliability of Alternative 3 is greater than the others.

5.2.2.9 IRP Site 2 – State Acceptance

Alternatives 1 and 2 are not expected to effectively treat hot spots of contamination in groundwater at IRP Site 2 and therefore are not expected to be acceptable to ODEQ. All of the remaining alternatives would likely reduce the size of the hot spots at IRP Site 2 through treatment as required by ODEQ. However, the use of potassium permanganate injection would be scrutinized by ODEQ the most due to the injection of an oxidizing fluid into the groundwater.

5.2.2.10 IRP Site 2 – Community Acceptance

Alternatives 1 and 2 are not expected to be acceptable to the community because they are not expected to treat hot spots of contamination in groundwater at IRP Site 2 within a reasonable timeframe.

All of the remaining alternatives would likely reduce the size of the hot spots at IRP Site 2 through treatment and should generally be acceptable to community residents. However, for Alternative 3 using potassium permanganate injection it will be important to implement a monitoring program that will sufficiently allow the public to review water quality data.

5.2.3 IRP Site 2 - Preferred Alternative

Alternative 3 is the preferred alternative because it best satisfies the protectiveness criteria and the remedy-selection balancing factors. Alternative 3 involves direct-push injection of potassium permanganate solution through the vertical extent of both the Shallow Zone and Deep Zone, combined with MNA. This alternative also includes the implementation of the common tasks described in Section 4.5.2. By implementation of Alternative 3, the following achievements are expected:

- Human health and the environment within the locality of facility would be protected over the long term.

- The residual risk associated with VOCs in groundwater remaining after completion of this alternative would be acceptable, as described in Section 6.2.

- Base workers would be protected from exposure to VOCs in groundwater through the use of institutional and engineering controls.

- Compared to the other alternatives, greater cost savings would be realized by utilizing permanganate injection to reduce VOC concentrations in IRP Site 2 groundwater.

The IRAC program described previously in Sections 2.8.2 and 3.2.4 will accomplish some of the components of the preferred alternative for IRP Site 2. The full-scale demonstration that is the second phase of the IRAC program involves the injection of potassium permanganate into Shallow Zone groundwater using the same direct-push injection technique described in this FS. The purpose of the second phase of the IRAC program is to test the effectiveness of the preferred technology from the first phase as it is implemented in a full-scale manner, while serving to destroy a large amount of VOC mass.

The second phase of the IRAC will involve a series of direct-push potassium permanganate injections performed in the southeast area of the VOC plume at IRP Site 2. This area has the highest VOC concentrations in Shallow Zone groundwater at the site.

5.3 IRP Site 9

5.3.1 IRP Site 9 - Individual Analysis of Alternatives

The following presents an evaluation of the RA alternatives for IRP Site 9 against the evaluation criteria. The remedial alternatives evaluated for IRP Site 9 include:

- Alternative 1: No Action

- Alternative 2: MNA

- Alternative 3: In Situ Oxidation – Sodium Persulfate Injection with MNA

- Alternative 4: In Situ Oxidation – Ozone Sparging with MNA
- Alternative 5: Enhanced Bioremediation with MNA
- Alternative 6: In-Well Aeration with MNA

5.3.1.1 IRP Site 9 - Alternative 1: No Action

The following is an evaluation of the application of Alternative 1 at IRP Site 9 with respect to the criteria described in Section 5.1.

Overall Protection of Human Health and Environment. The No Action Alternative would not be protective of human health and the environment in the short term because the risks associated with Shallow Zone groundwater are not immediately reduced, either by treatment or by implementing restrictions that would prevent exposure site groundwater, such as institutional controls. Because contaminated Shallow Zone groundwater has the potential to migrate off-site, the No Action Alternative would not provide long-term protection of human health and the environment.

Compliance with ARARs. The No Action Alternative does not meet chemical-specific ARARs because benzene in Shallow Zone groundwater currently exceeds ARARs. Natural processes may not degrade benzene in IRP Site 9 Shallow Zone groundwater prior to migration off-site, and this alternative provides no mechanism for monitoring potential migration.

Long-Term Effectiveness and Permanence. The No Action Alternative would not provide long-term effectiveness and permanence. Remaining untreated benzene in Shallow Zone groundwater would pose too great a residual risk to human and environmental receptors.

Reduction of TMV Through Treatment. The No Action Alternative does not include treatment to reduce TMV. As a result, it is possible that benzene will migrate laterally off-site, as well as vertically to the underlying Deep Zone. Biodegradation of benzene in Shallow Zone groundwater may continue to occur as observed in the past, but without active monitoring it is impossible to ascertain if the degradation rate is rapid enough to prevent migration. If migration of the plume occurs more rapidly than degradation, the volume of hazardous material could actually increase.

Short-Term Effectiveness. The No Action Alternative would present short-term, human health risks associated with benzene in groundwater. However, these risks are no greater than the existing risks at IRP Site 9.

Implementability. The No Action Alternative would not incur implementation obstacles, and there are no associated O&M requirements.

Cost. No costs would be associated with implementing the No Action Alternative. However, because this alternative is ineffective at meeting the RAOs for the site, it would not be protective and therefore a low degree of cost reasonableness is associated with this alternative.

Treatment of Hot Spots. The No Action Alternative does not meet Oregon's requirement that hot spots in water be treated to below the significant adverse-effect level.

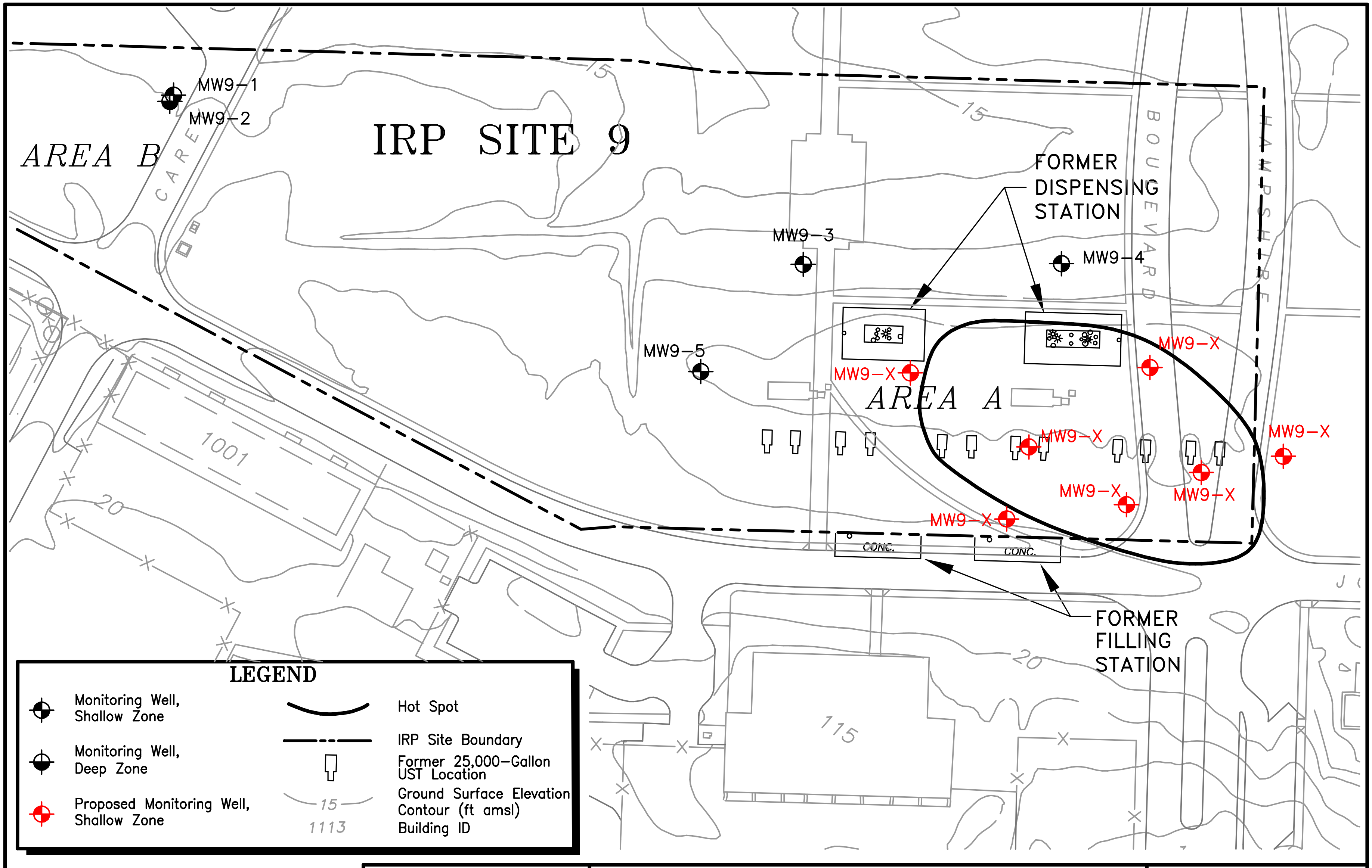
State Acceptance. The No Action Alternative would not be acceptable to ODEQ. Oregon requires that hot spots such as that present in groundwater at IRP Site 9 be treated to below the significant adverse-effect level.

Community Acceptance. The No Action Alternative is not expected to be acceptable to the community. The community is active at the Base in the form of a Restoration Advisory Board (RAB), and would not be accepting of leaving an area of groundwater impacted at the level of IRP Site 9 untreated.

5.3.1.2 IRP Site 9 - Alternative 2 : Monitored Natural Attenuation

The following is an evaluation of the application of Alternative 2 at IRP Site 9 with respect to the criteria described in Section 5.1. Figure 5-6 depicts the layout of the primary components of this alternative.

Overall Protection of Human Health and Environment. The MNA Alternative would be protective of human health and the environment in the short term. Near-future exposure to groundwater with unacceptable risk is prevented through the implementation of institutional and engineering controls at the Base. Groundwater with benzene concentrations above unacceptable risk levels has not migrated to any off-site receptors, and is not expected to in the near future. However, there is long-term risk associated with off-site migration of groundwater containing benzene. During the Natural Attenuation Evaluation conducted as part of the RI (ERM 2001a), it was concluded that natural biodegradation at IRP Site 9 has become stagnant. Because of this, it is



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IRP SITE 9
ALTERNATIVE 2
MONITORED NATURAL ATTENTUATION
LOCATION OF MONITORING WELLS
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FIGURE 5-6

possible that Shallow Zone groundwater containing benzene levels above the RAOs has the potential to migrate off-site. The MNA Alternative, therefore, would not provide long-term protection of human health and the environment.

Compliance with ARARs. The MNA Alternative does not meet chemical-specific ARARs because benzene in Shallow Zone groundwater currently exceeds ARARs, and is not expected to naturally degrade to acceptable levels within a reasonable timeframe, as compared to other methods.

Long-Term Effectiveness and Permanence. The MNA Alternative may provide long-term effectiveness and permanence due to eventual natural degradation of benzene below RAOs. However, this is unlikely to occur within a reasonable time period. It is uncertain if this alternative will treat groundwater to appropriate levels prior to migrating off-site, thereby violating the first RAO, and creating the potential need to replace this remedy.

The institutional and engineering controls implemented as part of this alternative should be reliable in the long term, based on the current and future land-use scenarios. However, care must be taken to ensure that the controls remain in effect with each future tenant, if the ownership or leaseholder of the Base property changes.

Reduction of TMV Through Treatment. The MNA Alternative may reduce the TMV of benzene at IRP Site 9 as natural degradation occurs. The toxicity of Shallow Zone groundwater may slowly diminish as concentrations decrease, but the mobility will remain unchanged. The volume of contaminated groundwater may actually increase due to potential further downgradient and vertical migration of slowly degrading benzene.

Short-Term Effectiveness. The MNA Alternative would present short-term human health risks associated with benzene in groundwater at IRP Site 9. The short-term risks associated with this alternative are a result of the expected time required to meet treatment objectives, expected to possibly exceed 30 years. Within that period, groundwater containing unacceptable benzene concentrations may migrate off-site, thereby violating the first RAO and presenting risk to off-site receptors.

The institutional and engineering controls implemented under this alternative are expected to prevent unacceptable risk to on-site receptors, including Base workers and workers implementing this RA.

Implementability. The MNA Alternative would not incur implementation obstacles. The additional proposed wells will ensure the ability to monitor the effectiveness of this alternative, and the technologies used for this alternative are readily available and implementable.

Cost. Capital and O&M costs associated with Alternative 2 are summarized in Table B-8, and detailed in Table B-9. Direct and indirect capital costs for this alternative are estimated to be $64,500, and include equipment, materials, contractor services, labor, project administration, and project management required for implementation. The O&M cost for the first year is estimated to be $40,400, which assumes quarterly groundwater sampling. The O&M cost for the following 30 years is estimated to be $10,100 per year, which assumes annual groundwater sampling. The net present value of 31 years of O&M costs is $159,700, which assumes a discount rate of 7.5 percent. This discount rate was selected based on ODEQ guidance. The total estimated cost for Alternative 2 is $292,000, including a 30 percent contingency. In accordance with USEPA and ODEQ Guidance, these estimates are expected to be accurate to +50 to –30 percent.

Because Alternative 2 is not expected to meet the RAOs for the site within a reasonable time period, this alternative is not considered protective and therefore has a low degree of cost reasonableness.

Treatment of Hot Spots. Although MNA is considered a treatment technology by the State of Oregon, it is not expected to treat the hot spot at IRP Site 9 to concentrations below the significant adverse-effect level in a timely manner. The hot spot, defined by the extent of contaminants above respective, significant adverse-effect levels, could potentially expand due to migration of the source area.

Treatment of Hot Spots. Although MNA is considered a treatment technology by the State of Oregon, the hot spot at IRP Site 2 is not expected to be treated to concentrations below the significant adverse-effect level in a timely manner under this alternative. The hot spot, defined by the extent of contaminants above respective significant adverse-effect levels, could potentially expand due to migration of the source area.

State Acceptance. The Natural Attenuation Alternative would not be expected to be acceptable to ODEQ. Oregon requires that hot spots such as that present in groundwater at IRP Site 9 be treated within a reasonable timeframe and this is not expected to occur using the Natural Attenuation alternative.

Community Acceptance. The Natural Attenuation Alternative is not expected to be acceptable to the community due to the expected duration required to meet treatment goals.

5.3.1.3 IRP Site 9 - Alternative 3: In Situ Oxidation – Sodium Persulfate Injection with Monitored Natural Attenuation

The following is an evaluation of the application of Alternative 3 at IRP Site 9 with respect to the criteria described in Section 5.1. Figure 5-7 depicts the layout of the primary components of this alternative.

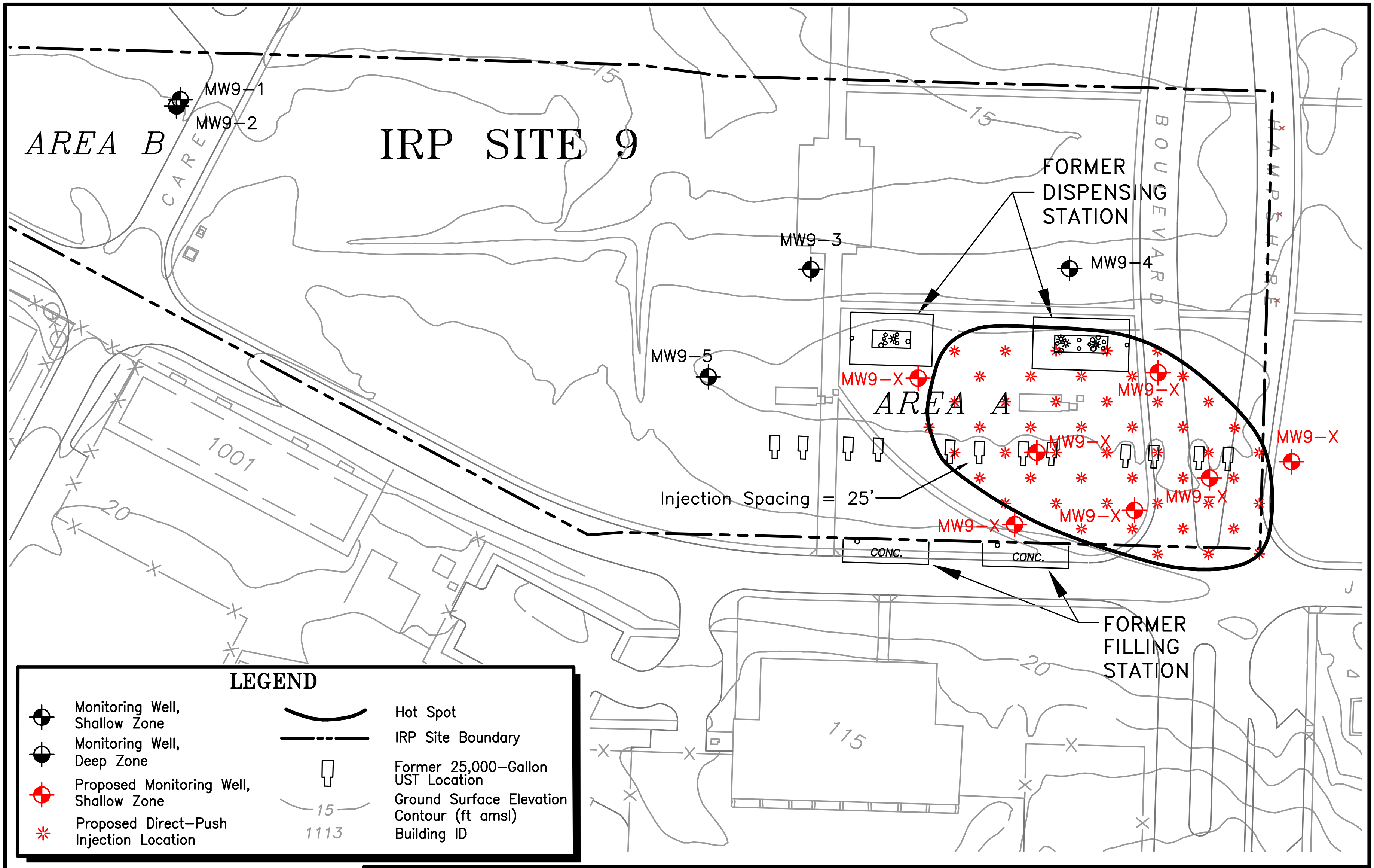
Overall Protection of Human Health and Environment. This alternative is expected to significantly reduce the benzene concentrations from IRP Site 9 Shallow Zone groundwater, and the associated risks of exposure to these compounds. The level of benzene reduction via sodium persulfate oxidation is uncertain, as this technology has not been tested on Base groundwater.

Compliance with ARARs. This alternative is expected to effectively reduce benzene concentrations in IRP Site 9 Shallow Zone groundwater. Any injection activities must be coordinated through the Oregon UIC program described in Section 4.1.3.6. Compliance with this program is expected to be achievable through registration, monitoring, and reporting.

Long-Term Effectiveness and Permanence. The residual risk posed by IRP Site 9 Shallow Zone groundwater would be reduced by this alternative because the contaminants associated with the risks would be destroyed. After the completion of this alternative, extended groundwater monitoring would be required to verify attainment of the RAOs.

The contaminants in the downgradient areas of the site treated by MNA are expected to be destroyed within a reasonable timeframe, due to enhanced conditions from upgradient persulfate injection.

The institutional and engineering controls implemented as part of this alternative should be reliable in the long term, based on the current and future land-use scenarios. However, care must be taken to ensure that the



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IRP SITE 9
ALTERNATIVE 3
IN SITU OXIDATION–SODIUM PERSULFATE
INJECTION WITH MONITORED NATURAL ATTENTUATION
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FIGURE 5–7

controls remain in effect with each future tenant, if the ownership or leaseholder of the Base property changes.

Reduction of TMV through Treatment. The use of sodium persulfate oxidation and MNA to treat benzene in groundwater will result in reduced TMV of hazardous materials in IRP Site 9 groundwater. This reduction is performed through chemical and biological destruction, rather than transfer of contaminants from one media to another. The treatment process is irreversible and would result in the production of only harmless byproducts.

Short-Term Effectiveness. Workers performing the injection will be in contact with sodium persulfate in solid or dissolved form. Worker exposure would be minimized by the use of appropriate health and safety personal protective equipment.

Adverse effects on groundwater used for drinking or irrigation is not expected. The oxidative effects of the sodium persulfate would diminish with time, as it reacts with organic material in the subsurface.

Risks associated with VOCs in groundwater are quickly reduced due to the rapid treatment resulting from persulfate oxidation. Destruction of VOCs in areas treated by sodium persulfate is expected to be complete within 1 to 2 years.

Implementability. The implementability of this alternative may be inhibited by site geology, as preferential flow paths and areas of low conductivity will determine the flow of the injected sodium persulfate. As such, the injected material may not reach limited regions of an aquifer; however, this can be overcome by reducing the grid spacing for the direct-push injection, and staggering the locations of later injections.

The injection of sodium persulfate will require coordination with the ODEQ UIC program, which may create scheduling delays due to the ODEQ's review and public participation requirements.

The technical aspects of the actual direct-push injection of sodium persulfate are basic, and should not present constraints.

Cost. Capital and O&M costs associated with Alternative 3 are summarized in Table B-8, and detailed in Table B-10. Direct and indirect capital costs for this alternative are estimated to be $319,000, and include equipment, materials, contractor services, labor, project administration, and project management required for implementation. The O&M cost for the first 2 years is estimated to be $80,800, which assumes quarterly groundwater sampling. The O&M cost for the following 5 years is estimated to be $10,100 per year, which assumes annual groundwater sampling. The net present value of 7 years of O&M costs is $121,700, which assumes a discount rate of 7.5 percent. This discount rate was selected based on ODEQ guidance. The total estimated cost for Alternative 3 is $573,000, including a 30 percent contingency. In accordance with USEPA and ODEQ Guidance, these estimates are expected to be accurate to a degree of +50 to –30 percent.

Alternative 3 is the least expensive of the alternatives that employ active remedial measures. Additionally, this alternative is expected to meet the RAOs for the site within a reasonable time period and is thus protective. As a result, this alternative has a high degree of cost reasonableness.

Treatment of Hot Spots. This alternative is expected to treat the benzene at IRP Site 9 to below significant adverse effect levels within a reasonable timeframe.

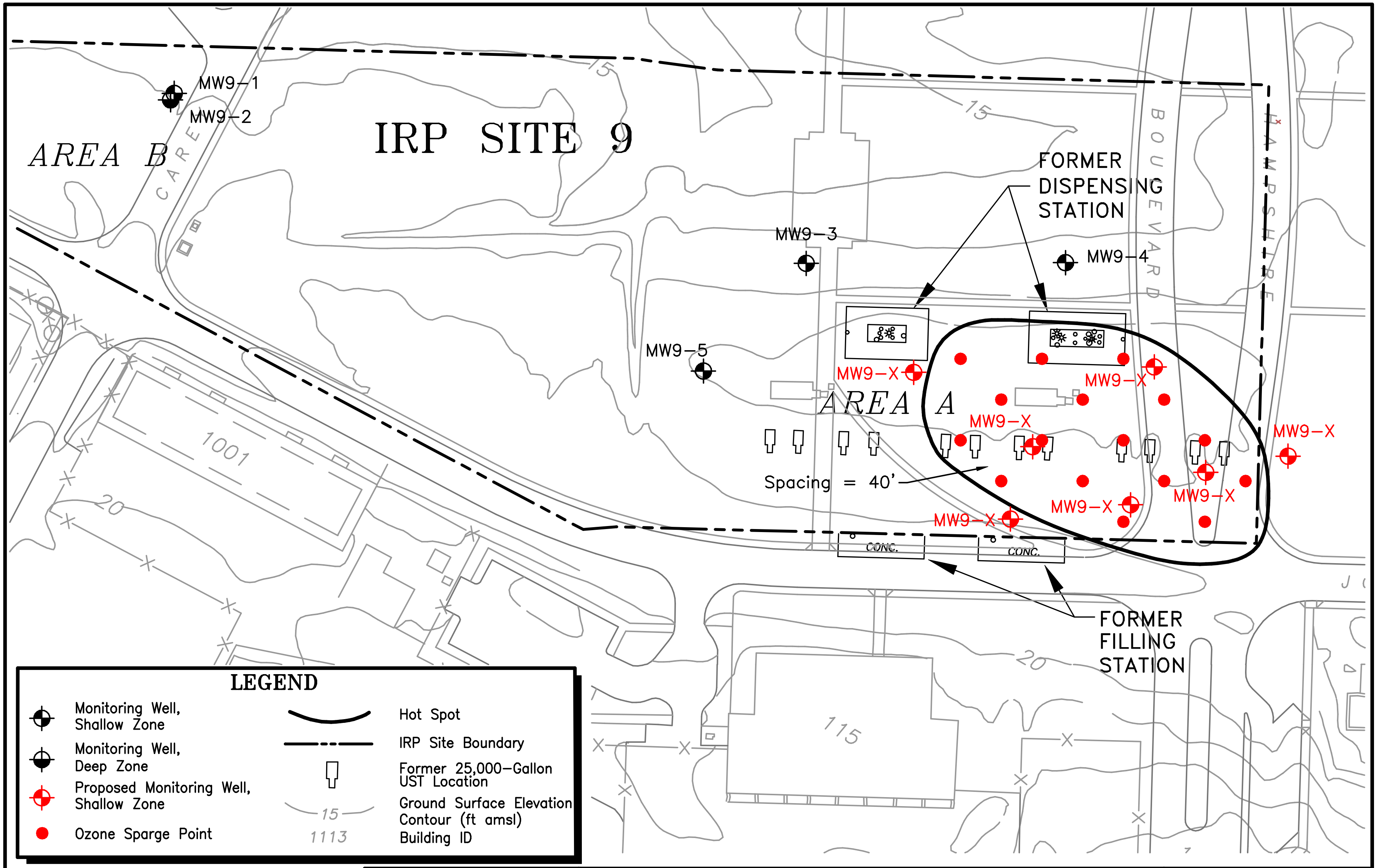
State Acceptance. The use of in situ oxidation to treat groundwater at the Base has been accepted by ODEQ for relatively small-scale implementation and is expected to be acceptable for full-scale application. However, ODEQ approval of a large scale use of sodium persulfate injection is likely to be contingent on an appropriate monitoring and reporting plan to ensure compliance with the UIC program.

Community Acceptance. The use of sodium persulfate is expected to have some community resistance since it relies on the injection of a foreign material into the groundwater. An appropriate monitoring and reporting system is an important component of this alternative to allow the public the opportunity to monitor water quality during the remedial action.

5.3.1.4 IRP Site 9 - Alternative 4: In Situ Oxidation – Ozonation with Monitored Natural Attenuation

The following is an evaluation of the application of Alternative 4 at IRP Site 9 with respect to the criteria described in Section 5.1. Figure 5-8 depicts the layout of the primary components of this alternative.

Overall Protection of Human Health and Environment. This alternative is expected to effectively remove or significantly reduce the benzene concentrations from IRP Site 9 groundwater. The risks associated with benzene exposure would be reduced to an acceptable level, based on current and future land use.



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IRP SITE 9
ALTERNATIVE 4
IN SITU OXIDATION-OZONATION WITH MONITORED NATURAL ATTENTUATION

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FIGURE 5-8

Compliance with ARARs. This alternative is expected to effectively reduce benzene concentrations in Shallow Zone groundwater to below the levels set by chemical-specific ARARs. Any injection activities must be coordinated through the Oregon UIC program described in Section 4.1.3.6. Compliance with this program is expected to be achievable through registration, monitoring, and reporting.

Long-Term Effectiveness and Permanence. The residual risk posed by IRP Site 9 Shallow Zone groundwater would be reduced by this alternative because the contaminants associated with the risks are destroyed. Groundwater monitoring would be required for an extended period after the completion of this alternative to verify attainment of the RAOs.

The contaminants in the downgradient areas of the site treated by MNA are expected to be destroyed within a reasonable timeframe, due to enhanced conditions from upgradient ozonation. However, if long-term monitoring indicates that benzene in this area has not degraded at an acceptable rate, expansion of the area of ozonation would be considered.

The institutional and engineering controls implemented as part of this alternative should be reliable in the long term, based on the current and future land-use scenarios. However, care must be taken to ensure that the controls remain in effect with each future tenant, if the ownership or leaseholder of the Base property changes.

Reduction of TMV Through Treatment. The use of ozonation will reduce the TMV of benzene in IRP Site 9 groundwater via chemical destruction, rather than transfer of contaminants from one media to another. This treatment process is irreversible, and would result in the production of only harmless byproducts.

Short-Term Effectiveness. Ozone is a strong oxidant and care must be taken to prevent worker or Base employee exposure to ozone generated for injection. This would include periodic monitoring of ozone in workspace air, and enclosing and locking the ozone generator and sparge wellheads to prevent tampering.

Adverse effects on groundwater used for drinking or irrigation purposes is not expected. The oxidative effects of ozone are short lived in groundwater.

Risks associated with benzene in groundwater are quickly reduced due to the rapid treatment resulting from ozonation. Destruction of VOCs in areas treated by ozonation is expected to be complete within approximately 3 years.

Implementability. Implementability issues associated with this alternative include installation of sub-grade piping across Base roads (if necessary), avoidance of underground utilities, and connection to Base utilities. The installation and monitoring of an ozone sparging system would require extensive labor as compared to technologies that simply involve injection and monitoring.

The implementability of this alternative may be inhibited by site geology, as preferential flow paths and areas of low conductivity will determine where sparged air will flow. This can usually be overcome by utilizing a pulsed sparging technique consisting of alternating periods of sparging and rest.

The injection of ozone will require coordination with the ODEQ UIC program, which could create scheduling delays due to ODEQ's review and public participation requirements.

Cost. Capital and O&M costs associated with Alternative 4 are summarized in Table B-8, and detailed in Table B-11. Direct and indirect capital costs for this alternative are estimated to be $570,700, and include all equipment, materials, contractor services, labor, project administration, and project management required for implementation. The O&M cost for the first 3 years is estimated to be $309,900, which assumes quarterly groundwater sampling and 3 years of treatment system operation. The O&M cost for the following 5 years is estimated to be $10,100 per year, which assumes annual groundwater sampling. The net present value of 8 years of O&M costs is $350,800, which assumes a discount rate of 7.5 percent. This discount rate was selected based on ODEQ guidance. The total estimated cost for Alternative 4 is $1,198,000, including a 30 percent contingency. In accordance with USEPA and ODEQ Guidance, these estimates are expected to be accurate to +50 to –30 percent.

Alternative 4 is expected to meet the RAOs for the site within a reasonable timeframe and is thus protective. However, Alternative 4 is the most expensive alternative, and therefore has a medium degree of cost reasonableness.

Treatment of Hot Spots. This alternative is expected to treat the benzene at IRP Site 9 to below significant adverse-effect levels within a reasonable timeframe.

State Acceptance. The use of ozonation to treat groundwater at the Base has been accepted by ODEQ for relatively small-scale implementation and is expected to be acceptable for full-scale application. However, ODEQ approval of larger scale use of an injection technology is likely to be contingent on an appropriate monitoring and reporting plan to ensure compliance with the UIC program.

Community Acceptance. The use of ozonation is expected to have less community resistance than other injection technologies since it relies on the injection of a short-lived gas rather than a liquid. However, an appropriate monitoring and reporting system is still an important component of this alternative to allow the public the opportunity to monitor water quality during the remedial action.

5.3.1.5 IRP Site 9 - Alternative 5: Enhanced Bioremediation with Monitored Natural Attenuation

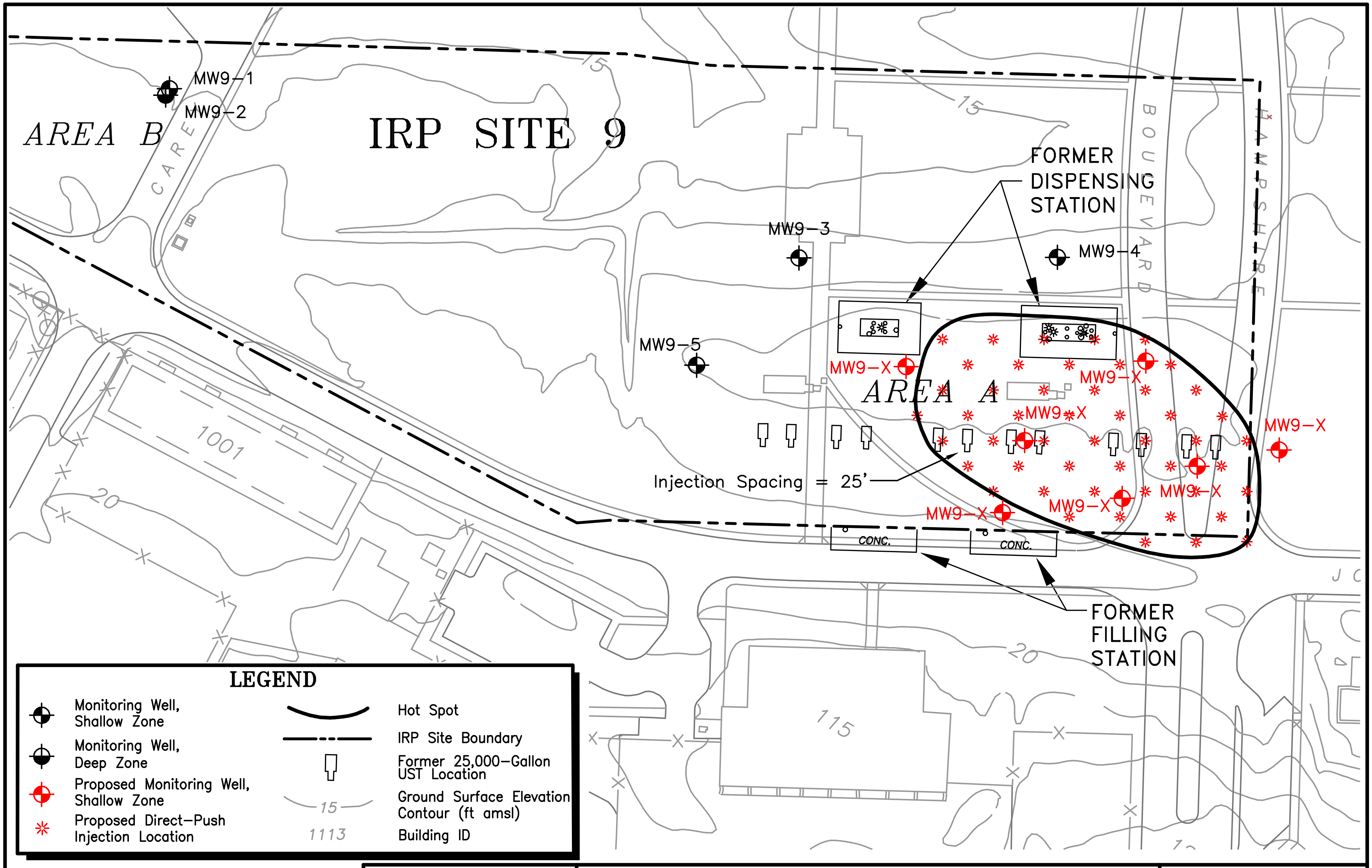
The following is an evaluation of the application of Alternative 5 at IRP Site 9 with respect to the criteria described in Section 5.1. Figure 5-9 depicts the layout of the primary components of this alternative.

Overall Protection of Human Health and Environment. This alternative is expected to effectively remove benzene from IRP Site 9 Shallow Zone groundwater, and the risks associated with exposure to this contamination. This alternative is expected to take longer than other alternatives because native microbes must acclimate to the enhanced environment following injection.

Compliance with ARARs. This alternative is expected to effectively reduce the concentration of benzene in Shallow Zone groundwater to below the levels set by chemical-specific ARARs. Any injection activities must be coordinated through the Oregon UIC program described in Section 4.1.3.6. Compliance with this program is expected to be achievable through registration, monitoring, and reporting.

Long-Term Effectiveness and Permanence. The residual risk posed by Shallow Zone groundwater at IRP Site 9 would be reduced by this alternative because the contaminants associated with the risks are degraded to harmless byproducts. Groundwater monitoring would be required for an extended period after the completion of this alternative to verify attainment of the RAOs.

The institutional and engineering controls implemented as part of this alternative would likely be reliable in the long term, based on the current



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IRP SITE 9
ALTERNATIVE 5
ENHANCED BIOREMEDIATION
WITH MONITORED NATURAL ATTENTUATION
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FIGURE 5-9

and future land-use scenarios. However, care must be taken to ensure that the controls remain in effect with each future tenant, if the ownership or leaseholder of the Base property changes.

Reduction of TMV Through Treatment. Enhancing bioremediation in IRP Site 9 groundwater will reduce the TMV of benzene. This is performed through irreversible biological destruction, rather than transfer of contaminants among media.

Short-Term Effectiveness. This alternative is expected to take a short period to begin effective removal, thus delaying the reduction of risk. Natural biological activity at IRP Site 9 has been shown to be stagnant, and would require acclimation following injection of an enhancing product.

Groundwater containing unacceptable benzene concentrations has not migrated off Base, and is not expected to reach Base boundaries in the very near future. Also, the institutional and engineering controls used as part of this alternative would prevent benzene exposure at the site. These factors limit the added risks related to the delayed effectiveness of this alternative.

Implementability. No issues have been identified for the installation of this alternative. The materials would be injected using a direct-push method.

The treatment of groundwater with oxygen releasing materials relies more heavily on the flow of groundwater past the injection locations, than the flow of injected material into surrounding groundwater. The shallow gradient of groundwater at IRP Site 9 would serve to limit the rate of transfer of oxygen created by the injected material to the surrounding groundwater.

The injection of any oxygen releasing material will require coordination with the ODEQ UIC program. This will create scheduling delays due to ODEQ review and public participation requirements.

Cost. Capital and O&M costs associated with Alternative 5 are summarized in Table B-8, and detailed in Table B-12. Direct and indirect capital costs for this alternative are estimated to be $336,200, and include all equipment, materials, contractor services, labor, project administration, and project management required for implementation. The O&M cost for the first 2 years is estimated to be $80,800, which assumes quarterly groundwater sampling. The O&M cost for the following 5 years is estimated to be $10,100 per year, which assumes annual groundwater sampling. The net present value of 7 years of O&M costs is $121,700, which assumes a discount rate of 7.5 percent. This discount rate was selected based on ODEQ guidance. The total estimated cost for Alternative 5, including a 30 percent contingency, is $596,000. In accordance with USEPA and ODEQ Guidance, these estimates are expected to be accurate to +50 to –30 percent.

Alternative 5 is one of the least expensive of the alternatives that employ active remedial measures. Additionally, this alternative is expected to meet the RAOs for the site within a reasonable time period, and is thus protective. As a result, this option has a high degree of cost reasonableness.

<u>Treatment of Hot Spots.</u> This alternative is expected to treat benzene at IRP Site 9 to below significant adverse-effect levels within a reasonable timeframe.

<u>State Acceptance.</u> The use of enhanced bioremediation to treat groundwater at the Base has been accepted by ODEQ for relatively small-scale implementation and is expected to be acceptable for full-scale application.

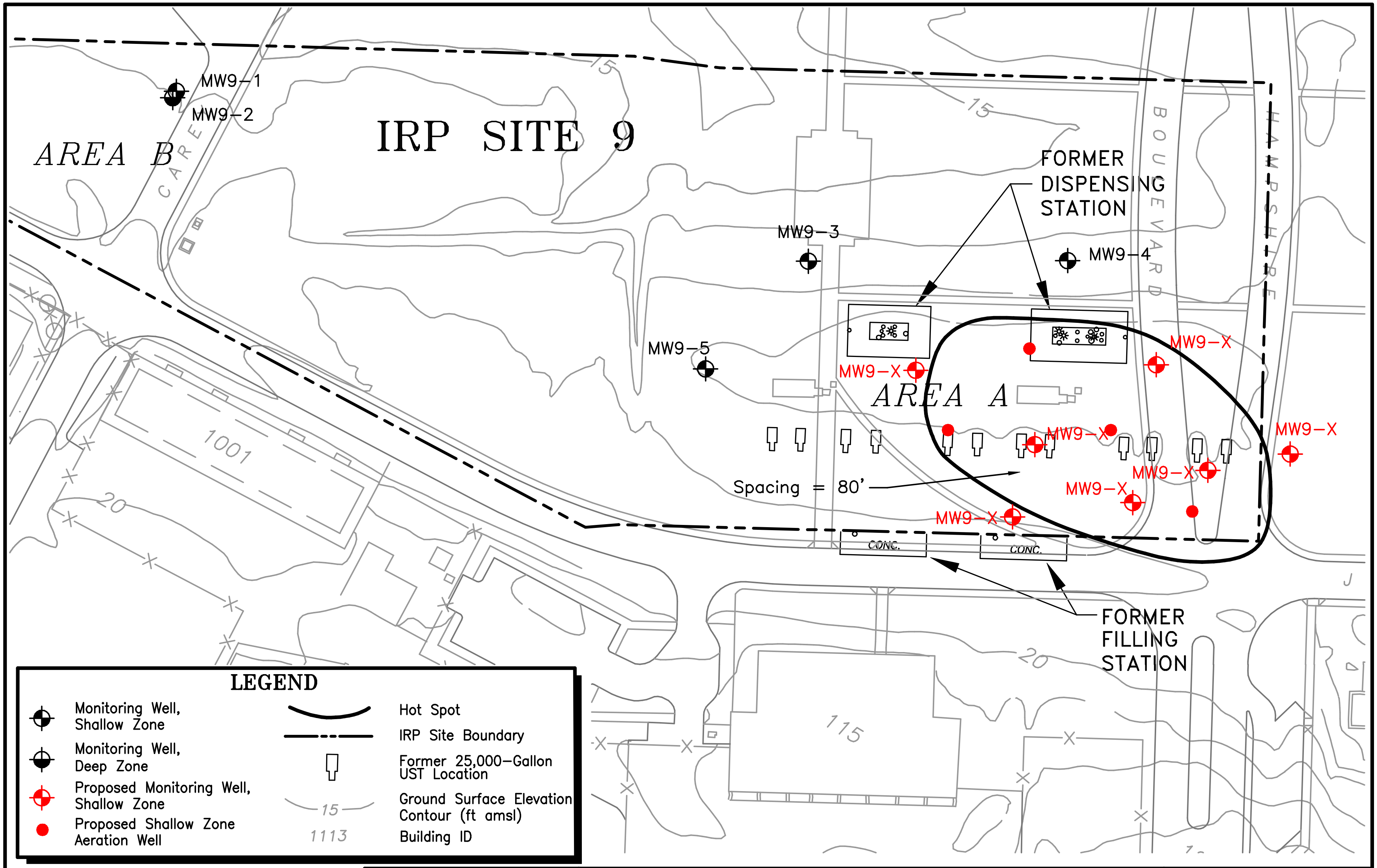
<u>Community Acceptance.</u> The use of enhanced bioremediation is not expected to have community resistance.

5.3.1.6 IRP Site 9 - Alternative 6: In-Well Aeration with Monitored Natural Attenuation

The following is an evaluation of the application of Alternative 6 at IRP Site 9 with respect to the criteria described in Section 5.1. Figure 5-10 depicts the layout of the primary components of this alternative.

<u>Overall Protection of Human Health and Environment.</u> This alternative would reduce the risk posed by IRP Site 9 by reducing benzene concentrations in Shallow Zone groundwater, as well as the potential for contaminated Shallow Zone groundwater to migrate to off-site receptors.

<u>Compliance with ARARs.</u> This alternative is expected to reduce benzene in IRP Site 9 groundwater to below chemical-specific ARARs. Groundwater within the zone of active treatment by in-well aeration is expected to be rapidly treated to concentrations below ARARs. MNA is expected to degrade benzene in downgradient groundwater outside of the



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IRP SITE 9
ALTERNATIVE 6
IN-WELL AERATION
WITH MONITORED NATURAL ATTENTUATION

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FIGURE 5-10

radius of influence of the in-well aeration system to below ARARs, although at a rate slower than that within the active treatment zone.

Long-Term Effectiveness and Permanence. The residual risk posed by IRP Site 2 would be reduced by this alternative because the risk posed by benzene in Shallow Zone groundwater would be significantly reduced. Groundwater monitoring would be required beyond the operation of the in-well aeration system to verify attainment of the cleanup goals.

The contaminants in the downgradient areas of the site treated by MNA are expected to be destroyed within a reasonable timeframe, due to enhanced aerobic conditions from upgradient aeration. However, if long-term monitoring indicates that VOCs in this area are not degrading at an acceptable rate, expansion of the aeration system to actively treat this area would be considered.

The institutional and engineering controls implemented as part of this alternative would likely be reliable in the long term, based on current and future land-use scenarios. However, care must be taken to ensure that the controls remain in effect with each future tenant, if the ownership or leaseholder of the Base property changes.

Reduction of TMV through Treatment. Unlike other treatment technologies discussed in this FS, this technology is based on the transfer of contaminants among media, rather than destruction. Transferring benzene from the groundwater to the activated carbon reduces the mobility and volume of the contaminants. The reduction of toxicity of the contaminants would depend on the final disposition of the spent carbon. For example, if the spent carbon is to be disposed of at a landfill, toxicity would not be reduced.

Short-Term Effectiveness. It is difficult to estimate with accuracy the time required to meet the remediation goal; however, the in-well aeration system should reduce benzene concentrations in groundwater to below treatment goals within 2 years. The area to be treated by MNA would not experience reductions at the same rate as that within the in-well aeration area. However, the risks associated with this area are much lower.

Implementability. Implementability issues identified with this alternative include installation of sub-grade piping across Base roads (if necessary), avoidance of underground utilities, and connection to Base utilities.

This technology has been shown to effectively remove VOCs from groundwater in locations with adequate subsurface flow characteristics.

However, it is still considered an innovative technology, and has not been tested as extensively as some others.

Cost. Capital and O&M costs associated with Alternative 6 are summarized in Table B-8, and detailed in Table B-13. Direct and indirect capital costs for this alternative are estimated to be $469,200, and include all equipment, materials, contractor services, labor, project administration, and project management required for implementation. The O&M cost for the first 3 years is estimated to be $316,200, which assumes quarterly groundwater sampling and 3 years of treatment system operation. The O&M cost for the following 5 years is estimated to be $10,100 per year, which assumes annual groundwater sampling. The net present value of 8 years of O&M costs is $357,100, which assumes a discount rate of 7.5 percent. This discount rate was selected based on ODEQ guidance. The total estimated cost for Alternative 6, including a 30 percent contingency, is $1,075,000. In accordance with USEPA and ODEQ Guidance, these estimates are expected to be accurate to +50 to -30 percent.

Alternative 6 is expected to meet the RAOs for the site within a reasonable time period, and would therefore be considered protective. This alternative is one of the most expensive alternatives, and therefore has a medium degree of cost reasonableness.

Treatment of Hot Spots. This alternative is expected to treat benzene at IRP Site 9 to below significant adverse-effect levels within a reasonable timeframe.

State Acceptance. The use of in-well aeration to treat groundwater at the Base would be expected to be acceptable by ODEQ for full-scale implementation. There are no significant water quality issues related to implementation of this technology, which is a major issue with ODEQ.

Community Acceptance. The use of in-well aeration to treat groundwater at the Base would be expected to be acceptable by community residents.

5.3.2 IRP Site 9 - Comparative Analysis of Alternatives

As discussed, the above-detailed evaluation comprised an individual analysis the six RA alternatives for IRP Site 9, with respect to protectiveness, compliance with ARARs, long-term effectiveness and permanence, reduction of TMV through treatment, short-term effectiveness, implementability, cost, and treatment of hot spots. Below, the alternatives are compared and rated based on how well each satisfies the evaluation criteria. Because all of the action alternatives involve the completion of a set of common tasks, the following comparative analysis will focus only on those actions that are in addition to the common tasks.

5.3.2.1 IRP Site 9 - Overall Protection of Human Health and the Environment

Chemically impacted groundwater at IRP Site 9 does not pose immediate risk to human health and the environment because it is not currently used. Therefore, all of the alternatives are equally protective in the immediate timeframe. However, since the exposure pathway used for this FS considers migration of impacted groundwater to other water bodies, such as deeper aquifers or surface water, the most protective alternative would be that which would most reliably, completely, and quickly remove those chemicals impacting groundwater at IRP Site 9.

Alternatives 1 and 2 are not expected to reliably, completely, or quickly reduce the benzene concentrations in IRP Site 9 groundwater to acceptable levels. The reliability of Alternative 6 is uncertain. Although a similar technology was shown to remove VOCs from groundwater extracted from the Shallow Zone at IRP Site 2, the technology proposed for Alternative 6 requires further testing. Alternatives 4 and 5 are expected to reliably and quickly reduce VOC concentrations.

The alternative most protective of human health and the environment is Alternative 3. This alternative is expected to reliably and quickly remove risks associated with benzene-impacted groundwater at IRP Site 9. Sodium persulfate has not been tested on groundwater containing benzene at the Base, but benzene is expected to be receptive to this oxidation mechanism.

5.3.2.2 IRP Site 9 - Compliance with ARARs

The ARAR that governs this FS is the federal MCL for each of the VOCs impacting groundwater, as is the case for benzene in IRP Site 9 groundwater. Alternatives 1 and 2 would not likely reduce benzene concentrations to below the MCL of 5 µg/l, and therefore would not comply with the ARAR for this compound.

Alternatives 4 and 6 have the potential to reduce benzene concentrations to below the respective ARARs.

Alternatives 3 and 5 would most reliably treat VOCs in groundwater to below ARARs. Because of its ability to aerobically degrade and the presence of additional carbon sources (petroleum hydrocarbons) at IRP Site 9, enhanced aerobic bioremediation is expected to successfully reduce benzene to below its MCL. Benzene is also expected to effectively treated by sodium persulfate oxidation.

5.3.2.3 IRP Site 9 - Long-Term Effectiveness and Permanence

Alternatives 1 and 2 would not provide long-term effectiveness. These alternatives are not expected to reduce concentrations of benzene in groundwater at IRP Site 9 to below the significant adverse-effect level.

Alternatives 3, 4, and 5 would provide equal long-term effectiveness, provided RAOs are equally met as well. These alternatives utilize technologies that provide in situ destruction of contaminants. These technologies are not reversible and do not pose additional risks after treatment goals are met.

Alternative 6 would provide similar long-term effectiveness as that provided by Alternative 3, 4, and 5. However, rather than destroying the contaminants in situ, Alternative 6 uses a technology that strips VOCs from groundwater, and moves them above ground through sparged air, where the VOCs are subsequently destroyed. This technology is also irreversible, and poses no additional risks after treatment goals are met.

Alternative 3 and 5 are the most effective alternatives in the long term because they are the alternatives most likely to be able to reach treatment goals, therefore not requiring replacement.

5.3.2.4 IRP Site 9 - Reduction of Toxicity, Mobility, or Volume through Treatment

Alternatives 1 and 2 will not significantly reduce TMV of benzene-impacted groundwater at IRP Site 9. Some reduction of toxicity may occur through reduction of benzene concentration at localized areas. However, the mobility and volume would likely remain unchanged, or could possibly increase.

Alternatives 3, 4, 5, and 6 are expected to effectively reduce the TMV of VOC-impacted groundwater at IRP Site 2. However, Alternative 3 and 5 are expected to provide the greatest reduction.

5.3.2.5 IRP Site 9 - Short-Term Effectiveness

The short-term effectiveness of Alternatives 1 and 2 is unacceptably low, based on the length of time required to reduce benzene concentrations in

IRP Site 9 groundwater. Groundwater containing unacceptable levels of benzene could possibly migrate off-site, or down to the CRSA, within the time required to reach cleanup goals under these alternatives.

Alternatives 3, 4, 5, and 6 all provide sufficient, short-term effectiveness. These alternatives will significantly reduce VOC concentrations in groundwater in a relatively quick fashion. Alternatives 3, 4, and 5 pose slight threats to workers in the form of exposure to the injection material used for each alternative. These threats could be controlled by the use of health and safety measures. No threats to workers are expected during implementation of Alternative 6, beyond the typical mechanical dangers associated with well drilling and installation of machinery.

5.3.2.6 IRP Site 9 - Implementability

Alternatives 1 and 2 are the easiest alternatives to implement. Alternative 1 requires no action, and Alternative 2 requires only installation of additional monitoring wells, and periodic monitoring of VOCs and natural attenuation parameters. However, the reliability of these alternatives is questionable, and it would be expected that they would require replacement at a later date.

The next easiest alternatives to implement are Alternatives 3 and 5. These alternatives involve the direct-push injection of a treatment material, and progress monitoring. Neither of these alternatives are expected to require replacement.

The implementation of Alternatives 4 and 6 involve the construction of several, complex sparge wells, and a system of piping, compressors, and controls. The systems for these alternatives would require periodic monitoring, trouble shooting, and maintenance.

5.3.2.7 IRP Site 9 - Cost

Alternative 1 and 2 are the least expensive alternatives; however these alternatives fail to satisfy the protectiveness criterion because they are not expected to meet the site RAOs within a reasonable time period. These alternatives are therefore not cost reasonable. Alternatives 4 and 6 are expected to meet the site RAOs within a reasonable time period, however these are two of the most expensive alternatives. Alternatives 3 and 5 meet the same level of protectiveness as Alternatives 4 and 6, but are less expensive. Alternative 3 and 5 are therefore the most cost reasonable alternatives.

5.3.2.8 IRP Site 9 - Treatment of Hot Spots

Alternatives 1 and 2 are not expected to effectively treat the hot spot of contamination in IRP Site 9 groundwater. The implementation of either of these alternatives would potentially allow the extent of this hot spot to increase.

Alternatives 3, 4, 5, and 6 are capable of treating VOCs to below the significant adverse-effect levels. However, the expected reliability of Alternative 3 is greater than the other alternatives.

5.3.2.9 IRP Site 9 – State Acceptance

Alternatives 1 and 2 are not expected to effectively treat hot spots of contamination in groundwater at IRP Site 9 and therefore are not expected to be acceptable to ODEQ. All of the remaining alternatives would likely reduce the size of the hot spots at IRP Site 9 through treatment as required by ODEQ. However, the use of sodium persulfate injection would be scrutinized by ODEQ the most due to the injection of an oxidizing fluid into the groundwater.

5.3.2.10 IRP Site 9 – Community Acceptance

Alternatives 1 and 2 are not expected to be acceptable to the community because they are not expected to treat hot spots of contamination in groundwater at IRP Site 9 within a reasonable timeframe.

All of the remaining alternatives would likely reduce the size of the hot spots at IRP Site 9 through treatment and should generally be acceptable to community residents. However, for Alternative 3 using sodium persulfate injection it will be important to implement a monitoring program that will sufficiently allow the public to review water quality data.

5.3.3 IRP Site 9 - Preferred Alternative

Alternative 3 is the preferred alternative because it best satisfies the protectiveness criteria, and most of the remedy-selection balancing factors. Alternative 3 involves direct-push injection of sodium persulfate through the vertical extent of the Shallow Zone, combined with MNA. This alternative also includes the implementation of the common tasks described in Section 4.5.2. By implementation of Alternative 3, the following achievements are expected:

- Human health and the environment within the locality of facility would be protected over the long term.
- The residual risk associated with VOCs in groundwater remaining after completion of this alternative would be acceptable, as described in Section 6.2.
- Base workers would be protected from exposure to VOCs in groundwater through the use of institutional and engineering controls.
- In situ oxidation using sodium persulfate would be one of the most cost-effective means of reducing concentrations of benzene in IRP Site 9 groundwater.

5.4 IRP Site 11

5.4.1 IRP Site 11 - Individual Analysis of Alternatives

The following presents an evaluation of the RA alternatives for IRP Site 11 against the evaluation criteria. The remedial alternatives evaluated for IRP Site 11 include:

- Alternative 1: No Action
- Alternative 2: MNA
- Alternative 3: In Situ Oxidation – Potassium Permanganate Injection with MNA
- Alternative 4: In Situ Oxidation – Ozone Sparging with MNA
- Alternative 5: Enhanced Bioremediation with MNA
- Alternative 6: In-Well Aeration with MNA

5.4.1.1 IRP Site 11 - Alternative 1: No Action

The following is an evaluation of the application of Alternative 1 at IRP Site 11 with respect to the criteria described in Section 5.1.

Overall Protection of Human Health and Environment. The No Action Alternative would not be protective of human health and the environment in the short-term, because the risks associated with Shallow Zone and Deep Zone groundwater are not immediately reduced, either by treatment or by implementing restrictions that would prevent exposure site groundwater, such as institutional controls. Because contaminated Shallow Zone and Deep Zone groundwater has the potential to migrate off-site, the No Action Alternative would not provide long-term protection of human health and the environment.

Compliance with ARARs. The No Action Alternative would not meet chemical-specific ARARs, because several chlorinated VOCs in Shallow Zone and Deep Zone groundwater currently exceed ARARs. The No Action Alternative would potentially reduce VOC concentrations to below respective ARARs in downgradient areas of IRP Site 11 due to natural processes. However, the higher concentration VOCs in the upgradient area of IRP Site 11 are not expected to naturally degrade to below ARARs within a reasonable timeframe.

Long-Term Effectiveness and Permanence. The No Action Alternative would not provide long-term effectiveness and permanence, because the residual risk to human and environmental receptors remaining from untreated chlorinated VOCs in Shallow Zone and Deep Zone groundwater is too great.

Reduction of TMV Through Treatment. The No Action Alternative does not include any treatment to reduce TMV. As a result, it is possible that chlorinated VOCs would continue to migrate laterally and vertically, and eventually reach off-site receptors. Biodegradation of TCE in Shallow Zone groundwater may continue to occur as observed in the past, but the natural degradation of lower-order chlorinated ethenes (cis-1,2-DCE and VC) in Shallow Zone and Deep Zone groundwater is not expected to be significant. The degradation is expected to be slower than migration, thereby increasing the volume of contaminated groundwater.

Short-Term Effectiveness. The No Action Alternative would present short-term, human health risks associated with chlorinated VOCs in groundwater at IRP Site 2. However, these risks are no greater than the existing risks at the site.

Implementability. The No Action Alternative would not incur implementation obstacles. In addition, there are no O&M requirements for the alternative.

Cost. No costs would be associated with implementing the No Action Alternative. Because this alternative is not effective in meeting the RAOs for the site, and is therefore not protective, it has a low degree of cost reasonableness.

Treatment of Hot Spots. The No Action Alternative does not meet Oregon's requirement that hot spots of contamination be treated to below the significant adverse-effect level.

State Acceptance. The No Action Alternative would not be acceptable to ODEQ. Oregon requires that hot spots such as that present in groundwater at IRP Site 11 be treated to below the significant adverse-effect level.

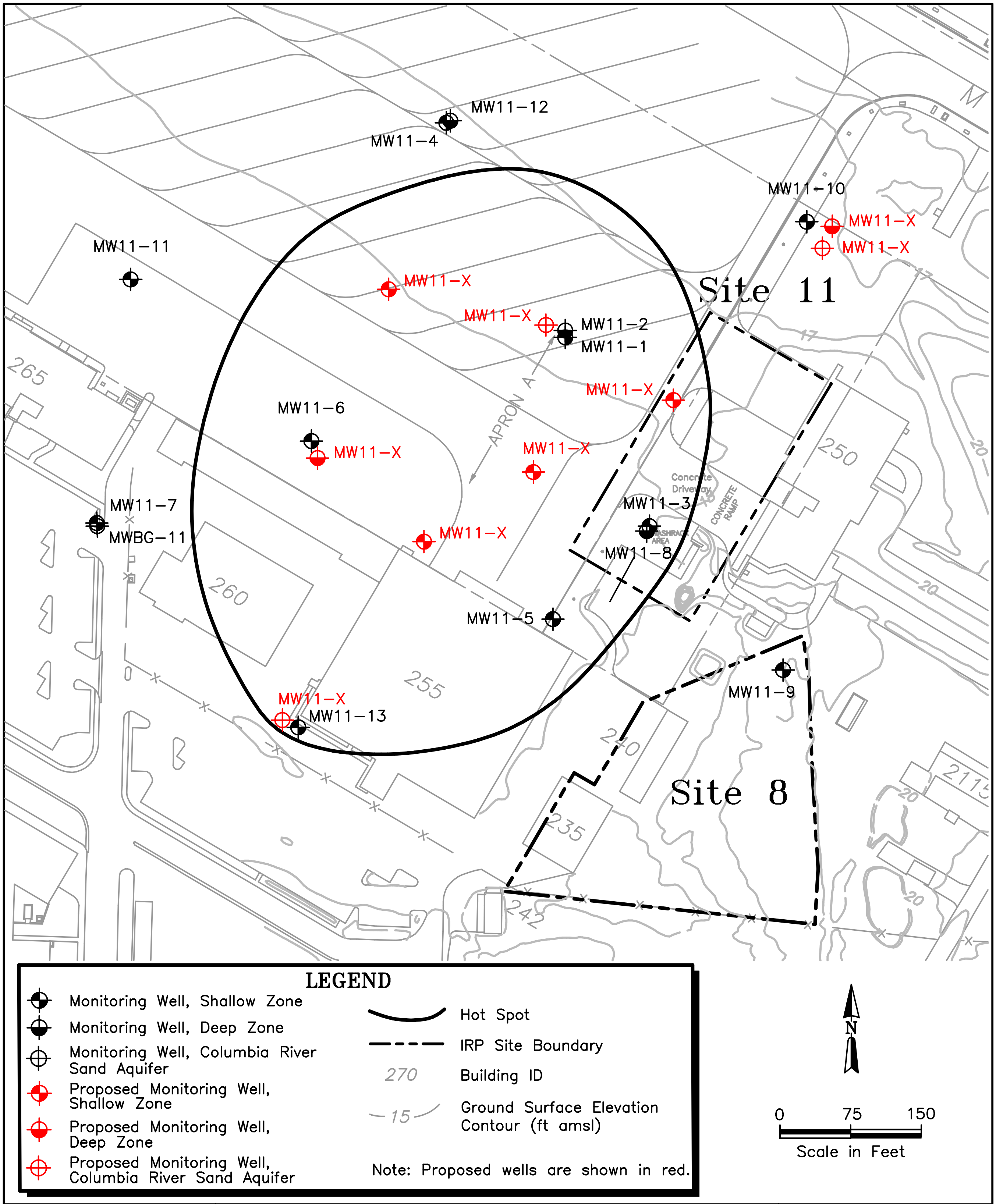
Community Acceptance. The No Action Alternative is not expected to be acceptable to the community. The community is active at the Base in the form of a Restoration Advisory Board (RAB), and would not be accepting of leaving an area of groundwater impacted at the level of IRP Site 11 untreated.

5.4.1.2 IRP Site 11 - Alternative 2: Monitored Natural Attenuation

The following is an evaluation of the application of Alternative 2 at IRP Site 11 with respect to the criteria described in Section 5.1. Figure 5-11 depicts the layout of the primary components of this alternative.

Overall Protection of Human Health and Environment. The MNA Alternative would be protective of human health and the environment in the short-term. Near-future exposure to groundwater with unacceptable risk is prevented through institutional and engineering controls implemented at the Base. Groundwater with VOC concentrations above unacceptable risk levels has not migrated to any off-site receptors and is not expected to do so in the near future. However, there is long-term risk associated with off-site migration of groundwater containing VOCs.

During the Natural Attenuation Evaluation that was conducted as part of the RI (ERM 2001a) it was concluded that the degradation rate of VC is very slow. Because of this, it is possible that Shallow Zone and Deep Zone groundwater containing levels of VC above the RAOs has the potential to migrate off-site. The MNA Alternative, therefore, would also not provide long-term protection of human health and the environment.



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IRP SITE 11
ALTERNATIVE 2
MONITORED NATURAL ATTENUATION
LOCATION OF MONITORING WELLS

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FIGURE 5−11

<u>Compliance with ARARs.</u> The MNA Alternative does not meet chemical-specific ARARs because chlorinated VOCs in Shallow Zone and Deep Zone groundwater currently exceed ARARs and are not expected to naturally degrade to below levels determined by the chemical-specific ARARs within a time frame that is reasonable compared to that offered by other methods.

<u>Long-Term Effectiveness and Permanence.</u> The MNA Alternative may provide long-term effectiveness and permanence due to eventual natural degradation of VOCs below RAOs. However, this is unlikely to occur within a reasonable time period. It is uncertain if this alternative will treat groundwater to appropriate levels prior to migrating off-site, thereby violating the first RAO. This uncertainty creates the potential need to replace this remedy.

The institutional and engineering controls implemented as part of this alternative should be reliable in the long term, based on the current and future land use scenarios. However, care must be taken to ensure that the controls remain in effect with each future tenant if the ownership or leaseholder of the Base property changes.

<u>Reduction of TMV Through Treatment.</u> The MNA Alternative is not expected to significantly reduce the TMV of VOCs at IRP Site 11 within a reasonable timeframe. Natural biodegradation of lower order chlorinated ethenes cis-1,2-DCE and VC is not expected to be rapid. The toxicity of Shallow Zone and Deep Zone groundwater may be slowly reduced as areas of higher concentration VOCs are slowly treated. As VC is produced through reductive dechlorination of dichloroethene, the mobility will actually increase due to the increased solubility and decreased sorption tendency of VC in relation to its parent compounds. If natural degradation proves to be slower than the migration rate, the volume of contaminated groundwater may actually increase due to potential further downgradient and vertical migration of slowly degrading VOCs.

<u>Short-Term Effectiveness.</u> The MNA Alternative would present short-term human health risks associated with chlorinated VOCs in groundwater at IRP Site 11. The short-term risks associated with this alternative are a result of the expected duration required to meet treatment objectives. The required duration of MNA could exceed 30 years. Within that period, groundwater containing unacceptable concentrations of VOCs may migrate off-site, violating the first RAO and presenting risk to off-site receptors.

The institutional and engineering controls implemented under this alternative are expected to prevent unacceptable risk to on-site receptors, including base workers and workers implementing this RA.

Implementability. The MNA Alternative would not have implementation obstacles. The additional proposed wells will ensure the ability to monitor the effectiveness of this alternative. The technologies used for this alternative are readily available and implementable.

Cost. Capital and O&M costs associated with Alternative 2 are summarized in Table B-14 and detailed in Table B-15. Direct and indirect capital costs for this alternative are estimated to be $151,700, and include all equipment, materials, contractor services, labor, project administration, and project management required for implementation. The O&M cost for the first year is estimated to be $110,000, which assumes quarterly groundwater sampling. The O&M cost for the following 30 years is estimated to be $27,500 per year, which assumes annual groundwater sampling. The net present value of 31 years of O&M costs is $434,800, which assumes a discount rate of 7.5 percent. This discount rate was selected based on ODEQ guidance. The total estimated cost for Alternative 2, including a 30 percent contingency, is $763,000. In accordance with USEPA and ODEQ Guidance, these estimates are expected to be accurate to +50 to –30 percent.

Because Alternative 2 does not meet the RAOs for the site within a reasonable time period, this alternative is not protective and therefore has a low degree of cost reasonableness.

Treatment of Hot Spots. Although MNA is considered a treatment technology by Oregon State, the hot spot at IRP Site 11 is not expected to be treated to concentrations below the significant adverse effect level in a timely manner under this alternative. The hot spot, defined by the extent of contaminants above respective significant adverse effect levels, could potentially expand due to migration of the source area.

State Acceptance. The Natural Attenuation Alternative would not be expected to be acceptable to ODEQ. Oregon requires that hot spots such as that present in groundwater at IRP Site 11 be treated within a reasonable timeframe and this is not expected to occur using the Natural Attenuation alternative.

Community Acceptance. The Natural Attenuation Alternative is not expected to be acceptable to the community due to the expected duration required to meet treatment goals.

5.4.1.3 *IRP Site 11 - Alternative 3: In Situ Oxidation - Potassium Permanganate Injection with Monitored Natural Attenuation*

The following is an evaluation of the application of Alternative 3 at IRP Site 11 with respect to the criteria described in Section 5.1. Figure 5-12 depicts the layout of the primary components of this alternative.

Overall Protection of Human Health and Environment. This alternative is expected to effectively remove or significantly reduce the concentrations of VOCs from groundwater at IRP Site 11. The risks associated with exposure to these compounds would be reduced to an acceptable level based on the current and future land use.

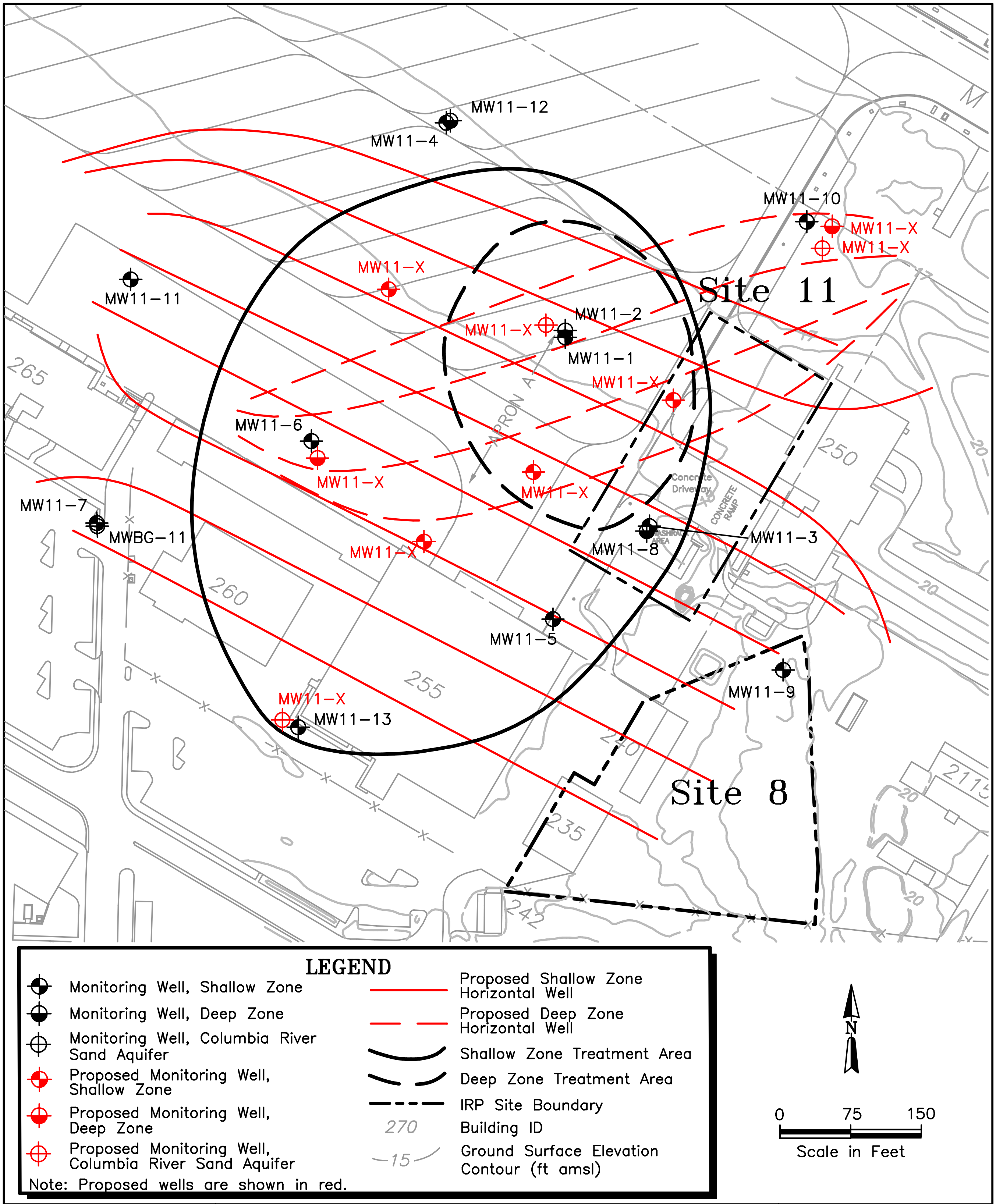
Compliance with ARARs. This alternative is expected to effectively reduce the concentrations of VOCs in groundwater to below the levels set by chemical-specific ARARs.

Long-Term Effectiveness and Permanence. The residual risk posed by groundwater at IRP Site 11 would be reduced by this alternative because the contaminants associated with the risks are destroyed. Groundwater monitoring would be required for an extended period after the completion of this alternative in order to verify attainment of the RAOs.

The contaminants in the downgradient areas of the Site treated by MNA are expected to be destroyed within a reasonable time frame, due to enhanced conditions from upgradient permanganate injection. However, if long-term monitoring indicates that VOCs in this area are not degrading at an acceptable rate, potassium permanganate can be injected in additional injection wells installed in this area.

The institutional and engineering controls implemented as part of this alternative should be reliable in the long term, based on the current and future land use scenarios. However, care must be taken to ensure that the controls remain in effect with each future tenant if the ownership or leaseholder of the Base property changes.

Reduction of TMV Through Treatment. The use of potassium permanganate oxidation and MNA to treat VOCs in groundwater will result in reduced toxicity, mobility, and volume of hazardous materials in IRP Site 11 groundwater. This reduction is performed through chemical and biological destruction rather than transfer of contaminants from one media to another. The treatment process is irreversible and will result in the production of only harmless byproducts.



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IRP SITE 11
ALTERNATIVE 3
IN SITU OXIDATION-POTASSIUM PERMAGNATE INJECTION WITH MONITORED NATURAL ATTENUATION PLAN VIEW OF TREATMENT SYSTEM LAYOUT

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FIGURE 5-12

Short-Term Effectiveness. Workers performing the injection will be in contact with potassium permanganate in solid or dissolved form. Worker exposure would be minimized by the use of appropriate health and safety personal protective equipment.

Adverse effects on groundwater that is used for drinking or irrigation is not expected, as described in Section 4.4.5.1. The oxidative effects of the potassium permanganate will diminish with time as it reacts with organic material in the subsurface.

Risks associated with VOCs in groundwater are quickly reduced due to the rapid treatment resulting from permanganate oxidation. Destruction of VOCs in areas treated by potassium permanganate is expected to be complete within 1 to 2 years.

Implementability. Implementation obstacles within the zone of active remediation by potassium permanganate injection include ensuring the avoidance of underground utilities, coring through the thick concrete on the flight apron to install wells, working around secure buildings, and coordinating well installation and permanganate injection with flight operations and Base personnel. The use of directionally-drilled horizontal wells will avoid the need to install numerous vertical injection wells. However, the installation of the horizontal wells requires a great deal of precision, expertise, equipment and space, compared to conventional drilling. Closure of areas at the drilling locations may be required. This alternative has been developed to allow full use of the flight apron during construction, with the exception of the installation of a small number of monitoring wells.

The implementability of this alternative may be inhibited by the geology at the site. Preferential flow paths and areas of low conductivity will dictate where the injected potassium permanganate will flow. This may result in small regions of an aquifer not receiving injected material. This can be overcome by performing multiple injections of potassium permanganate.

The injection of potassium permanganate will require coordination with the ODEQ UIC program. This will create scheduling delays due to ODEQ review and public participation requirements.

Cost. Capital and O&M costs associated with Alternative 3 are summarized in Table B-14 and detailed in Table B-16. Direct and indirect capital costs for this alternative are estimated to be $1,673,950, and include all equipment, materials, contractor services, labor, project administration, and project management required for implementation. The O&M cost for the first 2 years is estimated to be $220,000, which assumes quarterly groundwater sampling. The O&M cost for the following 5 years is estimated to be $27,500 per year, which assumes annual groundwater sampling. The net present value of 7 years of O&M costs is $331,300, which assumes a discount rate of 7.5 percent. This discount rate was selected based on ODEQ guidance. The total estimated cost for Alternative 3, including a 30 percent contingency, is $2,607,000. In accordance with USEPA and ODEQ Guidance, these estimates are expected to be accurate to +50 to –30 percent.

Alternative 3 is the least expensive of the alternatives that employ active remedial measures. Additionally, this alternative is expected to meet the RAOs for the site within a reasonable time period and is thus protective. As a result, this alternative has a high degree of cost reasonableness.

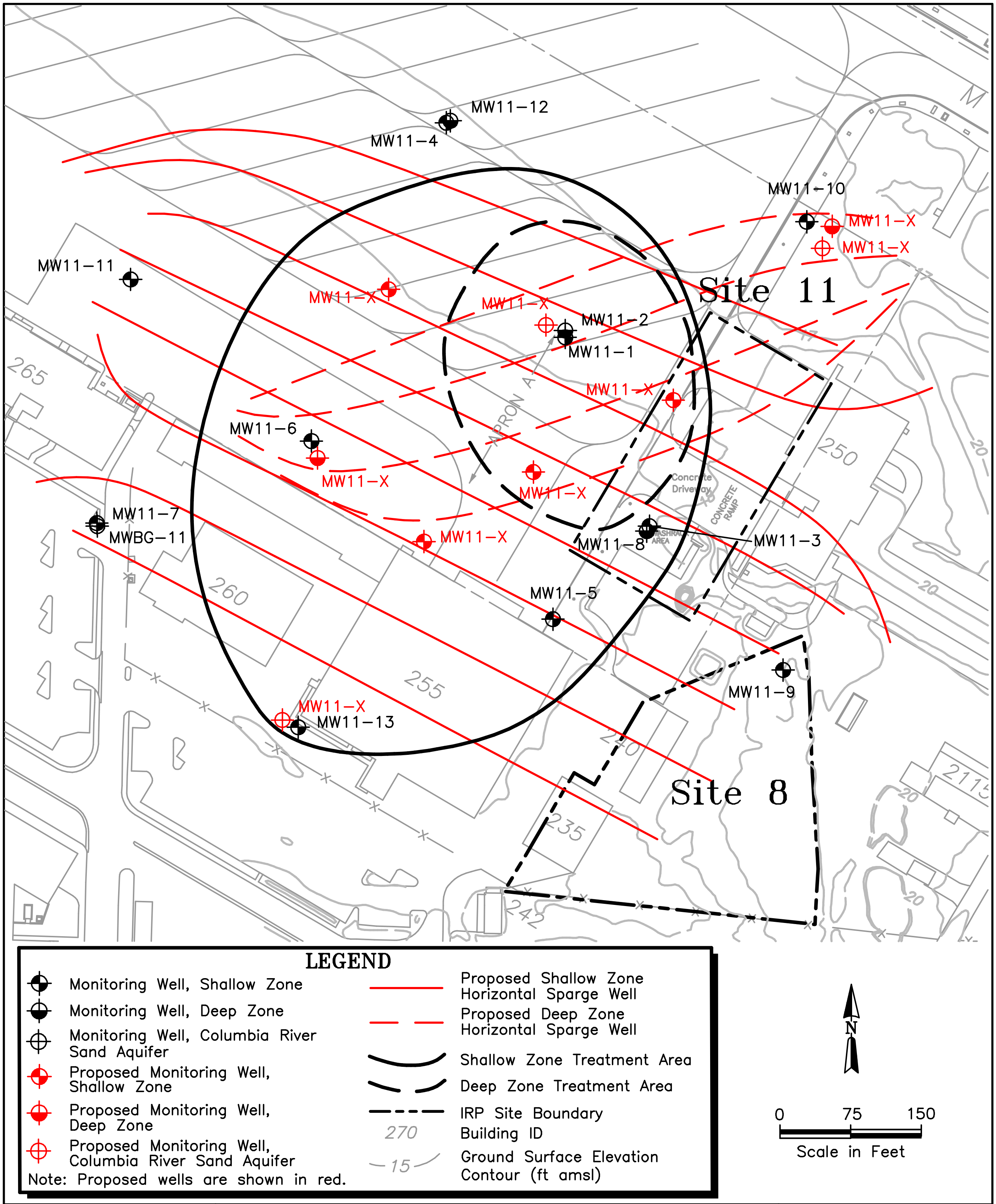
Treatment of Hot Spots. This alternative is expected to treat the VOCs at IRP Site 11 to below significant adverse effect levels within a reasonable timeframe.

State Acceptance. The use of potassium permanganate to treat groundwater at the Base has been accepted by ODEQ for relatively small-scale implementation and is expected to be acceptable for full-scale application. However, ODEQ approval of larger scale use of potassium permanganate injection is likely to be contingent on an appropriate monitoring and reporting plan to ensure compliance with the UIC program.

Community Acceptance. The use of potassium permanganate is expected to have some community resistance since it relies on the injection of a foreign material into the groundwater and the perception that it will cause groundwater flowing away from the site to remain purple. An appropriate monitoring and reporting system is an important component of this alternative to allow the public the opportunity to monitor water quality during the remedial action.

5.4.1.4 IRP Site 11 - Alternative 4: In Situ Oxidation - Ozonation with Monitored Natural Attenuation

The following is an evaluation of the application of Alternative 4 at IRP Site 11 with respect to the criteria described in Section 5.1. Figure 5-13 depicts the layout of the primary components of this alternative.



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IRP SITE 11
ALTERNATIVE 4
IN SITU OXIDATION–OZONATION
WITH MONITORED NATURAL ATTENUATION
PLAN VIEW OF TREATMENT SYSTEM LAYOUT

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FIGURE 5–13

Overall Protection of Human Health and Environment. This alternative is expected to effectively remove, or significantly reduce, the VOC concentrations from IRP Site 11 groundwater. The risks associated with exposure to these compounds would be reduced to an acceptable level, based on current and future land use.

Compliance with ARARs. This alternative is expected to effectively reduce the VOC concentrations in Shallow Zone and Deep Zone groundwater to below the levels set by chemical-specific ARARs.

Long-Term Effectiveness and Permanence. The residual risk posed by groundwater at IRP Site 11 would be reduced by this alternative because the contaminants associated with the risks are destroyed. Groundwater monitoring would be required for an extended period after the completion of this alternative to verify attainment of the RAOs.

The contaminants in the downgradient areas of the site treated by MNA are expected to be destroyed within a reasonable timeframe, due to enhanced conditions from upgradient ozonation. However, if long-term monitoring indicates that VOCs in this area are not degrading at an acceptable rate, expansion of the area of ozonation would be considered.

The institutional and engineering controls implemented as part of this alternative should be reliable in the long term, based on the current and future land-use scenarios. However, care must be taken to ensure that the controls remain in effect with each future tenant, if the ownership or leaseholder of the Base property changes.

Reduction of TMV Through Treatment. The use of ozonation and MNA to treat VOCs in groundwater will result in reduced TMV of hazardous materials in IRP Site 11 groundwater. This reduction would be performed through chemical and biological destruction, rather than transfer of contaminants among media. The treatment process is irreversible and will result in the production of only harmless byproducts.

Short-Term Effectiveness. Ozone is a strong oxidant and care must be taken to prevent worker or base employee exposure to ozone generated for injection. This would include periodic monitoring of ozone in workspace air, and enclosing and locking the ozone generator and sparge wellheads to prevent tampering.

Adverse effects on groundwater used for drinking or irrigation purposes would not be likely expected, as the oxidative effects of ozone are short-lived.

Risks associated with VOCs in groundwater are quickly reduced due to the rapid treatment resulting from ozonation. Destruction of VOCs in areas treated by ozonation is expected to be complete within 3 years.

Implementability. Implementation obstacles within the zone of active remediation include ensuring the avoidance of underground utilities, coring through the thick concrete on the flight apron to install wells, working around secure buildings, and coordinating well installation and system operation with flight operations. The use of directionally-drilled horizontal wells will avoid the need to install numerous vertical sparge wells and extensive underground piping in the flight apron area. However, the installation of the horizontal wells requires a great deal of precision, expertise, equipment, and space, compared to conventional drilling. Closure of areas at the drilling locations may be required. This alternative has been developed to allow full use of the flight apron during construction, with the exception of the installation of a small number of monitoring wells. Also, the use of horizontal wells precludes the use of in-well water-recirculating pumps that are occasionally used to increase the radius of influence of ozone sparge wells.

The implementability of this alternative may be inhibited by the site geology. Preferential flow paths and areas of low conductivity would dictate where sparged air would flow; however, this could likely be overcome by utilizing a pulsed sparging technique consisting of alternating periods of sparging with periods of rest.

The injection of ozone would require coordination with the ODEQ UIC program, which would likely will create scheduling delays due to ODEQ's review and public participation requirements.

This would entail more equipment and maintenance than other alternatives. In addition, installation and monitoring of the system would require extensive labor as compared to technologies that simply involve injection and monitoring.

Cost. Capital and O&M costs associated with Alternative 4 are summarized in Table B-14 and detailed in Table B-17. Direct and indirect capital costs for this alternative are estimated to be $2,592,850, and include all equipment, materials, contractor services, labor, project administration, and project management required for implementation. The O&M cost for the first 3 years is estimated to be $685,800, which assumes quarterly groundwater sampling and 3 years of treatment system operation. The O&M cost for the following 5 years is estimated to be $27,500 per year, which assumes annual groundwater sampling. The net present value of 8 years of O&M costs is $798,600 , which assumes a discount rate of 7.5 percent. This discount rate was selected based on ODEQ guidance. The total estimated cost for Alternative 4, including a 30 percent contingency, is $4,409,000. In accordance with USEPA and ODEQ Guidance, these estimates are expected to be accurate to +50 to –30 percent.

Alternative 4 is expected to meet the RAOs for the site within a reasonable timeframe and is thus protective. Additionally, Alternative 4 is one of the least expensive alternatives that employ active remedial measures. Therefore, it has a high degree of cost reasonableness.

Treatment of Hot Spots. This alternative is expected to treat the VOCs at IRP Site 11 to below significant adverse-effect levels within a reasonable timeframe.

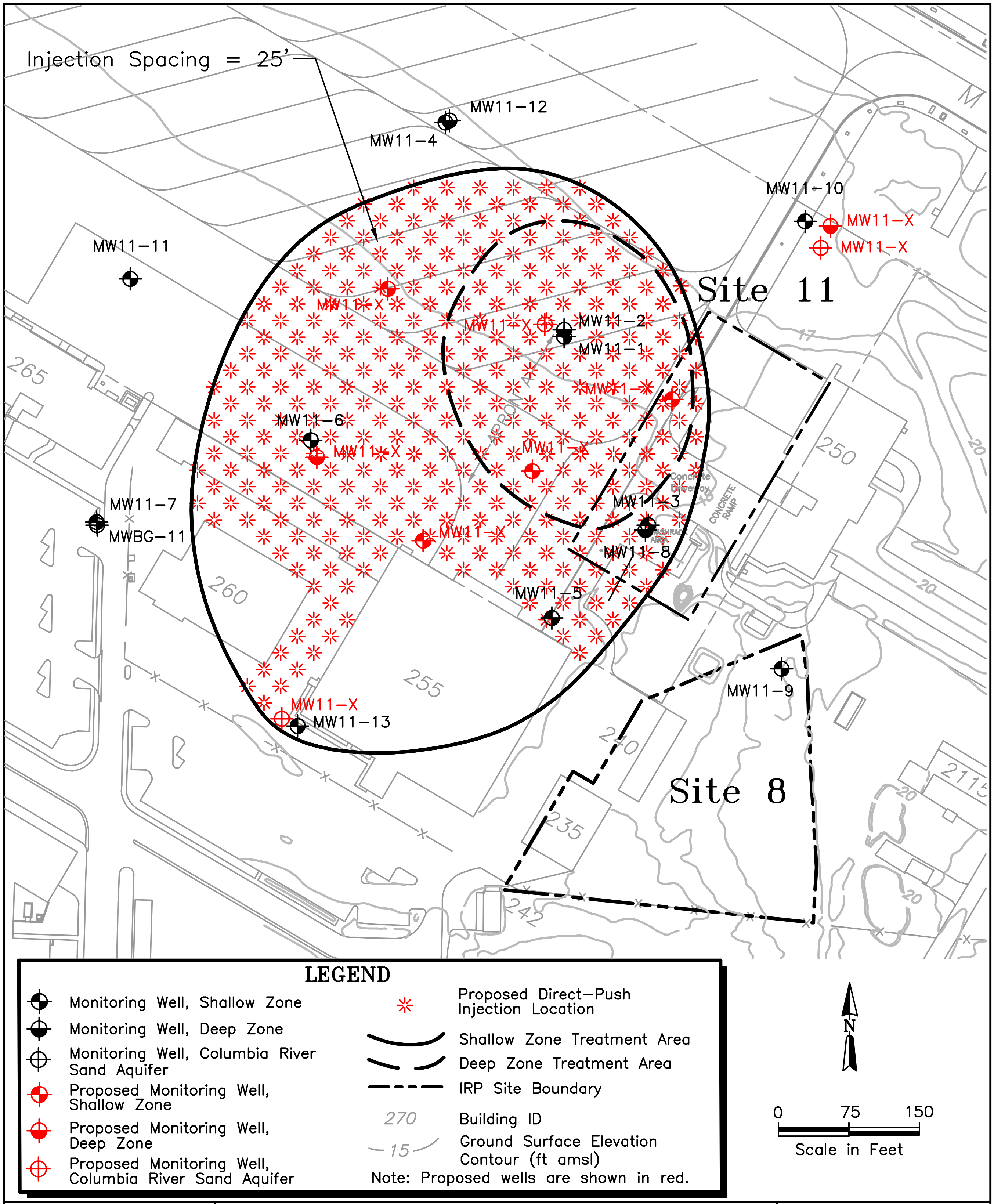
State Acceptance. The use of ozonation to treat groundwater at the Base has been accepted by ODEQ for relatively small-scale implementation and is expected to be acceptable for full-scale application. However, ODEQ approval of larger scale use of an injection technology is likely to be contingent on an appropriate monitoring and reporting plan to ensure compliance with the UIC program.

Community Acceptance. The use of ozonation is expected to have less community resistance than other injection technologies since it relies on the injection of a short-lived gas rather than a liquid. However, an appropriate monitoring and reporting system is still an important component of this alternative to allow the public the opportunity to monitor water quality during the remedial action.

5.4.1.5 IRP Site 11 - Alternative 5: Enhanced Bioremediation with Monitored Natural Attenuation

The following is an evaluation of the application of Alternative 5 at IRP Site 11 with respect to the criteria described in Section 5.1. Figure 5-14 depicts the layout of the primary components of this alternative.

Overall Protection of Human Health and Environment. This alternative is expected to effectively reduce VOCs in Shallow Zone and Deep Zone groundwater at IRP Site 11, and the risks associated with exposure to this contamination. However, the effectiveness of this alternative is uncertain, as the use of oxygen releasing materials to treat groundwater containing VC has not been performed extensively. Approximately 75 percent removal of VC was observed during a pilot test performed using ORC® at IRP Site 2 It is expected that VC and cis-1,2-DCE will



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IRP SITE 11
ALTERNATIVE 5
ENHANCED BIOREMEDIATION
WITH MONITORED NATURAL ATTENUATION
PLAN VIEW OF TREATMENT SYSTEM LAYOUT
142nd FW, PORTLAND ANGB
PORTLAND INTERNATIONAL AIRPORT
PORTLAND, OREGON

FIGURE 5-14

degrade following the creation of enhanced aerobic conditions, but it is uncertain whether the treatment will reduce concentrations to below RAOs.

This alternative is expected to take longer to begin significant reduction of VOCs versus other alternatives, because native microbes must acclimate to the enhanced environment following injection.

Compliance with ARARs. The ability of this alternative to reach ARARs through treatment is uncertain. The effectiveness of this technology at reducing VC to the very low concentrations specified by chemical specific ARARs is uncertain.

Long-Term Effectiveness and Permanence. The residual risk posed by Shallow Zone and Deep Zone groundwater at IRP Site 11 would be reduced by this alternative because the contaminants associated with the risks are degraded to harmless byproducts. Although it is uncertain if this alternative would reduce VC to below the significant adverse-effect level at the site, the resulting reduction should be sufficient to prevent off-site migration, thereby meeting the first RAO. Groundwater monitoring would be required for an extended period to verify attainment of this RAO.

The institutional and engineering controls implemented as part of this alternative would likely be reliable in the long term, based on current and future land-use scenarios. However, care must be taken to ensure that the controls remain in effect with each future tenant, if the ownership or leaseholder of the Base property changes.

Reduction of TMV Through Treatment. Enhancing bioremediation in IRP Site 11 groundwater would reduce the TMV of VOCs. This would be accomplished through irreversible biological destruction, rather than transfer of contaminants among media. The amount of VOCs that would be degraded by enhanced bioremediation at this site is unknown. A significant reduction of VOC concentration is expected, though, which would result in significant reduction of toxicity. Mobility and volume of contaminated groundwater would also be expected to decrease.

Short-Term Effectiveness. This alternative is expected to take a short period to begin effective removal, thus delaying the reduction of risk. Natural biological activity at IRP Site 11 has been shown to be stagnant, and would require acclimation following injection of an enhancing product.

Groundwater containing unacceptable VOC concentrations has not migrated off Base, and is not expected to reach Base boundaries in the very near future. Also, the institutional and engineering controls used as part of this alternative would prevent VOC exposure at the site. These factors would likely limit the added risks related to the delayed effectiveness of this alternative.

Implementability. Implementation obstacles within the zone of active remediation include ensuring the avoidance of underground utilities, coring through the thick concrete on the flight apron for each direct-push injection location, working around secure buildings, and coordinating well installation and direct-push injection with flight operations. Certain areas at the edge of the hot spot at IRP Site 11 would not be conducive to treatment due to the presence of buildings, such as Buildings 260 and 255 at the south end of the hot spot (Figure 5-14). Coordinating the extensive coring and patching of the surface to original conditions would be difficult on the flight apron. This alternative also relies on multiple staggered injections in closely spaced locations. Coring the concrete surface at this interval may impact the structural integrity of the concrete surface. This alternative is considered infeasible based on these factors.

The treatment of groundwater by the injection of an oxygen releasing material more greatly relies on the flow of groundwater past the injection locations, than the flow of injected material into surrounding groundwater. The shallow gradient of groundwater at IRP Site 11 would limit the rate of transfer of oxygen created to the surrounding groundwater.

The injection of any material would require coordination with the ODEQ UIC program, which could likely create scheduling delays due to ODEQ's review and public participation requirements.

Cost. Capital and O&M costs associated with Alternative 5 are summarized in Table B-14, and detailed in Table B-18. Direct and indirect capital costs for this alternative are estimated to be $2,983,150, and include all equipment, materials, contractor services, labor, project administration, and project management required for implementation. The O&M cost for the first 2 years is estimated to be $220,000, which assumes quarterly groundwater sampling. The O&M cost for the following 5 years is estimated to be $27,500 per year, which assumes annual groundwater sampling. The net present value of 7 years of O&M costs is $331,300, which assumes a discount rate of 7.5 percent. This discount rate was selected based on ODEQ guidance. The total estimated cost for Alternative 5, including a 30 percent contingency, is $4,309,000. In accordance with USEPA and ODEQ Guidance, these estimates are expected to be accurate to +50 to –30 percent.

Alternative 5 is one of the most expensive of the alternatives that employ active remedial measures. Also, this alternative is not expected to meet the RAOs for the site in a reasonable time period, and would not therefore be considered protective. As a result, this alternative has a low degree of cost reasonableness.

Treatment of Hot Spots. This alternative is expected to treat most VOCs at IRP Site 11 to below respective significant adverse-effect levels within a reasonable timeframe. It is unknown if VC could be treated by this method to its significant adverse-effect level of 2 µg/l (ODEQ 1998c) within a reasonable timeframe.

State Acceptance. The use of enhanced bioremediation to treat groundwater at the Base has been accepted by ODEQ for relatively small-scale implementation and is expected to be acceptable for full-scale application.

Community Acceptance. The use of enhanced bioremediation is not expected to have community resistance. However, since this technology is less established for treatment of chlorinated hydrocarbons, the community may be skeptical that it would effectively achieve cleanup goals.

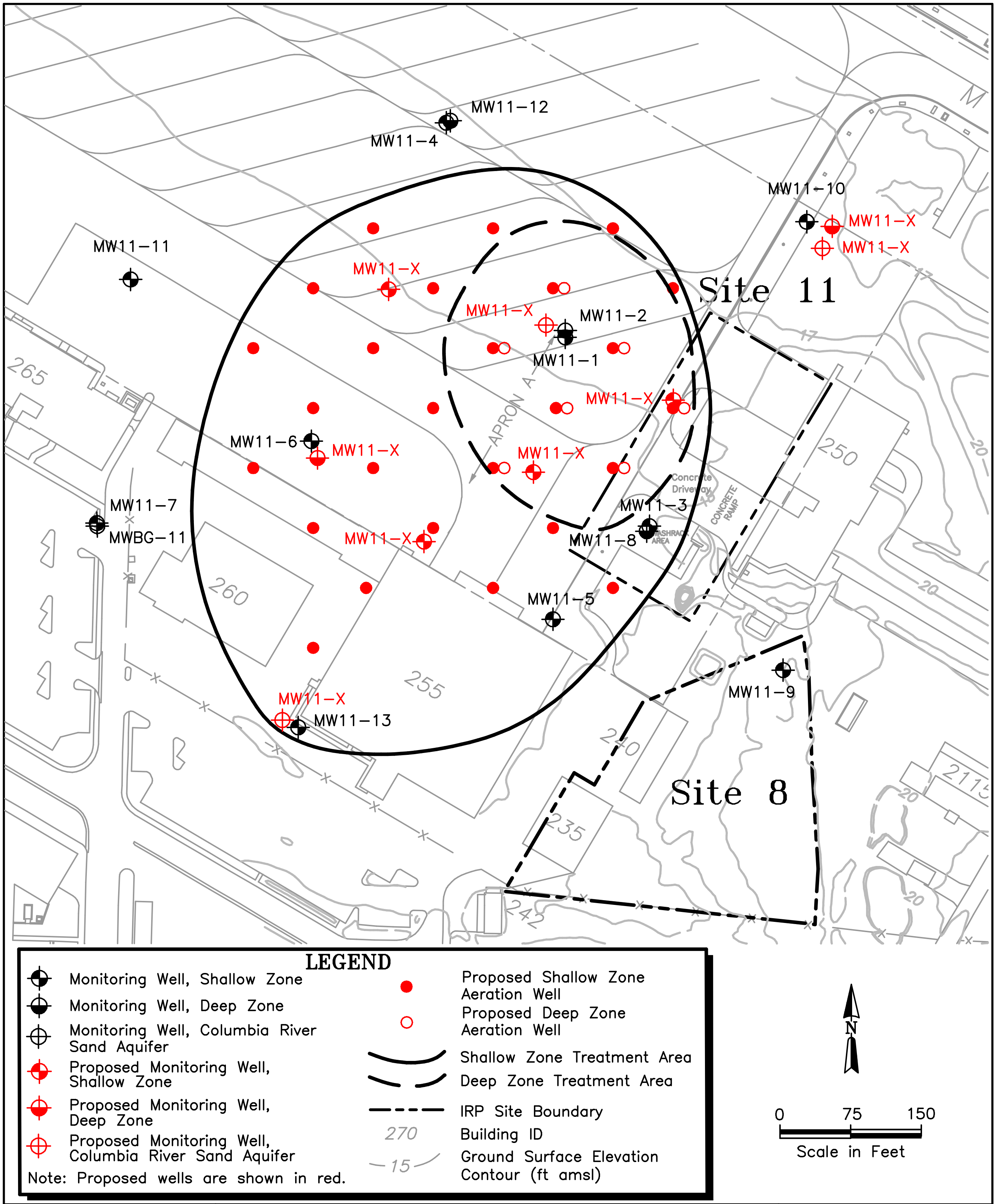
5.4.1.6 IRP Site 11 - Alternative 6: In-Well Aeration with Monitored Natural Attenuation

The following is an evaluation of the application of Alternative 6 at IRP Site 11 with respect to the criteria described in Section 5.1. Figure 5-15 depicts the layout of the primary components of this alternative.

Overall Protection of Human Health and Environment. This alternative would reduce the risk posed by IRP Site 11 by reducing the VOC concentrations in Shallow Zone and Deep Zone groundwater, and the potential for contaminated groundwater to migrate to off-site receptors. The risks associated with exposure to these compounds would be reduced to an acceptable level, based on current and future land use.

Risks might be posed by regeneration or disposal of spent activated carbon associated with vapor treatment.

Compliance with ARARs. This alternative is expected to reduce VOCs in IRP Site 11 groundwater to below chemical-specific ARARs.



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IRP SITE 11
ALTERNATIVE 6
IN-WELL AERATION
WITH MONITORED NATURAL ATTENUATION
PLAN VIEW OF TREATMENT SYSTEM LAYOUT
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FIGURE 5–15

Groundwater within the zone of active treatment by in-well aeration is expected to be rapidly treated to concentrations below ARARs. MNA is expected to degrade VOCs in downgradient groundwater outside of the radius of influence of the in-well aeration system to below ARARs, although at a slower rate than within the active treatment zone.

<u>Long-Term Effectiveness and Permanence.</u> The residual risk posed by IRP Site 11 would be reduced by this alternative because the risk posed by the VOCs in Shallow Zone and Deep Zone groundwater would be significantly reduced. Groundwater monitoring would be required beyond the operation of the in-well aeration system to verify attainment of cleanup goals.

The contaminants in the downgradient areas of the site treated by MNA are expected to be destroyed within a reasonable timeframe, due to enhanced aerobic conditions from upgradient aeration. However, if long-term monitoring indicates that VOCs in this area are not degrading at an acceptable rate, expansion of the system to actively treat this area would be considered.

The institutional and engineering controls implemented as part of this alternative would likely be reliable in the long term, based on current and future land-use scenarios. However, care must be taken to ensure that the controls remain in effect with each future tenant, if the ownership or leaseholder of the Base property changes.

<u>Reduction of TMV through Treatment.</u> Unlike other treatment technologies discussed in this FS, this technology is based on the transfer of contaminant among media, rather than destruction. Transferring the VOCs from the groundwater to the activated carbon would reduce the mobility and volume of the contaminants. The reduction of toxicity of the contaminants would depend on the final disposition of the spent carbon. For example, if the spent carbon is disposed of at a landfill, the toxicity would not be reduced. This process is irreversible if the activated carbon is handled properly.

<u>Short-Term Effectiveness.</u> It is difficult to estimate with accuracy the time required to achieve the remediation goal; however, based on similar scenarios, the in-well aeration system would likely reduce VOC concentrations in groundwater to below treatment goals within 3 years. The area to be treated by MNA would not experience reductions at the same rate as those within the in-well aeration area. However, the risks associated with this area are much lower.

Implementability. Implementation obstacles within the zone of active remediation include avoiding underground utilities, coring through the thick concrete on the flight apron to install wells, working around secure buildings, and coordinating well installation and system operation with flight operations. Certain areas at the edge of the hot spot at IRP Site 11 would not be conducive to treatment due to the presence of buildings (i.e., Buildings 260 and 255) at the south end of the hot spot. Installation of sub-grade wellhead connections and piping across the flight apron would also be required. Coordinating extensive cutting, trenching, pipe laying, and finishing of the concrete surface of the flight apron would be difficult. Horizontal installation of an in-well aeration system is not feasible.

Trenching, drilling, and other construction activities associated with installation of the in-well aeration system will require significant shut down of flight operations at the site. This will also effect the implementability of this alternative. This alternative is considered infeasible based on these factors.

Alternative 6 would entail more equipment and maintenance than other alternatives. In addition, installation and monitoring of the system would require extensive labor as compared to technologies that simply involve injection and monitoring.

Cost. Capital and O&M costs associated with Alternative 6 are summarized in Table B-14, and detailed in Table B-19. Direct and indirect capital costs for this alternative are estimated to be $3,287,050, and include all equipment, materials, contractor services, labor, project administration, and project management required for implementation. The O&M cost for the first 3 years is estimated to be $902,100, which assumes quarterly groundwater sampling and 3 years of treatment system operation. The O&M cost for the following 5 years is estimated to be $27,500 per year, which assumes annual groundwater sampling. The net present value of 8 years of O&M costs is $985,200, which assumes a discount rate of 7.5 percent. This discount rate was selected based on ODEQ guidance. The total estimated cost for Alternative 6, including a 30 percent contingency, is $5,554,000. In accordance with USEPA and ODEQ Guidance, these estimates are expected to be accurate to +50 to –30 percent.

Alternative 6 is expected to meet the RAOs for the site within a reasonable time period, and is therefore protective. However, this alternative is the most expensive alternative, and therefore has a medium degree of cost reasonableness.

Treatment of Hot Spots. This alternative is expected to treat the VOCs at IRP Site 11 to below significant adverse-effect levels within a reasonable timeframe.

State Acceptance. The use of in-well aeration to treat groundwater at the Base would be expected to be acceptable by ODEQ for full-scale implementation. There are no significant water quality issues related to implementation of this technology, which is a major issue with ODEQ.

Community Acceptance. The use of in-well aeration to treat groundwater at the Base would be expected to be acceptable by community residents.

5.4.2 IRP Site 11 - Comparative Analysis of Alternatives

The above-detailed evaluation consisted of an individual analysis of the six RA alternatives for IRP Site 11, with respect to protectiveness, compliance with ARARs, long-term effectiveness and permanence, reduction of TMV through treatment, short-term effectiveness, implementability, cost, and treatment of hot spots. Below, the alternatives are compared, and rated based on how well each satisfies the evaluation criteria. Because all of the action alternatives involve the completion of a set of common tasks, the following comparative analysis will focus only on those actions that are in addition to the common tasks.

5.4.2.1 IRP Site 11 - Overall Protection of Human Health and the Environment

Chemically impacted groundwater at IRP Site 11 does not pose immediate risk to human health and the environment because the groundwater is not currently used. Therefore, all of the alternatives are equally protective in the immediate timeframe. However, since the exposure pathway used for this FS considers migration of impacted groundwater to other water bodies, such as deeper aquifers or surface water, the most protective alternative would be that which would most reliably, completely, and quickly remove those chemicals impacting groundwater at IRP Site 11.

Alternative 1 and 2 are not expected to reliably, completely, or quickly remove the chlorinated VOCs impacting groundwater at IRP Site 11. The reliability of Alternative 6 is uncertain; however, a similar technology was shown to remove VOCs from groundwater extracted from Shallow Zone groundwater at IRP Site 2. However, the recirculation-well aspect of this technology proposed for this FS has not been tested at the Base. Alternative 5 is expected to reliably and quickly remove risks associated with chlorinated VOCs impacting groundwater at IRP Site 11, as shown during the IRAC treatability test performed at IRP Site 2. However, Alternative 5 is not expected to sufficiently reduce VOC concentrations to meet the RAOs. It is expected that the effectiveness of enhanced bioremediation would diminish, as the amount of VOCs and other organic material decreases.

Alternative 4 is expected to reliably and quickly reduce concentrations of VOCs. This alternative is expected to take longer than some of the other alternatives.

Alternative 3 is most protective of human health and the environment. Like alternatives based on other technologies, this alternative has been proven to quickly destroy chlorinated VOCs in Base groundwater. This alternative is much more reliable and complete than others because potassium permanganate provides residual treatment capacity, and the effectiveness of this technology is more easily monitored.

5.4.2.2 IRP Site 11 - Compliance with ARARs

The ARAR that governs this FS is the federal MCL for each of the chlorinated VOCs impacting groundwater, as is the case for IRP Site 11 groundwater. Alternatives 1, 2, and 5 are not expected to comply with this ARAR, as VC concentrations are not expected to be reduced below the MCL of 2 µg/l for this compound.

Alternatives 4 and 6 have the potential to reduce VOC concentrations to below the respective ARARs. The in-well aeration technology of Alternative 6 has not been completely tested at the Base. Ozone sparging has been tested at the Base during the IRAC test, with some success.

Alternative 3 would most likely reliably treat VOCs in groundwater to below ARARs. Because of the complete destruction of VOCs that occurs upon contact with potassium permanganate solution, this alternative could likely be tailored in the field to provide complete destruction of VOCs impacting groundwater at IRP Site 11.

5.4.2.3 IRP Site 11 - Long-Term Effectiveness and Permanence

Alternatives 1 and 2 do not provide long-term effectiveness. These alternatives are not expected to reduce VOC concentrations in groundwater at IRP Site 11 to below the significant adverse-effect levels.

Alternatives 3, 4, and 5 would provide equal long-term effectiveness, provided RAOs are equally met. These alternatives utilize technologies that provide in situ destruction of contaminants. These technologies are not reversible, and do not pose additional risks after meeting treatment goals.

Alternative 6 would provide similar long-term effectiveness, to that of Alternative 3, 4, and 5. However, rather than destroying the contaminants in situ, Alternative 6 would utilize a technology that strips VOCs from groundwater, and moves them above ground through sparged air, where they are then destroyed. This technology is also irreversible, and poses no additional risks after treatment goals are met.

Alternative 3 would be the most effective alternative in the long term, because of the greater residual ability of potassium permanganate to destroy VOCs.

5.4.2.4 IRP Site 11 - Reduction of Toxicity, Mobility, or Volume through Treatment

Alternatives 1 and 2 would not significantly reduce TMV of VOC-impacted groundwater impacted at IRP Site 11. Some reduction of toxicity may occur through reduction of VOC concentration at localized areas. However, the mobility and volume would likely remain unchanged, or possibly increase.

Alternatives 3, 4, and 6 are expected to effectively reduce the TMV of VOC-impacted groundwater at IRP Site 11. Alternatives 3 and 4 are expected to provide the greatest reduction.

Alternative 5 is expected to significantly reduce the toxicity of VOC-impacted groundwater. However, since this technology is not expected to provide effective treatment at lower concentrations, the reduction of the volume of impacted groundwater might not be as significant as the reduction expected with Alternatives 3, 4, and 6.

5.4.2.5 IRP Site 11 - Short-Term Effectiveness

The short-term effectiveness of Alternatives 1 and 2 is unacceptably low, based on the length of time required to reduce VOC concentrations in IRP Site 11 groundwater. VOCs could possibly migrate off-site, or down to the CRSA, within the time required to reach cleanup goals under these alternatives.

Alternatives 3, 4, 5, and 6 all provide sufficient, short-term effectiveness. These alternatives would significantly reduce VOC concentrations in groundwater in a relatively quick fashion. Alternatives 3 and 4 would pose threats to workers in the form of exposure to the oxidizers potassium permanganate and ozone. These threats could likely be controlled by the use of health and safety measures. No threats to workers are expected during implementation of Alternative 6, beyond the typical mechanical dangers associated with well drilling and machinery installation.

5.4.2.6 IRP Site 11 - Implementability

Alternatives 1 and 2 would be the easiest alternatives to implement. Alternative 1 requires no action, and Alternative 2 requires only installation of additional monitoring wells, and periodic monitoring of VOCs and natural attenuation parameters. However, the reliability of these alternatives is questionable, and it would be expected that they would require replacement at a later date.

Implementation of the remaining four alternatives would be difficult at IRP Site 11 due to the thick concrete present on the flight apron. Alternatives 5 and 6 are not feasible, due to the number of direct-push injections or well installations required (each of which require coring and patching of the concrete surface of the flight apron at IRP Site 11). Neither of these alternatives can be implemented using horizontal installation techniques similar to Alternatives 3 and 4. Oxygen-releasing material (Alternative 5) cannot be injected into a well similar to potassium permanganate, and thus requires a new injection location for each of the several applications. In-well aeration (Alternative 6) cannot be utilized with horizontal wells.

The most implementable alternatives are Alternatives 3 and 4 due to the use of horizontal drilling and installation methods. These techniques will allow implementation of these alternatives with little disruption of the flight apron concrete or flight operations. Alternative 4 would be more difficult to implement that Alternative 3 due to the amount of equipment (e.g., ozone generators, sparge points, etc.) required for operation. In addition, the installation of the SVE system would require significant additional horizontal drilling not required as part of the other alternatives.

5.4.2.7 IRP Site 11 - Cost

Alternative 1 and 2 are the least expensive alternatives, however these alternatives fail to satisfy the protectiveness criterion because they are not expected to meet the site RAOs within a reasonable time period. These alternatives are therefore not cost reasonable. Alternative 5 is also not expected to meet the RAOs within a reasonable time period. As a result, this alternative is not the most cost reasonable. Alternatives 4 and 6 are both expected to meet the RAOs within a similarly reasonable time period, however these alternatives are more expensive than Alternative 3, and therefore are not the most cost reasonable. Alternative 3 is expected to meet remedial objectives and it is the least expensive of the alternatives that employ active remedial measures. Alternative 3 is therefore the most cost reasonable.

5.4.2.8 IRP Site 11 - Treatment of Hot Spots

Alternatives 1 and 2 would not likely effectively treat hot spots of contamination in groundwater at IRP Site 11. The implementation of either of these alternatives would potentially allow the extent of this hot spot to increase.

All of the remaining alternatives would likely reduce the size of the hot spot at IRP Site 11 through treatment. It is uncertain whether Alternative 5 would be effective at treating VOCs, particularly VC, to below the significant adverse effect level.

Alternatives 3, 4, and 6 are potentially capable of treating VOCs to below the significant adverse-effect levels; however, the expected reliability of Alternative 3 would be greater than the other alternatives.

5.4.2.9 IRP Site 11 – State Acceptance

Alternatives 1 and 2 are not expected to effectively treat hot spots of contamination in groundwater at IRP Site 11 and therefore are not expected to be acceptable to ODEQ. All of the remaining alternatives would likely reduce the size of the hot spots at IRP Site 11 through treatment as required by ODEQ. However, the use of potassium permanganate injection would be scrutinized by ODEQ the most due to the injection of an oxidizing fluid into the groundwater.

5.4.2.10 IRP Site 11 – Community Acceptance

Alternatives 1 and 2 are not expected to be acceptable to the community because they are not expected to treat hot spots of contamination in groundwater at IRP Site 11 within a reasonable timeframe.

All of the remaining alternatives would likely reduce the size of the hot spots at IRP Site 11 through treatment and should generally be acceptable to community residents. However, for Alternative 3 using potassium permanganate injection it will be important to implement a monitoring program that will sufficiently allow the public to review water quality data.

5.4.3 IRP Site 11 - Preferred Alternative

Alternative 3 is the preferred alternative because it satisfies the protectiveness criteria and remedy-selection balancing factors. Alternative 3 is also the most cost reasonable alternative and is implementable due to the ability to utilize horizontal injection wells.

Alternative 3 involves injecting potassium permanganate through several horizontal injection wells screened in the Shallow Zone and Deep Zone, combined with MNA. This alternative also includes the implementation of the common tasks described in Section 4.5.2. By implementation of Alternative 3, the following is expected to be achieved:

- Human health and the environment within the locality of facility would be protected over the long term.
- The residual risk associated with VOCs in groundwater remaining after completion of this alternative would be acceptable, as described in Section 6.2.
- Base workers would be protected from exposure to VOCs in groundwater through the use of institutional and engineering controls.
- Potassium Permanganate injection would be the most cost-effective means of reducing concentrations of VOCs in groundwater at IRP Site 11.

The EE/CA program described previously in Sections 2.8.1 and 3.11.4 is expected accomplish some of the components of the preferred alternative for IRP Site 11. The implementation of the EE/CA program will involve the injection of potassium permanganate into Shallow Zone groundwater using the same horizontal injection technique described in this FS. The purpose of the groundwater EE/CA is to immediately implement a non-time critical groundwater remedy at IRP Site 11.

The groundwater EE/CA will involve injection of potassium permanganate into Shallow Zone groundwater impacted by the highest concentrations of VOCs. Horizontal injection wells will be used for injection. The initial area of treatment for the EE/CA is a small portion of that proposed in this FS. The first phase of the groundwater EE/CA will involve treating the area of Shallow Zone groundwater currently impacted by approximately 100 μg/l of combined VC and cis-1,2-DCE using potassium permanganate injection. Following completion of the first phase of the EE/CA, the conditions at IRP Site 11 will be reevaluated to determine if further treatment or a different treatment technology is necessary.

SECTION 6.0

RECOMMENDATIONS

This section summarizes the recommended RA alternatives for the IRP sites at the Base and presents a residual risk assessment. The RRA provides an assessment of the potential risk to human health and the environment, which might posed following the completion of the RAs at IRP Sites 2, 9, and 11.

6.1 Recommended Remedial Action Alternatives

6.1.1 IRP Site 1

As described in Section 3.1.4, the risks associated with soil at IRP Site 1 were deemed acceptable for all land-use scenarios, and therefore no further action related to soil is recommended at this location. As previously discussed, VOC-impacted groundwater within IRP Site 1 should be addressed as a portion of the plume originating from IRP Site 2, rather than as a separate groundwater plume. Accordingly, remedial alternatives developed for VOCs in IRP Site 2 groundwater will include the area of the plume that has migrated to IRP Site 1.

6.1.2 IRP Site 2

The risks associated with soil at IRP Site 2 were deemed acceptable for all land-use scenarios, and therefore no further action related to soil at this location is recommended.

As described in Section 5.2.3, Alternative 3, In Situ Oxidation - Potassium Permanganate Injection with MNA, is considered the preferred alternative for remediation of VOC-impacted groundwater at IRP Site 2 as it best satisfies the protectiveness criteria and the remedy-selection balancing factors. By implementation of Alternative 3, the following is expected to be achieved:

- Human health and the environment within the locality of facility would be protected over the long term.
- The residual risk associated with VOCs in groundwater remaining after completion of this alternative would be acceptable, as described in Section 6.2.
- Base workers would be protected from VOC exposure in groundwater through the use of institutional and engineering controls.
- Permanganate injection would be the most cost-effective means of reducing VOC concentrations in groundwater at IRP Site 2.

6.1.3 IRP Site 3

As described in Section 3.3.4, the risks associated with soil at IRP Site 3 were deemed acceptable for all land-use scenarios, and therefore no further action related to soil at this location is recommended. Further, VOC-impacted groundwater within IRP Site 3 should be addressed as a portion of the plume originating from IRP Site 2, rather than as a separate groundwater plume. Remedial alternatives developed for VOCs in IRP Site 2 groundwater will include the area of the plume that has migrated to IRP Site 3.

6.1.4 IRP Site 4

The baseline risk assessment performed during the RI (ERM 2001a) indicated that both the estimated carcinogenic risk and the noncarcinogenic hazard are acceptable for construction workers under USEPA and ODEQ guidelines. Additionally, contaminants detected in surface water and sediment in the Main Drainage Ditch do not pose unacceptable risks to potential on- or off-site ecological receptors. However, because off-site habitats along the Columbia Slough are considered to be of moderate-to-high value to wildlife, surface water monitoring should be continued to evaluate the potential for contaminants to migrate off-site via the Main Drainage Ditch. Based on recommendations from ODEQ, a Level II ecological risk assessment is planned to further evaluate potential risks to ecological receptors at the Main Drainage Ditch. Based on the results of this assessment, further action may be warranted at the Main Drainage Ditch.

6.1.5 IRP Site 5

The baseline risk assessment indicated that both the estimated carcinogenic risks and the noncarcinogenic hazards are acceptable for Base workers, construction workers, reservists, hypothetical on-site residents, and by extension, off-site residents, under USEPA and ODEQ guidelines. Consequently, no further action is recommended for soil or groundwater at this location.

6.1.6 IRP Site 7

The baseline risk assessment performed during the RI (ERM 2001a) indicated that the total estimated carcinogenic risk and noncarcinogenic hazard for Base workers, construction workers, reservists, hypothetical on-site residents, and by extension, off-site residents, are acceptable under USEPA and ODEQ guidelines. Ecological risks to the IRP Site 7 Ditch and Columbia Slough are not expected, based on the results of the Level I scoping assessment and groundwater monitoring.

The constituents detected in groundwater at IRP Site 7 are isolated detections and do not indicate persistent groundwater contamination. The risk associated with these groundwater detections is acceptable based on all anticipated land and water use scenarios. However, several groundwater samples in which PAHs were not detected were analyzed using detection limits greater than risk-based action levels, which may have underestimated associated risk. It is therefore recommended that one round of groundwater samples be collected at IRP Site 7 and analyzed using a lower detection limit to ensure that detectable concentrations of PAHs are not present. No further remedial action is recommended for this site at this time.

Regarding soil at IRP Site 7, on-site residential soil exposures are not anticipated due to current and planned industrial land use of the Portland ANGB property. In addition, because the potential risks associated with industrial soil exposures were determined to be acceptable, no further action is recommended for soil.

6.1.7 IRP Site 8

The baseline risk assessment indicated that the estimated noncarcinogenic hazards are acceptable for Base workers, construction workers, reservists, hypothetical on-site residents, and by extension, off-site residents, under

USEPA and ODEQ guidelines. Consequently, no further action is recommended for soil or groundwater at this location.

6.1.8 IRP Site 9

The baseline risk assessment indicates that the total estimated carcinogenic risk for hypothetical on-site residents exceeds USEPA and ODEQ acceptable levels, primarily as a result of assumed exposures to benzene and PAHs in groundwater under this scenario. Additionally, the carcinogenic risk associated with benzo(a)pyrene in soil under the on-site residential scenario exceeds the ODEQ benchmark for acceptable risk associated with an individual constituent. The noncarcinogenic hazard for hypothetical on-site residents also exceeds both USEPA and ODEQ guidelines, primarily as a result of benzene in groundwater. By extension of the results for the on-site residential scenario, the potential future risks to off-site residents related to the possible off-site migration and residential use of contaminated groundwater also exceed USEPA and ODEQ criteria.

On-site residential soil exposures are not anticipated due to the current and planned future industrial land use of the Portland ANGB property. Because the potential risks associated with industrial soil exposures were determined to be acceptable, no further action is recommended for soil.

As described in Section 5.3.3, the preferred RA for IRP Site 9 is Alternative 3, In Situ Oxidation – Sodium Persulfate Injection with MNA. This alternative best satisfies the protectiveness criteria and the remedy-selection balancing factors. By implementation of Alternative 3, the following is expected to be achieved:

- Human health and the environment within the locality of facility would be protected over the long term.

- The residual risk associated with VOCs in groundwater remaining after completion of this alternative would be acceptable, as described in Section 6.2.

- Base workers would be protected from exposure to VOCs in groundwater through the use of institutional and engineering controls.

- Persulfate Oxidation would be a cost-effective means of reducing benzene concentrations in groundwater at IRP Site 9.

6.1.9 IRP Site 10

The baseline risk assessment indicated that both the estimated carcinogenic risks and the noncarcinogenic hazards are acceptable for Base workers, construction workers, reservists, hypothetical on-site residents, and by extension, off-site residents, under USEPA and ODEQ guidelines. Consequently, no further action is recommended for soil or groundwater at this location.

6.1.10 IRP Site 11

The baseline risk assessment indicated that the total carcinogenic risk and noncarcinogenic hazard for hypothetical on-site residents exceed both USEPA and ODEQ levels of acceptable risk, as a result of assumed exposures to groundwater under this scenario. By extension of the results for the on-site residential scenario, the potential future risks to off-site residents related to the possible off-site migration and residential use of contaminated groundwater also exceed USEPA and ODEQ criteria. The residual soil contamination that exists near the water table in the area of the former washrack represents a potential continuing source of groundwater contamination.

Soil remaining following the 1999 soil removal action that contains elevated VOCs should be remediated. The SVE system that was partially installed adjacent to the excavated area during the removal action should be completed and placed in operation to provide treatment for the contaminated soil. SVE should provide effective removal of VOCs through volatilization and enhanced aerobic bioremediation through aeration.

As described in Section 5.4.3, the preferred alternative for remediating groundwater at IRP Site 11 is considered Alternative 3, In Situ Oxidation – Potassium Permanganate Injection with MNA. This alternative satisfies the protectiveness criteria and the remedy-selection balancing factors, and is the most protective alternative that is reasonably implementable at IRP Site 11. By implementation of Alternative 3, the following is expected to be achieved:

- Human health and the environment within the locality of facility would be protected over the long term.

- The residual risk associated with VOCs in groundwater remaining after completion of this alternative would be acceptable as described in Section 6.2.

- Base workers would be protected from exposure to VOCs in groundwater through the use of institutional and engineering controls.

- Permanganate injection would be one of the most cost-effective means of reducing VOC concentrations in groundwater at IRP Site 11.

6.2 Residual Risk Assessment

In accordance with ODEQ requirements (ODEQ 1998b), this FS includes a RRA to evaluate the potential risks associated with constituents remaining in groundwater following completion of the proposed remedial activities at IRP Sites 2, 9, and 11. This section describes the methodology used to develop the RRA and presents the results of the analysis.

As described in the ODEQ FS guidance (ODEQ 1998b), the protectiveness of the preferred remedial alternative is demonstrated through an RRA. An RRA is typically performed to provide one of the following evaluations, based on site-specific conditions:

- A quantitative assessment of the potential risk resulting from concentrations of untreated waste or treatment residuals remaining at a subject facility at the conclusion of any treatment or excavation and off-site disposal activities, taking into consideration current and reasonably likely future land- and water-use scenarios and the exposure assumptions used in the baseline risk assessment; or

- A qualitative or quantitative assessment of the adequacy and reliability of any institutional or engineering controls to be used for management of treatment residuals and untreated hazardous substances remaining at a subject facility.

Each of the above-referenced assessments is described in the following subsections.

6.2.1 Residual Risks Following Treatment

The first component of an RRA uses standard risk assessment methods to estimate the potential risk at a particular site following remediation. This step requires the determination of residual concentrations for COCs for groundwater. As discussed below, the estimation of residual groundwater concentrations can be difficult, and requires that assumptions be made regarding treatment effectiveness. One option for estimating residual contaminant concentrations in groundwater involves measuring concentrations of concern in an area(s) immediately outside of the treatment area following completion of the RA. However, it can be reasonably predicted that at the Portland ANGB IRP sites, concentrations measured immediately outside the RA areas would not be constant through the long duration of remediation. Indeed, it is likely that these concentrations would begin to decrease at some point in the future, as a result of both reduced concentrations within the treatment areas and the effects of natural attenuation.

Alternatively, residual contaminant concentrations could be estimated based on the cleanup goals for each of the target compounds. However, this method typically results in a significant overestimate of residual risk at sites where there are multiple target analytes with significantly different concentrations and treatment goals, as is the case at IRP Site 2, as described below.

At IRP Site 2, the target compounds are TCE; cis-1,2-DCE; trans-1,2-DCE; and VC. The cleanup level for the treatment area at this site corresponds to the respective MCLs for the individual target compounds (5 µg/l for TCE; 70 µg/l for cis-1,2-DCE; 100 µg/l for trans-1,2-DCE; and 2 µg/l for VC). The percent removal required to achieve the cleanup level for VC is higher than that required for trans-1,2-DCE. At this particular site, the VC concentrations are relatively high as compared to the cleanup level for this compound. It is reasonable to assume that trans-1,2-DCE will be treated at a rate similar to VC, given the similarities in chemical properties exhibited by the two compounds. Thus, the residual concentration of trans-1,2-DCE would likely be far below its cleanup level. It follows that using the cleanup level for trans-1,2-DCE to calculate residual risk would be unnecessarily conservative.

The method used to calculate residual contaminant concentrations in this RRA addresses the limitations associated with the previous example. At each IRP site, the percent removal necessary to achieve the chemical-specific cleanup goal was calculated for each compound. Subsequently, the highest removal rate required to reach a defined cleanup level was applied to the maximum concentrations of the other compounds to calculate the maximum residual concentrations of all target analytes at a given IRP site. For example, if the concentrations of the four target compounds listed in the previous paragraph were all 200 µg/l, it was assumed that all compounds would be treated with 99 percent efficiency to reach a concentration of 2 µg/l. This residual concentration is equal to the cleanup goal for VC and is less than the cleanup goal for each of the other compounds. The initial concentrations and cleanup levels used for these calculations, together with the resulting residual concentrations, are presented in Table 6-1.

6.2.1.1 Exposure Assessment

As described in Section 4.2, the exposure pathways used for this FS consist of residential use (i.e., for drinking, showering, etc.) of groundwater extracted from the CRSA in the vicinity of the WEA by municipal water supply recipients, and ingestion of groundwater extracted from the CRSA within the Base boundary by Base workers. However, for the purposes of the RRA, it was assumed that shallow, on-site groundwater was used for residential water supply. This assumption is consistent with exposure scenarios evaluated in the baseline human health risk assessment (presented in the Final RI Report, ERM 2001a) and with ODEQ's requirement for considering all beneficial uses for groundwater. In considering this scenario, two points deserve emphasis:

- The residential use of shallow groundwater on-site represents a hypothetical exposure, and
- The actual use of shallow groundwater for residential supply can be prevented by the implementation of institutional controls.

The cleanup goals used for treatment at the Portland Base correspond to the MCLs for the individual COCs. These cleanup goals are consistent with the requirements of the National Oil and Hazardous Substances Pollution Contingency Plan (NCP, USEPA 1990). In addition, these cleanup goals are expected to prevent off-Base or downward migration of groundwater impacted by contaminant concentrations above that which would produce unreasonable risk to potential groundwater users or other receptors. Finally, these cleanup goals are protective of on-site exposure pathways such as the migration of VOCs from groundwater into ambient or indoor air.

6.2.1.2 Toxicity Assessment

The toxicity data used in the RRA were consistent with data used to perform the risk assessment calculations presented in the Final RI Report (ERM 2001a)

TABLE 6-1

Residual Risk Calculations

142nd FW, Portland ANGB, Portland, Oregon

Constituent	Cleanup Goal (MCL)	Maximum Treatment Zone Groundwater Concentration	Percent Removal Required to Achieve Cleanup Goal (%)	Calculated Maximum Residual Groundwater Concentration	Tap Water PRG (carcinogenic effects)	Carcinogenic Risk	Tap Water PRG (noncarcinogenic effects)	Noncarcinogenic Hazard Index
IRP Site 2								
Vinyl Chloride	2	984	99.8%	2.0	0.041	5E-05	72	0.03
Trichloroethene	5	639	99.2%	1.3	1.6	8E-07	37	0.04
cis-1,2-Dichloroethene	70	724	90.3%	1.5			61	0.02
trans-1,2-Dichloroethene	100	800	87.5%	1.6			120	0.01
					Total Risk	**5E-05**	**Total HI**	**1E-01**
IRP Site 9								
Benzene	5	1200	99.6%	5	0.35	1E-05	1.1E+01	0.45
					Total Risk	**1E-05**	**Total HI**	**5E-01**
IRP Site 11								
Vinyl Chloride	2	92.5	97.8%	2	0.041	5E-05	72	0.03
cis-1,2-Dichloroethene	70	108	35.2%	2.3			61	0.04

NOTES:

1E-02 - 0.01

HI - Hazard Index

MCL - Maximum Contaminant Level (Enforceable Level) (USEPA, February, 1996, Drinking Water and Health Advisories)

PRG - Preliminary Remediation Goal (USEPA Region 9, 2000, Region 9 Preliminary Remediation Goals)

Note - Cleanup levels, constituent concentrations, and preliminary remediation goals are expressed in units of micrograms per liter.

6.2.1.3 Risk Characterization

The calculation of residual risks followed the basic approach used for the baseline human health risk assessment presented in the Final RI Report (ERM 2001a) and is consistent with ODEQ risk assessment guidance (ODEQ 2000). The specific steps used to calculated residual risks are described below. The numeric values and calculations described are shown in Table 6-1.

- The target compounds for each IRP site are listed, along with their respective cleanup goals. The cleanup goal for each of the target compounds is the MCL. These target compounds represent the most widely detected and highest concentration compounds for the IRP site in question.

- Next, the maximum treatment zone concentrations detected during the October 2000 groundwater monitoring event are listed for the target compounds.

- Then, the maximum treatment zone concentration for each compound is compared to the corresponding cleanup goal to obtain a percent removal required to reach the cleanup goal at the location with the highest concentration.

- Applying the highest required percent removal at each site to all of the target compounds at that site, a maximum residual concentration was calculated for each target compound. These values represent upper bound estimates of the residual contaminant concentrations following completion of treatment, assuming destruction of each compound at approximately the same rate. This assumption is reasonable in light of the fact that the COCs are chemically similar and are expected to responds similarly to treatment.

- Tap water PRGs developed by USEPA Region 9 (2000) were identified for each constituent. For constituents with both carcinogenic and noncarcinogenic effects (i.e., VC, TCE, and benzene), tap water PRGs were identified based on both toxicity endpoints. Tap water PRGs are risk-based screening levels that may be used to address potential risks associated with the use of water for residential supply. These levels consider potential exposures associated with both water ingestion and inhalation of volatile constituents.

- Using the estimated residual concentrations, potential carcinogenic risks were calculated according to the following formula:

Risk = (Calculated Maximum Residual Groundwater Concentration / PRG) x (1 x 10^{-6})

- The residual HI was estimated for each noncarcinogenic constituent, according to the following formula: HI = (Calculated Maximum Residual Groundwater Concentration / PRG)

- The total excess lifetime carcinogenic risk was then calculated as the sum of the constituent risks; similarly, the total HI was calculated as the sum of the constituent hazard indices. These calculations were performed for IRP Sites 2, 9, and 11 separately.

- As shown in Table 6-1, the total excess lifetime carcinogenic risk[2] is 5x 10^{-5} for IRP Site 2, 1 x 10^{-5} for IRP Site 9, and 5 x 10^{-5} for IRP Site 11. All of these risks are within the range of acceptable risk defined by USEPA in the NCP (1990). The estimated risks for one or more constituents at each IRP site exceed ODEQ requirements (1998d) for individual constituent risk. In addition, the cumulative risks exceed ODEQ requirements (1998d) for total risk at IRP Sites 2 and 11. However, it must be emphasized again that these estimated risks are based on a hypothetical exposure scenario, and that the use of shallow ground water will be prevented through the implementation of institutional controls.

- As shown in Table 6-1, the total noncarcinogenic hazard indices are all less than one, and, thus, no adverse health effects are anticipated as a result of the defined conditions of exposure. The estimated hazard indices are all considered acceptable under USEPA and ODEQ guidelines.

The risks calculated for this RRA represent hypothetical risks associated with the use of shallow groundwater within the treatment area for residential water supply. This is a far more conservative scenario than that represented by the exposure pathways developed in Section 4.2 of this FS. It would be more realistic to estimate risk based on the potential concentrations reaching groundwater in the CRSA, the source of groundwater for the exposure pathways. A solute transport model is currently being developed for the Portland ANGB. This model will provide a mechanism for estimating a potential future concentration of VOCs in the CRSA at the three IRP sites mentioned above, based on the

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[2] A risk of 1 x 10^{-6} represents an upper bound probability of one in one million that an excess carcinogenic response will occur during an individual's lifetime as a result of the defined conditions of exposure.

calculated residual concentrations in the treatment area. Until these calculations can be performed, the residual risks based on the exposure pathways considered for this FS can not accurately be evaluated.

6.2.2 Adequacy or Reliability of Institutional and Engineering Controls

The institutional and engineering controls presented as part of the recommended remedial alternatives for IRP Sites 2, 9, and 11 are intended to prevent human exposure to groundwater containing unacceptable levels of VOCs. These controls were developed into the tasks presented in Section 4.5.2 to be implemented with each RA. These tasks, if implemented immediately and effectively, will adequately reduce the risk of exposure to groundwater containing VOCs. This is performed through the restriction of access to site groundwater for extraction and during site activities. Health and safety provisions prevent exposure to workers during subsurface construction activities. Groundwater monitoring provides a means of detecting VOC-impacted groundwater that may migrate off the Base.

The reliability of these controls is dependent on their ability to be quickly implemented and effectively maintained. The reliability of some controls, such as deed and zoning controls is uncertain because they will require coordination with local government, the Port of Portland, and the Base. However, these controls are less crucial since they would primarily be used to control activities on the Base property at the time that the ANG vacates the Base. The recommended remedial action will likely be complete at that time and controls would serve to limit access to groundwater containing contaminants at levels only slightly above unacceptable risk levels. Controls implemented by the Base, such as groundwater monitoring, health and safety controls, and access restrictions would be more reliable. These activities are currently implemented on some level at the Base and would be simple to upgrade to the level required by this FS.

SECTION 7.0

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APPENDIX A

INSTALLATION RESTORATION PROGRAM SUMMARY

APPENDIX A

INSTALLATION RESTORATION PROGRAM SUMMARY

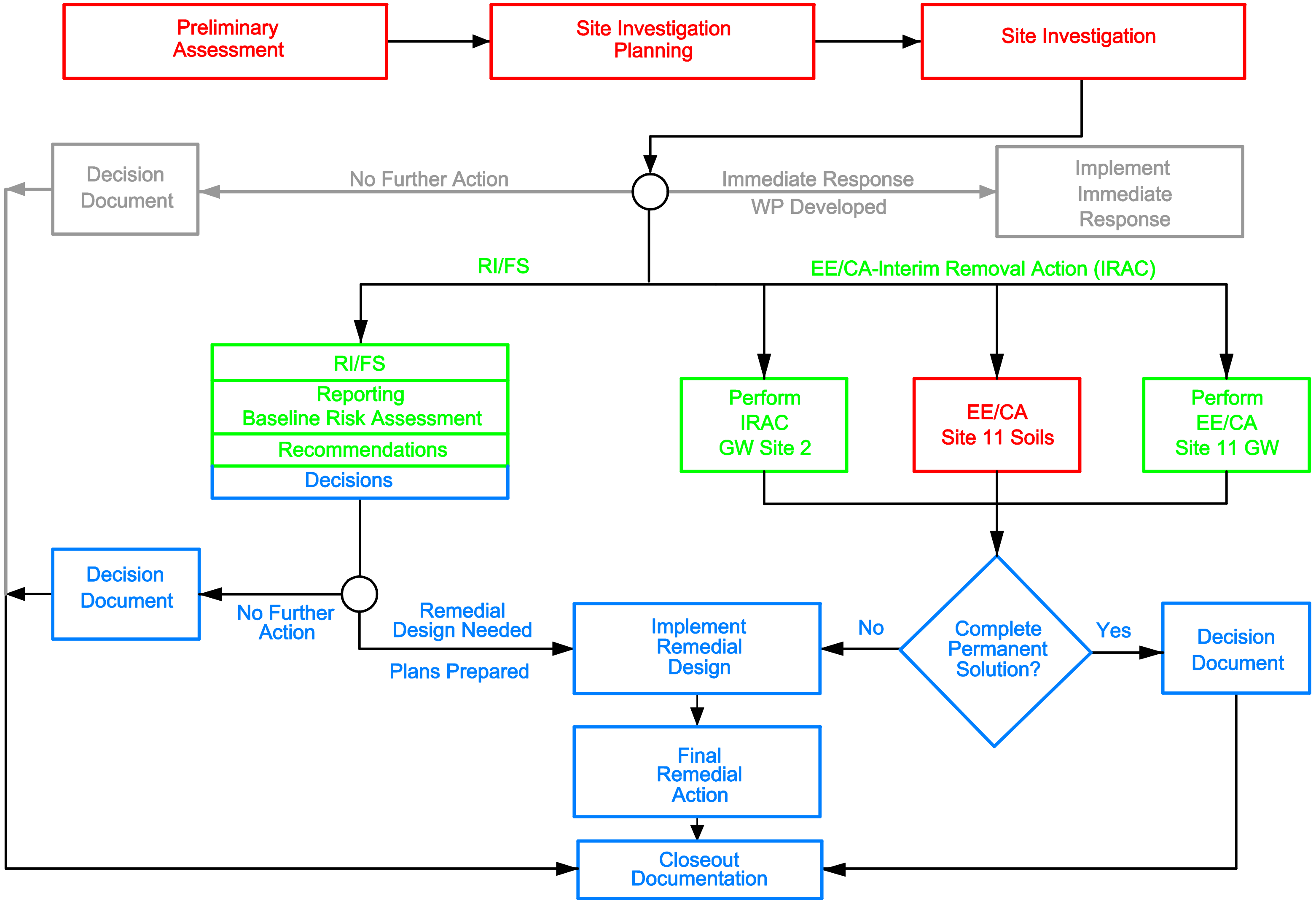
Installation Restoration Program Summary

The Defense Environmental Restoration Program (DERP) was established in 1984 to promote and coordinate efforts for the evaluation and cleanup of contamination at Department of Defense (DOD) installations. On 23 January 1987, Presidential Executive Order 12580 was issued which assigned the responsibility for carrying out DERP within the overall framework of the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 and the Superfund Amendments and Reauthorization Act of 1986 to the Secretary of Defense. The Installation Restoration Program (IRP) was established under DERP to identify, investigate, and remediate contamination at DOD installations. The IRP focuses on cleanup of contamination associated with past DOD activities to ensure that threats to public health are eliminated and to restore natural resources for future use.

The IRP decision process is separated into phases as illustrated in Figure A-1. The phases of the IRP process that have been performed at the Portland Air National Guard Base (Portland ANGB) are defined and described in general terms below.

Preliminary Assessment

A Preliminary Assessment (PA) was conducted at the Portland ANGB in 1987. A PA consists of personnel interviews, a records search, and site inspections to identify and evaluate past disposal and/or spill sites that might pose a threat to human health or the environment. Previously undocumented information is obtained through the interviews. The records search focuses on obtaining information from the following sources:



EXPLANATION

Red - Task Completed
Gray - Not Applicable
Green - Ongoing Task
Blue - Future Task

ERM

ANG PORTLAND PROJECT OVERVIEW

142nd FW, Portland ANGB
Portland, Oregon

Figure A-1

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- Aerial photographs;
- Installation plans;
- Facility inventory documents;
- Lists of hazardous materials used and hazardous wastes generated;
- Subcontractor reports;
- Correspondence;
- Material Safety Data Sheets;
- Federal/state agency reports on endangered or threatened species and critical habitats; and
- Other relevant documents from local government offices and standard reference sources.

As a result of the PA completed at the Portland ANGB, IRP Sites 1 through 8 were identified as potentially contaminated sites. Additional investigation was recommended for Sites 1, 2, 3, 4, 5, 7, and 8; No Further Action (NFA) was recommended for Site 6.

Site Investigation

A Site Investigation (SI) was conducted at the Portland ANGB in 1989. An SI consists of field sampling to determine whether contamination is present at the sites identified during the PA. The SI also includes a preliminary (screening) assessment of potential risks to human health and the environment.

The activities performed during the SI generally fall into three categories: screening, confirmation, and optional activities. Screening activities are conducted to gather preliminary data on each site. Confirmation activities include specific media sampling and laboratory analysis to confirm the presence or absence of contamination, chemical concentrations, and the potential for contaminant migration. Information obtained during the SI is also used to define the hydrology, geology, and soil characteristics of the sites. The data collected during the PA and SI may be sufficient to reach a decision point for a site, such as: no further IRP action is warranted; prompt removal of contaminants is necessary; or further IRP work is required.

The general approach for the SI is to sequence the field activities so that data are acquired and used as the field investigation progresses. This is done to determine the presence or absence of contamination in a relatively short period of time, optimize data collection and data quality, and minimize costs.

As a result of the SI completed at the Portland ANGB, contamination above applicable regulatory levels was confirmed at IRP Sites 2, 4, and 5. Contaminants also were detected at IRP Sites 1, 3, and 7. Geophysical anomalies, possibly indicating disturbed soil, were detected at IRP Site 8; no samples were collected at Site 8. Following the SI, IRP Sites 10 and 11 were established based on analytical results from samples collected by Air National Guard personnel.

Remedial Investigation

A two-part Remedial Investigation (RI) was conducted at the Portland ANGB between 1995 and 2000. Phase I of the RI was conducted in 1995 and 1996, and Phase II was conducted from 1998 through 2000. The objectives of the RI are to determine the nature and extent of contamination, quantify potential threats to human health and the environment, and provide a basis for determining the response actions to be considered (e.g., NFA, Feasibility Study [FS], Remedial Design (RD), and/or Remedial Action [RA]).

Field activities performed during the RI include the installation of soil borings and groundwater monitoring wells and the collection and analysis of water, soil, and/or sediment samples. Hydrogeologic studies are conducted to characterize stratigraphy, groundwater flow directions and rates, and the potential for contaminant migration. Careful documentation and quality control procedures are implemented during RI field activities to ensure the validity of the collected data.

A baseline risk assessment is conducted to evaluate the potential threats to human health and the environment in the absence of any RA. The baseline risk assessment provides the basis for determining whether remediation may be necessary to mitigate such threats.

The RI results in the recommendation of one or more of the following response actions at each IRP site:

- NFA: The results of investigations do not indicate the presence of contamination posing an unacceptable risk to human health or the environment. Therefore, no further IRP action is warranted and a Decision Document is typically prepared to close the site.
- Long-Term Monitoring (LTM): The results of investigations do not indicate the presence of sufficient contamination to justify costly remediation. LTM may be recommended to detect possible future changes in conditions.
- Engineering Evaluation/Cost Analysis (EE/CA): The results of investigations indicate the presence of sufficient contamination to justify remediation. An EE/CA may be recommended to compare the effectiveness and costs of removal action alternatives.
- FS: The results of investigations confirm the presence of contamination that may pose a threat to human health or the environment. An FS may be recommended to establish remedial action objectives and develop remedial alternatives.

Engineering Evaluation/Cost Analysis

An EE/CA was conducted at the Portland ANGB in 1998 to address contaminated soil at IRP Site 11. At any time during an IRP project, an EE/CA can be implemented to evaluate remedial options for cleaning up contamination. An EE/CA can be completed for all non-time-critical removal actions that are not addressed by an FS. The purpose of the EE/CA is to: (1) satisfy environmental review and administrative requirements for removal actions; (2) provide a framework for evaluating and selecting alternative remediation technologies; and (3) select a remedy that significantly and permanently reduces toxicity, mobility, or volume of hazardous contaminants and is cost-effective.

An EE/CA is similar to an RI/FS but is less comprehensive because remediation is presumed to be necessary; it is often completed as a parallel effort to an RI/FS. Activities associated with the EE/CA include the following:

- Preparation of an Approval Memorandum that identifies the need for an EE/CA;
- Preparation of an EE/CA report that establishes removal action objectives and identifies and analyzes removal action alternatives; and
- Preparation of an Action Memorandum that recommends the preferred removal action alternative.

The end result of the EE/CA is the selection of the most appropriate removal action alternative with concurrence by state or Federal regulatory agencies. The EE/CA conducted at the Portland ANGB provided the necessary information to complete an Interim Remedial Action (IRA) (soil removal action) at IRP Site 11 in 1999.

Feasibility Study

Based on the results of the RI and a review of state and Federal regulatory requirements, an FS may be prepared to develop, screen, and evaluate alternatives for the remediation of contaminated media. The overall objectives of the FS include developing and evaluating remedial alternatives and selecting a remedy that is protective of human health and the environment, considers applicable or relevant and appropriate requirements, satisfies the preference for a treatment that significantly and permanently reduces toxicity, mobility, or volume of hazardous contaminants as a principal element, and maximizes cost-effectiveness.

Activities associated with the FS include the following:

- Development of remedial alternatives;
- Preliminary screening of alternatives;
- Detailed analysis of alternatives;
- Comparative analysis of alternatives; and
- Recommendation of the preferred remedial alternative in an FS report.

The end result of the FS is the selection of the most appropriate remedial alternative with concurrence by state or Federal regulatory agencies.

Remedial Design

RD involves the development and approval of the engineering plans and drawings required to implement the selected cleanup remedy identified in an EE/CA or FS. RD for the Portland ANGB was conducted in 1998 and 1999 as part of the IRA (soil removal action) performed at IRP Site 11 in September 1999.

Remedial Action

The RA phase is the actual implementation of a selected cleanup remedy. An RA may be conducted as an interim measure (i.e., an IRA), or following completion of an FS. The objective of the RA is to eliminate risks associated with environmental contamination or, at a minimum, to reduce the risks to acceptable levels. Examples of remedial alternatives that might be implemented include covering a landfill with a low-permeability cap, pumping and treating contaminated groundwater, installing a new water distribution system, and monitoring or augmenting in-situ bioremediation of contaminated soil or groundwater. In some cases, after the RA has been completed, LTM may be conducted as a precautionary measure to detect possible contaminant migration or to document the effectiveness of remediation.

An IRA (soil removal action) was conducted at the Portland ANGB in September 1999. Approximately 260 cubic yards of contaminated soil in the Site 11 source area (former washrack and oil/water separator) were excavated and treated off site. It is anticipated that other RAs will be conducted to address contaminated groundwater at the Base.

Immediate Action Alternatives

It may be determined at any point during the IRP process that a contaminated site poses an immediate threat to human health or the environment, thus necessitating prompt action to reduce the threat. Immediate action, such as limiting access to the site, capping or removing contaminated soils, or providing an alternative water supply, may suffice as effective control measures. Sites requiring immediate action maintain IRP status in order to determine the need for additional RA or LTM after the immediate action is completed. Immediate actions may be implemented during any phase of an IRP project.

APPENDIX B

COST TABLES

TABLE B-1

List of Assumptions Used in Cost Estimation
142nd FW, Portland ANGB, Portland, Oregon

Item	Value		
Indirect Costs			
Contractor Overhead & Profit	15%	TDC	
Engineering and Construction Oversight	15%	TDC	
Health and Safety Costs	3%	TDC	
Project Management & Administration	10%	TDC	
Annual O&M Replacement Costs	3%	TDC	
General Contingency	30%	Cap and O&M costs	
Well Installation and Sampling			
Site 11 Cost Multiplier (for airport concrete)	1.2		
Well Installation Costs (incl. labor & expenses)	*Sites 2 & 9*	*Site 11*	
Shallow Zone Monitoring Well Cost	$5,000	$6,000	
Deep Zone Monitoring Well Cost	$7,000	$8,400	
CRSA Monitoring Well Cost (incl. telescoping drill method)	$10,000	$12,000	
Shallow Zone Ozone Sparging Well Cost	$7,000	$8,400	
Deep Zone Ozone Sparging Well Cost	$9,800	$11,800	
Shallow Zone Injection Well Cost	$3,500	$4,200	
Deep Zone Injection Well Cost	$4,900	$5,900	
Horizontal Injection Well Cost (per foot)	$100	$120	
Horizontal Well Costs			
Horizontal Well Contractor Mobilization		$45,000	
Horizontal Well Drilling Cost (per foot)		$27	
Horizontal Well screen (per foot)		$7	
Horizontal Well Blank Casing (per foot)		$5	
Horizontal Well Other Materials (per well)		$500	
Horizontal Well Development (per well)		$7,200	
Horizontal Well Standby Cost (per hour)		$500	
Horizontal Well Miscellaneous			
Well Vaults, 2 per well (per well)		$4,000	
Well installation duration (days per well)		5	
Soil Disposal Container Rental (per day)		$50	
Water Disposal Container Rental (per day)		$50	
Permit and Utility Planning		$2,560	
Waste Characterization Samples, 20 at $150 each		$3,000	
Contractor Oversight (per day)		$1,600	
Waste Disposal (per well)		$3,000	
Miscellaneous Equipment (per day)		$500	
Shallow Zone Aeration Well Installation (6-inch dia)	$15,000	$18,000	
Deep Zone Aeration Well Installation (6-inch dia)	$21,000	$25,200	
Well Sampling Labor and Equipment	$400	$480	per well

TABLE B-1

List of Assumptions Used in Cost Estimation
142nd FW, Portland ANGB, Portland, Oregon

Item	**Value**		
	Site 2:	*Site 9:*	*Site 11:*
No. of Wells Sampled Per Event (incl. proposed new wells)	26	10	23
Deep Zone/Shallow Zone Multipliers			
Deep Zone / Shallow Zone Extent of Contam. Mult.	0.25		
Deep Zone / Shallow Zone Cost Multiplier	1.4		
Laboratory Costs			
VOCs - Air (TO-15)	$150		
VOCs - GW (8260)	$150		
MNA Parameters	$400		
	Site 2:	*Site 9:*	*Site 11:*
No. of MNA Samples	10	3	10
% QA / QC Samples - VOCs	50%		
% QA / QC Samples - MNA Parameters	30%		
Labor Rates			
Field Technician	$60	per hour	
Data Validating / Reporting	$100	per hour	
Misc. Direct Cost Items			
Deep Zone Direct-Push Investigation (30 VOC samples, 5 days of drilling, 10 days of consultant staff)	$17,150		
Monitored Natural Attenuation Work Plan	$10,000		
Work Plan (incl. 35%, 90%, and Final Designs)	$50,000		
As-Built Drawings and O&M Manual Preparation	$20,000		
System Startup and Optimization	$10,000		
Airport Concrete Coring (per location)	$300		
Airport Concrete Repair (per location)	$300		
Airport Concrete Coring, Excavation, and Repair for Horizontal Well location (per location)	$2,000		
% Wells and Injections Requiring Concrete Coring at Site 11	75%		
Trench, install, and backfill lines (/ lf)	$20		
Trench, install, and backfill lines in 24-inch concrete (/ lf)	$75		
System Building (incl. concrete pad)	$7,000		
Freight	$500	per unit	
Electrical Power (Capital)	$10,000		
Equipment Rental Costs (daily)			
Daily Cost of Geoprobe	$1,250		
Miscellaneous O&M Costs			
Electrical Power (Annual O&M)	$5,000		

TABLE B-1

List of Assumptions Used in Cost Estimation
142nd FW, Portland ANGB, Portland, Oregon

Item	**Value**	
Monitoring Period		
Alternative 2	30	
Alternatives 3 through 6	5	
Economic Information		
Discount Rate (i)	7.5%	
P / A for n=30	11.810	mult by A to get P
P / A for n=5	4.046	mult by A to get P
Alternative 3 (Permanganate or Persulfate)		
Potassium Permanganate Cost	$2.00	per pound
Sodium Persulfate Cost (incl. iron amendment)	$1.50	per pound
SHALLOW ZONE		
No. of Central Applications (in excess of 10 ppb conc.)	4	
No. of Periphery Applications (1/2 No. of Central)	2	
No. of Horizontal Applications	4	
Direct-Push Injection of Oxidizer (incl. Drilling, pump, mixer, equip., expenses, survey, and labor)	$500	per injection
Injection of Permanganate through Horizontal Injection Well (Site 11)	$3,750.00	per well
Setup and injection time	1.5	days per well
Equipment costs	$1,000.00	per day
Labor costs	$1,500.00	per day
Per Event	*Site 2:*	*Site 9:*
Effective Area of Shallow Zone Treatment Area (ft^2)	191,050	29,900
Injection Spacing (ft)	25	25
Total Number of Injections	310	50
No. of Central Injection Locations (80% Total)	250	50
No. of Periphery Injection Locations (20% Total)	60	N / A
lbs per location	35	95
Per Event Using Horizontal Wells	*Site 11:*	
Effective Area of Shallow Zone Treatment Area (ft^2)	266,300	
Number of Horizontal Wells	8	
Feet of Well Screen	3465	
Feet of Riser	3375	
lbs per foot of screen	2	

TABLE B-1

List of Assumptions Used in Cost Estimation
142nd FW, Portland ANGB, Portland, Oregon

Item	Value	
DEEP ZONE		
No. of Applications	4	
No. of Horizontal Applications	4	
Direct-Push Injection of Oxidizer (incl. Drilling, pump, mixer, equip., expenses, survey, and labor)	$700	per injection
Injection of Permanganate through Horizontal Injection Well (Site 11)	$3,750.00	per well
Setup and injection time	1.5	days per well
Equipment costs	$1,000.00	per day
Labor costs	$1,500.00	per day
Per Event	*Site 2:*	
No. of Injection Locations (25% total # shallow injections)	80	
Per Event Using Horizontal Wells	*Site 11:*	
Number of Horizontal Wells	4	
Feet of Well Screen	900	
Feet of Riser	2205	
lbs per foot of screen	2	
Alternative 4 (Ozone Sparging)		
SVE System (incl. blower, ozone decomposer, piping, valves, gages)	$25,000	
	Site 2:	*Site 9:*
Effective Area of Shallow Zone Treatment Area (ft^2)	191,050	29,900
Radius of Influence	50	25
Ozone Sparge Point Spacing (approx. 80% x 2 x ROI)	77	43
No. of Shallow Zone Sparge Points	32	16
No. of Deep Zone Sparge Points (25% # shallow pts)	8	N / A
Site 11 Horizontal Well Ozone System		
Ozone Sparging System (incl. oxygen generator, ozone generator, compressor, manifold system, and controls)	$85,500	
Shallow Zone Wells		
Ozone Sparge Wells		
Number of Horizontal Wells	8	
Feet of Well Screen	3,465	
Feet of Riser	3,375	
SVE Wells		
Number of Horizontal Wells	8	
Feet of Well Screen	3,465	
Feet of Riser	3,375	

TABLE B-1

List of Assumptions Used in Cost Estimation
142nd FW, Portland ANGB, Portland, Oregon

Item	Value		
Deep Zone Wells			
Ozone Sparge Wells			
Number of Horizontal Wells	4		
Feet of Well Screen	900		
Feet of Riser	2,205		
SVE Wells			
Number of Horizontal Wells	4		
Feet of Well Screen	900		
Feet of Riser	2,205		
Alternative 5 (Enhanced Bioremediation)			
Oxygen Releasing Chemicals Cost	$15	per lb	
Hydrogen Releasing Chemicals Cost	$10	per lb	
SHALLOW ZONE			
No. of Central Applications (in excess of 10 ppb conc.)	4		
No. of Periphery Applications (1/2 No. of Central)	2		
Direct-Push Injection (incl. Drilling, pump, mixer, equip., expenses, survey, and labor)	$300	per injection	
Oxygen Releasing Chemicals Per Event:	*Site 2:*	*Site 9:*	*Site 11:*
Effective Area of Shallow Zone Treatment Area (ft^2)	191,050	29,900	211,300
Injection Spacing (ft)	25	25	25
Total Number of Injections	310	50	340
No. of Central Injection Locations (80% Total)	250	50	270
No. of Periphery Injection Locations (20% Total)	60	N / A	70
lbs per location	30	30	30
Hydrogen Releasing Chemicals Per Event:	*Site 2:*		
No. of Injection Locations	10		
Initial lbs per location	30		
DEEP ZONE			
No. of Applications	4		
Direct-Push Injection (incl. Drilling, pump, mixer, equip., expenses, survey, and labor)	$420	per injection	
Oxygen Releasing Chemicals Per Event:	*Site 2:*	*Site 9:*	*Site 11:*
No. of Injection Locations (25% total # shallow injections)	80	10	90

TABLE B-1

List of Assumptions Used in Cost Estimation
142nd FW, Portland ANGB, Portland, Oregon

Item	Value		
Alternative 6 (In-Well Aeration)			
Shallow Zone Aeration Unit (incl. blower, moisture knockout, pump, packer, stripping reactor, piping, & gages)	$8,300	per unit	
Deep Zone Aeration Unit (incl. blower, moisture knockout, pump, packer, stripping reactor, piping, & gages)	$11,600	per unit	
Well Rehabilitation Cost to Treat Fouling	$2,000	per well	
Cost of Carbon ($/lb)	$2.00		
	Site 2:	*Site 9:*	*Site 11:*
Effective Area of Shallow Zone Treatment Area (ft^2)	191,050	29,900	211,300
Radius of Influence	60	60	60
Aeration Well Spacing (approx. 80% x 2 x ROI)	96	96	96
No. of Shallow Zone Aeration Wells	21	4	23
No. of Deep Zone Aeration Wells (25% # shallow wells)	5	N/A	6
Carbon Mass Calculation	*Site 2:*	*Site 9:*	*Site 11:*
Estimated Mass of Contamination (lbs)	10	5	10
Carbon Efficiency by Wt.	0.05%	1.00%	0.05%
Wt of Carbon Req'd (lbs)	20,000	500	20,000
Annualized Wt. Over 2 Years (lb/year)	10,000	250	10,000

TABLE B-2

Summary of Costs Associated with Each Alternative
IRP Site 2
142nd FW, Portland ANGB, Portland, Oregon

Alternative	Description	Direct and Indirect Capital Costs	NPW of Total O&M Costs	General Contingency (30%)	Estimated Total Cost
Alternative 1	No Action	$0	$0	$0	**$0**
Alternative 2	Monitored Natural Attenuation	$116,100	$434,800	$165,300	**$717,000**
Alternative 3	Permanganate Oxidation	$1,438,550	$331,300	$531,000	**$2,301,000**
Alternative 4	Ozone Sparging	$1,940,750	$752,100	$807,900	**$3,501,000**
Alternative 5	Enhanced Bioremediation	$1,806,850	$331,300	$641,400	**$2,780,000**
Alternative 6	In-Well Aeration	$1,971,250	$891,000	$858,700	**$3,721,000**

Notes:

Net present worth calculated using equal series present worth analysis where i = 7.5%

TABLE B-3

Alternative 2 - Monitored Natural Attenuation
IRP Site 2 Cost Estimate
142nd FW, Portland ANGB, Portland, Oregon

DESCRIPTION	QUANTITY		COST	
	Number	Unit	Unit Cost	Total Cost
DIRECT CAPITAL COSTS				
Deep Zone Direct-Push Investigation	1	ea.	$17,150	$17,150
Monitored Natural Attenuation Work Plan	1	ea.	$10,000	$10,000
Installation of Additional Shallow Zone Monitoring Wells	4	ea.	$5,000	$20,000
Installation of Additional Deep Zone Monitoring Wells	2	ea.	$7,000	$14,000
Installation of Additional CRSA Monitoring Wells	2	ea.	$10,000	$20,000
TOTAL DIRECT CAPITAL COSTS				**$81,200**
INDIRECT CAPITAL COSTS				
Contractor Overhead & Profit (15% Total Direct Costs)	1	LS	$12,200	$12,200
Engineering and Construction Oversight (15% Total Direct Costs)	1	LS	$12,200	$12,200
Health and Safety Costs (3% Total Direct Costs)	1	LS	$2,400	$2,400
Project Management & Administration (10% Total Direct Costs)	1	LS	$8,100	$8,100
TOTAL INDIRECT CAPITAL COSTS				**$34,900**
TOTAL CAPITAL COSTS (Direct and Indirect)				***$116,100***
O & M COSTS				
Groundwater Monitoring Cost Per Event				
Well Sampling Labor and Equipment	26	wells	$400	$10,400
Ground Water Analysis - VOCs (26 wells + 50% QA / QC)	39	samples	$150	$5,900
Ground Water Analysis - MNA Parameters (10 wells + 30% QA / QC)	13	samples	$400	$5,200
Contractor Overhead & Profit (15% Total Direct Costs)	1	LS	$3,200	$3,200
Health and Safety Costs (3% Total Direct Costs)	1	LS	$600	$600
Project Management & Administration (10% Total Direct Costs)	1	LS	$2,200	$2,200
SUBTOTAL				**$27,500**
FIRST YEAR O&M COSTS (quarterly sampling)				**$110,000**
REMAINING O&M COSTS (annual sampling for 30 years) (1)				**$324,800**
TOTAL O & M COSTS				***$434,800***
TOTAL CAPITAL AND O & M COSTS				***$550,900***
General Contingency (30% of Total Capital and O&M Costs)				***$165,300***
TOTAL COST OF ALTERNATIVE (PRESENT WORTH)				***$717,000***

Notes:

(1) Present worth calculated using equal series present worth analysis where i = 7.5%

TABLE B-4

Alternative 3 - Permanganate Oxidation
IRP Site 2 Cost Estimate
142nd FW, Portland ANGB, Portland, Oregon

DESCRIPTION	QUANTITY		COST	
	Number	Unit	Unit Cost	Total Cost
DIRECT CAPITAL COSTS				
Preparation Work				
Work Plan (incl. 35%, 90%, and Final Designs)	1	ea.	$50,000	$50,000
Deep Zone Direct-Push Investigation	1	ea.	$17,150	$17,150
Installation of Additional Shallow Zone Monitoring Wells	4	ea.	$5,000	$20,000
Installation of Additional Deep Zone Monitoring Wells	2	ea.	$7,000	$14,000
Installation of Additional CRSA Monitoring Wells	2	ea.	$10,000	$20,000
SUBTOTAL				**$121,150**
Potassium Permanganate Injection				
Shallow Zone (Central) Direct-Push Injection of Potassium Permanganate (250 locations and 4 applications)	1,000	Injection	$500	$500,000
Shallow Zone (Periphery) Direct-Push Injection of Potassium Permanganate (60 locations and 2 applications)	120	Injection	$500	$60,000
Deep Zone Direct-Push Injection of Potassium Permanganate (80 locations and 4 applications)	320	Injection	$700	$224,000
Potassium Permanganate (1440 injections at 35 lbs per injection)	50,400	lbs.	$2.00	$100,800
SUBTOTAL				**$884,800**
TOTAL DIRECT CAPITAL COSTS				***$1,005,950***
INDIRECT CAPITAL COSTS				
Contractor Overhead & Profit (15% Total Direct Costs)	1	LS	$150,900	$150,900
Engineering and Construction Oversight (15% Total Direct Costs)	1	LS	$150,900	$150,900
Health and Safety Costs (3% Total Direct Costs)	1	LS	$30,200	$30,200
Project Management & Administration (10% Total Direct Costs)	1	LS	$100,600	$100,600
TOTAL INDIRECT CAPITAL COSTS				**$432,600**
TOTAL CAPITAL COSTS (Direct and Indirect)				***$1,438,550***
O & M COSTS				
Groundwater Monitoring Cost Per Event				
Well Sampling Labor and Equipment	26	wells	$400	$10,400
Ground Water Analysis - VOCs (26 wells + 50% QA / QC)	39	samples	$150	$5,900
Ground Water Analysis - MNA Parameters (10 wells + 30% QA / QC)	13	samples	$400	$5,200
Contractor Overhead & Profit (15% Total Direct Costs)	1	LS	$3,200	$3,200
Health and Safety Costs (3% Total Direct Costs)	1	LS	$600	$600
Project Management & Administration (10% Total Direct Costs)	1	LS	$2,200	$2,200
SUBTOTAL				**$27,500**
FIRST TWO YEARS O&M COSTS (quarterly sampling)				**$220,000**
REMAINING O&M COSTS (annual sampling for 5 years) (1)				**$111,300**
TOTAL O & M COSTS				*$331,300*
TOTAL CAPITAL AND O & M COSTS				***$1,769,850***
General Contingency (30% of Total Capital and O&M Costs)				***$531,000***
TOTAL COST OF ALTERNATIVE (PRESENT WORTH)				***$2,301,000***

Notes:

(1) Present worth calculated using equal series present worth analysis where i = 7.5%

TABLE B-5

Alternative 4 - Ozone Sparging
IRP Site 2 Cost Estimate
142nd FW, Portland ANGB, Portland, Oregon

DESCRIPTION	**QUANTITY**		**COST**	
	Number	**Unit**	**Unit Cost**	**Total Cost**
DIRECT CAPITAL COSTS				
Preparation Work				
Work Plan (incl. 35%, 90%, and Final Designs)	1	ea.	$50,000	$50,000
Deep Zone Direct-Push Investigation	1	ea.	$17,150	$17,150
Installation of Additional Shallow Zone Monitoring Wells	4	ea.	$5,000	$20,000
Installation of Additional Deep Zone Monitoring Wells	2	ea.	$7,000	$14,000
Installation of Additional CRSA Monitoring Wells	2	ea.	$10,000	$20,000
SUBTOTAL				**$121,150**
Ozone Sparging System				
Shallow Zone Ozone Sparging Well Installation	32	ea.	$7,000	$224,000
Shallow Zone Ozone Sparging System (incl. master panels, in-well units, below-well sparge units, misc. costs)	8	ea.	$33,200	$265,600
Deep Zone Ozone Sparging Well Installation	8	ea.	$9,800	$78,400
Deep Zone Ozone Sparging System (incl. master panels, in-well units, below-well sparge units, misc. costs)	2	ea.	$46,500	$93,000
Freight	10	ea.	$500	$5,000
Injection and SVE Piping Installation (trench, install, fill)	6,000	lf	$20	$120,000
System Building	10	ea.	$7,000	$70,000
Electrical Installation	10	ea.	$10,000	$100,000
SVE System (incl. blower, ozone decomposer, piping, valves, gages)	10	ea.	$25,000	$250,000
As-Built Drawings and O&M Manual Preparation	1	LS	$20,000	$20,000
System Startup and Optimization	1	LS	$10,000	$10,000
SUBTOTAL				**$1,236,000**
TOTAL DIRECT CAPITAL COSTS				***$1,357,150***
INDIRECT CAPITAL COSTS				
Contractor Overhead & Profit (15% Total Direct Costs)	1	LS	$203,600	$203,600
Engineering and Construction Oversight (15% Total Direct Costs)	1	LS	$203,600	$203,600
Health and Safety Costs (3% Total Direct Costs)	1	LS	$40,700	$40,700
Project Management & Administration (10% Total Direct Costs)	1	LS	$135,700	$135,700
TOTAL INDIRECT CAPITAL COSTS				**$583,600**
TOTAL CAPITAL COSTS (Direct and Indirect)				***$1,940,750***
O & M COSTS				
Annual Treatment System O&M (1)				
Air Sampling and Analysis - VOCs	40	samples	$150	$6,000
Operation and Maintenance Labor	310	hours	$60	$18,600
Electrical Power	1	LS	$5,000	$5,000
Reporting	144	hours	$100	$14,400
Replacment Costs (3% Total Direct Costs)	1	LS	$40,700	$40,700

TABLE B-5

Alternative 4 - Ozone Sparging
IRP Site 2 Cost Estimate
142nd FW, Portland ANGB, Portland, Oregon

DESCRIPTION	**QUANTITY**		**COST**	
	Number	**Unit**	**Unit Cost**	**Total Cost**
Contractor Overhead & Profit (15% Total Direct Costs)	1	LS	$6,600	$6,600
Engineering and Construction Oversight (15% Total Direct Costs)	1	LS	$6,600	$6,600
Health and Safety Costs (3% Total Direct Costs)	1	LS	$1,300	$1,300
Project Management & Administration (10% Total Direct Costs)	1	LS	$4,400	$4,400
SUBTOTAL				**$103,600**
Groundwater Monitoring Cost Per Event				
Well Sampling Labor and Equipment	26	wells	$400	$10,400
Ground Water Analysis - VOCs (26 wells + 50% QA / QC)	39	samples	$150	$5,900
Ground Water Analysis - MNA Parameters (10 wells + 30% QA / QC)	13	samples	$400	$5,200
Contractor Overhead & Profit (15% Total Direct Costs)	1	LS	$3,200	$3,200
Health and Safety Costs (3% Total Direct Costs)	1	LS	$600	$600
Project Management & Administration (10% Total Direct Costs)	1	LS	$2,200	$2,200
SUBTOTAL				**$27,500**
FIRST THREE YEARS O&M COSTS (treatment O&M and quarterly sampling) (1)				**$640,800**
REMAINING O&M COSTS (annual sampling for 5 years) (2)				**$111,300**
TOTAL O & M COSTS				***$752,100***
TOTAL CAPITAL AND O & M COSTS				***$2,692,850***
General Contingency (30% of Total Capital and O&M Costs)				***$807,900***
TOTAL COST OF ALTERNATIVE (PRESENT WORTH)				***$3,501,000***

Notes:

(1) Assume 2 years of system operation

(2) Present worth calculated using equal series present worth analysis where i = 7.5%

TABLE B-6

Alternative 5 - Enhanced Bioremediation
IRP Site 2 Cost Estimate
142nd FW, Portland ANGB, Portland, Oregon

DESCRIPTION	QUANTITY		COST	
	Number	Unit	Unit Cost	Total Cost
DIRECT CAPITAL COSTS				
Preparation Work				
Work Plan (incl. 35%, 90%, and Final Designs)	1	ea.	$50,000	$50,000
Deep Zone Direct-Push Investigation	1	ea.	$17,150	$17,150
Installation of Additional Shallow Zone Monitoring Wells	4	ea.	$5,000	$20,000
Installation of Additional Deep Zone Monitoring Wells	2	ea.	$7,000	$14,000
Installation of Additional CRSA Monitoring Wells	2	ea.	$10,000	$20,000
SUBTOTAL				**$121,150**
Enhanced Bioremediation Treatment				
Shallow Zone Hydrogen Releasing Chemical Injection (10 locations and 4 applications)	40	Injection	$300	$12,000
Hydrogen Releasing Chemicals (40 injections at 30 lbs per injection)	1,200	lbs	$10	$12,000
Shallow Zone (Central) Oxygen Releasing Chemical Injections (250 locations and 4 applications)	1,000	Injection	$300	$300,000
Shallow Zone (Periphery) Oxygen Releasing Chemical Injections (60 locations and 2 applications)	120	Injection	$300	$36,000
Deep Zone Oxygen Releasing Chemical Injections (80 locations and 4 applications)	320	Injection	$420	$134,400
Oxygen Releasing Chemicals (1440 injections at 30 lbs per injection)	43,200	lbs	$15	$648,000
SUBTOTAL				**$1,142,400**
TOTAL DIRECT CAPITAL COSTS				***$1,263,550***
INDIRECT CAPITAL COSTS				
Contractor Overhead & Profit (15% Total Direct Costs)	1	LS	$189,500	$189,500
Engineering and Construction Oversight (15% Total Direct Costs)	1	LS	$189,500	$189,500
Health and Safety Costs (3% Total Direct Costs)	1	LS	$37,900	$37,900
Project Management & Administration (10% Total Direct Costs)	1	LS	$126,400	$126,400
TOTAL INDIRECT CAPITAL COSTS				**$543,300**
TOTAL CAPITAL COSTS (Direct and Indirect)				***$1,806,850***
O & M COSTS				
Groundwater Monitoring Cost Per Event				
Well Sampling Labor and Equipment	26	wells	$400	$10,400
Ground Water Analysis - VOCs (26 wells + 50% QA / QC)	39	samples	$150	$5,900
Ground Water Analysis - MNA Parameters (10 wells + 30% QA / QC)	13	samples	$400	$5,200
Contractor Overhead & Profit (15% Total Direct Costs)	1	LS	$3,200	$3,200
Health and Safety Costs (3% Total Direct Costs)	1	LS	$600	$600
Project Management & Administration (10% Total Direct Costs)	1	LS	$2,200	$2,200

TABLE B-6

Alternative 5 - Enhanced Bioremediation
IRP Site 2 Cost Estimate
142nd FW, Portland ANGB, Portland, Oregon

DESCRIPTION	QUANTITY		COST	
	Number	Unit	Unit Cost	Total Cost
SUBTOTAL				**$27,500**
FIRST TWO YEARS O&M COSTS (quarterly sampling)				**$220,000**
REMAINING O&M COSTS (annual sampling for 5 years) (1)				**$111,300**
TOTAL O & M COSTS				***$331,300***
TOTAL CAPITAL AND O & M COSTS				***$2,138,150***
General Contingency (30% of Total Capital and O&M Costs)				***$641,400***
TOTAL COST OF ALTERNATIVE (PRESENT WORTH)				***$2,780,000***

Notes:
(1) Present worth calculated using equal series present worth analysis where i = 7.5%

TABLE B-7

Alternative 6 - In-Well Aeration
IRP Site 2 Cost Estimate
142nd FW, Portland ANGB, Portland, Oregon

DESCRIPTION	QUANTITY		COST	
	Number	Unit	Unit Cost	Total Cost
DIRECT CAPITAL COSTS				
Preparation Work				
Work Plan (incl. 35%, 90%, and Final Designs)	1	ea.	$50,000	$50,000
Deep Zone Direct-Push Investigation	1	ea.	$17,150	$17,150
Installation of Additional Shallow Zone Monitoring Wells	4	ea.	$5,000	$20,000
Installation of Additional Deep Zone Monitoring Wells	2	ea.	$7,000	$14,000
Installation of Additional CRSA Monitoring Wells	2	ea.	$10,000	$20,000
SUBTOTAL				**$121,150**
In-Well Aeration System				
Shallow Zone Aeration Well Installation	21	ea.	$15,000	$315,000
Shallow Zone Aeration Unit (incl. blower, moisture knockout, pump, packer, stripping reactor, piping, & gages)	21	ea.	$8,300	$174,300
Deep Zone Aeration Well Installation	5	ea.	$21,000	$105,000
Deep Zone Aeration Unit (incl. blower, moisture knockout, pump, packer, stripping reactor, piping, & gages)	5	ea.	$11,600	$58,000
Freight	26	ea.	$500	$13,000
Injection Piping Installation (trench, install, fill)	6,000	lf	$20	$120,000
System Building	26	ea.	$7,000	$182,000
Electrical Installation	26	ea.	$10,000	$260,000
As-Built Drawings and O&M Manual Preparation	1	LS	$20,000	$20,000
System Startup and Optimization	1	LS	$10,000	$10,000
SUBTOTAL				**$1,257,300**
TOTAL DIRECT CAPITAL COSTS				***$1,378,450***
INDIRECT CAPITAL COSTS				
Contractor Overhead & Profit (15% Total Direct Costs)	1	LS	$206,800	$206,800
Engineering and Construction Oversight (15% Total Direct Costs)	1	LS	$206,800	$206,800
Health and Safety Costs (3% Total Direct Costs)	1	LS	$41,400	$41,400
Project Management & Administration (10% Total Direct Costs)	1	LS	$137,800	$137,800
TOTAL INDIRECT CAPITAL COSTS				**$592,800**
TOTAL CAPITAL COSTS (Direct and Indirect)				***$1,971,250***
O & M COSTS				
Annual Treatment System O&M (1)				
Air Sampling and Analysis - VOCs	104	samples	$150	$15,600
Operation and Maintenance Labor	310	hours	$60	$18,600
Electrical Power	1	LS	$5,000	$5,000
GAC Disposal and Replacement	10,000	lbs.	$2	$20,000

TABLE B-7

Alternative 6 - In-Well Aeration

IRP Site 2 Cost Estimate

142nd FW, Portland ANGB, Portland, Oregon

DESCRIPTION	**QUANTITY**		**COST**	
	Number	**Unit**	**Unit Cost**	**Total Cost**
Reporting	144	hours	$100	$14,400
Well Rehabilitation to Treat Fouling (20% wells/year)	5	wells	$2,000	$10,000
Replacment Costs (3% Total Direct Costs)	1	LS	$41,400	$41,400
Contractor Overhead & Profit (15% Total Direct Costs)	1	LS	$8,700	$8,700
Engineering and Construction Oversight (15% Total Direct Costs)	1	LS	$8,700	$8,700
Health and Safety Costs (3% Total Direct Costs)	1	LS	$1,700	$1,700
Project Management & Administration (10% Total Direct Costs)	1	LS	$5,800	$5,800
SUBTOTAL				**$149,900**
Groundwater Monitoring Cost Per Event				
Well Sampling Labor and Equipment	26	wells	$400	$10,400
Ground Water Analysis - VOCs (26 wells + 50% QA/QC)	39	samples	$150	$5,900
Ground Water Analysis - MNA Parameters (10 wells + 30% QA/QC)	13	samples	$400	$5,200
Contractor Overhead & Profit (15% Total Direct Costs)	1	LS	$3,200	$3,200
Health and Safety Costs (3% Total Direct Costs)	1	LS	$600	$600
Project Management & Administration (10% Total Direct Costs)	1	LS	$2,200	$2,200
SUBTOTAL				**$27,500**
FIRST THREE YEARS O&M COSTS (treatment O&M and quarterly sampling) (1)				**$779,700**
REMAINING O&M COSTS (annual sampling for 5 years) (2)				**$111,300**
TOTAL O & M COSTS				***$891,000***
TOTAL CAPITAL AND O & M COSTS				***$2,862,250***
General Contingency (30% of Total Capital and O&M Costs)				***$858,700***
TOTAL COST OF ALTERNATIVE (PRESENT WORTH)				***$3,721,000***

Notes:

(1) Assume 2 years of system operation

(2) Present worth calculated using equal series present worth analysis where i = 7.5%

TABLE B-8

Summary of Costs Associated with Each Alternative
IRP Site 9
142nd FW, Portland ANGB, Portland, Oregon

Alternative	**Description**	**Direct and Indirect Capital Costs**	**NPW of Total O&M Costs**	**General Contingency (30%)**	**Estimated Total Cost**
Alternative 1	No Action	$0	$0	$0	**$0**
Alternative 2	Monitored Natural Attenuation	$64,500	$159,700	$67,300	**$292,000**
Alternative 3	Sodium Persulfate	$319,000	$121,700	$132,200	**$573,000**
Alternative 4	Ozone Sparging	$570,700	$350,800	$276,500	**$1,198,000**
Alternative 5	Enhanced Bioremediation	$336,200	$121,700	$137,400	**$596,000**
Alternative 6	In-Well Aeration	$469,200	$357,100	$247,900	**$1,075,000**

Notes:

Net present worth calculated using equal series present worth analysis where i = 7.5%

TABLE B-9

Alternative 2 - Monitored Natural Attenuation
IRP Site 9 Cost Estimate
142nd FW, Portland ANGB, Portland, Oregon

DESCRIPTION	QUANTITY		COST	
	Number	**Unit**	**Unit Cost**	**Total Cost**
DIRECT CAPITAL COSTS				
Monitored Natural Attenuation Work Plan	1	ea.	$10,000	$10,000
Installation of Additional Shallow Zone Monitoring Wells	7	ea.	$5,000	$35,000
Installation of Additional Deep Zone Monitoring Wells	0	ea.	$7,000	$0
Installation of Additional CRSA Monitoring Wells	0	ea.	$10,000	$0
TOTAL DIRECT CAPITAL COSTS				**$45,000**
INDIRECT CAPITAL COSTS				
Contractor Overhead & Profit (15% Total Direct Costs)	1	LS	$6,800	$6,800
Engineering and Construction Oversight (15% Total Direct Costs)	1	LS	$6,800	$6,800
Health and Safety Costs (3% Total Direct Costs)	1	LS	$1,400	$1,400
Project Management & Administration (10% Total Direct Costs)	1	LS	$4,500	$4,500
TOTAL INDIRECT CAPITAL COSTS				**$19,500**
TOTAL CAPITAL COSTS (Direct and Indirect)				***$64,500***
O & M COSTS				
Groundwater Monitoring Cost Per Event				
Well Sampling Labor and Equipment	10	wells	$400	$4,000
Ground Water Analysis - VOCs (10 wells + 50% QA / QC)	15	samples	$150	$2,300
Ground Water Analysis - MNA Parameters (3 wells + 30% QA / QC)	4	samples	$400	$1,560
Contractor Overhead & Profit (15% Total Direct Costs)	1	LS	$1,200	$1,200
Health and Safety Costs (3% Total Direct Costs)	1	LS	$200	$200
Project Management & Administration (10% Total Direct Costs)	1	LS	$800	$800
SUBTOTAL				**$10,100**
FIRST YEAR O&M COSTS (quarterly sampling)				**$40,400**
REMAINING O&M COSTS (annual sampling for 30 years) (1)				**$119,300**
TOTAL O & M COSTS				***$159,700***
TOTAL CAPITAL AND O & M COSTS				***$224,200***
General Contingency (30% of Total Capital and O&M Costs)				***$67,300***
TOTAL COST OF ALTERNATIVE (PRESENT WORTH)				***$292,000***

Notes:
(1) Present worth calculated using equal series present worth analysis where i = 7.5%

FINAL

TABLE B-10
Alternative 3 - Persulfate Oxidation
IRP Site 9 Cost Estimate
142nd FW, Portland ANGB, Portland, Oregon

DESCRIPTION	QUANTITY		COST	
	Number	Unit	Unit Cost	Total Cost
DIRECT CAPITAL COSTS				
Preparation Work				
Work Plan (incl. 35%, 90%, and Final Designs)	1	ea.	$50,000	$50,000
Installation of Additional Shallow Zone Monitoring Wells	7	ea.	$5,000	$35,000
Installation of Additional Deep Zone Monitoring Wells	0	ea.	$7,000	$0
Installation of Additional CRSA Monitoring Wells	0	ea.	$10,000	$0
SUBTOTAL				**$85,000**
Potassium Permanganate Injection				
Shallow Zone Direct-Push Injection of Sodium Persulfate (50 locations and 4 applications)	200	Injection	$500	$100,000
Sodium Persulfate (200 injections at 95 lbs per injection)	19,000	lbs.	$2.00	$38,000
SUBTOTAL				**$138,000**
TOTAL DIRECT CAPITAL COSTS				***$223,000***
INDIRECT CAPITAL COSTS				
Contractor Overhead & Profit (15% Total Direct Costs)	1	LS	$33,500	$33,500
Engineering and Construction Oversight (15% Total Direct Costs)	1	LS	$33,500	$33,500
Health and Safety Costs (3% Total Direct Costs)	1	LS	$6,700	$6,700
Project Management & Administration (10% Total Direct Costs)	1	LS	$22,300	$22,300
TOTAL INDIRECT CAPITAL COSTS				**$96,000**
TOTAL CAPITAL COSTS (Direct and Indirect)				***$319,000***
O & M COSTS				
Groundwater Monitoring Cost Per Event				
Well Sampling Labor and Equipment	10	wells	$400	$4,000
Ground Water Analysis - VOCs (10 wells + 50% QA / QC)	15	samples	$150	$2,300
Ground Water Analysis - MNA Parameters (3 wells + 30% QA / QC)	4	samples	$400	$1,560
Contractor Overhead & Profit (15% Total Direct Costs)	1	LS	$1,200	$1,200
Health and Safety Costs (3% Total Direct Costs)	1	LS	$200	$200
Project Management & Administration (10% Total Direct Costs)	1	LS	$800	$800
SUBTOTAL				**$10,100**
FIRST TWO YEARS O&M COSTS (quarterly sampling)				**$80,800**
REMAINING O&M COSTS (annual sampling for 5 years) (1)				**$40,900**
TOTAL O & M COSTS				***$121,700***
TOTAL CAPITAL AND O & M COSTS				***$440,700***
General Contingency (30% of Total Capital and O&M Costs)				***$132,200***
TOTAL COST OF ALTERNATIVE (PRESENT WORTH)				***$573,000***

Notes:

(1) Present worth calculated using equal series present worth analysis where i = 7.5%

TABLE B-11

Alternative 4 - Ozone Sparging
IRP Site 9 Cost Estimate
142nd FW, Portland ANGB, Portland, Oregon

DESCRIPTION	**QUANTITY**		**COST**	
	Number	**Unit**	**Unit Cost**	**Total Cost**
DIRECT CAPITAL COSTS				
Preparation Work				
Work Plan (incl. 35%, 90%, and Final Designs)	1	ea.	$50,000	$50,000
Installation of Additional Shallow Zone Monitoring Wells	7	ea.	$5,000	$35,000
Installation of Additional Deep Zone Monitoring Wells	0	ea.	$7,000	$0
Installation of Additional CRSA Monitoring Wells	0	ea.	$10,000	$0
SUBTOTAL				**$85,000**
Ozone Sparging System				
Shallow Zone Ozone Sparging Well Installation	16	ea.	$7,000	$112,000
Shallow Zone Ozone Sparging System (incl. master panels, in-well units, below-well sparge units, misc. costs)	2	ea.	$21,500	$43,000
Freight	2	ea.	$500	$1,000
Injection and SVE Piping Installation (trench, install, fill)	2,200	lf	$20	$44,000
System Building	2	ea.	$7,000	$14,000
Electrical Installation	2	ea.	$10,000	$20,000
SVE System (incl. blower, ozone decomposer, piping, valves, gages)	2	ea.	$25,000	$50,000
As-Built Drawings and O&M Manual Preparation	1	LS	$20,000	$20,000
System Startup and Optimization	1	LS	$10,000	$10,000
SUBTOTAL				**$314,000**
TOTAL DIRECT CAPITAL COSTS				***$399,000***
INDIRECT CAPITAL COSTS				
Contractor Overhead & Profit (15% Total Direct Costs)	1	LS	$59,900	$59,900
Engineering and Construction Oversight (15% Total Direct Costs)	1	LS	$59,900	$59,900
Health and Safety Costs (3% Total Direct Costs)	1	LS	$12,000	$12,000
Project Management & Administration (10% Total Direct Costs)	1	LS	$39,900	$39,900
TOTAL INDIRECT CAPITAL COSTS				**$171,700**
TOTAL CAPITAL COSTS (Direct and Indirect)				***$570,700***
O & M COSTS				
Annual Treatment System O&M (1)				
Air Sampling and Analysis - VOCs	8	samples	$150	$1,200
Operation and Maintenance Labor	250	hours	$60	$15,000
Electrical Power	1	LS	$5,000	$5,000
Reporting	144	hours	$100	$14,400
Replacment Costs (3% Total Direct Costs)	1	LS	$12,000	$12,000
Contractor Overhead & Profit (15% Total Direct Costs)	1	LS	$5,300	$5,300
Engineering and Construction Oversight (15% Total Direct Costs)	1	LS	$5,300	$5,300
Health and Safety Costs (3% Total Direct Costs)	1	LS	$1,100	$1,100
Project Management & Administration (10% Total Direct Costs)	1	LS	$3,600	$3,600
SUBTOTAL				**$62,900**

TABLE B-11

Alternative 4 - Ozone Sparging
IRP Site 9 Cost Estimate
142nd FW, Portland ANGB, Portland, Oregon

DESCRIPTION	QUANTITY		COST	
	Number	**Unit**	**Unit Cost**	**Total Cost**
Groundwater Monitoring Cost Per Event				
Well Sampling Labor and Equipment	10	wells	$400	$4,000
Ground Water Analysis - VOCs (10 wells + 50% QA / QC)	15	samples	$150	$2,300
Ground Water Analysis - MNA Parameters (3 wells + 30% QA / QC)	4	samples	$400	$1,560
Contractor Overhead & Profit (15% Total Direct Costs)	1	LS	$1,200	$1,200
Health and Safety Costs (3% Total Direct Costs)	1	LS	$200	$200
Project Management & Administration (10% Total Direct Costs)	1	LS	$800	$800
SUBTOTAL				**$10,100**
FIRST THREE YEARS O&M COSTS (treatment O&M and quarterly sampling) (1)				**$309,900**
REMAINING O&M COSTS (annual sampling for 5 years) (2)				**$40,900**
TOTAL O & M COSTS				***$350,800***
TOTAL CAPITAL AND O & M COSTS				***$921,500***
General Contingency (30% of Total Capital and O&M Costs)				***$276,500***
TOTAL COST OF ALTERNATIVE (PRESENT WORTH)				***$1,198,000***

Notes:

(1) Assume 2 years of system operation

(2) Present worth calculated using equal series present worth analysis where i = 7.5%

TABLE B-12

Alternative 5 - Enhanced Bioremediation
IRP Site 9 Cost Estimate
142nd FW, Portland ANGB, Portland, Oregon

DESCRIPTION	**QUANTITY**		**COST**	
	Number	**Unit**	**Unit Cost**	**Total Cost**
DIRECT CAPITAL COSTS				
Preparation Work				
Work Plan (incl. 35%, 90%, and Final Designs)	1	ea.	$50,000	$50,000
Installation of Additional Shallow Zone Monitoring Wells	7	ea.	$5,000	$35,000
Installation of Additional Deep Zone Monitoring Wells	0	ea.	$7,000	$0
Installation of Additional CRSA Monitoring Wells	0	ea.	$10,000	$0
SUBTOTAL				**$85,000**
Enhanced Bioremediation Treatment				
Oxygen Releasing Chemical Injection (50 locations and 4 applications)	200	Injection	$300	$60,000
Oxygen Releasing Chemicals (200 injections at 30 lbs per injection)	6,000	lbs	$15	$90,000
SUBTOTAL				**$150,000**
TOTAL DIRECT CAPITAL COSTS				***$235,000***
INDIRECT CAPITAL COSTS				
Contractor Overhead & Profit (15% Total Direct Costs)	1	LS	$35,300	$35,300
Engineering and Construction Oversight (15% Total Direct Costs)	1	LS	$35,300	$35,300
Health and Safety Costs (3% Total Direct Costs)	1	LS	$7,100	$7,100
Project Management & Administration (10% Total Direct Costs)	1	LS	$23,500	$23,500
TOTAL INDIRECT CAPITAL COSTS				**$101,200**
TOTAL CAPITAL COSTS (Direct and Indirect)				***$336,200***
O & M COSTS				
Groundwater Monitoring Cost Per Event				
Well Sampling Labor and Equipment	10	wells	$400	$4,000
Ground Water Analysis - VOCs (10 wells + 50% QA/QC)	15	samples	$150	$2,300
Ground Water Analysis - MNA Parameters (3 wells + 30% QA/QC)	4	samples	$400	$1,560
Contractor Overhead & Profit (15% Total Direct Costs)	1	LS	$1,200	$1,200
Health and Safety Costs (3% Total Direct Costs)	1	LS	$200	$200
Project Management & Administration (10% Total Direct Costs)	1	LS	$800	$800
SUBTOTAL				**$10,100**
FIRST TWO YEARS O&M COSTS (quarterly sampling)				**$80,800**
REMAINING O&M COSTS (annual sampling for 5 years) (1)				**$40,900**
TOTAL O & M COSTS				***$121,700***
TOTAL CAPITAL AND O & M COSTS				***$457,900***
General Contingency (30% of Total Capital and O&M Costs)				***$137,400***
TOTAL COST OF ALTERNATIVE (PRESENT WORTH)				***$596,000***

Notes:
(1) Present worth calculated using equal series present worth analysis where i = 7.5%

TABLE B-13

Alternative 6 - In-Well Aeration
IRP Site 9 Cost Estimate
142nd FW, Portland ANGB, Portland, Oregon

DESCRIPTION	QUANTITY		COST	
	Number	Unit	Unit Cost	Total Cost
DIRECT CAPITAL COSTS				
Preparation Work				
Work Plan (incl. 35%, 90%, and Final Designs)	1	ea.	$50,000	$50,000
Installation of Additional Shallow Zone Monitoring Wells	7	ea.	$5,000	$35,000
Installation of Additional Deep Zone Monitoring Wells	0	ea.	$7,000	$0
Installation of Additional CRSA Monitoring Wells	0	ea.	$10,000	$0
SUBTOTAL				**$85,000**
In-Well Aeration System				
Shallow Zone Aeration Well Installation	4	ea.	$15,000	$60,000
Shallow Zone Aeration Unit (incl. blower, moisture knockout, pump, packer, stripping reactor, piping, & gages)	4	ea.	$8,300	$33,200
Freight	4	ea.	$500	$2,000
Injection Piping Installation (trench, install, fill)	2,500	lf	$20	$50,000
System Building	4	ea.	$7,000	$28,000
Electrical Installation	4	ea.	$10,000	$40,000
As-Built Drawings and O&M Manual Preparation	1	LS	$20,000	$20,000
System Startup and Optimization	1	LS	$10,000	$10,000
SUBTOTAL				**$243,200**
TOTAL DIRECT CAPITAL COSTS				***$328,200***
INDIRECT CAPITAL COSTS				
Contractor Overhead & Profit (15% Total Direct Costs)	1	LS	$49,200	$49,200
Engineering and Construction Oversight (15% Total Direct Costs)	1	LS	$49,200	$49,200
Health and Safety Costs (3% Total Direct Costs)	1	LS	$9,800	$9,800
Project Management & Administration (10% Total Direct Costs)	1	LS	$32,800	$32,800
TOTAL INDIRECT CAPITAL COSTS				**$141,000**
TOTAL CAPITAL COSTS (Direct and Indirect)				***$469,200***
O & M COSTS				
Annual Treatment System O&M (1)				
Air Sampling and Analysis - VOCs	16	samples	$150	$2,400
Operation and Maintenance Labor	260	hours	$60	$15,600
Electrical Power	1	LS	$5,000	$5,000
GAC Disposal and Replacement	250	lbs.	$2	$500
Reporting	144	hours	$100	$14,400
Well Rehabilitation to Treat Fouling (20% wells / year)	1	wells	$2,000	$2,000
Replacment Costs (3% Total Direct Costs)	1	LS	$9,800	$9,800

TABLE B-13

Alternative 6 - In-Well Aeration
IRP Site 9 Cost Estimate
142nd FW, Portland ANGB, Portland, Oregon

DESCRIPTION	QUANTITY		COST	
	Number	Unit	Unit Cost	Total Cost
Contractor Overhead & Profit (15% Total Direct Costs)	1	LS	$5,300	$5,300
Engineering and Construction Oversight (15% Total Direct Costs)	1	LS	$5,300	$5,300
Health and Safety Costs (3% Total Direct Costs)	1	LS	$1,100	$1,100
Project Management & Administration (10% Total Direct Costs)	1	LS	$3,600	$3,600
SUBTOTAL				**$65,000**
Groundwater Monitoring Cost Per Event				
Well Sampling Labor and Equipment	10	wells	$400	$4,000
Ground Water Analysis - VOCs (10 wells + 50% QA/QC)	15	samples	$150	$2,300
Ground Water Analysis - MNA Parameters (3 wells + 30% QA/QC)	4	samples	$400	$1,560
Contractor Overhead & Profit (15% Total Direct Costs)	1	LS	$1,200	$1,200
Health and Safety Costs (3% Total Direct Costs)	1	LS	$200	$200
Project Management & Administration (10% Total Direct Costs)	1	LS	$800	$800
SUBTOTAL				**$10,100**
FIRST THREE YEARS O&M COSTS (treatment O&M and quarterly sampling) (1)				**$316,200**
REMAINING O&M COSTS (annual sampling for 5 years) (2)				**$40,900**
TOTAL O & M COSTS				***$357,100***
TOTAL CAPITAL AND O & M COSTS				***$826,300***
General Contingency (30% of Total Capital and O&M Costs)				***$247,900***
TOTAL COST OF ALTERNATIVE (PRESENT WORTH)				***$1,075,000***

Notes:

(1) Assume 2 years of system operation

(2) Present worth calculated using equal series present worth analysis where i = 7.5%

TABLE B-14

Summary of Costs Associated with Each Alternative

IRP Site 11

142nd FW, Portland ANGB, Portland, Oregon

Alternative	Description	Direct and Indirect Capital Costs	NPW of Total O&M Costs	General Contingency (30%)	Estimated Total Cost
Alternative 1	No Action	$0	$0	$0	**$0**
Alternative 2	Monitored Natural Attenuation	$151,700	$434,800	$176,000	**$763,000**
Alternative 3	Permanganate Oxidation	$1,673,950	$331,300	$601,600	**$2,607,000**
Alternative 4	Ozone Sparging	$2,592,850	$798,600	$1,017,400	**$4,409,000**
Alternative 5	Enhanced Bioremediation	$2,983,150	$331,300	$994,300	**$4,309,000**
Alternative 6	In-Well Aeration	$3,287,050	$985,200	$1,281,700	**$5,554,000**

Notes:

Net present worth calculated using equal series present worth analysis where i = 7.5%

TABLE B-15

Alternative 2 - Monitored Natural Attenuation
IRP Site 11 Cost Estimate
142nd FW, Portland ANGB, Portland, Oregon

DESCRIPTION	QUANTITY		COST	
	Number	Unit	Unit Cost	Total Cost
DIRECT CAPITAL COSTS				
Deep Zone Direct-Push Investigation	1	ea.	$17,150	$17,150
Monitored Natural Attenuation Work Plan	1	ea.	$10,000	$10,000
Installation of Additional Shallow Zone Monitoring Wells	4	ea.	$6,000	$24,000
Installation of Additional Deep Zone Monitoring Wells	2	ea.	$8,400	$16,800
Installation of Additional CRSA Monitoring Wells	3	ea.	$12,000	$36,000
Concrete Coring Well and Injection Locations (75%)	7	ea.	$300	$2,100
TOTAL DIRECT CAPITAL COSTS				**$106,100**
INDIRECT CAPITAL COSTS				
Contractor Overhead & Profit (15% Total Direct Costs)	1	LS	$15,900	$15,900
Engineering and Construction Oversight (15% Total Direct Costs)	1	LS	$15,900	$15,900
Health and Safety Costs (3% Total Direct Costs)	1	LS	$3,200	$3,200
Project Management & Administration (10% Total Direct Costs)	1	LS	$10,600	$10,600
TOTAL INDIRECT CAPITAL COSTS				**$45,600**
TOTAL CAPITAL COSTS (Direct and Indirect)				***$151,700***
O & M COSTS				
Groundwater Monitoring Cost Per Event				
Well Sampling Labor and Equipment	23	wells	$480	$11,040
Ground Water Analysis - VOCs (23 wells + 50% QA / QC)	35	samples	$150	$5,300
Ground Water Analysis - MNA Parameters (10 wells + 30% QA / QC)	13	samples	$400	$5,200
Contractor Overhead & Profit (15% Total Direct Costs)	1	LS	$3,200	$3,200
Health and Safety Costs (3% Total Direct Costs)	1	LS	$600	$600
Project Management & Administration (10% Total Direct Costs)	1	LS	$2,200	$2,200
SUBTOTAL				**$27,500**
FIRST YEAR O&M COSTS (quarterly sampling)				**$110,000**
REMAINING O&M COSTS (annual sampling for 30 years) (1)				**$324,800**
TOTAL O & M COSTS				***$434,800***
TOTAL CAPITAL AND O & M COSTS				***$586,500***
General Contingency (30% of Total Capital and O&M Costs)				***$176,000***
TOTAL COST OF ALTERNATIVE (PRESENT WORTH)				***$763,000***

Notes:
(1) Present worth calculated using equal series present worth analysis where i = 7.5%

TABLE B-16

Alternative 3 - Permanganate Oxidation
IRP Site 11 Cost Estimate
142nd FW, Portland ANGB, Portland, Oregon

DESCRIPTION	QUANTITY		COST	
	Number	Unit	Unit Cost	Total Cost
DIRECT CAPITAL COSTS				
Preparation Work				
Work Plan (incl. 35%, 90%, and Final Designs)	1	ea.	$50,000	$50,000
Deep Zone Direct-Push Investigation	1	ea.	$17,150	$17,150
Installation of Additional Shallow Zone Monitoring Wells	4	ea.	$6,000	$24,000
Installation of Additional Deep Zone Monitoring Wells	2	ea.	$8,400	$16,800
Installation of Additional CRSA Monitoring Wells	3	ea.	$12,000	$36,000
Concrete Coring Well Locations	4	ea.	$300	$1,200
Concrete Coring and Preparation of Horizontal Well Entrance Locations	12	ea.	$2,000	$24,000
Horizontal Well Contractor Mobilization	1	lump sum	$45,000	$45,000
SUBTOTAL				**$214,150**
Shallow Zone Potassium Permanganate Injection				
Drilling of Shallow Zone Horizontal Injection Well	6,840	feet	$27	$184,700
Horizontal Injection Well Screen	3,465	feet	$7	$24,300
Horizontal Injection Well Blank Casing	3,375	feet	$5	$16,875
Horizontal Injection Well Other Materials	8	well	$500	$4,000
Horizontal Injection Well Standby	80	hours	$500	$40,000
Horizontal Injection Well Development	8	well	$7,200	$57,600
Miscellaneous Horizontal Injection Well Costs	1	lump sum	$149,560	$149,600
Shallow Zone Injection of Potassium Permanganate (8 wells and 4 applications)	32	well	$3,750	$120,000
Potassium Permanganate (13860 feet at 2 lbs per screen foot)	27,720	lbs.	$2.00	$55,400
Deep Zone Potassium Permanganate Injection				
Drilling of Deep Zone Horizontal Injection Well	3,105	feet	$27	$83,800
Horizontal Injection Well Screen	900	feet	$7	$6,300
Horizontal Injection Well Blank Casing	2,205	feet	$5	$11,025
Horizontal Injection Well Other Materials	4	well	$500	$2,000
Horizontal Injection Well Standby	40	hours	$500	$20,000
Horizontal Injection Well Development	4	well	$7,200	$28,800
Miscellaneous Horizontal Injection Well Costs	1	lump sum	$77,560	$77,600
Deep Zone Injection of Potassium Permanganate (4 wells and 4 applications)	16	well	$3,750	$60,000
Potassium Permanganate (3600 feet at 2 lbs per screen foot)	7,200	lbs.	$2.00	$14,400
SUBTOTAL				**$956,400**
TOTAL DIRECT CAPITAL COSTS				***$1,170,550***
INDIRECT CAPITAL COSTS				
Contractor Overhead & Profit (15% Total Direct Costs)	1	LS	$175,600	$175,600
Engineering and Construction Oversight (15% Total Direct Costs)	1	LS	$175,600	$175,600
Health and Safety Costs (3% Total Direct Costs)	1	LS	$35,100	$35,100
Project Management & Administration (10% Total Direct Costs)	1	LS	$117,100	$117,100
TOTAL INDIRECT CAPITAL COSTS				**$503,400**
TOTAL CAPITAL COSTS (Direct and Indirect)				***$1,673,950***
O & M COSTS				
Groundwater Monitoring Cost Per Event				
Well Sampling Labor and Equipment	23	wells	$480	$11,040
Ground Water Analysis - VOCs (23 wells + 50% QA / QC)	35	samples	$150	$5,300
Ground Water Analysis - MNA Parameters (10 wells + 30% QA / QC)	13	samples	$400	$5,200
Contractor Overhead & Profit (15% Total Direct Costs)	1	LS	$3,200	$3,200
Health and Safety Costs (3% Total Direct Costs)	1	LS	$600	$600
Project Management & Administration (10% Total Direct Costs)	1	LS	$2,200	$2,200

TABLE B-16

Alternative 3 - Permanganate Oxidation
IRP Site 11 Cost Estimate
142nd FW, Portland ANGB, Portland, Oregon

DESCRIPTION	**QUANTITY**		**COST**	
	Number	**Unit**	**Unit Cost**	**Total Cost**
SUBTOTAL				**$27,500**
FIRST TWO YEARS O&M COSTS (quarterly sampling)				**$220,000**
REMAINING O&M COSTS (annual sampling for 5 years) (1)				**$111,300**
TOTAL O & M COSTS				***$331,300***
TOTAL CAPITAL AND O & M COSTS				***$2,005,250***
General Contingency (30% of Total Capital and O&M Costs)				***$601,600***
TOTAL COST OF ALTERNATIVE (PRESENT WORTH)				***$2,607,000***

Notes:

(1) Present worth calculated using equal series present worth analysis where i = 7.5%

TABLE B-17

Alternative 4 - Ozone Sparging
IRP Site 11 Cost Estimate
142nd FW, Portland ANGB, Portland, Oregon

DESCRIPTION	**QUANTITY**		**COST**	
	Number	**Unit**	**Unit Cost**	**Total Cost**
DIRECT CAPITAL COSTS				
Preparation Work				
Work Plan (incl. 35%, 90%, and Final Designs)	1	ea.	$50,000	$50,000
Deep Zone Direct-Push Investigation	1	ea.	$17,150	$17,150
Installation of Additional Shallow Zone Monitoring Wells	4	ea.	$6,000	$24,000
Installation of Additional Deep Zone Monitoring Wells	2	ea.	$8,400	$16,800
Installation of Additional CRSA Monitoring Wells	3	ea.	$12,000	$36,000
Concrete Coring Well Locations (75%)	10	ea.	$300	$3,000
Concrete Coring and Preparation of Horizontal Well Entrance Locations	12	ea.	$2,000	$24,000
Horizontal Well Contractor Mobilization	1	lump sum	$45,000	$45,000
SUBTOTAL				**$215,950**
Shallow Zone Ozone Sparging Wells				
Drilling of Shallow Zone Horizontal Sparge Well	6,840	feet	$27	$184,700
Horizontal Injection Well Screen	3,465	feet	$7	$24,300
Horizontal Injection Well Blank Casing	3,375	feet	$5	$16,875
Horizontal Injection Well Other Materials	8	well	$500	$4,000
Horizontal Injection Well Standby	80	hours	$500	$40,000
Horizontal Injection Well Development	8	well	$7,200	$57,600
Miscellaneous Horizontal Injection Well Costs	1	lump sum	$149,560	$149,600
Deep Zone Ozone Sparging Wells				
Drilling of Deep Zone Horizontal Sparge Well	3,105	feet	$27	$83,800
Horizontal Injection Well Screen	900	feet	$7	$6,300
Horizontal Injection Well Blank Casing	2,205	feet	$5	$11,025
Horizontal Injection Well Other Materials	4	well	$500	$2,000
Horizontal Injection Well Standby	40	hours	$500	$20,000
Horizontal Injection Well Development	4	well	$7,200	$28,800
Miscellaneous Horizontal Injection Well Costs	1	lump sum	$77,560	$77,600
SUBTOTAL				**$706,600**
Shallow Zone SVE Wells				
Drilling of Shallow Zone Horizontal SVE Well	6,840	feet	$27	$184,700
Horizontal Injection Well Screen	3,465	feet	$7	$24,300
Horizontal Injection Well Blank Casing	3,375	feet	$5	$16,875
Horizontal Injection Well Other Materials	8	well	$500	$4,000
Horizontal Injection Well Standby	80	hours	$500	$40,000
Horizontal Injection Well Development	8	well	$7,200	$57,600
Miscellaneous Horizontal Injection Well Costs	1	lump sum	$149,560	$149,600
Deep Zone SVE Wells				
Drilling of Deep Zone Horizontal SVE Well	3,105	feet	$27	$83,800
Horizontal Injection Well Screen	900	feet	$7	$6,300
Horizontal Injection Well Blank Casing	2,205	feet	$5	$11,025
Horizontal Injection Well Other Materials	4	well	$500	$2,000
Horizontal Injection Well Standby	40	hours	$500	$20,000
Horizontal Injection Well Development	4	well	$7,200	$28,800
Miscellaneous Horizontal Injection Well Costs	1	lump sum	$77,560	$77,600
SUBTOTAL				**$706,600**
Ozone Sparging System				
Shallow Zone Ozone Sparging System	1	ea.	$128,250	$128,250
Deep Zone Ozone Sparging System	1	ea.	$85,500	$85,500
Freight	1	lump sum	$5,000	$5,000
Injection and SVE Piping Installation (trench, install, fill)	1,000	lf	$75	$75,000
System Building	2	ea.	$7,000	$14,000
Electrical Installation	1	ea.	$10,000	$10,000
SVE System (incl. blower, ozone decomposer, piping, valves, gages)	2	ea.	$25,000	$50,000
As-Built Drawings and O&M Manual Preparation	1	LS	$20,000	$20,000
System Startup and Optimization	1	LS	$10,000	$10,000
SUBTOTAL				**$184,000**

TABLE B-17

Alternative 4 - Ozone Sparging
IRP Site 11 Cost Estimate
142nd FW, Portland ANGB, Portland, Oregon

DESCRIPTION	QUANTITY		COST	
	Number	Unit	Unit Cost	Total Cost
TOTAL DIRECT CAPITAL COSTS				***$1,813,150***
INDIRECT CAPITAL COSTS				
Contractor Overhead & Profit (15% Total Direct Costs)	1	LS	$272,000	$272,000
Engineering and Construction Oversight (15% Total Direct Costs)	1	LS	$272,000	$272,000
Health and Safety Costs (3% Total Direct Costs)	1	LS	$54,400	$54,400
Project Management & Administration (10% Total Direct Costs)	1	LS	$181,300	$181,300
TOTAL INDIRECT CAPITAL COSTS				**$779,700**
TOTAL CAPITAL COSTS (Direct and Indirect)				***$2,592,850***
O & M COSTS				
Annual Treatment System O&M (1)				
Air Sampling and Analysis - VOCs	48	samples	$150	$7,200
Operation and Maintenance Labor	310	hours	$60	$18,600
Electrical Power	1	LS	$5,000	$5,000
Reporting	144	hours	$100	$14,400
Replacment Costs (3% Total Direct Costs)	1	LS	$54,400	$54,400
Contractor Overhead & Profit (15% Total Direct Costs)	1	LS	$6,800	$6,800
Engineering and Construction Oversight (15% Total Direct Costs)	1	LS	$6,800	$6,800
Health and Safety Costs (3% Total Direct Costs)	1	LS	$1,400	$1,400
Project Management & Administration (10% Total Direct Costs)	1	LS	$4,500	$4,500
SUBTOTAL				**$119,100**
Groundwater Monitoring Cost Per Event				
Well Sampling Labor and Equipment	23	wells	$480	$11,040
Ground Water Analysis - VOCs (23 wells + 50% QA / QC)	35	samples	$150	$5,300
Ground Water Analysis - MNA Parameters (10 wells + 30% QA / QC)	13	samples	$400	$5,200
Contractor Overhead & Profit (15% Total Direct Costs)	1	LS	$3,200	$3,200
Health and Safety Costs (3% Total Direct Costs)	1	LS	$600	$600
Project Management & Administration (10% Total Direct Costs)	1	LS	$2,200	$2,200
SUBTOTAL				**$27,500**
FIRST THREE YEARS O&M COSTS (treatment O&M and quarterly sampling) (1)				**$687,300**
REMAINING O&M COSTS (annual sampling for 5 years) (2)				**$111,300**
TOTAL O & M COSTS				***$798,600***
TOTAL CAPITAL AND O & M COSTS				***$3,391,450***
General Contingency (30% of Total Capital and O&M Costs)				***$1,017,400***
TOTAL COST OF ALTERNATIVE (PRESENT WORTH)				***$4,409,000***

Notes:

(1) Assume 2 years of system operation

(2) Present worth calculated using equal series present worth analysis where i = 7.5%

TABLE B-18

Alternative 5 - Enhanced Bioremediation
IRP Site 11 Cost Estimate
142nd FW, Portland ANGB, Portland, Oregon

DESCRIPTION	QUANTITY		COST	
	Number	Unit	Unit Cost	Total Cost
DIRECT CAPITAL COSTS				
Preparation Work				
Work Plan (incl. 35%, 90%, and Final Designs)	1	ea.	$50,000	$50,000
Deep Zone Direct-Push Investigation	1	ea.	$17,150	$17,150
Installation of Additional Shallow Zone Monitoring Wells	4	ea.	$6,000	$24,000
Installation of Additional Deep Zone Monitoring Wells	2	ea.	$8,400	$16,800
Installation of Additional CRSA Monitoring Wells	3	ea.	$12,000	$36,000
Concrete Coring Well and Injection Locations (75%)	1,190	ea.	$300	$357,000
Airport Concrete Repair	1,190	ea.	$300	$357,000
SUBTOTAL				**$857,950**
Enhanced Bioremediation Treatment				
Shallow Zone (Central) Oxygen Releasing Chemical Injections (270 locations and 4 applications)	1,080	Injection	$300	$324,000
Shallow Zone (Periphery) Oxygen Releasing Chemical Injections (70 locations and 2 applications)	140	Injection	$300	$42,000
Deep Zone Oxygen Releasing Chemical Injections (90 locations and 4 applications)	360	Injection	$420	$151,200
Oxygen Releasing Chemicals (1580 injections at 30 lbs per injection)	47,400	lbs	$15	$711,000
SUBTOTAL				**$1,228,200**
TOTAL DIRECT CAPITAL COSTS				***$2,086,150***
INDIRECT CAPITAL COSTS				
Contractor Overhead & Profit (15% Total Direct Costs)	1	LS	$312,900	$312,900
Engineering and Construction Oversight (15% Total Direct Costs)	1	LS	$312,900	$312,900
Health and Safety Costs (3% Total Direct Costs)	1	LS	$62,600	$62,600
Project Management & Administration (10% Total Direct Costs)	1	LS	$208,600	$208,600
TOTAL INDIRECT CAPITAL COSTS				**$897,000**
TOTAL CAPITAL COSTS (Direct and Indirect)				***$2,983,150***
O & M COSTS				
Groundwater Monitoring Cost Per Event				
Well Sampling Labor and Equipment	23	wells	$480	$11,040
Ground Water Analysis - VOCs (23 wells + 50% QA / QC)	35	samples	$150	$5,300
Ground Water Analysis - MNA Parameters (10 wells + 30% QA / QC)	13	samples	$400	$5,200
Contractor Overhead & Profit (15% Total Direct Costs)	1	LS	$3,200	$3,200
Health and Safety Costs (3% Total Direct Costs)	1	LS	$600	$600
Project Management & Administration (10% Total Direct Costs)	1	LS	$2,200	$2,200
SUBTOTAL				**$27,500**
FIRST TWO YEARS O&M COSTS (quarterly sampling)				**$220,000**
REMAINING O&M COSTS (annual sampling for 5 years) (1)				**$111,300**
TOTAL O & M COSTS				***$331,300***
TOTAL CAPITAL AND O & M COSTS				***$3,314,450***
General Contingency (30% of Total Capital and O&M Costs)				***$994,300***
TOTAL COST OF ALTERNATIVE (PRESENT WORTH)				***$4,309,000***

Notes:

(1) Present worth calculated using equal series present worth analysis where i = 7.5%

TABLE B-19

Alternative 6 - In-Well Aeration

IRP Site 11 Cost Estimate

142nd FW, Portland ANGB, Portland, Oregon

DESCRIPTION	QUANTITY		COST	
	Number	**Unit**	**Unit Cost**	**Total Cost**
DIRECT CAPITAL COSTS				
Preparation Work				
Work Plan (incl. 35%, 90%, and Final Designs)	1	ea.	$50,000	$50,000
Deep Zone Direct-Push Investigation	1	ea.	$17,150	$17,150
Installation of Additional Shallow Zone Monitoring Wells	4	ea.	$6,000	$24,000
Installation of Additional Deep Zone Monitoring Wells	2	ea.	$8,400	$16,800
Installation of Additional CRSA Monitoring Wells	3	ea.	$12,000	$36,000
Concrete Coring Well Locations	38	ea.	$300	$11,400
SUBTOTAL				**$155,350**
In-Well Aeration System				
Shallow Zone Aeration Well Installation	23	ea.	$18,000	$414,000
Shallow Zone Aeration Unit (incl. blower, moisture knockout, pump, packer, stripping reactor, piping, & gages)	23	ea.	$8,300	$190,900
Deep Zone Aeration Well Installation	6	ea.	$25,200	$151,200
Deep Zone Aeration Unit (incl. blower, moisture knockout, pump, packer, stripping reactor, piping, & gages)	6	ea.	$11,600	$69,600
Freight	29	ea.	$500	$14,500
Injection Piping Installation (trench, install, fill)	10,400	lf	$75	$780,000
System Building	29	ea.	$7,000	$203,000
Electrical Installation	29	ea.	$10,000	$290,000
As-Built Drawings and O&M Manual Preparation	1	LS	$20,000	$20,000
System Startup and Optimization	1	LS	$10,000	$10,000
SUBTOTAL				**$2,143,200**
TOTAL DIRECT CAPITAL COSTS				***$2,298,550***
INDIRECT CAPITAL COSTS				
Contractor Overhead & Profit (15% Total Direct Costs)	1	LS	$344,800	$344,800
Engineering and Construction Oversight (15% Total Direct Costs)	1	LS	$344,800	$344,800
Health and Safety Costs (3% Total Direct Costs)	1	LS	$69,000	$69,000
Project Management & Administration (10% Total Direct Costs)	1	LS	$229,900	$229,900
TOTAL INDIRECT CAPITAL COSTS				**$988,500**
TOTAL CAPITAL COSTS (Direct and Indirect)				***$3,287,050***
O & M COSTS				
Annual Treatment System O&M (1)				
Air Sampling and Analysis - VOCs	116	samples	$150	$17,400
Operation and Maintenance Labor	310	hours	$60	$18,600
Electrical Power	1	LS	$5,000	$5,000
GAC Disposal and Replacement	10,000	lbs.	$2	$20,000

TABLE B-19

Alternative 6 - In-Well Aeration
IRP Site 11 Cost Estimate
142nd FW, Portland ANGB, Portland, Oregon

DESCRIPTION	**QUANTITY**		**COST**	
	Number	**Unit**	**Unit Cost**	**Total Cost**
Reporting	144	hours	$100	$14,400
Well Rehabilitation to Treat Fouling (20% wells / year)	6	wells	$2,000	$12,000
Replacment Costs (3% Total Direct Costs)	1	LS	$69,000	$69,000
Contractor Overhead & Profit (15% Total Direct Costs)	1	LS	$8,700	$8,700
Engineering and Construction Oversight (15% Total Direct Costs)	1	LS	$8,700	$8,700
Health and Safety Costs (3% Total Direct Costs)	1	LS	$1,700	$1,700
Project Management & Administration (10% Total Direct Costs)	1	LS	$5,800	$5,800
SUBTOTAL				**$181,300**
Groundwater Monitoring Cost Per Event				
Well Sampling Labor and Equipment	23	wells	$480	$11,040
Ground Water Analysis - VOCs (23 wells + 50% QA / QC)	35	samples	$150	$5,300
Ground Water Analysis - MNA Parameters (10 wells + 30% QA / QC)	13	samples	$400	$5,200
Contractor Overhead & Profit (15% Total Direct Costs)	1	LS	$3,200	$3,200
Health and Safety Costs (3% Total Direct Costs)	1	LS	$600	$600
Project Management & Administration (10% Total Direct Costs)	1	LS	$2,200	$2,200
SUBTOTAL				**$27,500**
FIRST THREE YEARS O&M COSTS (treatment O&M and quarterly sampling) (1)				**$873,900**
REMAINING O&M COSTS (annual sampling for 5 years) (2)				**$111,300**
TOTAL O & M COSTS				***$985,200***
TOTAL CAPITAL AND O & M COSTS				***$4,272,250***
General Contingency (30% of Total Capital and O&M Costs)				***$1,281,700***
TOTAL COST OF ALTERNATIVE (PRESENT WORTH)				***$5,554,000***

Notes:

(1) Assume 2 years of system operation

(2) Present worth calculated using equal series present worth analysis where i = 7.5%